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Relationship Between Growth Performance, Passive Immunity and Health In Preweaned Lambs*

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Abstract: This study was designed to investigate associations between transfer of passive immunity, selected illnesses (diarrhoea, pneumonia, and fatigue anorexia syndrome-FAS) and growth performance [body weight (BW) and average daily gain (ADG)] in preweaned lambs. A total of 347 lambs were blood sampled at 24±1 h of age after birth and the serum IgG concentration for each lamb was measured after colostrum intake using a commercial ELISA kit. Lambs were weighed on a scale immediately after birth (before colostrum intake) and reweighed on day 28 (end of neonatal period) and day 84 (age of weaning). Lambs ADG was calculated from 0 to 28 d of life, from 29 to 84d of life, and from 0 to 84 d of life. Growth performance (BW and ADG) of lambs with diarrhoea and FAS in the neonatal period and with pneumonia in the postneonatal period was significantly lower than that of healthy lambs of the same period (P<0.05). BW of lambs with serum IgG concentration at 24th hour after the birth (SIgGC-24)<600 mg/dL and <1000 mg/ml was significantly lower on days 28 and 84 than that of lambs with SIgGC-24 >600 mg/dL and >1000 mg/ml (P<0.001). Similarly, the ADG of lambs with SIgGC-24 <600 mg/dL and <1000 mg/ml was significantly lower on days from 0-28, 29-84 and 0-84 of age than those of lambs with SIgGC-24 >600 mg/dL and >1000 mg/ml (P<0.001). In conclusion, our findings show that low serum IgG concentration in lambs, as well as the presence of pneumonia, diarrhea and FAS, reduces growth performance in pre-weaning lambs.
Keywords: Growth, health, IgG cut off, lambs, performance

Sütten Kesilmiş Kuzularda Büyüme Performansı, Pasif Bağışıklık ve Sağlık Arasındaki Ilişki

Öz: Bu çalışmanın amacı, sütten kesim dönemi kuzularda pasif bağışıklık transferi ile bazı hastalıklar (ishal, pnömoni, fatigue anoreksi sendromu-FAS) ve büyüme performansı [vücut ağırlığı (BW) ve ortalama günlük ağılık artışı (ADG)] arasındaki ilişkiyi araştırmaktır. Toplam olarak 347 kuzudan kolostrum alınımından ya da doğumdan sonra 24±1 saat kan örnekleri toplanmış ve her bir kuzu için serum IgG konsantrasyonu ticari bir ELISA kiti kullanılarak ölçülmüştür. Kuzular doğumdan hemen sonra (kolostrum alımından önce) tartılmış ve 28. günde (neonatal dönemin sonunda) ve 84. günde (sütten kesim yaşı) tekrar tartılmıştır. Kuzuların ADG'si yaşamın 0 ila 28. günleri arasında, yaşamın 29 ila 84. günleri arasında ve yaşamın 0 ila 84. günleri arasında hesaplanmıştır. Neonatal dönemde ishalli ve FAS tanılı ve postneonatal dönemde pnömonili kuzuların büyüme performansı (BW ve ADG) aynı dönemdeki sağlıklı kuzulara göre önemli ölçüde düşük bulundu (P<0.05). Doğumdan sonraki 24. saatte serum IgG konsantrasyonu (SIgGC-24) <600 mg/dL ve <1000 mg/ml olan kuzuların canlı ağırlıkları 28. ve 84. günlerde SIgGC-24 >600 mg/dL ve >1000 mg/ml olan kuzulardan önemli ölçüde daha düşüktü (P <0.001). Benzer şekilde, SIgGC-24 <600 mg/dL ve <1000 mg/ml olan kuzuların günlük canlı ağırlık artışının 0-28, 29-84 ve 0-84 yaş günlerinde SIgGC-24 >600 mg/dL ve >1000 mg/ml olan kuzulardan önemli ölçüde daha düşüktü (P<0.001). Sonuç olarak, bulgularımız düşük serum IgG konsantrasyonunu ile birlikte pnömoni, ishal ve FAS bulunması kuzularda sütten kesim öncesi büyüme performansını azaltmaktadır.
Anahtar kelimeler: Büyüme performansı, IgG eşik değerleri, kuzu, sağlık

Introduction

Neonatal diseases are the most common problem in animal husbandry. Diseases such as diarrhea, pneumonia, and FAS in preweaning lambs cause significant economic losses every year due to high mortality rate, decreased growth performance and treatment expenses (Gökçe et al., 2014; Kenyon et al., 2019). Preweaning colostrum management is an important predictor of lamb health and growth performance and should be assessed regularly. The first step in in-

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creasing farm yield and profitability is to ensure adequate passive transfer (Elsohaby et al., 2019). Growth in the preweaning period is influenced by many different factors, including passive colostral immunity, disease, nutrition, management practices, and environmental conditions.

The syndesmochorial structure of the ovine placenta does not allow transfer of maternal immunoglobulins to the fetus during pregnancy. Therefore, the lamb is a gammaglobulinemic at birth and dependent on passive transfer of IgG from maternal colostrum within the first hours of life. The transfer of maternal antibodies is critical for protection of new born lambs as their immune systems is not yet fully competent. The passive transfer of colostral immunity occurs through the absorbtion of colostral Ig by pinocytosis in the small intestinal epithelium (Kozyr et al., 2019). Newborn lambs absorb colostral IgG during the first 24 hours after birth; after which the absorption capacity decreases over time as the digestive system matures. Therefore, the 24th hour after birth is the best time to determine the passive immune status in the lamb sera (Alves et al., 2015). Studies suggest that adequate IgG absorption is associated with reduced morbidity due to infection and therefore reduced use of antibiotics, and improved growth performance (Aydogdu et al., 2018; Agenbag et al., 2021; Johnson et al., 2022). Thus, determination of serum IgG concentrations in new born lamb is essential in order to take appropriate measures to reduce morbidity, mortality and improve growth performance (Vatankhah, 2013; Santiago et al., 2020). However, to date, there has been little research into developing strategies for optimizing passive immunity transfer in lambs, especially in Turkey.

Low serum IgG concentration absorbed from colostrum is defined as failure of passive transfer (FPT) (Tsiligianni et al., 2012; Hernández-Castellano et al., 2014; Gökçe et al., 2021a). FPT has been associated with many neonatal ruminant diseases, including the respiratory system, diarrhea, septicemia, and omphalophlebitis (Herndon et al., 2011). FPT also increases the duration of illness, contagiousness, or pathogen shedding, and reduces growth in preweaning lambs (first few months of life) (Massimini et al., 2006; Andres et al., 2007; Turquino et al., 2011, Atkinson et al., 2017, Bond, 2020). Recommended best practices to prevent FPT include feeding a minimum of 50 ml/kg of colostrum within 6 h of lambing in a total of 150-290 ml/kg in 18-24 h, to have sufficient passive immunity (Aydoğdu et al., 2018).

There is no internationally accepted threshold value for FPT in lambs. For this reason, studies to date have generally used two different thresholds of IgG <600 and <1000 mg/dl at 24 hours after birth, indicating inadequate passive transfer (Gilbert et al., 1988; Britti et al., 2005; Gökçe et al., 2019). Poor health and growth in young lambs can have lasting effects on their development and future production. Improving growth performance also motivates producers. The effect of diseases such as pneumonia and diarrhoea on the growth performance of lambs is not well understood. This may be due to the length of time required for disease detection, health examination and observation.

This study was designed to determine the relationship between the transfer of passive immunity (24^{th} h postpartum IgG concentration) and growth performance (weight gain-WG and average daily gain-ADG) in preweaned dairy lambs in relation to selected diseases, as there seems to be a lack of knowledge about it.

Materials and Methods

The study protocol was authorized by the Institutional Ethics Committee for the Care and Use of Animals, Kafkas University (KAU-HADYEK, 2008-23).

Animals

The details of the study design are given elsewhere (Gokce et al., 2013). Briefly, a longitudinal observational study was designed in which 347 Akkaraman crossbred lambs from two neighbouring farms with similar management practices and feeding regimes in Kars, Turkey, agreed to participate. All ewes were housed as set out by management procedures of the farms. Ewes were not given any drugs or other substances during gestation or parturition. Flock management was typical of the region, with lambs being born in winter (December to February) or spring (March to May) and was supervised by stockmen during the entire lambing period and lambs were allowed to suckle colostrum on their own within 24 hours of birth. Lambs and their dams were housed in individual pens for up to seven days, after which the lambs were, then moved to group pens, allowed to suckle twice a day (morning and evening), fed hay only for three weeks after the first week of life, and straw and commercial growth feed (Bayramoglu AS, Türkiye) in addition to hay for three months. The lambs were intensively reared.

Daily weight gain

The study included only lambs that were regarded as healthy after birth. Plastic ear tags were placed on each ear of the lambs shortly after birth. The lambs were weighed at birth before colostrum intake (n=347) using a scale [CASIA DB2-150 kg (±30 g)] and then let to naturally suckle their dams. The lambs were not given any vaccinations, drugs or other substances during the study period. The lambs were weighed again on day 28 (at the end of the neonatal period, n=291) and day 84 (weaning time, n=290) using the same scale. Lambs ADG was calculated

from 0 to 28 d of life, from 29 to 84d of life, and from 0 to 84 d of life as previously reported (Elsohaby et al., 2019).

Blood sampling

All lambs were blood sampled at 24±1 h after birth, provided they had received colostrum, by jugular vein puncture into an 8.5 mL clot-activated tube (BD Vacutainer, BD, Franklin Lakes, NJ). Serum was obtained following centrifugation at 4000 rpm for 30 minutes and stored at -20^{o}C until analyses.

IgG assays

A commercially available ELISA test (Bio-X Competitive ELISA Kit for Ovine blood serum IgG Assay-BIO K 350, Bio-X Diagnostics, Belgium) was used to measure serum IgG concentrations in lambs. The test was performed and interpreted according to the manufacturer's instructions.

Clinical examination

Routine clinical examinations of lambs were undertook to determine clinical problems (diarrhea, pneumonia, suspected septicemia, fatigue-anorexia syndrome, other or unknown) in neonatal lambs based on case definition as previously described (Gökçe and Erdoğan, 2009). Lamb health was monitored on daily visits during the neonatal period (0-28 days) and every two days after neonatal period until weaning.

Statistical analysis

Data was entered on to a database (Microsoft access). The distribution of the data was tested for conformity to a normal distribution by the Shapiro-Wilk test. Mean ± SE (standard error) values for serum IgG concentrations and growth performance (ADG and WG) was calculated. The results of clinical examination were categorized in term of health as healthy and sick and life period as the neonatal (first four weeks of life) and postneonatal (the period from 5 to 12 weeks after birth). An independent two-sample t-test was used to compare SIgGC-24 and in different categories of health status in both periods. In addition, the same test was used to compare growth performance (ADG and WG) and different categories of health status such as diarrhea and pneumonia in neonatal and postneonatal periods. An independent two-sample t- test was used to compare the growth performance (ADG and WG) of the lambs in neonatal and postneonatal period according to the post-colostral (24th hour after birth) IgG cut-off point (<600 versus >600 and <1000 versus >1000 mg/dl) (Gilbert et al., 1988; Britti et al., 2005; Gökçe et al., 2019). Correlations between growth performance and SIgGC-24 for selected diseases were determined using Pearson correlation test. Lambs that died, sold or not measured between the two periods were excluded from the growth performance analyses. P value <0.05 was considered as significant.

Results

Health status

The morbidity and mortality rates in the neonatal period were 17.3% (60/347) and 3.7% (13/347) respectively. The proportions of diarrhoea, pneumonia, suspected septicaemia and fatigue anorexia syndrome (FAS) in neonatal lambs were 9.2% (32/347), 1.7% (6/347), 3.2% (11/347) and 3.2% (11/347) respectively. Of the deaths in this period, 10 lambs died of suspected of septicemia and 9 in the first week of life.

The proportions of sick and dead lambs in the post neonatal period were 32.4% (108/333) and 4.5% (15/333) respectively. Most common postneonatal health problems were diarrhoea (18.6%, 62/333), pneumonia (7.5%, 25/333), suspected septicemia (1.2%, 4/333) and others/unknown causes (5.1%, 17/333).

Growth performance and IgG concentrations

The serum IgG concentration at 24 hours after birth (SIgGC-24) ranged from 8 to 5302 mg/mL (2199±1160). The mean live body weight measured at birth, 28 and 84 days after birth was 4.06±0.646 g (2.260 to 5.900 g), 9.281±1.164 g (5.800 to 14.020 g) and 20.789±4.057 g (11.850 to 29.800 g), respectively. Mean ADG for 0-28, 29-84 and 0-84 days were 0.184±0.047 g/d (0.103 to 0.449 g/d), 0.210±0.044 g/d (0.105 to 0.449g/d), and 0.247±0.048 g/d (0.141 to 0.355 g/d), respectively.

A comparison of growth performance in relation to the health status of pre-weaned lambs is shown in Table 1. Growth performance (BW and ADG) of lambs with diarrhoea and FAS in the neonatal period and with pneumonia in the postneonatal period was significantly lower than that of healthy lambs of the same period (P<0.05).

Changes in growth performance at different serum IgG thresholds are shown in Figure 1. The BW of lambs with SIgGC-24 <600 mg/dL was significantly lower (P<0.001) at 28 and 84 days of age (5.91 kg and 14.26 kg, respectively) than that of lambs with SIgGC-24 >600 mg/dL (8.91 kg and 20.53 kg, respectively) (Figure 1A). Similarly, lambs with SIgGC-24 <600 mg/dL had significantly lower ADG from days 0-28, 29-84 and 0-84 of age (0.07 g, 0.16 g and 0.17 g, respectively) than lambs with SIgGC-24 >600 mg/dL on the same days (0.18 g, 0.21 g and 0.24 g, respectively) (P<0.001) (Figure 1B).

Lambs with SIgGC-24 <1000 mg/dL had significantly lower BW on days 28 and 84 (7.14 kg and 16.19 kg, respectively) than those with SIgGC-24 >1000 mg/dLon the same days (8.98 kg and 20.72 kg, respectively), (P<0.001) (Figure 1C). Similarly, lambs with

Table 1. Growth performance of pre-weaned lambs in relation to health status

	Period*			
	Neonatal (first 4 weeks after birth)		Postneonatal (5-12 weeks after birth)	
Clinical Diagnosis	**ADG (g/day) (Mean ± SE)**	**BW (kg) (Mean ± SE)**	**ADG (g/day) (Mean ± SE)**	**BW (kg) (Mean ± SE)**
Diarhoea	0.137±0.01 (n=30) **P<0.001**	7.7±0.39 (n=30) **P=0.002**	0.173±0.007 (n=60) **P<0.001**	9.73±0.41 (n=60) **P<0.001**
Pneumonia	0.113±0.03 (n=6) **P=0.126**	6.77±0.89 (n=6) **P=0.126**	0.182±0.009 (n=20) **P=0.018**	10.22±0.55 (n=20) **P=0.018**
FAS*	0.133±0.02 (n=9) **P=0.048**	7.03±0.76 (n=9) **P=0.049**	None	None
Other	None	None	0.193±0.006 (n=12) **P=0.326**	10.84±0.35 (n=12) **P=0.359**
Healthy (n)	0.178±0.003 (n=272)	9.09±0.11 (n=272)	0.28±0.003 (n=213)	12.15±0.19 (n=213)

Mean ± SE (standart error), n= number of lambs, None: no cases, ADG=Average Daily Gain, BW=Body Weight, FAS=Fatigue-Anorexia Syndrome (Mismothering, hypotermia and starvation), significantly different from healthy lambs. * Exclusion of lambs unavailable (death, sale, not measured) between neonatal and post-neonatal period accounts for the difference in numbers.*

SIgGC-24 <1000 mg/dL was significantly lower the ADG on days from 0-28, 29-84 and 0-84 age (0.13 g, 0.16 g and 0.19 g, respectively) than those with SIgGC-24 >1000 mg/dL (0.18 g, 0.21 g and 0.25 g, respectively), (P<0.001) (Figure 1D).

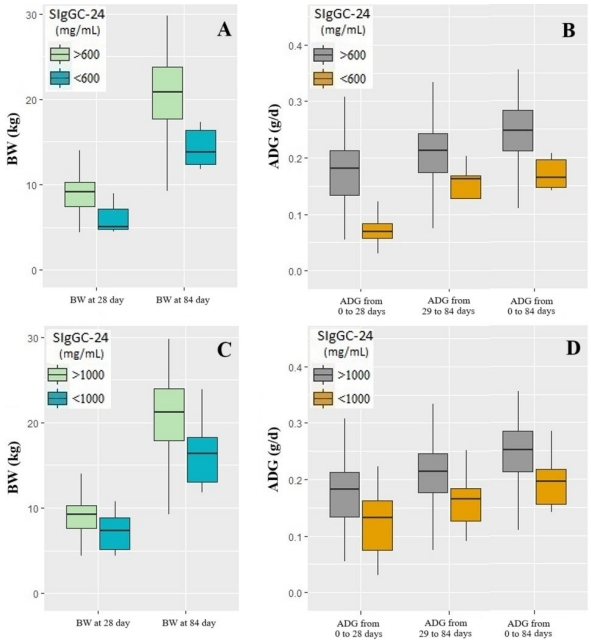

Figure 1: Box plots illustrating variability in (A, C) body weight (BW) at 28 days and weaning age; average daily gain (ADG) from 0 to 28, 29 to 84, and 0 to 84 days of life (B, D) in Akkaraman lambs with adequate transfer of passive immunity (IgG>600 and IgG>1000 mg/dL) and failure of transfer of passive immunity (IgG<600 and IgG<1000 mg/dL).

Discussion and Conclusion

Growth performance and morbidity rates have been shown to be suitable indicators for assessing lamb health and welfare at flock level. Growth performance reflects appropriate nutrition and feeding strategies for lambs, but it can be affected if lambs are sick or stressed. Colostrum management is also an important predictor of health and growth performance and should be assessed early in life. Passive transfer of colostral immunity (PTCI) may better reflect health and flock management, whereas FPT requires monitoring of individuals that may require additional treatment and preventive measures (Gökçe et al., 2019). In addition to the implications for infections, lambs with sufficient colostral immunoglobulins may develop a more efficient metabolic system and achieve normal growth, in contrast to lambs with FPT who have reduced feed intake (Massimini et al., 2007).

The present study evaluated passive immunity and diseases on growth performance of pre-weaned lambs. Studies to date have reported that there is no single threshold value of IgG indicating FPT in lambs (Gilbert et al., 1988; Britti et al., 2005; Gökçe et al., 2019). Therefore, two different previously suggested values threshold (serum IgG <600 mg/mL and <1000 mg/mL) were used in our study.

Despite the ambiguity of the results, studies, especially in calves (Caldow et al., 1988), disclosed a positive association between sufficient colostral immunity and growth performance (Atkinson et al., 2017; Al and Sayed-Ahmed, 2020), while FPT together with diseases reduced growth performance (Gokce et al., 2013; Windeyer et al., 2014). This was the case in our study where FPT and concurrent disease were associated with poor growth performance in pre-weaned lambs. Poor growth performance is to be

expected as FPT causes an inability to overcome infections (diarrhoea, pneumonia), resulting in disease onset, which consequently leads to reduced intestinal nutrient utilization and feed intake, thus depriving the animal of nutrients required for growth and immunity. This may explain the reduced growth performance of lambs with FPT compared to those with adequate PTCI in our study. Similar associations were reported by reseracher in calves and lambs (Elsohaby et al., 2019; Pesca et al., 2020). Studies also reported local protective action of colostrum in the intestine (Nocek et al., 1984) and enhanced growth through morphological changes and functional maturation of the gastrointestinal tracts of neonates (Gascoigne and Davies, 2019; Elsohaby et al., 2019; Bond, 2020). Since colostrum is known to contain many substances (lymphocytes, cytokines, lactoferrin, acute phase proteins, growth factors, fat, lactose, vitamins, minerals, carnitine, antioxidant, enzymes, etc.) in addition to immunoglobulins (Mastellone et al., 2011; Hernández-Castellano et al, 2014, Hedegaard and Heegaard, 2016; Ahmadi et al., 2016; Gökçe et al., 2021a; Gökçe et al., 2021b; Agenbag et al., 2021; Gökçe et al., 2022), it is possible that colostrum could have influenced the growth response or the immune and metabolic systems of the Akkaraman lambs in this study

In conclusion, our results indicate that low serum IgG concentration in lambs reduces growth performance in preweaning lambs, as well as pneumonia, diarrhoea and FAS. It may also suggest that appropriate colostrum management may help to maintain health and growth performance, thus improving productivity and profitability of preweaning lambs on sheep farms. However, further studies are needed to better understand the relationship between growth performance, disease and FPT.

References

Agenbag B, Swinbourne AM, Petrovski K, van Wettere WH. Lambs need colostrum: A review. Livest Sci 2021; 251: 104624.

Ahmadi M, Boldura O, Milovanov C, Dronca D, Mircu C, Hutu I, Tulcan C. 2016. Colostrum from different animal species-A product for health status enhancement. Bulletin UASVM Anim Sci Biotech 2016; 73(1): 2016.

Ali MAE, Sayed-Ahmed ME. Relationship between passive immunity levels and morbidity, mortality and growth rates of friesian calves in Egypt. J Anim Poult Prod 2020; 11(12): 629-36.

Alves AC, Alves NG, Ascari IJ, Junqueira FB, Coutinho AS, Lima RR, Abreu LR. Colostrum composition of Santa Inês sheep and passive transfer of immunity to lambs. J Dairy Sci 2015; 98(6): 3706 -16.

Andrés S, Jiménez A, Sánchez J, Alonso JM, Gómez L, Lopez F, Rey J. Evaluation of some etiological factors predisposing to diarrhoea in lambs in "La Serena" (Southwest Spain). Small Rum Res 2007; 70(2-3): 272-5.

Atkinson DJ, Von Keyserlingk MAG, Weary DM. Benchmarking passive transfer of immunity and growth in dairy calves. J Dairy Sci 2017; 100(5): 3773-82.

Aydogdu U, Coskun A, Yuksel M, Basbug O, Agaoglu ZT. The effect of dystocia on passive immune status, oxidative stress, venous blood gas and acid-base balance in lambs. Small Rum Res 2018; 166: 115-20.

Bond C. Evaluation of lamb colostrum supplements. Vet Rec 2020; 187(11): e100.

Britti D, Massimini G, Peli A, Luciani A, Boari A. Evaluation of serum enzyme activities as predictors of passive transfer status in lambs. J Am Vet Med Assoc 2005; 226(6): 951-5.

Caldow GL, White DG, Kelsey M, Peters AR, Solly KJ. Relationship of calf antibody status to disease and performance. Vet Rec 1988; 122(3): 63-5.

Elsohaby I, Cameron M, Elmoslemany A, McClure J, Keefe G. Effect of passive transfer of immunity on growth performance of preweaned dairy calves. Can J Vet Res 2019; 83(2): 90-6.

Gascoigne E, Davies P. An approach to neonatal lamb post-mortem examinations. Livestock 2019; 24(4): 193-8.

Gilbert RP, Gaskins CT, Hillers JK, Parker CF, McGuire TC. Genetic and environmental factors affecting immunoglobulin G1 concentrations in ewe colostrum and lamb serum. J Anim Sci 1988; 66(4): 855-63.

Gokce E, Atakisi O, Kirmizigul AH, Unver A, Erdogan HM. Passive immunity in lambs: Serum lactoferrin concentrations as a predictor of IgG concentration and its relation to health status from birth to 12 weeks of life. Small Rum Res 2014; 116(2-3): 219-28.

Gokce E, Erdogan HM. An epidemiological study on neonatal lamb health. Kafkas Univ Vet Fak Derg 2009; 15(2): 225-36.

Gokce E, Kirmizigul AH, Atakisi O, Kuru M, Erdogan HM. Passive immunity in lambs: Colostral and serum γ-glutamyltransferase as a predictor of IgG concentration and related to the diseases from birth to 12 weeks of life. Vet Med 2021a; 66(2): 45-57.

Gökçe E, Atakişi O, Kırmızıgül AH, Erdoğan HM. Risk factor sassociated with passive immunity, health, birth weight and growth performance in lambs: II. Effects of passive immunity and some risk factors on growth performance during the first 12 weeks of life. Kafkas Univ Vet Fak Derg 2013; 19(4): 619-27.

Gökçe E, Atakişi O, Kırmızıgül AH, Erdogan HM. Interrelationships of serum and colostral IgG (passive immunity) with total protein concentrationsand health in lambs. Kafkas Univ Vet Fak Derg 2019; 25(3): 387-96.

Gökçe E, Cihan P, Atakişi E, Kırmızıgül AH, Erdoğan HM. Oxidative stress in neonatal lambs and its relation to health status and passive colostral immunity. Vet Immunol Immunopathol 2022; 251: 110470.

Gökçe E, Sözmen M, Gülmez C, Bozukluhan B, Gökce G, Atakişi E, Erdoğan HM. Carnitine concentrations in healthy and septicaemia suspected neonatal calves and its relation to passive immunty. Turk J Vet Anim Sci 2021b; 45(2): 229-37.

Hedegaard CJ, Heegaard PM. Passive immunisation, an old idea revisited: basic principles and application to modern animal production systems. Vet Immunol Immunopathol 2016; 174: 50-63.

Hernández-Castellano LE, Almeida AM, Ventosa M, Coelho AV, Castro N, Argüello A. The effect of colostrum intake on blood plasma proteome profile in newborn lambs: Low abundance proteins. BMC Vet Res 2014; 10(1):1-9.

Herndon CN, Shanthalingam S, Knowles DP, Call DR, Srikumaran S. Comparison of passively transferred antibodies in bighorn and domestic lambs reveals one factor in differential susceptibility of these species to Mannheimia haemolytica-induced pneumonia. Clin Vaccine Immun 2011; 18(7): 1133-8.

Johnson T, Jacobson BT, Jones, K, Mosdal C, Jones S, Vitkovic M, Bimczok D. Transfer and persistence of bovine immunoglobulins in lambs fed a colostrum replacer. Vet Rec 2022; 191(10): 1974.

Kenyon PR, Roca Fraga FJ, Blumer S, Thompson AN. Triplet lambs and their dams–a review of current knowledge and management systems. New Zealand J Agric Res 2019; 62(4): 399-437.

Kozyr VS, Antonenko PP, Mylostyvyi RV, Suslova NI, Skliarov PM, Reshetnychenko OP, Pushkar TD, Sapronova VO, Pokhyl OM. Effect of herbal feed additives on the quality of colostrum, immunological indicators of newborn calves blood and growth energy of young animals. Theor Appl Vet Med 2019; 7 (3): 137-42.

Massimini G, Mastellone V, Britti D, Lombardi P, Avallone L. Effect of passive transfer status on preweaning growth performance in dairy goat kids. J Am Vet Med Assoc 2007; 231(12): 1873-7.

Massimini G, Britti D, Peli A, Cinotti S. Effect of passive transfer status on preweaning growth performance in dairy lambs. J Am Vet Med Assoc 2006; 229(1): 111-5.

Mastellone V, Massimini G, Pero ME, Cortese L, Piantedosi D, Lombardi P, Avallone L. Effects of passive transfer status on growth performance in buffalo calves. Asian-Australas J Anim Sci 2011; 24(7): 952-6.

Nocek JE, Braund DG, Warner RG. Influence of neonatal colostrum administration, immunoglobulin, and continued feeding of colostrum on calf gain, health, and serum protein. J Dairy Sci 1984; 67(2): 319-33.

Pesca C, Forti K, Felici A, Scoccia E, Forte C, Antenucci P, Crotti S. Enzootic pneumonia in sheep: ewe and lamb immune response after Mannheimia haemolytica vaccine administration under field condition in Italy. Large Anim Rev 2020; 26(2): 73-6.

Santiago MR, Fagundes GB, do Nascimento DM, Faustino LR, da Silva CMG, Dias FEF, Cavalcante TV. Use of digital Brix refractometer to estimate total protein levels in Santa Inês ewes' colostrum and lambs' blood serum. Small Rum Res 2020; 182: 78-80.

Tsiligianni T, Dovolou E, Amiridis GS. Efficacy of feeding cow colostrum to newborn lambs. Livestock Sci 2012; 149(3): 305-9.

Turquino CF, Flaiban KKM, Lisbôa JAN. Transferência de imunidade passiva em cordeiros de corte manejados extensivamente em clima tropical. Pesqui Vet Bras 2011; 31(3): 199-205.

Vatankhah, M. Relationship between immunoglobulin concentrations in the ewe's serum and colostrum, and lamb's serum in Lori-Bakhtiari sheep, Iran. J Appl Anim Sci 2013; 3(3): 539-44.

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(2): 2