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Scientific Article

Correlation between serum biochemical parameters and colostrum and milk composition of lactating sows

Correlação entre parâmetros bioquímicos séricos e composição do colostro e do leite de suínas lactantes

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ABSTRACT - Monitoring the serum biochemical parameters of sows' blood, colostrum, and milk during and after calving aims to guide and understand the physiological, nutritional, and health status of peri-calving sows. Thus, this study aimed to analyze and correlate serum biochemical parameters and the composition of colostrum and milk of lactating sows. Colostrum, milk, and blood from 13 sows were collected after the birth of the first calf before suckling (M1) and 72 hours after M1 (M2). Crude protein (CP), fat content (FAT), lactose (LAC), nonfat solids (NFS), total solids (TS), and gamma-glutamyltransferase (GGT) activity concentrations were determined in colostrum and milk samples. The blood biochemical profiles analyzed were GGT, glucose (GLU), total cholesterol (COL), triglycerides (TRI), creatine kinase (CK), total protein (TP), albumin (ALB), globulins (GLO), and the albumin/globulin ratio (A/G). Descriptive and correlation analyses were performed using the SAS statistical program (9.3). Significant differences were observed in the composition of colostrum and milk. COL and CK in the blood showed significant differences between M1 and M2. There was no correlation (P>0.05) between serum biochemical and colostrum bromatological parameters. ALB correlated positively with LAC and NFS. GLO correlated negatively with LAC and NFS. The A/G ratio showed a positive correlation with LAC. These correlations suggest that monitoring serum biochemical parameters may be helpful for the health surveillance of lactating sows and assessing the quality of colostrum and milk.

Keywords: Monitoring. Sows. Animal production. Animal health.

RESUMO – Monitorar os parâmetros bioquímicos séricos do sangue, colostro e leite de fêmeas durante e após o parto visa orientar e entender o estado fisiológico, nutricional e de saúde em suínos no periparto. Assim, objetivou-se analisar e correlacionar parâmetros bioquímicos séricos e a composição do colostro e leite de fêmeas suínas lactantes. Colostro, leite e sangue de 13 matrizes suínas foram coletados em dois momentos: após o nascimento do primeiro filhote antes de mamar (M1) e 72 horas após M1 (M2). Nas amostras de colostro e leite, concentrações de proteína bruta (CP), teor de gordura (FAT), lactose (LAC), sólidos não gordurosos (NFS), sólidos totais (TS) e a atividade de gama glutamiltransferase (GGT) foram determinados. Os perfis bioquímicos sanguíneos analisados foram: GGT, glicose (GLU), colesterol total (COL), triglicerídeos (TRI), creatina quinase (CK), proteína total (TP), albumina (ALB), globulinas (GLO) e a razão albumina/globulina (A/G). Análises descritivas e de correlações foram realizadas com o programa estatístico SAS (9.3). Diferenças significativas foram observadas na composição do colostro e do leite. O COL e a CK no sangue mostraram diferenças significativas entre M1 e M2. Não houve correlação (P>0,05) entre os paramentos bioquímicos séricos com os parâmetros bromatológicos do colostro. A ALB correlacionou positivamente com LAC e NFS. A GLO correlacionou negativamente com LAC e NFS. A relação A/G apresentou correlação positiva com LAC. Essas correlações sugerem que o monitoramento dos parâmetros bioquímicos séricos pode ser útil para a vigilância da saúde das suínas lactantes e para avaliar a qualidade do colostro e leite.

Palavras-chave: Monitorização. Porcas. Produção animal. Saúde animal.

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INTRODUCTION

Despite the steady expansion of pig farming, the industry still faces persistent challenges, such as transboundary diseases, variations in feed costs, and pre-weaning mortality of piglets (TSAI et al., 2024). Monitoring pig health through clinical and laboratory diagnostics is an important practice in pig farming. It ensures animal health and welfare and promotes early diagnosis and effective treatment of various infectious diseases and nutritional and metabolic disorders (GOECKE et al., 2020).

The analysis of blood serum biochemical parameters, such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), and gamma-glutamyltransferase (GGT) activity, as well as the concentration of bilirubin, albumin, glucose, triglycerides, and cholesterol in the blood serum, allows a global assessment of liver processes to evaluate the animals' health status (DJOKOVIC et al., 2013). Milk parameters originate from blood and feed components. Clarifying the appropriate relationships between these parameters individually in blood and milk helps understand the animals' health and production status (NOZAD et al., 2007).

The activities of the enzymes ALT, AST, GGT, and FAL were monitored in the milk and blood serum of cows. The correlation analysis and regressive models showed a close relationship between the values of these parameters observed in the two types of samples (MOHAMED, 2014). In this context, there is a gap in the literature regarding the simultaneous monitoring of serum biochemical parameters and the composition of colostrum and milk in pigs, especially during calving and postpartum periods.

The current production chain has increasingly sought to increase the number of piglets born, which can further affect piglet maintenance during lactation, especially in the first three days of life (MUNS; NUNTAPAITOON; TUMMARUK, 2016). In this sense, monitoring the dynamics of the sows' serum biochemical parameters during and after calving allows us to guide their physiological, nutritional, and health status and provide subsidies on the quality and nutritional efficiency of colostrum and milk (KOSTER et al., 2019). Thus, this study aimed to analyze and correlate serum biochemical parameters and the bromatological composition of the colostrum and milk of lactating sows.

MATERIAL AND METHODS

All procedures were submitted and executed following the guidelines of the Ethics Commission on Animal Use (CEUA) of the Universidade Federal Rural do Semi-Árido, identified by protocol 22/2021.

The experiment was conducted in a commercial farm located in the district of Croatá, municipality of São Gonçalo do Amarante, state of Ceará, Brazil. Thirteen hyperproliferous commercial line sows (TN70, Topigs Norvins) with three to five calves were used. The sows were transferred to the calving rooms at approximately 110 days of gestation, where they remained until weaning.

The sows were selected based on body weight and calving order. Feeding followed the recommendations of the TOPIGS NORSVIN manual (2023), with some adaptations. The sows received corn and soybean meal-based bran feed formulated to meet the nutritional requirements of lactating sows, as described in the technical manual of the lineage (TOPIGS NORSVIN, 2023, Table 1). A total of 2.0 kg of lactation feed was provided until calving. The feed supply was adjusted gradually during the lactational period: on the first day after delivery, 1.0 kg; on the second day, 2.0 kg; and on the third day, 3.0 kg. The daily amount of feed was divided into four feedings, administered at 6h, 10h, 16h, and 22h. The sows had access to water at will.

Table 1. Components of the diet for lactating sows.

Ingredients	Lactation
Corn 8% CP	54.43
Soybean meal 46% CP	32.10
Wheat flour	2.00
Lignocellulose †	0.20
Sugar	3.00
Soybean oil	3.80
Vitamin D250 (25OHD3) ‡	0.03
Vitamin and mineral premix ‡‡	4.00
Mycotoxin adsorbent	0.10
DL- Methionine	0.05
Lysine 70% §	0.09
Guanidinoacetic acid (GAA 96%) ¶	0.10
Biotin 2%	0.01
Probiotic †††	0.01
Probiotic ¶¶	0.10
Total	100.00
Nutritional composition	
Metabolizable energy (Kcal/kg)	3,450
Crude protein (%)	19.81
Calcium (%)	0.95
Available phosphorus (%)	0.44
Digestible lysine (%)	0.97
Methionine + digestible cystine (%)	0.57
Digestible threonine (%)	0.63
Digestible tryptophan (%)	0.21
Digestible arginine (%)	1.31
Digestible valine (%)	0.82

† Source of fiber; ‡ Vitamin D250 supplement: (25-OH-D3) (physiological precursor of the active hormone – vitamin D3) as the active ingredient; ‡‡ Content per kilogram of product: Folic Acid (15 mg/kg), Pantothenic Acid (400 mg/kg), BHT (100 mg/kg), Biotin (10 mg/kg), Calcium (200 mg/kg), Cobalt (5 mg/kg), Copper 1,500 mg/kg), Choline (10 mg/kg), Chromium (5 mg/kg), Iron (1750 mg/kg), Phytase (12.50 FTU/kg), Phosphorus (82 g/kg), Iodine (25 mg/kg), L-carnitine (1,261 mg/kg), Manganese (1,000 mg/kg), Niacin (750 mg/kg), Selenium (7.5 mg/kg), Sodium (48.75 g/kg), Vitamin A (250,000 UI/kg), Vitamin B1 (38 mg/kg), Vitamin B12 (500 mcg/kg), Vitamin B2 (125 mg/kg), Vitamin B6 (25 mg/kg), Vitamin D3 (40,000 UI/kg), Vitamin E (1,500 UI/kg), Vitamin K3 (50mg/kg); § Contains 70% lysine; ¶ 96% guanidinoacetic acid (GAA) as a precursor of creatine; ††† *Bacillus subtilis* e *B. licheniformes*; ¶¶ Live strain *Saccharomyces cerevisiae*.

Production performance analysis

The sows were weighed before transfer, in the maternity, and after calving. In the latter, weight was estimated by subtracting the weight obtained in the maternity from the weight of the piglets and placenta. The calving duration was measured using the birth of the first piglet, the litter's size and weight, and the placenta's weight (Table 2).

Colostrum and milk analysis

Samples of milk secretion were collected after the birth of the first piglet before suckling (M1) and 72 hours after M1 (M2) by applying 10 IU of injectable oxytocin in the auricular vein. Approximately 80 mL of milk were collected in sterilized jars by manual milking of the functional glands of each sow, homogenized, and stored at -20 °C for subsequent analysis.

Crude protein (CP), fat content (FAT), lactose (LAC), nonfat solids (NFS), and total solids (TS) were determined by infrared absorption (Bentley 2000®, Bentley Instruments Inc., Chaska, MN, USA). To evaluate the transfer of passive immunity to neonates through colostrum and milk, the gamma -glutamyltransferase (GGT) activity in whey was analyzed using commercial kits (®Vida Biotecnologia) under enzymatic colorimetric end-point or kinetic methods on a semi-automatic biochemical analyzer.

The equation suggested by Theil et al. (2014) was used to estimate the sow's colostrum production, in which *IC* is the intake of colostrum, t is the duration of feeding, P_{24} is the weight at 24 hours after birth, P_0 is the weight at birth, and t_{fs} it is the interval from birth to the first feeding. The sow's production is obtained after estimating the individual consumption of the piglets.

$$\text{IC} = -217.4 + 0.217t + 1861019 \times \frac{P_{24}}{t} + P_0\left(54.80 - \frac{1861019}{t}\right) \times \left(0.9985 - 3.7 \times 10^{-4} t_{fs} + 6.1 \times 10^{-7} t_{fs}^2\right)$$

Blood parameter analysis

Blood samples from the sows were collected after the birth of the first calf before suckling (M1) and 72 hours after M1 (M2). The collection was performed by physical containment and puncture of the auricular vein using 5 mL syringes and 25 mm x 0.70 mm hypodermic needles, later transferred to blood collection tubes with a coagulation activator for serum separation. Subsequently, the samples were transferred to microtubes and frozen (-20 ºC) until analysis. The following serum biochemical parameters were analyzed: gamma-glutamyltransferase (GGT), glucose (GLU), total cholesterol (COL), triglycerides (TRI), creatine kinase (CK), total protein (TP), albumin (ALB), globulin (GLO), and the albumin/globulin (A/G) ratio. In a semi-automatic biochemical analyzer, direct analyses were performed using commercial kits (®Vida Biotecnologia) under end-point colorimetric or kinetic enzymatic methods.

Statistical analysis

SAS Analytics Software (9.3) was used for statistical analysis. The descriptive analyses were obtained through the PROC UNIVARIATE procedure of the SAS (9.3), in which the maximum, minimum, mean, and standard deviation were obtained. The data were submitted to the Shapiro-Wilk Test at the level of 5% probability to verify data normality. Data with normal distribution were compared using the analysis of variance F-test. When possible, data that did not present normal distribution were normalized by the PROC RANK procedure, and the non-normalized data were compared by the KrusKal-Wallis test at the level of 5% probability. For correlation analysis, Pearson's test was used for parametric data, and Spearman's test was used for non-parametric data at a probability of 5%.

Pearson and Spearman correlation coefficients were obtained using the SAS PROC CORR procedure (9.3) and analyzed for intensity when P<0.05, according to Mukaka (2012), considering the variables FAT, CP, LAC, NFS, TS, GGT, GLU, COL, TRI, CK, GGT, TP, ALB, GLO, A/G.

RESULTS AND DISCUSSION

The productive performance of the sows (Table 2) showed a linear relationship between the litter's size and the calving duration, which is consistent with the literature (QUESNEL; FARMER; DEVILLERS, 2012). In our study, the maximum postpartum body weight was 284.24 kg, which is within the recommended standard for mothers of the same lineage, whose weight should vary between 270 kg and 295 kg for sows between three and five calvings (TOPIGS NORSVIN, 2023). Adherence to these standards suggests that the management and nutrition practices adopted in the study were adequate to keep the sows within the ideal weight range, which is fundamental to ensure their health and reproductive performance. Thus, maintaining sows within this postpartum weight pattern may reflect a good nutritional status during pregnancy and efficient management during calving, which may contribute positively to the quality of biochemical blood and bromatological parameters of the colostrum and milk (NOZAD et al., 2007; BELINSKAIA; VORONINA; GONCHAROV, 2021).

The high number of piglets (17.38) and the good colostrum production (5.91 kg) were within the standards observed for the category, where the average number of piglets can vary between 11.05 and 15.85 (MOREIRA et al., 2019), and the average amount of colostrum produced in 24 hours is 3.25 kg (QUESNEL; FARMER; DEVILLERS, 2012). However, colostrum intake can still be affected when relating the two parameters, considering there is significant competitiveness for the teats in large dairy farms (MOREIRA et al., 2019). In addition, in cases of prolonged calving, the last 20% to 30% of fetuses do not have access to high-quality colostrum, as the quantity and quality of colostrum decreases rapidly between 16 and 34 hours after the birth of the first piglet (THEIL; LAURIDSEN; QUESNEL, 2014). These factors can result in reduced immunity and the emergence of diseases during the growth/fattening phases (PELTONIEMI et al., 2021).

Regarding the colostrum (M1) and milk (M2) component parameters, FAT increased (P<0.05) by 3.54 percentage points. However, the CP, LAC, NFS, and TS concentrations decreased (P<0.05) by 2.94, 5.70, 9.39, and 5.92 percentage points, respectively. GGT concentrations did not differ (P>0.05) (Table 3). These results confirm the end of the transition between colostrum and milk (HURLEY, 2015).

Table 2. Characterization of sows' productive performance, including maximum, minimum, mean, and standard deviation (SD) values.

Parameters	Maximum	Minimum	Mean ± SD
Calving duration (min)	350.00	89.00	201.62 ± 90.53
Prepartum weight (kg)	311.70	236.20	274.68 ± 20.48
Parity order (n)	5.00	3.00	4.00 ± 0.91
Postpartum weight (kg)	284.24	214.58	248.57 ± 19.43
Placental weight (kg)	5.28	3.49	4.13 ± 0.51
Post-weaning sow weight (kg)	281.70	210.80	243.93 ± 19.18
Litter size (n)	24.00	13.00	17.38 ± 3.20
Average litter weight (kg)	30.54	17.36	21.98 ± 3.83
Colostrum production in 24h (kg)	7.91	4.18	5.91 ± 1.14

Table 3. Maximum, minimum, mean, and standard deviation (SD) values for the variables of the colostrum (M1) and milk (M2) components of sows.

Parameters		Maximum	Minimum	Mean ± SD	*P* Value
FAT (%)	M1	5.17	1.19	3.18 ± 1.27	< 0.0001*
	M2	9.05	4.16	6.72 ± 1.56	
CP (%)	M1	8.40	6.23	7.64 ± 0.70	< 0.0001*
	M2	5.42	4.02	4.70 ± 0.45	
LAC (%)	M1	12.84	8.61	11.01 ± 1.30	< 0.0001*
	M2	6.23	4.42	5.31 ± 0.56	
NFS (%)	M1	24.31	16.30	20.87 ± 2.39	< 0.0001*
	M2	13.28	9.95	11.48 ± 0.99	
TS (%)	M1	27.72	19.17	24.04 ± 2.34	< 0.0001*
	M2	21.58	15.61	18.12 ± 2.17	
GGT (U/L)	M1	440.00	107.70	216.16 ± 89.80	0.1262
	M2	303.40	85.00	168.27 ± 67.02	

*Statistically significant, FAT – fat content, CP – Crude protein, LAC – lactose, NFS - nonfat solids, TS – total solids, GGT – gamma-glutamyltransferase.

The CP content was significantly higher in colostrum (7.64%) compared to milk (4.70%). This occurs because colostrum is rich in immunoglobulins and other proteins involved in immunity, such as lactoferrin and lysozyme, essential to provide passive immunity to the calf (HURLEY, 2015; THEIL; HURLEY, 2016). This is particularly important because neonates, such as pigs, are born with an immature immune system (ROTHKÖTTER; SOWA; PABST, 2002), considering that the type of placentation is epithelial-chorial, in which there is no mixture of maternal and fetal blood during gestation. Therefore, there is no placental transmission of γ-globulins (GONZÁLEZ; SILVA, 2017). Thus, at birth, the animal is entirely dependent on the passive transfer of maternal immunoglobulins through colostrum (MACIAG et al., 2022).

The fat contents were significantly higher in milk (6.72%) than in colostrum (3.18 %). This occurs because, initially, the primary function of colostrum is to provide immunity and essential nutrients (HURLEY, 2015). Energy and growth needs become priorities as the neonate's digestive and immune systems mature, increasing fat content (INDRIO et al., 2022).

Regarding the lactose content, the proportions were significantly higher in colostrum (11.01%) compared to milk (5.31%), which corroborates the findings of Chen et al. (2020), that the lactose content is highest (11.6%) in the first hours postpartum and gradually decreases over the first few days (5.98%-14 days), remaining at stable levels throughout lactation (6.07% - 21 days). The synthesis of lactose, the primary osmol in sow milk, is responsible for attracting water to the Golgi apparatus and secretory vesicles during milk synthesis (THEIL; HURLEY, 2016). In addition, bioactive carbohydrate-based components such as oligosaccharides are linked to lactose, which assists in absorbing minerals, especially calcium (MARTIN; LING; BLACKBURN, 2016).

Non-fat solids are determined by subtracting the fat percentage from the total solids. In colostrum, the content of non-fatty solids (20.87%) was significantly higher than milk's (11.48%). This shows that protein and lactose levels are higher in the first hours after calving, gradually reducing with time, while the amount of fat increases (THEIL; HURLEY, 2016; CHEN et al., 2020). Similarly, the total solids of colostrum (24.04%) were higher than milk's (18.12%). This higher content of total solids in colostrum occurs because the concentration of these components is higher in the first hours after calving since a significant part of these total solids is composed of non-fatty solids.

Although GGT concentrations did not differ statistically between colostrum and milk, the mean GGT content was higher in colostrum (216.16 U/L) than in milk (168.27 U/L). The reduction of GGT in milk relative to colostrum observed in this study is consistent with the findings of Baroza et al. (2019) in cows and goats, suggesting a mammalian-like pattern. GGT is involved in the breakdown of glutathione. The degradation of glutathione by GGT leads to the release of amino acids, such as cysteine, which are essential for various functions, including the synthesis of immunoglobulins in colostrum and the neurotransmitter hormone neurophysin, a polypeptide responsible for the transport of oxytocin from the hypothalamus to the posterior pituitary (GONZÁLEZ; SILVA, 2017). Therefore, the higher content of GGT in colostrum relative to milk indirectly indicates the transfer of passive immunity to piglets due to its enzymatic relationship with the synthesis of immunoglobulins. In addition, GGT indirectly participates in the transport and storage of oxytocin, which is responsible for milk secretion.

Regarding the analysis of serum biochemical parameters of sow blood in M1 and M2, CK and COL increased (P<0.05) in 1097.54 U/L and 17.44 mg/dL, respectively. The other parameters did not differ statistically (P>0.05) (Table 4).

Table 4. Maximum, minimum, mean, and standard deviation (SD) values for the variables of the serum biochemical components of the blood of sows in M1 and M2.

Parameters		Maximum	Minimum	Mean ± SD	*P* Value
GGT (U/L)	M1	104.98	9.41	63.46 ± 33.15	0.972
	M2	112.26	11.72	64.08 ± 35.65	
GLU (mg/dL)	M1	115.69	19.05	63.59 ± 34.53	0.352
	M2	92.16	15.95	49.28 ± 25.08	
COL (mg/dL)	M1	93.00	51.00	63.67 ± 13.64	0.010*
	M2	98.00	61.00	81.11 ± 11.68	
TRI (mg/dL)	M1	108.89	20.92	46.25 ± 29.53	0.310
	M2	131.37	25.60	61.69 ± 32.71	
CK (U/L)	M1	1184.00	707.00	932.13 ± 170.12	0.005*
	M2	3693.00	799.00	2,029.67 ± 980.27	
TP (g/dL)	M1	11.10	6.90	8.09 ± 1.35	0.271
	M2	9.40	7.60	8.16 ± 0.58	
ALB (g/dL)	M1	7.40	4.58	6.34 ± 0.77	0.788
	M2	7.10	4.56	6.29 ± 0.89	
GLO (g/dL)	M1	5.07	0.32	1.75 ± 1.48	0.849
	M2	3.55	0.60	1.87 ± 1.12	
A/G	M1	20.88	1.19	6.82 ± 6.03	0.793
	M2	11.83	1.33	5.20 ± 4.00	

*Statistically significant, GGT – gamma-glutamyltransferase, GLU – glucose, COL – total cholesterol, TRI – triglycerides, CK – creatine kinase, TP – total protein, ALB – albumin, GLO – globulin, A/G – albumin/globulin ratio.

The statistically significant differences observed in serum biochemical parameters, such as COL and CK, can be attributed to the abrupt change in the sows' physiological state. This change is consistent with what was reported by González and Silva (2017), who highlight that a series of factors such as breed, age, environment, stress, and physiological state of the animal influence the change in biochemical parameters.

Increased serum COL levels in the blood (81.11 mg/dL) 72 hours after calving may be a consequence of increased intestinal lipid absorption (YAN; MENG; KIM, 2012), added to its synthesis by the liver (GONZÁLEZ; SILVA, 2017). Both mechanisms are related to increased fat in the milk, whereas the maturation of this compound is linked to increased fat content (HURLEY, 2015).

The analysis of the serum's biochemical profile also revealed a high activity of the enzyme CK, with high concentrations in the serum during calving (932.13 mg/dL) and even higher values after calving (2029.67 mg/dL). CK is an enzyme derived from muscle tissue, which is elevated a few hours after a muscle injury, reaching its maximum value in approximately 12 hours. The serum increase in this enzyme is related to events such as mobilization of muscle proteins, intense physical exercise, prolonged labor, myositis, contractions, muscle bruises and traumas, and myocardial infarction, among others (GONZÁLEZ; SILVA, 2017). In commercial pig farming, sows are kept in cages where they spend most of their time lying down, getting up only for physiological needs (PEDERSEN, 2018). The prolonged time in decubitus, low muscle activity, and associated catabolism may justify the significant increase in serum levels of this enzyme in the blood during maternity. Given the above, CK can be considered a sensitive indicator of well-being for lactating sows.

Although there was no difference between calving and 72 hours postpartum, the serum GGT content showed high values (63.46 U/L and 64.08 U/L, respectively) compared to the standard established for the porcine species (10-60 U/L)

(KANEKO; HARVEY; BRUSS, 2008). This increase may indicate the ability to transfer immunity to the milk through colostrum, the period of highest concentration of this enzyme due to high protein metabolism and increased immunoglobulins (ZANELLO et al., 2013). Thus, the high concentration of plasma GGT in sows during and after calving may partially help us infer the better composition of colostrum and milk, passive immunity, and the development of neonates observed in this study.

Although the serum ALB content did not vary significantly between calving (6.34 g/dL) and 72 hours later (6.29 g/dL), they were higher than that established for the species as a reference (1.80 - 3.30 g/dL) (KANEKO; HARVEY; BRUSS, 2008). This suggests hyperproteinemia, specifically hyperalbuminemia, which can be caused by various factors, including dehydration (GONZÁLEZ; SILVA, 2017) and the animal's good nutritional status (BELINSKAIA; VORONINA; GONCHAROV, 2021). This explanation is plausible for the females in this study since physical exertion during calving can cause a slight degree of dehydration, and there is a more significant mobilization of water for milk production during lactation (TIAN et al., 2022).

No significant correlation (P>0.05) was observed between the analyzed correlations between serum biochemical parameters and colostrum bromatological parameters (Table 5). The absence of correlation can be attributed to metabolic and physiological factors that independently influence these two sets of variables. Serum biochemical parameters reflect the sows' overall metabolic and nutritional status at the time of blood collection (DJOKOVIC et al., 2013), while the composition of colostrum is primarily determined by the local activity of the mammary gland (HURLEY; THEIL, 2011). Colostrum is a highly dynamic product whose composition varies rapidly in the first hours after calving (THEIL; LAURIDSEN; QUESNEL, 2014). This suggests that the interaction between systemic metabolism and colostrum production is more complex and multifactorial than a linear relationship between the evaluated parameters.

Table 5. Pearson's correlation coefficients between serum biochemical parameters of blood and bromatological parameters of the colostrum of sows (n=13).

Parameters	GGT (U/L)	GLU (mg/dL)	COL (mg/dL)	TRI (mg/dL)	CK (U/L)	TP (g/dL)	ALB (g/dL)	GLO (g/dL)	A/G
GGT (%)	-0.62	-0.16	-0.30	-0.50	0.56	-0.14	0.57	-0.42	-0.09
FAT (%)	-0.12	0.47	-0.51	-0.48	0.00	0.10	0.70	-0.57	0.49
CP (%)	-0.26	-0.14	0.27	0.50	0.09	0.24	-0.04	0.26	-0.01
LAC (%)	-0.23	-0.22	0.40	0.61	0.09	0.21	-0.24	0.42	-0.16
NFS (%)	-0.27	-0.16	0.31	0.53	0.10	0.23	-0.15	0.36	-0.09
TS (%)	-0.26	0.04	0.00	0.24	0.05	0.28	0.26	0.02	0.20

GGT – gamma-glutamyltransferase, GLU – glucose, COL – total cholesterol, TRI – triglycerides, CK – creatine kinase, TP – total protein, ALB – albumin, GLO – globulin, A/G – albumin/globulin ratio, FAT – fat content, CP – crude protein, LAC – lactose, NFS - nonfat solids, TS – total solids.

There was no correlation of GGT, GLI, COL, TRI, CK, and TP with the other parameters analyzed in milk regarding the correlations analyzed between serum biochemical parameters and milk bromatological parameters. ALB showed a positive and significant correlation with milk LAC (r=0.84 and p=0.009) and NFS (r=0.76 and p=0.049). However, GLO correlated negatively and significantly with milk LAC (r=-0.93 and p=0.001) and NFS (r=-0.79 and p=0.036). The A/G ratio showed a positive and significant correlation with the milk's LAC (r=0.95 and p=0.001) (Table 6).

Table 6. Spearman's correlation coefficients between blood serum biochemical parameters and milk composition parameters of sows 72 hours after calving (n=13).

Parameters	GGT (U/L) †	GLU (mg/dL)	COL (mg/dL)	TRI (mg/dL)	CK (U/L)	TP (g/dL)	ALB (g/dL) †	GLO (g/dL)	A/G
GGT (%)	-0.18	0.13	-0.28	-0.15	0.46	-0.04	0.00	0.22	-0.08
FAT (%)	0.02	-0.02	-0.07	-0.26	0.36	-0.25	0.04	-0.10	0.02
CP (%)	0.36	-0.07	0.36	0.05	-0.19	-0.16	0.20	-0.38	0.24
LAC (%)	0.69	-0.50	-0.07	-0.36	-0.52	-0.28	0.84*	-0.93*	0.95*
NFS (%) †	0.61	-0.36	-0.21	-0.43	-0.14	-0.47	0.76*	-0.79*	0.75
TS (%)	0.17	-0.12	-0.31	-0.52	-0.12	0.01	0.31	-0.33	0.31

*Significant statistical correlation, †Shapiro-Wilk test with a probability lower than 5%, GGT – gamma-glutamyltransferase, GLU – glucose, COL – total cholesterol, TRI – triglycerides, CK – creatine kinase, TP – total protein, ALB – albumin, GLO – globulin, A/G – albumin/globulin ratio, FAT – fat content, CP – crude protein, LAC – lactose, NFS - nonfat solids, TS – total solids.

Although the study observed a positive relationship between serum ALB and the production of LAC and NFS, this relationship is not physiologically direct since the production of LAC and NFS depends on specific processes of the mammary gland. At the same time, ALB is related to the transport of substances in the bloodstream, such as hormones and fatty acids, and plays an essential role in maintaining osmotic pressure in the blood, which helps regulate blood volume (GONZÁLEZ; SILVA, 2017). The same reasoning explains the positive relationship between the A/G ratio and the production of LAC since there is a higher concentration of ALB in the A/G ratio.

The significant and negative correlation of serum GLO with milk LAC and NFS can be justified because lactation is a period of high metabolic demand in which milk production competes with other physiological processes for using amino acids and energy (NOZAD et al., 2007). In this sense, we believe that an increase in serum GLO may reflect the prioritization of systemic responses to the detriment of the synthesis of certain milk constituents, which leads to the diversion of metabolic resources that could be destined for the production of milk LAC and NFS.

CONCLUSION

As for the analysis of biochemical parameters, the increase in serum COL is associated with an increase in FAT in the milk. Blood CK is a sensitive indicator of well-being in lactating sows. Elevated levels of GGT in colostrum and milk indicate the transfer of immunity. Regarding correlations, significant associations were identified between serum biochemical parameters (ALB, GLO, and A/G) and milk composition (LAC and NFS) of sows. These analyses and correlations suggest that monitoring serum biochemical parameters may be a relevant tool for the health surveillance of these animals.

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