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Metabolic profile of Moxotó breed goats during the gestation, delivery and postpartum periods.

Perfil metabólico de cabras da raça Moxotó nos períodos de gestação, parto e pós-parto

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Abstract

There is particular interest in knowledge of the physiological alterations that occur during the transition period, with the aim of understanding the intensity of metabolic alterations and their impacts on animal health. Due to the paucity of data on Moxotó females, related to the dynamics of the energy profile, protein, and mineral metabolites, the present study aimed to evaluate the profile of some blood biomarkers during the transition period. There was significant variation in metabolic dynamics related to energy, protein, and mineral profiles. There is a need for further study of other parameters, rendering them reference values in the different periods of gestation, particularly in the final third of gestation, when metabolic diseases can occur, putting the lives of the animals at risk.
Keywords: Clinical biochemistry, metabolism, gestation, small ruminants, welfare

Resumo

É grande o interesse pelo conhecimento das modificações fisiológicas que ocorrem no período de transição, visando conhecer a intensidade das alterações metabólicas e seus reflexos na saúde animais. Mediante a escassez de dados com fêmeas da raça Moxotó relacionado à dinâmica de metabólitos do perfil energético, proteico e mineral, objetivou-se avaliar o perfil de alguns biomarcadores sanguíneos durante os períodos de transição. Verificou-se significativa variação na dinâmica de metabólicos relacionados aos perfis energético, proteico e mineral. Há necessidade de melhor estudar outros parâmetros, tornando-os como valores referenciais nos diferentes períodos da gestação, particularmente no terço final da gestação, quando enfermidades metabólicas podem ocorrer, colocando em risco a vida dos animais.
Palavras-chave: Bioquímica clínica, metabolismo, gestação, pequenos ruminantes, sanidade

Introduction

The northeastern region of Brazil occupies a prominent place in the production scenario of goat breeding, this being an outstanding activity from an economic and social point of view, constituting an important local productive arrangement. It is known that the states of Bahia, Pernambuco, Ceará, and Piauí have the largest herds of goats in this region. In a system of production of livestock animals, females play a prominent role, making it important to consider the relevance of studies that make it possible to understand the physiological dynamics of females in different stages of gestation and lactation.

Several factors are responsible for altering the physiological state of animals, and gestation is one that deserves special attention. Obtaining data on the metabolic alterations in pregnant goats is necessary so that preventive measures can be taken when they present problems that endanger the health of the females as well as their offspring.

Evaluation of the metabolic profile of the blood, taking into account the characteristics of the herd and physiological state of the animals, provides an important tool to promptly detect metabolic disorders, often present in subclinical form, that affect animal health (GONZÁLES et al., 2000; SOARES et al., 2008; SANTOS et l. 2011).

PACHECO et al. (2016) and SOUZA et al. (2018) emphasize physiological changes related to nutrient expenditure with fetal growth, placental functioning, increased fetal covering and fluid, uterine wall, and mammary glands, highlighting the increase in the metabolic rate that occurs with the proximity of delivery, due to the higher requirement of energy, protein, and minerals.

The mechanisms that alter blood levels of metabolites in pregnant sheep and goats are still poorly studied (THOMAS et al., 2001; SANTOS et al. 2012), especially when considering the breed factor. Some studies have been developed to characterize the dynamics of biomarkers in Santa Inês (ARAUJO et al., 2014), Dorper (SOARES et al., 2014), Morada Nova sheep (SANTOS et al., 2014) and Saanen and Alpine Brown dairy goats (OLIVEIRA at al., 2019) during the transition period. These studies demonstrated that the gestational period influences the metabolic response of several biochemical parameters, besides which the data serve as tools for the diagnosis of metabolic disorders that occur in the transition period related to breed, rearing system, and type of pregnancy, single or twin.

Goats of the Moxotó breed are well adapted to arid regions, with a good capacity for adaptation and management, being animals with a high index of pregnancies and prolificacy. However, these animals gain weight fast and this factor, in excess, can compromise health, with the appearance of metabolic disorders. Currently, there are no data available on the changes that occur during the transition period, making this subject of great relevance to understand the intensity of the metabolic alterations and their impact on the health of these animals. Based on the above, the objective of the present study was to evaluate the profile of blood biomarkers in goats of the Moxotó breed reared in semi-extensive systems during the gestation, delivery, and postpartum periods.

Materials and Methods

The experiment was carried out at Fazenda São Roque, located in the municipality of São Caetano, Pernambucano. The farm is located at 8°19 '47.99" S 36° 8' 45.28" and, 152 km away from Recife, Zona Agreste do Pernambuco State. Ten goats of the Moxotó breed were used, reared in a semi-intensive system, with hay supply, concentrated feed containing soybean meal and corn, mineral salt, and water *ad libitum*, constituting, therefore, a completely randomized design.

The goats were monitored during the reproductive cycle, checking estrus synchronization, dates, and artificial insemination (AI) criteria, when they were recorded in the protocols of the property, for effective control of the probable period of delivery and, therefore, collection of biological material.

All animals had been previously wormed after laboratory parasitological analysis and, on the day before AI, all animals were weighed and evaluated for body score. Thirty days after AI, all the animals were submitted to ultrasonographic evaluation to register the positivity of the pregnancy, as well as the number of fetuses. From 90 days of gestation, biological material was collected for laboratory analyzes, carried out at the following moments: - 60, - 30, - 15, - 7 days before delivery, day of delivery, and 7 and 15 days postpartum.

Blood samples were collected by jugular venipuncture in siliconized vacutainer® tubes, without and with the following anticoagulants, fluoride and diethylene diamine tetra acetic acid - EDTA, to obtain serum and plasma, respectively. The blood samples without anticoagulant were kept at room temperature, while the others with anticoagulant were homogenized, immediately refrigerated, and then taken to the laboratory for further processing. All these tubes were centrifuged for 15 minutes at 500G. Serum and plasma aliquots were then conditioned in Eppendorf tubes and stored at a temperature of–20^{o} C.

The biomarkers evaluated were: total protein, albumin, globulin, urea, creatinine, glucose, cholesterol, triglyceride, fructosamine, Aspartate aminotransferase (AST), Gamma-glutamyl transferase (GGT), alkaline phosphatase (AP), calcium (Ca), phosphorus (P), and magnesium (Mg). The globulin concentration was determined by the difference between the serum concentrations of total protein and albumin. The serum concentration of fructosamine was determined through the kinetic method using the nitroblue tetrazolium technique, which was corrected for both total protein and albumin, using the formula described by COPPO et al., (1996). The biochemical blood determinations were carried out in an automated biochemical analyzer LABMAX 240 (LABTEST®).

Urine samples were obtained through spontaneous urination of the animals using a plastic colostomy bag, which has a central hole with a diameter of 50 mm radius, and a capacity of 500 mL (Mark Med®). The bag was attached to the peri-vulvar region with adhesive glue. Immediately after urination, the urine was conditioned in a sterile urine collecting container (Cral-Plast®), with a capacity of 50 mL, which was immediately processed to evaluate the presence of ketone bodies with the use of a reagent strip.

The data are described as means and standard deviations. The parameters were initially tested for normal distribution using the Kolmogorov-Smirnov test. Those that did not meet the normality and homogeneity of variance assumptions were submitted to logarithmic transformation (Log_{X+1}). Data that met the normal or transformed premises were subsequently submitted to analysis of variance (Test F), which separated, as causes of variation, the effects of collection moments in the prepartum, delivery, and postpartum periods. When significance was found in the F test, the means were compared by the Student-Newman-Keuls test for the least significant difference (LSD). Regression analyzes and their respective determination coefficients were also performed according to the days of the prepartum and delivery period (-30, -15, -7, and day of delivery). For all statistical analyzes, a level of significance (p) of 5% was adopted. The data were analyzed with the Statistical Analysis System (SAS, 2010), using the General Linear Model (GLM) procedure of SAS.

Results

In the analysis of biomarkers of the protein and energy profiles, significant variations were observed in the following blood constituents in the different gestation periods: total protein ($p<0.0035$), albumin ($p<0.0475$), globulin ($p<0.001$), urea ($p<0.0004$), creatinine ($p<0.0069$), triglyceride ($p<0.0018$), and fructosamine ($p<0.001$); while no variations were observed in blood cholesterol concentration ($p=0.8890$) (Table 1).

Higher serum concentrations of PT, albumin, and globulin were observed in the periods prior to delivery compared to the time of delivery, and these values were similar to the prepartum period in the first 15 days postpartum (Table 1). With respect to urea, higher concentrations were observed in the prepartum period, with significantly lower means on the day of delivery and in the postpartum period in relation to the prepartum period. Lower mean serum creatinine concentrations were recorded at 30 and 15 days prior to delivery compared to the other collection moments (Table 1).

A gradual decrease in plasma glucose concentration was recorded from the prepartum period until the first week postpartum; however, in the second week postpartum, recovery occurred in relation to 60 days prepartum. Cholesterol concentrations remained similar throughout all periods, while lower serum triglyceride levels were observed at 60 days prepartum and 15 days postpartum (Table 1).

A higher serum concentration of fructosamine was observed at 60 days prepartum, with a significant decrease occurring until the day of delivery and the first week postpartum, after which it was possible to observe recovery in the second week postpartum (Table 1).

Regarding the enzymatic activities, variations were observed only in AST ($p=0.0078$), while GGT ($p=0.2049$) and AP ($p=0.5104$) activities remained similar at all collection moments, in the different periods. The highest AST averages were recorded at 7 days (115.39 U/L) and 15 days (121.03 U/L) postpartum (Table 2).

Regarding the parameters of the mineral profile, significant variations were observed in serum concentration of Ca ($p<.0001$), P ($p=0.0226$), and Mg ($p=0.0003$). Lower serum concentration of Ca was recorded on the day of delivery, when compared to the collections performed in the prepartum and postpartum periods. With respect to P concentration, higher concentrations were observed at 15 days (9.10 mg/dL) prepartum and lower concentrations at 15 days (5.77 mg/dL) postpartum. Lower concentrations of Mg were observed throughout the prepartum and delivery days, and higher concentrations at 15 and 30 days postpartum (Table 2).

In relation to the regression analysis, as a function of the prepartum and delivery periods, negative linear behavior was observed for the following biomarkers: total protein ($p<.0001$), albumin ($p=0.0109$), globulin ($p=0.0001$), glucose ($p=0.0011$), fructosamine ($p=0.0010$), GGT ($p=0.0500$), and Ca ($p <.0001$); although a positive linear effect was recorded for creatinine ($p=0.0155$) (Table 3) (Figure 1). Quadratic behavior was observed for serum concentration of urea with a maximum point -7 days prepartum and AST activity with a minimum point -15 days prepartum (Table 3).

Table 1. Mean, standard deviation, and level of significance (*p*) values of blood biochemical parameters of Moxotó goats in the prepartum, delivery, and postpartum periods

Parameters	Periods of Gestation / Days							"*p*"
	Prepartum Period					Postpartum period		
	-60	-30	-15	-7	Delivery	7	15	
	Protein and Energy Profiles							
Total protein (g/L)	89.04 ±10.43a	94.49 ±6.48a	90.42 ±6.03a	85.33 ±5.49ab	79.07 ±12.10b	84.83 ±5.33ab	87.79 ±7.62ab	0.0035
Albumin (g/L)	28.34 ±4.24a	27.77 ±2.40ab	27.51 ±2.66ab	26.68 ±2.54ab	24.04 ±3.71b	25.44 ±2.42ab	26.47 ±3.11ab	0.0475
Globulin (g/L)	60.70 ±7.39ab	66.72 ±5.85a	62.92 ±4.83ab	58.65 ±4.87ab	55.03 ±9.11b	59.39 ±5.75ab	61.32 ±6.62ab	0.0098
Urea (mmol/L)	7.12 ±2.13b	7.71 ±0.70ab	7.84 ±0.68ab	9.11 ±1.34a	7.13 ±1.29b	6.92 ±1.54b	6.15 ±1.05b	0.0004
Creatinine (µmol/L)	89.70 ±21.71a	75.19 ±8.32ab	65.81 ±9.61b	88.15 ±15.45a	87.55 ±17.22a	87.24 ±14.50a	85.15 ±16.60a	0.0069
Glucose (mmol/L)	5.33 ±1.43a	5.13 ±0.97ab	4.78 ±0.44ab	4.04 ±0.62ab	3.88 ±1.24b	3.82 ±0.96b	5.44 ±1.66a	0.0021
Cholesterol (mmol/L)	2.05 ±0.85a	2.21 ±0.62a	2.18 ±0.60a	2.26 ±0.64a	1.93 ±0.52a	2.26 ±0.60a	2.03 ±0.64a	0.8890
Triglyceride (mmol/L)	0.17 ±0.06b	0.25 ±0.05ab	0.39 ±0.04a	0.26 ±0.09ab	0.35 ±0.15a	0.37 ±0.17a	0.18 ±0.07b	0.0018
Fructosamine (µmol/L)	201.44 ±25.94a	164.59 ±14.07b	177.36 ±23.70b	149.98 ±13.55c	131.26 ±29.01d	121.59±7 .83e	147.58±2 1.24 cd	<.0001

Different lowercase letters on the same line differ at the 5% probability level.

Table 2. Mean, standard deviation, and level of significance (*p*) values of blood enzymatic and mineral parameters of Moxotó goats in the prepartum, delivery, and postpartum periods

Parameters	Periods of Gestation / Days							"*p*"
	Prepartum Period					Pospartum Period		
	-60	-30	-15	-7	Delivery	7	15	
	Enzyme Activity Profile							
AST (U/L)	91.77 ±15.47ab	102.61 ±13.33ab	84.55 ±12.80b	91.72 ±13.28ab	96.92 ±22.25ab	115.39 ±21.08a	121.03 ±46.22a	0.0078
GGT (U/L)	23.45 ±7.42a	29.86 ±8.03a	28.21 ±8.71a	26.12 ±7.89a	22.93 ±6.20a	26.86 ±7.92a	30.46 ±6.48a	0.2049
AP (U/L)	46.24 ±31.11a	47.24 ±24.87a	54.19 ±25.32a	51.23 ±26.10a	34.92 ±13.45a	36.02 ±14.47a	38.88 ±13.38a	0.5104
	Minerals Profile							
Ca (mg/dL)	8.46 ±1.03a	8.74 ±0.59a	8.56 ±0.25a	8.11 ±0.25a	7.24 ±1.01b	8.24 ±0.28a	8.04 ±0.58a	<.0001
P (mg/dL)	8.25 ±3.78ab	8.10 ±1.76ab	9.10 ±1.36a	7.32 ±1.41ab	8.06 ±1.63ab	7.72 ±1.57ab	5.77 ±1.19b	0.0226
Mg (mg/dL)	2.70 ±0.37b	2.37 ±0.23b	2.34 ±0.17b	2.60 ±0.22b	2.45 ±0.38b	2.72 ±0.25ab	2.99 ±0.52a	0.0003

Different lowercase letters on the same line differ at the 5% probability level.

Table 3. Regression analysis, as a function of the days of the prepartum and delivery periods, of blood metabolites of Moxotó goats in the prepartum, delivery, and postpartum periods

	Prepartum Period				Regression Analysis			
Parameters	-30	-15	-7	Parto	Linear	Quadratic	Cubic	CV*
Total Protein (g/L)	94.49	90.42	85.33	79.07	<.0001	-	-	9.21
Albumin (g/L)	27.77	27.51	26.68	24.04	0.0109	-	-	10.89
Globulin (g/L)	66.72	62.92	58.65	55.03	0.0001	-	-	10.64
Urea (mmol/L)	7.71	7.84	9.11	7.13	-	0.0187	-	13.30
Creatinine (µmol/L)	75.19	65.81	88.15	87.55	0.0155	0.0479	-	16.79
Glucose (mmol/L)	5.13	4.78	4.04	3.88	0.0011	-	-	19.71
Fructosamine (µmol/L)	164.59	177.36	149.98	131.26	0.0010	0.0019	-	13.79
Cholesterol (mmol/L)	2.21	2.18	2.26	1.93	-	-	-	18.30
Triglyceride (mmol/L)	0.25	0.39	0.26	0.35	-	-	-	19.10
AST (U/L)	102.61	84.55	91.72	96.92	-	0.0223	-	17.09
GGT (U/L)	29.86	28.21	26.12	22.93	0.0500	-	-	19.49
AP (U/L)	47.24	54.19	51.23	34.92	-	-	-	13.00
Ca (mg/dL)	8.74	8.56	8.11	7.24	<.0001	0.0084	-	7.48
P (mg/dL)	8.10	9.10	7.32	8.06	-	-	-	19.22
Mg (mg/dL)	2.37	2.34	2.60	2.45	-	-	-	10.70

*CV - Coefficient of variation

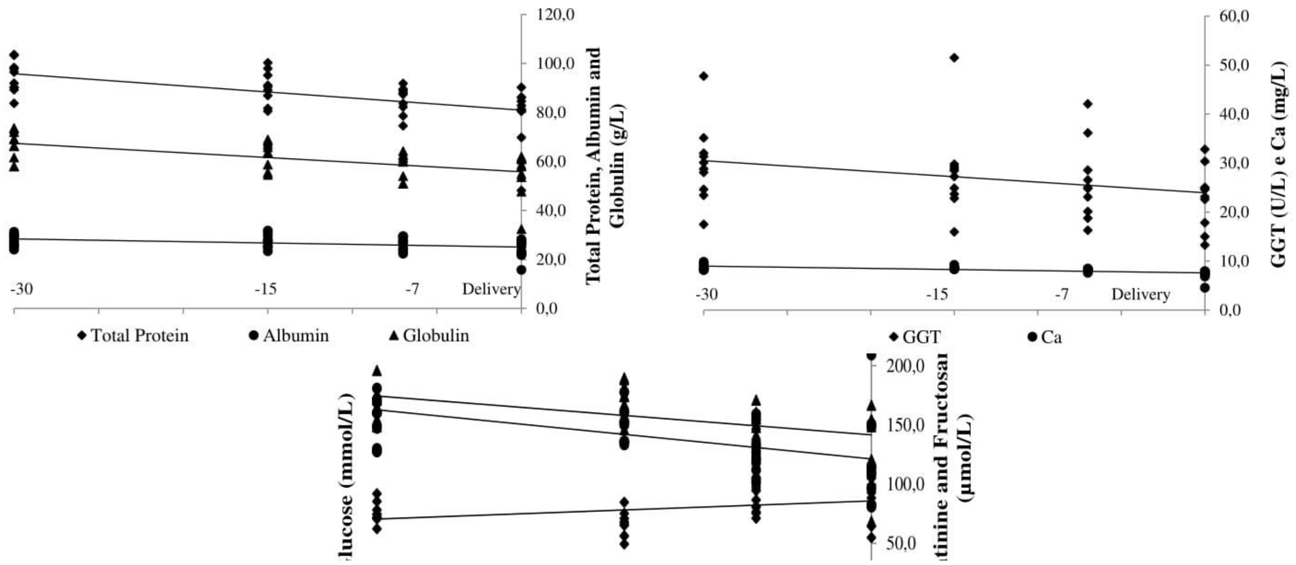

Figure 1 – Graphical representation of the metabolic dynamics of the blood of goats of the Moxotó breed in the prepartum (-30, -15, -7 days) and delivery periods.

Discussion

Blood levels of total protein, albumin, and globulin presented negative linear behavior in the prepartum period and at delivery, with elevations in these concentrations in the postpartum period. Gestation, delivery, and lactation are events that have an effect on the concentration of the majority of metabolites used in the metabolic profile of production animals. However, most animals present recovery in their concentrations rapidly (GONZÀLEZ, 2000; CAMPOS et al., 2010; SILVA et al., 2013; SANTOS et al., 2014; ARAUJO et al., 2014; SOARES et al., 2014). After delivery, although an increase is observed in both energy and protein requirements for milk synthesis, several factors are involved in the difficulty of providing enough nutrients for lactating animals, due to the low consumption of food in this phase (SANTOS et al. 2011), which may justify the profile of certain metabolites, such as those observed in this study.

In the present study it was categorical that gestation had an influence on the dynamics of these metabolites, the final month of gestation as well as the delivery period being underlined as requiring attention for monitoring pregnant females. One factor to consider is the feeding system of this breed of animals that were reared outside, in which nutritional support can maintain or compromise the gestation and health of the animals depending on other factors, such as the environment. Many native pastures, such as those found in the Northeastern semi-arid region, depending on the time of year, are able to provide enough nutrients to the animals, whether in gestation or not. The protein intake of these animals seems to have been adequate, since the serum concentrations of proteins and globulins in the prepartum period were above reference values (CONTRERAS; PHIL, 2000), although they decreased linearly from the moment of delivery.

In the analysis of the protein profile, albumin concentrations on the day of delivery and in the first fortnight postpartum were below normal for the species (CONTRERAS; PHIL, 2000). As synthesis occurs in the liver (BARAKAT et al., 2011 and HEFNAWY et al., 2011) and no hepatic dysfunction was observed in these animals, this decrease is more probably related to mobilization for colostrum production. In addition, albumin plays an important role in the conduction of non-esterified fatty acids, where they are used by peripheral tissues as a source of energy (GONZÁLES; SILVA, 2003). As albumin concentration is a good indicator of long periods of protein restriction (CALDEIRA, 2005), the results obtained confirm the non-occurrence of protein deficiency in the animals under study.

GONZÁLEZ e SILVA (2003) cite that its decrease may be present in situations where there is fatty infiltration in animals with high lipo mobilization and may be an indicator of hepatic function. In this context, in specific situations of gestational toxemia, as reported by SOUTO et al (2013) in goats, the reduction in albumin concentrations occurs due to hepatic or renal failure, as a consequence of the worsening of the clinical framework of the disease, a situation that was not recorded in the animals of the present study.

The observed increase in total proteins, albumin, and globulin after delivery may be related to the lactation phase. The increase in total serum proteins is proportional to the stage of lactation in goats. Albumin decreases near delivery and reaches lower levels in the first month of lactation, while globulins are higher during this period (MBASSA; POULSEN, 1991).

The dynamics of the serum albumin in these animals was more significant in relation to globulin and total protein at the time of delivery and early lactation. Decreasing serum albumin values in sheep at the end of gestation and during lactation were also reported by KARAPEHLIVAN et al. (2007) and CARDOSO et al. (2010).

The reasons for the albumin dynamics to decrease and remain low in the postpartum period can also be determined by the reduction in the proteins in the diet as well as the demand for amino acids for protein synthesis in milk, which may reduce the synthesis of other proteins and, therefore, the concentration of albumin decreases as lactation progresses (GONZÀLEZ et al., 2000).

The protein and energy indicators are not modified only by nutritional imbalances. Consideration should be given to the analysis of biomarkers in goats during the transition period, in addition to feeding, aspects of rearing management, health, and physiological status (GONZÀLEZ et al., 2000).

In relation to proteins, the two primary indicators of the protein metabolism in ruminants are the parameters of urea and albumin; urea shows the protein status of the animal in the short term, whereas albumin confirms the status in the long term (PAYNE; PAYNE, 1987). Urea increased with gestation and decreased with the onset of lactation. A quadratic effect was observed, peaking at -7 days before delivery, with progressive reduction from delivery until the first fortnight postpartum. The Moxotó goats were reared in a feed supply system with an adequate balance of nutrients necessary to maintain health, which may have favored the consumption of degraded protein in the rumen, promoting a greater amount of ammonia converted to urea (HERDT, 2000; CONTRERAS et al., 2000; GONZÁLEZ et al., 2000). A similar result was obtained by SOARES et al. (2014) in Dorper sheep, and MOGHADDAM; HASSANPOUR (2008), who observed an increase in urea concentration in sheep at the end of gestation, relating the elevation to the increase in protein metabolism during gestation or the nutritional management employed.

The dynamics of increasing creatinine concentration prepartum in Moxotó goats reflects the mobilization of muscle protein with the purpose of producing energy at the beginning of lactation, and these results are similar to those obtained by BERTONI (1996) and CHIOFALO et al. (2009), who observed an increase in creatinine concentration in the moments before delivery in dairy cows and goats. Postpartum, these values were similar to the previous moments, reflecting the adequate use. SOARES et al. (2014), with sheep of the breed Dorper and SANTOS et al. (2014) with Morada Nova sheep observed a decrease in postpartum creatinine, differently from Moxotó goats. It is probable the requirements of sheep in the lactation stage provided greater mobilization of nutrient reserves in the animals, with the intention of maintaining dairy production. It is also important to consider the nutritional standard offered to the animals, whose supplementation with concentrated feed at adequate levels reflected significantly in the initial lactation phase, through less nutrient mobilization. Frameworks of hepatic insufficiency and degenerative muscular alterations are observed in animals with decreasing creatinine concentration (GONZÁLEZ et al., 2000); conditions not observed in the animals studied.

The negative linear behavior of glucose in the prepartum period until delivery and consequent recovery with a slight elevation in its concentration in the postpartum period possibly reflects the energy concentration of the diet and consequently adequate supply of glucose to the fetuses close to delivery. In Moxotó goats, the data are coincident with other studies performed with sheep (MBASSA; POULSEN, 1991; SANTOS et al., 2014). Regarding the study by SOARES et al. (2014), the authors detected hypoglycemia in Dorper sheep at the time of delivery, but with a negative linear effect in the prepartum period. LIMA et al. (2012) report that different glycemic states are justified when the reduction in plasma glucose concentration in the prepartum period is concomitant to the reduction in glucose turnover in pregnant sheep, making them more sensitive to the negative energy balance with a risk of production of ketone bodies. The mean values were in the reference range for the species, having a direct relation with the composition of the diet offered, in which the energy levels did not propitiate mobilization of corporeal energy reserves.

Contrary to the data observed in the present study, in which normoglycemia was observed at the time of delivery, some authors found hyperglycemia (ARAÚJO et al., 2014; SANTOS et al., 2006; SANTOS et al., 2011), justifying that at delivery there may be an increase in glucagon and glucocorticoid concentrations that promote the depletion of hepatic glycogen stores (GRUMMER,

1995) and/or may be a consequence of the release of glucocorticoids as a sign of labor in sheep (GONZÁLEZ et al., 2000).

SANDEBE et al. (2004), in their study with 20 goats, observed a significant difference in glucose concentrations. MBASSA; POULSEN (1991) reported that serum glucose concentration decreased in the final third of gestation and increased soon after delivery. However, analyzes by MUNDIM et al. (2007), affirm that the reduction in glucose levels is due to the greater contribution by the mammary gland to obtain energy and lactose synthesis. Furthermore, according to the authors, glucose is the least expressive indicator to determine the animal energy profile, since there is an insensitivity of glucose to nutritional changes and it is sensitive to stress.

The profiles represented by the cholesterol and triglyceride concentrations were within the normal range at different collection moments and without a regression effect in function of the days of the prepartum period. These data are discordant with those observed by SANTOS et al (2014) and SOARES et al. (2014), who observed a decrease in the mean values of cholesterol and triglycerides until delivery and this continued to decrease in the postpartum period. GONZÁLEZ et al. (2000) and GONZÁLEZ e SILVA (2003) state that their plasma levels are adequate indicators of total plasma lipids. It could be considered that the diet of the animals provided an adequate energy supply, causing no alterations in the lipidogram.

The decrease in the concentrations of fructosamine during the prepartum period, continuing with decreases up to 15 days postpartum are coincident with the data observed by SANTOS et al. (2014), in Morada Nova sheep, and contrary to those observed by SOARES et al. (2014), who found no variation in the dynamics of fructosamine in Dorper sheep, during the same periods. Fructosamine is a blood biochemical variable that has not previously been used in metabolic energetic profile studies in Moxotó goats during gestation, delivery, and postpartum periods, being pioneered in this study.

The determination of fructosamine provides an idea of the mean of the glycemia in the previous two to three weeks, being a parameter of metabolic control, which should be analyzed together with the results of glucose (JENSEN et al., 1993; COPPO, 1996). In this context, it was observed that the dynamics of the fructosamine followed the glucose dynamics in the same prepartum and postpartum periods. It is important to consider the investigation of the diagnostic value of fructosamine for glucose homeostasis in this species. SOARES et al. (2014) found that the fructosamine demonstrated a significant relationship not only with plasma glucose in Dorper sheep, but also with total protein, albumin, and cholesterol. Due to the importance of glucose in the intermediary metabolism and its relationship with amino acids and the lipid metabolism, the measurement of fructosamine can be a diagnostic tool associated with other biomarkers, such as protein, albumin, and cholesterol, to monitor health and metabolic status (SANTOS et al., 2011, SANTOS et al., 2012, SOUTO et al., 2013). There are few studies with fructosamine in small ruminants and in different situations of metabolic profile analysis. These results are significant for understanding the dynamics of this biomarker in Moxotó goats under the conditions in which they were reared. It is worth noting that fructosamine is a stable ketoamine formed by the non-enzymatic reaction of glucose with amine groups of proteins (mainly albumin), and its blood concentration is related to the balance between the synthesis and elimination of these protein compounds and glucose. The serum level of fructosamine depends on the mean glucose concentration during the previous two weeks and the half-life of blood proteins and is not subject to change due to transient hyperglycemia (AMBRUSTER, 1987; FILIPOVI’C et al., 2011).

A quadratic effect was observed in AST activity, with a minimum point -15 days postpartum and higher concentrations postpartum, although within normal values for the species. Regarding GGT, there was a linear decrease in the prepartum and delivery periods. In situations in which low or normal

GGT activity and high AP are detected, bone origin alteration is very likely. If this did not occur in the present study, in which the AP activity was below the reference value, a value of low or normal GGT activity indicates that animals are unlikely to have hepatic insufficiency. According to RUKKWAMSUK et al. (1999), alterations in hepatic function may occur in cases of hepatic lipidosis, in varying degrees, resulting in increased serum activity of hepato specific enzymes, although without destruction of hepatocytes, which was not observed in the present study.

AP remained below the lower normal range for the species (KANEKO et al., 2008), which agrees with data obtained by MUNDIM et al. (2007) and YANAKA et al. (2012), who described that the variation in AP activities may occur due to physiological variations of the individual, age, nutritional management, breed, and environmental factors. SOARES et al. (2014) also recorded the same profile in Morada Nova sheep, in the same periods of observation as the present study. According to ZAIRRILLI et al. (2003), this condition is justified both by the lower activity of AP and the secretion of this enzyme in colostrum. Therefore, the scarcity of data to standardize values that can be safely used in analysis of the profile of animals in the transition period is evident.

The serum Ca concentrations demonstrated significant variations and a negative linear effect in the prepartum to delivery periods. According to AZAB; ABDEL-MAKSOUD (1999), SOUTO et al. (2013), and SHARMA et al. (2015), concentrations of this mineral decrease about four weeks before delivery and at the time of delivery in goats due to the demand for bone mineralization of the fetuses or the production of maternal colostrum that requires a considerable amount of circulating levels of the element. The serum Ca profile was similar to the serum protein profile of these animals. VIEIRA (2007) reports that calcium is distributed in the body in three ways: ionized (biological functions), protein-bound (mainly albumin), and complex-bound. Furthermore, according to the author, any alteration in the serum protein level, especially albumin, leads to a change in serum calcium, as observed in the present study, and there was a direct relationship between these nutrients in the gestational period of Moxotó goats.

The serum concentrations of P and Mg were normal for the species. Lower mean Mg values were recorded in the prepartum period at delivery and higher in the postpartum period. The significant variations observed in these minerals are due to their necessary contribution for fetal bone formation, as well as milk production. Similar results were described by MBASSA; POULSEN (1991) and MUNDIN et al. (2007), in goats, with a decrease in this mineral. During pregnancy, the plasma Mg level decreased significantly, which could be related to the physico-chemical alterations occurring in the blood during pregnancy, which favored the passage of Mg from the mother to the fetus (ASMED et al., 2000), as well as being associated with high amounts of Mg migrating to milk during early lactation with a concomitant decrease in the plasma Mg level in the blood (MBASSA; POULSEN, 1991). Based on the identification of adequate concentrations of Mg in the first fortnight postpartum, MUNDIM et al. (2007) stated that during lactation the Mg values varied within the physiological limits for the species, since they present great sensitivity to reduce the excretion of this mineral.

According to GONZALES et al., (2000) Ca does not play a role as good indicator of the nutritional status of the herd due to the endocrine control of calcemia, while P and Mg better reflect nutritional levels. The minerals fundamental for development should be prioritized in goat production systems as they play essential roles in tissue structure and participation as enzymatic cofactors and precursors of hormonal action and play an important role in osmotic pressure and acid-base balance (GONZÁLEZ et al., 2000; SANTOS et al., 2011).

The profile of these macro minerals was influenced by physiological alterations in goats during the final third of gestation, evidencing that during pregnancy the fetal demand for elements such as

Mg resulted in decreased levels of these elements in the maternal system. Similarly, the milk demand reduced the concentrations of Ca, P, and Mg and necessitated the mobilization of these elements from their original locations to be secreted into the milk.

Conclusions

Goats of the Moxotó breed, during the transition period, present significant variation in metabolic dynamics related to the energetic, protein, enzymatic, and mineral profiles. There is a need to better study other parameters, creating reference values in the different periods of gestation, particularly in the final third of gestation, when metabolic diseases can occur, putting the lives of the animals at risk.

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