ORIGINAL ARTICLE

https://doi.org/10.21708/avb.2023.17.3.12040

Incidence of subclinical ketosis in dairy cows in the semi-arid region of the state of Paraíba

Incidência de cetose subclínica em vacas leiteiras na região semiárida da Paraíba

Daniel Cézar da Silva[1]*, Gilderlândio Pinheiro Rodrigues[2], Beatriz Dantas Fernandes[3], Jéssica Monique dos Santos Lima[4], Bismark Alves da Silva[3], Evaristo Jorge Oliveira de Souza[5]

ABSTRACT: Subclinical ketosis (SCK) is one of the main metabolic diseases to occur during the transition period in dairy herds. The aim of this study was to evaluate the localized incidence of SCK in dairy cows in the semi-arid region of the state of Paraíba, Brazil, and to correlate this data with the number of weeks of lactation and the body condition score (BCS). Samples were collected from the coccygeal vein of 257 lactating dairy cows, with a view to determining serum ketone and glucose body levels. Animals that presented serum ketone body levels equal to or greater than 1.2 mmol/dL were considered to have SCK. It was found that 5.45% of the dairy cows presented SCK. The weeks of lactation and the BCS had no influence (P > 0.05) on the levels of serum ketone bodies or glucose of the dairy cows. For serum ketone body levels, 94.55% (243) of the cows remained within the normal limits for metabolites. Most of the cows, 67.70% (174) were within normal serum glucose levels, while 23.35% (60) presented hypoglycaemia, and 8.95% (23) presented hyperglycaemia. The BCS and serum glucose levels are negatively correlated, with a coefficient of -0.1329 (P = 0.0335). No significance was found 0.087 (P = 0.1608) for the correlation between the BCS and serum ketone body levels. The localized incidence of SCK in this study was 5.45% of the total number of cows, with the BCS and number of weeks of lactation having no influence on incidence of the disorder.

KEYWORDS: Animal production; Brazilian semi-arid; β-hydroxybutyrate; Metabolic disorders.

RESUMO: A cetose subclínica (CSB) é uma das principais doenças metabólicas que ocorrem durante o período de transição em rebanhos leiteiros. O objetivo deste estudo foi avaliar a incidência pontual de CSB em vacas leiteiras no semiárido do estado da Paraíba, Brasil, e correlacionar esses dados com as semanas de lactação e escore da condição corporal (ECC). Foram coletadas amostras da veia coccígea de 257 vacas leiteiras lactantes, com o objetivo de determinar os níveis corporais séricos de corpos cetônicos e glicose. Os animais que apresentaram níveis séricos de corpos cetônicos igual ou superior a 1,2 mmol/dL foram considerados com CSB. Verificou-se que 5,45% das vacas leiteiras apresentavam CSB. As semanas de lactação e ECC não influenciaram (P > 0,05) os níveis séricos de corpos cetônicos e de glicose das vacas leiteiras. Para os níveis séricos de corpos cetônicos, 94,55% (243) das vacas leiteiras permaneceram dentro dos limites normais do metabólito. A maioria das vacas, 67,70% (174) estavam dentro dos níveis séricos normais de glicose, enquanto 23,35% (60) apresentavam hipoglicemia, e 8,95% (23) apresentavam hiperglicemia. O ECC e os níveis séricos de glicose foram negativamente correlacionados, com coeficiente de -0,1329 (P = 0,0335). Não foi encontrada significância 0,087 (P = 0,1608) para a correlação entre ECC e os níveis séricos de corpos cetônicos. A incidência pontual de cetose subclínica neste estudo foi de 5,45% do total de vacas, com ECC e número de semanas de lactação não apresentando influência na incidência do transtorno.

PALAVRAS-CHAVE: Produção animal; β-hidroxibutirato; Desordens metabólicas; Semiárido Brasileiro.

INTRODUCTION

During the transition period, which includes the three weeks before and three weeks after calving, cows require more energy to produce colostrum and milk and without correct nutritional management can face various problems. This period is represented by metabolic, reproductive, and digestive changes. Challenges during this period include the occurrence of various diseases, especially ketosis (Deniz; Aksoy; Metin, 2020; Schneider *et al.*, 2020).

[1] Federal Institute of Education, Science and Technology of Paraíba, Paraíba, Brazil
[2] Independent Veterinary, Juazeiro do Norte, Ceará, Brazil
[3] Postgraduate Program in Animal Science of the University Federal Rural of Semiarid, Rio Grande do Norte, Brazil
[4] Independent Veterinary, Paulista, Paraíba, Brazil
[5] University Federal Rural of Pernambuco, Serra Talhada Academic Unit, Serra Talhada, Brazil
*Corresponding author: daniel.cezar@ifpb.edu.br
Received: 12/10/2023 Accepted: 28/06/2023

At the start of lactation, cows commonly experience a negative energy balance, which corresponds to a rapid increase in energy requirements for milk production together with a lower capacity for food intake. When this physiological state is pronounced or prolonged, it leads to partial oxidation of non-esterified fatty acids as a source of energy and, consequently, to increased concentrations of β-hydroxybutyrate in the blood, which determines the development of ketosis in post-partum dairy cows (Rodriguez-Jimenez *et al.,* 2018; Steeneveld *et al.,* 2020).

Ketosis can present in the clinical or subclinical form. For a diagnosis of subclinical ketosis (SCK), blood β-hydroxybutyrate limits vary between 1.2 and 1.4 mmol/L, with no clinical symptoms. When β-hydroxybutyrate concentrations are greater than 3.0 mmol/L with clinical symptoms, clinical ketosis should be considered (Brunner *et al.,* 2018).

Another parameter aid to diagnosing ketosis is an assessment of blood glucose. Healthy animals have serum glucose levels in the range of 45 to 75 mg/dL, while cows with SCK have levels of around 35 to 45 mg/dL, and cows that have developed the clinical form, of less than 35 mg/dL (Guliński, 2021; Zhang; Ametaj, 2020).

Dairy cows with SCK are at increased risk of developing production-related diseases such as clinical ketosis, abomasum displacement, placental retention, lameness, mastitis and metritis, which can affect the welfare of the animal (Brunner *et al.,* 2018; Djoković *et al.,* 2019). Furthermore, the subclinical form results in greater losses and higher costs compared to clinical ketosis, being associated with lower milk production, lower reproductive performance, and an increase in the number of cows destined for culling (Steeneveld *et al.,* 2020).

In the semi-arid regions of Brazil, rainfall is scarce or poorly distributed, which compromises food production for maintaining the herds. Due to the temporal and spatial irregularity of the rain, the supply of forage is not constant throughout the year (Silva *et al.,* 2020). This indicates a need to complement and adapt the diet based on the status and production of each individual dairy cow.

In milk production systems in semi-arid regions, such as the Sousa micro-region of Paraíba, there are limitations on the nutritional management of herds due to the qualitative and quantitative seasonality of forage and grain production. In such a situation, the animals are fed on unbalanced diets that are deficient in certain nutrients (Silva *et al.,* 2019). In addition, the lack of information/professionalism of the rural producers in the region, or the lack of technical monitoring, can also be risk factors for the development of ketosis.

The aim of this research was to evaluate the localized incidence of SCK and associate this with the parameters of body condition score (BCS) and weeks of lactation in dairy herds inserted in milk production systems in the Sousa micro-region of the state of Paraíba, Brazil.

MATERIAL AND METHODS

Geographical location, property, and animal selection

This research was approved under registration no. 23000.000469.2018/81 submitted to the Ethics Commission for the Use of Animals (CEUA) of the Federal Institute of Education, Science and Technology of Paraíba, Sousa Campus.

The research was carried out in the Sousa, in an area of 4,784,729 km^2, covering the following municipalities: Sousa, located at 06º50`22" S, 38º17`42" W, at an altitude of 220 meters; Pombal, 6°46'8" S, 37°47'45" W, altitude 175 meters; Aparecida, 6°46'18" S, 38°2'52" W, altitude 237 meters; São João do Rio do Peixe, 6°43'52" S, 38°26'53" W, altitude 243 meters. According to Köppen-Geiger, the predominant climate in the region is type Bsh, hot semi-arid (Beck *et al.,* 2018), with an average annual rainfall in 2018 of 910.6 mm, concentrated from January to June, an average annual temperature of 34.01°C, and average relative humidity of 69.77%. In 2019, the average annual rainfall was 845.9 mm, with an average temperature of 34.39 °C and relative humidity of 69.66%, (INMET, 2021).

The localized incidence survey of SCK took place from June 2018 to March 2019. A total of 12 dairy farms participated in the research, which received visits from the team to collect blood from 257 dairy cows in postpartum. The criterion for selecting the properties was a minimum production of 200 liters of milk per day. To select the animals, the criteria were first-calf heifers, and lactating cows independent of the number of births, within a period of from one to fifteen weeks of lactation and showing no signs of clinical ketosis or infectious disease. The dairy cows were Holstein and crossbreed Holstein, with average daily production/cow was 15.7 ± 4.84 L/day, having as a food base with *Brachiaria* spp. or *Panicum* sp. roughage, in a rotational grazing system, and supplemented with grains, silages, and a commercial mineral supplement (Novo Bovigold Tortuga®) in the following concentrations: Ca 190-220 g/kg, P 60 g/kg, S 20 g/kg, Mg 20 g/kg, K 35 g/kg, Na 70 g/kg, Cl 119 g/kg, Co 15 mg/kg, Cu 700 mg/kg, Cr 10 mg/kg, Fe 700 mg/kg, I 40 mg/kg, Mn 1600 mg/kg, Se 19 mg/kg, Zn 2500 mg/kg and F 600 mg/kg, were offered to the cows following the manufacturer's recommendations of 20 to 30 g per 100 kg of body weight/day respectively.

The BCS was evaluated by the same veterinarian in all the experimental animals, considering a scale of from 1 to 5, with intervals of 0.50, following the recommendations of Bell *et al.* (2018).

Blood sample collection

Blood samples were collected from the coccygeal vein with the aid of a needle and a Vacutainer® tube with clot activator.

A total of 257 blood samples (dairy cows) were collected by venipuncture from cows that were between the first and fifteenth week of lactation. After collection, the samples were placed in a cool box and sent to the Clinical Analysis Laboratory of the Veterinary Hospital at the Federal Institute of Education, Science and Technology of Paraíba, Sousa Campus, for later analysis.

Determination of ketone body and glucose serum concentrations

Ketone body concentrations (β-hydroxybutyrate) were determined by rapid electronic field diagnosis, using the Abbott portable FreeStyle® Optium Neo monitor (ANVISA – 80146501882, Abbott Laboratórios do Brasil LTDA, Brooklin-SP, CNPJ: 56.998.701/0001-16). Immediately after collecting a blood sample from the coccygeal vein, a volume equal to one drop of blood was placed on the reagent strip test for β-hydroxybutyrate, which was then inserted into the portable device and the reading taken after 10 seconds. The equipment was set up to measure the levels of β-hydroxybutyrate in both venous and capillary blood, with the analytical values expressed from 0 to 8.0 mmol/L. Animals that presented a total ketone body concentration equal to or greater than 1.2 mmol/L with no clinical signs were diagnosed with SCK, as per Brunner *et al.* (2018).

The tubes containing the blood samples were centrifuged at 3600 rpm for 10 minutes. The serum was then removed to determine the glucose concentration by colorimetry using the LabTest Glucose Liquiform biochemical kit (Glucose – Ref. 133, Labtest Diagnóstica, ANVISA – 10009010236, LabTest Diagnóstica S.A., CNPJ: 16.516.296/0001-38, Lagoa Santa, Minas Gerais). Animals with a serum glucose concentration of between 45 - 75mg/dL were considered normoglycaemic (Guliński, 2021). The analyses were carried out using a BIO-2000 IL Semi-Automatic Biochemical Analyser (Bioplus, Products for Laboratories Ltda, Barueri, São Paulo).

Statistical analysis

The data were analyzed following the PROC MEANS procedure of the SAS statistical package (2001), using descriptive statistics for the mean, standard deviation, and coefficient of variation. In addition, adherence of the data to the normality curve was tested using the PROC UNIVARIATE procedure, with discrimination carried out by the Shapiro-Wilk test at 5% significance. After verifying normal distribution, the mean value test was chosen based on the variability of the parameters under evaluation. A correlation analysis to study the influence of feed management and production aspects on SCK was carried out as per the PROC CORR procedure, adopting a significance level of 5%. The PROC CANCORR procedure was used to diagnose the effect of multicollinearity or linear dependence between the variables. The evaluated characteristics, BCS, glucose and β-hydroxybutyrate, were then submitted to principal component analysis using the procedure FACTOR of SAS (method = print) with Kaiser's criterion (*i.e.*, Eigenvalue ≥ 1.0) to extract the principal components. No rotation method was applied to the principal components. This procedure generated loading and score vectors, where loading vectors are the correlations between the variables and the extracted principal components and score vectors are the scores of each individual case on each principal component. Only the first two principal components were plotted since they represented most of the total variation.

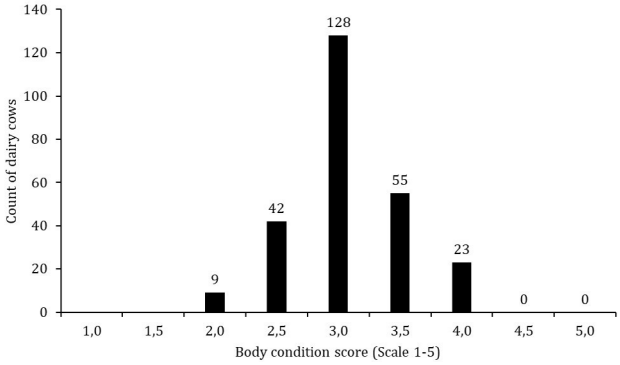
RESULTS AND DISCUSSIONS

Evaluation of the body score of the dairy cows

For the BCS, it was found that most dairy cows were classified as Score 3 (128), considered a satisfactory result. The others were ranked as Score 2 (9), Score 2.5 (42), Score 3.5 (55) and Score 4 (23) (Figure 1).

The greater number of dairy cows in BCS 2.5 to 3 can be attributed to the technological level of production adopted on the properties participating in the research. The 12 dairy farms had high technological level, with mechanical milking, continuous use of grains, silages, and commercial mineral supplement. According to Middleton; Minela; Pursley (2019) BCS is a key indicator of cow health and a useful tool in monitoring the nutritional state of dairy cattle.

Despite the productive situation of the dairy farms in this research, all the scores under evaluation showed at least one dairy cow that developed SCK, just as cows within each of the scores and weeks of lactation presented hypoglycaemia. This can be associated with the supply of low-quality feed, as well as unbalanced diets during the pre- and postpartum periods when the energy requirement of dairy cows is greater. According to Wang *et al.* (2021), the BCS has the potential to indicate the occurrence of SCK, since it correlated negatively ($P < 0.05$) with β-hydroxybutyrate serum levels. In the 63 cows that participated in the research, the



Source: collected by the author.

Figure 1. Count of dairy cows by body condition score from properties in the Sousa micro-region, Paraíba, Brazil.

BCS taken 10 days before and 10 days after calving, was 2.81 ± 0.38 and 2.65 ± 0.34, respectively, which are statistically different (P < 0.05).

Under the conditions of the present research, no significance was found r = 0.087 (P = 0.1608) when evaluating the correlation between the BCS and SCK serum levels (Table 1). This can be attributed to the experimental design, which sought to evaluate the BCS and blood metabolites of cows during the postpartum period between the first and fifteenth week of lactation, not just the 10-day interval before and after calving.

Evaluation of the serum ketone body levels of the dairy cows

The weeks of lactation had no influence (P > 0.05) on serum ketone body levels. It was found that most cows, 94.55% (243), remained within normal metabolite limits (0 - 1.1 mmol/L), while 5.45% (14) of the animals under evaluation presented higher values (1.2 - 3.0 mmol/L), indicating cases of subclinical ketosis (Figure 2).

The BCS (Figure 3) was found to have no influence (P > 0.05) on serum ketone body levels. Animals with above-normal values, which fit the subclinical form of ketosis, were recorded for each of the scores evaluated in this research.

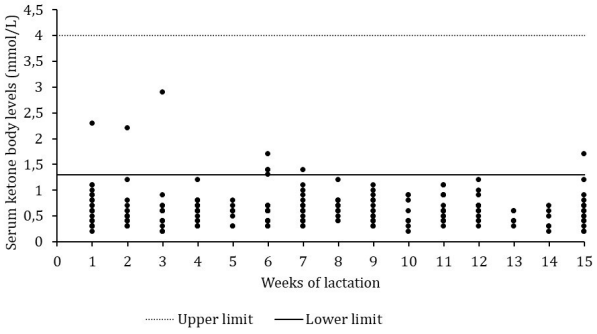
Ketosis can occur due to multiple factors related to energy metabolism, with animals that develop the disorder usually presenting hypoglycaemia and hyperketonaemia (Biswal; Nayak; Sardar, 2016). The development of ketosis can vary according to the breed of the animal, individual adaptive mechanisms, milk production, management conditions, nutrition, season, and region (Carvalho *et al.*, 2018).

Multiparous cows undergo more challenging metabolic changes compared to primiparous cows due to the greater milk production. This predisposes multiparous cows to a more-pronounced negative energy balance, leading to higher concentrations of β-hydroxybutyrate and greater difficulty for the metabolism to adapt during the post-partum period (Benedet *et al.,* 2019; Freitas *et al.,* 2020).

Evaluating β-hydroxybutyrate serum levels in 63 dairy cows, Wang *et al.* (2021) estimated an incidence of 42.25% for SCK in samples collected on the tenth day postpartum. Torres *et al.* (2020), when evaluating β-hydroxybutyrate serum levels and BCS in 181 primiparous and multiparous dairy cows on the seventh day postpartum, estimated a partial incidence of 4.8%.

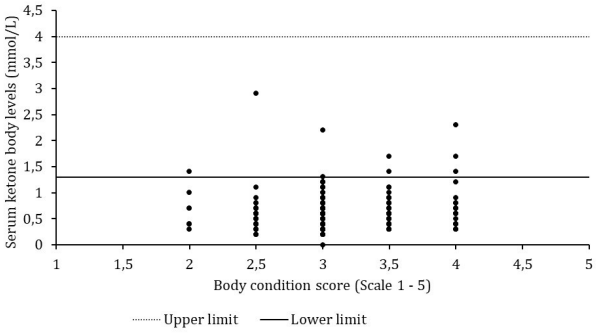
In the present research, the period from the first to the fifteenth week of lactation was considered when calculating localized incidence, estimating a value of 5.45% for an interval of between 1.2 mmol/L and 4.0 mmol/L ketone bodies in the blood. Although the incidence may be considered low, the occurrence of SCK in dairy cows evaluated in this research cannot be minimized, since it is still necessary to consider serum glucose levels when interpreting the results, this being the principal carbohydrate involved in energy metabolism. This research indicated a 23.35% localized incidence of hypoglycaemia of (Figure 4).

The highest incidence of ketosis occurs two to seven weeks after calving, with the early weeks being more critical for the



Source: collected by the author.

Figure 2. Serum ketone body levels (mmol/L) as a function of weeks of lactation in dairy cows in the Sousa micro-region, Paraíba, Brazil.



Source: collected by the author.

Figure 3. Serum ketone body levels (mmol/L) as a function of the body condition score in dairy cows in the Sousa micro-region, Paraíba, Brazil.

Table 1. Correlation coefficient between body condition score, serum ketone bodies and serum glucose levels in dairy cows in the Sousa micro-region, Paraíba, Brazil.

Variable	Variable		
	Body condition score	Serum ketone bodies	Serum glucose levels
Body condition score	1	-	-
Serum ketone bodies levels	0.087 (P = 0.1608)	1	-
Serum glucose levels	-0.1329 (P = 0.0335)	-0.1520 (P = 0.0149)	1

development of subclinical ketosis. Dairy cows that present the disorder during the first few weeks are more likely to develop adverse health conditions, such as abomasum displacement, metritis, and placental retention, in addition to reduced milk production (Benedet *et al.,* 2019; Cascone *et al.,* 2022).

Reserves of body fat during the dry period predispose cows to a significant reduction in BCS after calving, leading to an increase in overall lipid mobilization. This increase in lipid mobilization affects insulin-regulated carbohydrate and lipid metabolism, and reduces food intake, which can further aggravate the negative energy balance status during lactation and compromise the health of the cows (Chapel *et al.,* 2017; Šamanc *et al.,* 2015). This reduction in food intake by cows with high BCS, whether due to intra-abdominal fat deposits limiting their consumption capacity, or to cows with a low BCS not having sufficient energy reserves for their post-partum requirements, may explain the negative correlation between the parameters evaluated in this study (Table 1).

Under the conditions of this research no were identified super-conditioned animals, i.e., animals that are overfed and have a BCS greater than four (on a scale of one to five) are more susceptible to negative energy balance after calving due to a lower dry matter intake compared to cows with a BCS of between three and three and a half, which is considered adequate. In addition, the more intense the negative energy balance, the greater the mobilization of lipid reserves, predisposing the occurrence of ketosis.

Evaluation of the serum glucose levels of the dairy cows

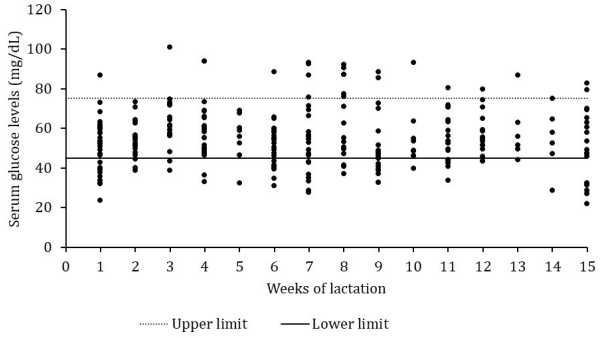
The weeks of lactation had no influence (P > 0.05) on serum glucose levels. It was found that most of the cows, 67.70% (174), were within normal levels (45 - 75 mg/dL), while 23.35% (60) presented hypoglycaemia, and 8.95% (23) had greater than normal concentrations and showed signs of hyperglycaemia (Figure 4). The serum levels varied each week, with no high concentration of cows with either hypoglycaemia or hyperglycaemia during any one period.

The BCS of the dairy cows had no influence (P > 0.05) on serum glucose levels (Figure 5). Most cows presenting hypoglycaemia or hyperglycaemia were classified as Score 3 or 3.5, representing 18.68% (48) of the cows with hypoglycaemia and 8.17% (21) with hyperglycaemia.

Glucose is the main precursor of lactose, and its synthesis is related to the volume of milk produced. As a result, lactating cows need four times more glucose compared to non-lactating cows, and for this reason more attention should be paid during this period (García-Roche *et al.,* 2021). When nutritional management does not meet the metabolic requirements after calving, there is greater demand on the liver to synthesize more glucose from noncarbohydrate precursors. According to Rodríguez; Mellado; Bustamante (2020), a reduction in the ruminal production of propionic acid, the main glucose precursor in ruminants, results in hypoglycaemia, leading to the mobilization of free fatty acids and glycerol from fat reserves.

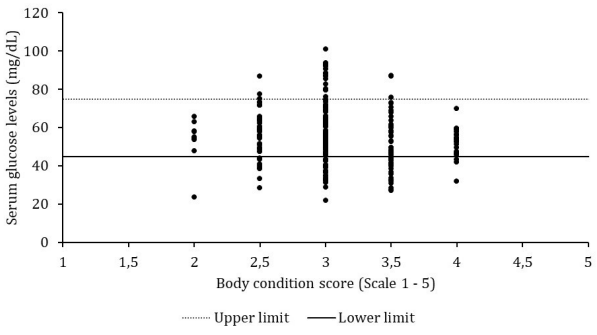
In this study, the presence of cows with hypoglycaemia may infer that nutritional management on some of the properties was not carried out in a balanced way to meet the energy demands of the animals. This aspect of nutritional management should always be considered because, according to Ingvartsen; Moyes (2015), glucose levels are related to animal immunity, and a low concentration of this metabolite during the post-partum period leads to immunosuppression in cows. Although this deficiency is considered normal during some stages, such as early lactation, the limit between normal levels and the disorder are close and easily crossed.

Considering the technological level of the properties participating in this research, it can be inferred that even with having as a food base with *Brachiaria* spp. or *Panicum* sp. roughage, associated with the use of grains, silages, and commercial mineral supplement, there was a high incidence of dairy cows in hypoglycaemia conditions, which is associated with a negative correlation with BCS and serum ketone body concentrations, coefficient of -0.1329 (P = 0.0335) and -0.1520 (P = 0.0149), respectively, may indicate failure in food management and also the absence of measures to



Source: collected by the author.

Figure 4. Serum glucose levels (mg/dL) as a function of weeks of lactation in dairy cows in the Sousa micro-region, Paraíba, Brazil.



Source: collected by the author.

Figure 5. Serum glucose levels (mg/dL) as a function of the body condition score in dairy cows in the Sousa micro-region, Paraíba, Brazil.

monitor and prevent the occurrence of metabolic disorders in the animals evaluated.

Correlation and multivariate analysis of the parameters

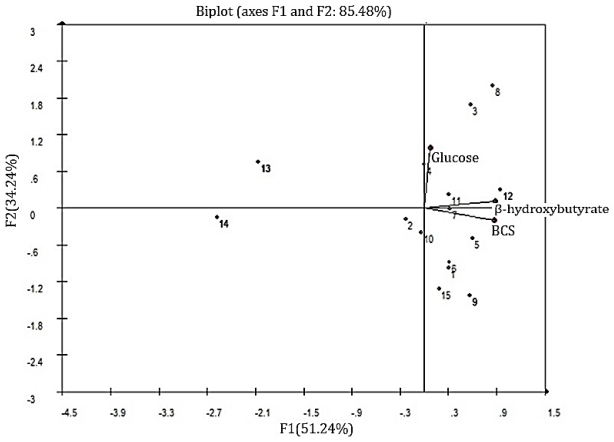
From the correlation analysis between the parameters (Table 1), it was found that BCS and serum glucose levels were negatively correlated, with a coefficient of -0.1329 (P = 0.0335), i.e., when the BCS increases, the serum glucose levels decrease. No significance was found 0.087 (P = 0.1608) when evaluating the correlation between BCS and serum ketone body concentrations. In evaluating the correlation between ketone bodies and serum glucose, these also showed a negative correlation, with a correlation coefficient of -0.1520 (P = 0.0149).

Glucose also had a negative correlation with ketone bodies, i.e., the higher the glucose levels, the lower the ketone body levels. This result is expected, since when ketone body levels are high, they reflect in a severe energy deficit, whereas when glucose is at normal levels, enough to supply the energy demand of the cow, fat is not mobilized as a response to the negative energy balance.

In the present study, this effect was clearly seen from the principal component analysis, in which serum glucose levels did not follow the trend observed for serum ketone bodies or BCS during most of the weeks of lactation (Figure 6). This reflects the need for constant monitoring of blood metabolites in dairy cows.

From the principal component analysis (Figure 6), the accumulated variance for components F1 (serum glucose levels) and F2 (serum ketone bodies) was 85.48%. The ketone body parameter (β-hydroxybutyrate) follows the same trend as the BCS, showing a relationship between these parameters, while the serum glucose parameter shows a divergent trend. All the observed effects were predominant from the first to the twelfth week.

In general, ketosis is more frequently seen in high-producing cows with a BCS greater than four. This is due to the larger amount of adipose tissue, and consequently, greater mobilization of fatty acids for milk production, with an increase in production and the release of ketone bodies into the bloodstream (Carvalho *et al.*, 2018; Viña *et al.*, 2017). However, in this study, there were no animals with a BCS greater than 4, which may have resulted in a lack of significance between the BCS and ketone body levels.



Source: collected by the author.

Figure 6. Principal component analysis for serum glucose and ketone body levels as a function of the body condition score in dairy cows in the Sousa micro-region, Paraíba, Brazil.

CONCLUSIONS

The localized incidence of subclinical ketosis in this study was 5.45% of the total number of cows under evaluation, with BCS and number of weeks of lactation having no influence on the incidence of the disorder. In addition, most of the cows had serum glucose levels within the normal range, the metabolite being negatively correlated with both the BCS and ketone body levels. Due to the resulting, the diagnosis and early treatment of ketosis should be carried out, particularly at the start of lactation.

ACKNOWLEDGMENTS

The authors would like to thank the Empresa de Assistência Técnica e Extensão Rural da Paraíba and the Indústria de Indústria de Laticínios Isis in the district of Sousa, Paraíba, Brazil for their support. The authors would also like to thank the Pro-Reitoria de Pesquisa, Inovação e Pós-Graduação (PRPIPG) of the Instituto Federal de Educação, Ciência e Tecnologia da Paraíba (IFPB), *Chamada Interconecta* – No. 01/2018, for the financial support (bench fee and scientific initiation grant) that made this research possible.

REFERENCES

BECK, H. E. *et al.* Present and future Köppen-Geiger climate classification maps at 1-km resolution. **Scientific Data**, v. 5, n. 180214, p. 1-12, 2018.

BELL, M. J.; *et al.* Comparison of methods for monitoring the body condition of dairy cows. **Frontiers in Sustainable Food Systems**, v. 2, n. 80, p. 1–7, 2018.

BENEDET, A. *et al.* Invited review: β-hydroxibutirate concentration on blood and milk and its associations with cow performance. **Animal**, v. 13, n. 8, p. 1676-1689, 2019.

BISWAL, S.; NAYAK, D. C.; SARDAR, K. K. Prevalence of ketosis in dairy cows in milk shed areas of Odisha state, India. **Veterinary World**, v. 9, n. 11 p. 1241-1247, 2016.

BRUNNER, N. *et al.* Prevalence of subclinical ketosis and production diseases in dairy cows in Central and South America, Africa, Asia, Australia, New Zealand, and Eastern Europe. **Translational Animal Science**, v. 3, n. 1, p. 84-92, 2018.

CARVALHO, A. F. S. *et al.* Relação do escore de condição corporal sob a incidência de retenção de placenta e cetose em bovinos de leite. **Revista da Universidade Vale do Rio Verde**, v. 16, n. 3, p. 1-7, 2018.

CASCONE, G. *et al.* Subclinical Ketosis in Dairy Herds: Impact of Early Diagnosis and Treatment. **Frontiers in Veterinary Science**, v. 9, n. 27, p. 1-8, 2022.

CHAPEL, J. M. *et al.* Relationship of BCS prepartum with reproductive performance and lipomobilization in Holstein dairy cows. **Pakistan Veterinary Journal**, v. 37, n. 2, p. 215-219, 2017.

DENIZ, A.; AKSOY, K.; METIN, M. Transition period and subclinical ketosis in dairy cattle: association with milk production, metabolic and reproductive disorders and economic aspects. **Medycyna Weterynaryjna**, v. 76, n. 9, p. 495-502, 2020.

DJOKOVIĆ, R. *et al.* Diagnosis of subclinical ketosis in dairy cows. **Biotechnology in Animal Husbandry**, v. 35, n. 2, p. 111-125, 2019.

FREITAS, B. B. *et al.* Cetose subclínica em vacas leiteiras na Região dos Campos Gerais no estado do Paraná. **Brazilian Journal of Development**, v. 6, n. 5, p. 30398-30405, 2020.

GARCÍA-ROCHE, M. *et al.* Glucose and Fatty Acid Metabolism of Dairy Cows in a Total Mixed Ration or Pasture-Based System During Lactation. **Frontiers in Animal Science**, v. 2, n. 01, p. 1-14, 2021.

GULIŃSKI, P. Ketone bodies – causes and effects of their increased presence in cows' body fluids: A review. **Veterinary World**, v. 14, n. 13, p. 1492-1503, 2021.

INGVARTSEN, K. L.; MOYES, K. M. Factors contributing to immunosuppression in the dairy cow during the periparturient period. **Japanese Journal of Veterinary Research**, v. 63, supl. 1, p. 15-24, 2015.

INMET - Instituto Nacional de Meteorologia. **Normais climatológicas** [Online]. Disponível em: http:/www.inmet.gov.br/portal/index.p Acesso em: 15 Julho de 2021.

MIDDLETON, E. L.; MINELA, T.; PUSLEY, J. R. The high-fertility cycle: How timely pregnancies in one lactation may lead to less body condition loss, fewer health issues, greater fertility, and reduced early pregnancy losses in the next lactation. **Journal of Dairy Science**, v. 102, n. 6, p. 5577-5587, 2019.

RODRÍGUEZ, A.; MELLADO, R.; BUSTAMANTE, H. prepartum fat mobilization in dairy cows with equal body condition and its impact on health, behavior, milk production and fertility during lactation. **Animal**, v. 10, n. 9, p. 1-13, 2020.

RODRIGUEZ-JIMENEZ, S. *et al.* Prepartal standing behavior as a parameter for early detection of postpartal subclinical ketosis associated with inflammation and liver function biomarkersin peripartal dairy cows. **Journal of Dairy Science**, v. 101, n. 9, p. 8224-8235, 2018.

SCHNEIDER, R. F. *et al.* Diagnóstico de cetose em vacas leiteiras, em diferentes sistemas de produção, por Optium Xceed® e Ketovet®. **Pubvet**, v. 14, n. 11, p. 1-7, 2020.

ŠAMANC, H. *et al.* Body condition score loss, hepatic lipidosis and selected blood metabolites in Holstein cows during transition period. **Animal Science Papers and Reports**, v. 33, n. 1, p. 35-47, 2015.

SAS INSTITUTE. Statistical Analysis System. **SAS/STAT User's Guide**. Cary, NC: SAS Institute, 2001.

SILVA, D. K. A. *et al.* Intake, performance, carcass traits and meat quality of goats grazing in the Caatinga rangeland. **Semina: Ciências Agrárias**, v. 41, n. 5, p. 1639-1652, 2020.

SILVA, D. C. *et al.* Prevalence of subclinical hypocalcemia in dairy cows in the Sousa city. **Tropical Animal Health and Production**, n. 51, p. 221-227, 2019.

STEENEVELD, W. *et al.* Estimating the combined costs of clinical and subclinical ketosis in dairy cows. **Plos One**, v. 15, n. 4, p. 1-13, 2020.

TORRES, E. *et al.* Serum metabolites and body condition score associated with metritis,endometritis, ketosis, and mastitis in Holstein cows. **Pesquisa Agropecuária Brasileira**, v. 55, p. 1- 10, 2020.

VIÑA, C. *et al.* Study on some risk factors and effects of bovine ketosis on dairy cows from the Galicia region (Spain). **Journal of Animal Physiology and Animal Nutrition**, v. 101, n. 5, p. 835-845, 2017.

WANG, D. et al. Subclinical ketosis risk prediction in dairy cows based on prepartum metabolic indices. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 73, n. 1, p. 11-17, 2021.

ZHANG, G.; AMETAJ, B. N. Ketosis an old story under a new approach. **Dairy**, v. 1, n. 1, p. 42- 60, 2020.