

Correlation between liver lipidosis, body condition score variation, and hepatic analytes in dairy cows

Correlação entre lipídose hepática, variação da condição corporal e analitos hepáticos em bovinos leiteiros

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Abstract

Liver lipidosis is a metabolic disorder mostly observed in high yielding dairy cattle, especially during the transition period. The aim of this study was to determine the correlation between hepatic lipid infiltration, biochemical indicators of liver function, and body condition score (BCS) variation in dairy cows. Fifty-one multiparous Holstein cows raised in a confined system were evaluated. Liver biopsies and blood samples were collected, and BCS was measured on days 3 and 28 postpartum. Lipid infiltration was determined by histologic examination. The plasma activity of aspartate aminotransferase, alkaline phosphatase, and gamma-glutamyl transferase and concentration of beta-hydroxybutyrate, non-esterified fatty acids, albumin, total bilirubin, and cholesterol were determined. BCS was measured using objective (camera) and subjective (visual) methods. Mild lipid infiltration was found in 3.92% of cows sampled on day 3 and 5.88% on day 28. Bilirubin was significantly higher on day 3 than on day 28 postpartum, and cholesterol was significantly higher on day 28 than on day 3 in all cows. There was no difference in biochemical analytes between cows with and without lipidosis. On day 3, mean subjective BCS was 3.10 and objective BCS was 3.16, while on day 28, these scores were 2.91 and 2.99, respectively. The calculated liver function index (LFI) was found to be a more sensitive indicator of liver function than the hepatic analytes evaluated. No correlation between BCS variation and lipid infiltration was found. Cholesterol and bilirubin levels showed the most remarkable changes during the early postpartum period. LFI is a potential indicator of postpartum liver function.

Keywords: hepatic lipidosis, weight, blood metabolites, hepatic function, calculated liver function index, dairy cattle.

Resumo

A lipídose hepática é um distúrbio metabólico principalmente observado nos bovinos de leite de alto rendimento, especialmente no período de transição. O objetivo deste estudo foi determinar a correlação entre infiltração lipídica hepática, indicadores bioquímicos de função hepática e variação da condição corporal em bovinos leiteiros. Foram avaliadas cinquenta e um vacas multíparas de raça Holandesa em confinamento. Coletaram-se biopsias de fígado e amostras de sangue, e a condição corporal (BCS) aferiu-se nos dias 3 e 28 pós-parto. A infiltração lipídica determinou-se mediante avaliação histológica. Mensuraram-se a atividade da aspartato aminotransferase, fosfatase alcalina e da gama-glutamil transferase, concentração de beta-hidroxibutirato, ácidos graxos não esterificados, albumina, bilirrubina total e colesterol. A BCS mediu-se utilizando método objetivo (câmera) e subjetivo (visualmente). Observou-se discreta infiltração lipídica em 3,92% dos bovinos amostrados no dia 3 e 5,88% no dia 28. Em todos os bovinos a bilirrubina foi significativamente mais alta no dia 3 do que no dia 28 e o colesterol foi superior no dia 28 do que no dia 3. Não houve diferença nos analitos bioquímicos dos bovinos com e sem lipídose. No dia 3, a média subjetiva da BCS foi 3,10 e a objetiva 3,16, enquanto no dia 28, obtiveram-se valores de 2,91, e 2,99 respectivamente. O índice calculado de função hepática mostrou ser um indicador mais sensível da função hepática do que os analitos avaliados individualmente. Não houve correlação entre a variação do BCS e infiltração lipídica.

Palavras-chave: lipídose hepática, peso, metabolitos sanguíneos, função hepática, índice calculado de função hepática, bovinos de leite.



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Introduction

The transition period is a challenging stage in the productive life of dairy cattle, going abruptly from a period of low feed consumption and demand to one of intense milk production requiring a high nutrient-dense diet (Divers & Peek, 2018). During the prepartum period, reduction in dry matter consumption is the most significant change, culminating in negative energy balance (NEB) (Esposito et al., 2014). In addition, corticoid and estrogen concentrations increase dramatically weeks before calving, contributing to a reduction of up to 30% of dry matter intake (Bell, 1995). Although dry matter consumption increases in the postpartum period, it is not enough to supply the increased energy demand due to the commencement of lactation (Santos, 2011), leading to NEB.

Lipid metabolism acts as an adaptation mechanism during the transition period, regulating NEB through mobilizing reserve lipids and fatty acid oxidation to form energy precursors (Corassin et al., 2011). Adipose tissue is catabolized by hormone-sensitive lipases during this phase, releasing free non-esterified fatty acids (NEFA) and glycerol (Divers & Peek, 2018). In addition to this adaptation on lipid metabolism, there is a great release of glucose by the liver, and the availability of glucose to the mammary gland is enhanced by a transient state of insulin resistance in peripheral tissues (Weber et al., 2016).

During periods of energy shortage, the concentration of hormones that stimulate lipolysis increases, such as adrenaline, glucagon, growth hormone, and cortisol (Santos, 2011), resulting in an increase in NEFA influx from adipose tissue into the liver. Some of these fatty acids are incorporated into milk synthesis (Jorjong et al., 2014).

In the liver, depending on the circulating levels of these fatty acids, a certain proportion is incorporated from the blood. NEFA concentrations above 700 $\mu\text{mol/L}$ are a strong indicator of intense lipomobilization (González et al., 2011). At such levels, fatty acids can undergo complete oxidation in the liver producing ketone bodies. Alternatively, they may be re-esterified and deposited as triglycerides (TG), which must attach to very low-density lipoproteins before being transported to peripheral tissues (Ospina et al., 2010).

Since dairy cows have low capacity to export TG-containing lipoproteins from the liver, excessive lipomobilization during NEB periods leads to significant accumulation of lipids in the liver that cannot be degraded or released in carrier lipoproteins (Gross et al., 2013). Hepatic lipodosis can affect more than 40% of dairy cows in the postpartum period (Jorritsma et al., 2001) and has been associated with peripartum diseases such as ketosis, abomasal displacement, placental retention, and mastitis (Ospina et al., 2010). Several studies have shown that NEB induces high serum NEFA and low insulin concentration (Weber et al., 2016), both associated with delayed first ovulation after calving and reduced pregnancy rates (Giuliodori et al., 2011; Garverick et al., 2013). Moreover, large (BCS) loss in dairy cows during the postpartum period has been related to poor reproductive performance (Pryce et al., 2001).

This study aimed to determine the correlation between liver lipid infiltration, BCS variation, and hepatic biochemical variables in the postpartum period in dairy cows.

Materials and methods

A cross-sectional study was performed in dairy cattle from a commercial farm using a confinement system in Southern Brazil, after approval by the Ethics Committee on Animal Use of the Federal University of Rio Grande do Sul under protocol number 32692.

Fifty-one multiparous Holstein cows were selected. The animals had between two and four lactations, with a mean daily milk production of 32.91 kg over 305 days in the previous lactation. Only cows that had not undergone surgery at the time of calving were included in the study. BCS evaluation, blood samples, and percutaneous liver biopsy were performed on days 3 and 28 postpartum. The total diet provided to the animals was balanced to fulfill the requirements for a milk production of 40 kg/day, with 3.5% fat, 3.2% protein, and 4.7% lactose and consisted of corn silage, oat silage, wheat straw, ground corn grain, soy bran, soy husk, mineral core, and vitamins. The chemical composition of the diet was as follows: 38% neutral detergent fiber, 1.6 Mcal/day of metabolizable energy, 18% crude protein, to meet the nutritional requirements of dairy cows (National Research Council, 2001).

BCS was evaluated using two techniques. The objective technique consisted of using a BCS DeLaval camera with 3D image recording (DeLaval, Tumba, Botkyrka, Sweden), which evaluates the angular conformation of the caudal region of the cow through image capture, records the data into software (Kinect Sensor for Windows version 2; Microsoft, Redmond, WA), and classifies BCS on a scale from 1 to 5, where 1 is very thin and 5 is very fat, with a range of 0.10 points. The subjective method was based on the scale developed by Ferguson et al. (1994), executed by a single evaluator using a classification from 1 (very thin) to 5 (very fat), with a range of 0.25 points.

Liver biopsies were performed using the method described by Braga et al. (1985). The area chosen for needle insertion (TruCut-type soft tissue biopsy needle; Somatex Medical Technologies GmbH, Berlin, Germany) corresponded to the right hepatic lobe's topographic position. The selected area was trichotomized and locally anesthetized with 2% lidocaine, and iodinated alcohol was used for antisepsis. The needle was then introduced into the liver via percutaneous and transthoracic approaches. Obtained samples were 0.5-1.5-cm long and 0.1-cm thick and were fixed in 10% formalin immediately after collection. The formalin-fixed tissues were embedded in paraffin, cut, stained with Oil Red and periodic acid Schiff (PAS), and evaluated at 40× magnification to quantify the mean proportion (%) of total lipids per light field in ten fields. Oil Red stains neutral lipids, TG and fatty acids with more intensity than other Sudan-type stains. PAS was used to identify glycogen and differentiate it from lipids. Biopsy lipid deposition was classified using the technique described by Bobe et al. (2004), which defines 1 to 5% TG as mild infiltration, 5 to 10% TG as moderate, and >10% TG per light field as severe infiltration.

Blood samples were collected via coccygeal venipuncture using 10-mL heparinized vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ, USA), following proper skin antisepsis. Samples were centrifuged at $1,650 \times g$ for 10 min. Plasma aliquots were stored at -20°C in microtubes for the posterior determination of beta-hydroxybutyrate (BHB), NEFA, albumin, bilirubin, and cholesterol concentrations, as well as aspartate transaminase (AST), alkaline phosphatase (ALP), and gamma-glutamyl transferase (GGT) activity using a CM-200 clinical analyzer (Wiener lab Group, Rosario, Argentina) and commercial diagnostic kits (Labtest for albumin, bilirubin, cholesterol, AST, ALP, and GGT; Randox for BHB and NEFA).

Liver functionality index (LFI) was calculated using albumin (g/L), cholesterol (mmol/L), and bilirubin ($\mu\text{mol/L}$) concentrations on both days 3 (VD3) and 28 (VD28), as described by Bertoni and Trevisi (2013). Values above zero are considered indicative of adequate liver function. The formula for calculating LFI is divided into two steps, as follows:

1. Step 1: Calculation of albumin, cholesterol, and bilirubin subindex:

$$\text{Albumin subindex (Alb I)} = 50\% \text{ VD3} + 50\% (\text{VD28} - \text{VD3}) \quad (1)$$

$$\text{Cholesterol subindex (Chol I)} = 50\% \text{ VD3} + 50\% (\text{VD28} - \text{VD3}) \quad (2)$$

$$\text{Bilirubin subindex (Bil I)} = 67\% + 33\%(\text{VD3} - \text{VD28}) \quad (3)$$

2. Step 2: Calculation of LFI

$$\text{LFI} = (\text{Alb I} - 17,71)/1,08 + (\text{Chol I} - 257)/0,43 - (\text{Bil I} - 6,08)/2,17 \quad (4)$$

For statistical analysis, SPSS software was used. Normality was assessed using the Shapiro-Wilk test and homoscedasticity was assessed using Bartlett tests. Agreement between objective and subjective BCS scores was determined using the Kappa test. The association between liver lipid infiltration degree and BCS loss was evaluated using the chi-square test. Liver function indicators in all cows and those with liver lipidosis were evaluated using the Fisher test, considering lactation days 3 and 28 as a fixed effect. The correlation between liver lipid infiltration degree and LFI was evaluated using the Pearson test. A *P*-value lower than 5% was considered significant for all statistical tests.

Results

On day 3, the mean objective and subjective BCS were 3.16 and 3.10, while on day 28, they were 2.99 and 2.91, respectively, with a mean BCS loss of 0.19 points with the subjective method and 0.17 points with the objective method between the two days. Subjective and objective BCS results showed a good correlation on day 3 ($r = 0.72$; $P < 0.01$) and day 28 ($r = 0.76$; $P < 0.01$).

According to the liver biopsy results, mild lipid infiltration (1 to 5% hepatic TG) was identified in 2 of 51 cows on day 3 and 3 of 51 cows on day 28. The association between lipid infiltration and BCS loss did not differ among animals. Bilirubin concentration was significantly higher on day 3 than on day 28 ($P < 0.05$). Inversely, cholesterol concentration was significantly higher on day 28 than on day 3 ($P < 0.05$). Although NEFA and ALP levels were higher on day 3, the difference was not statistically significant. Only the cholesterol concentration was below the lower limit (54.6 mg/dL), as shown in Table 1.

Table 1. Mean values and standard deviation (SD) of analytes and body condition score (BCS) on days 3 and 28 postpartum (N = 51) of Holstein cows in southern Brazil.

| Analyte (units) | Reference value* | Day 3 postpartum | Day 28 postpartum |
|-------------------------|------------------|----------------------------|-----------------------------|
| Albumin (g/L) | 27-35 | 32.94 ± 2.49 | 34.04 ± 2.18 |
| BHB (mmol/L) | <1.4 | 0.51 ± 0.20 | 0.47 ± 0.17 |
| Bilirubin (mg/dL) | <0.54 | 0.11 ^a ± 0.07 | 0.06 ^b ± 0.02 |
| Cholesterol (mg/dL) | 80-120 | 54.57 ^b ± 11.43 | 109.90 ^a ± 26.47 |
| AST (U/L) | <132 | 49.74 ± 17.34 | 48.68 ± 19.78 |
| ALP (U/L) | <196 | 138.01 ± 51.58 | 81.13 ± 24.55 |
| GGT (U/L) | <39 | 27.60 ± 9.79 | 26.96 ± 5.34 |
| NEFA (μmol/L) | <700 | 577 ± 371 | 364 ± 234 |
| Objective BCS (camera) | 1-5 | 3.16 ± 0.24 | 2.99 ± 0.24 |
| Subjective BCS (visual) | 1-5 | 3.10 ± 0.20 | 2.91 ± 0.20 |

* Reference values from González et al. (2011) and Cozzi et al. (2011). ^{a,b} Different superscripts in the same row indicate significant difference ($P < 0.05$). AST, aspartate aminotransferase; BHB, β-hydroxybutyrate; ALP, alkaline phosphatase; GGT, gamma-glutamyl transferase; NEFA, non-esterified fatty acids; BCS, body condition score.

When comparing hepatic analytes of cows with mild hepatic lipidosis with those without lipidosis, similar values were obtained (Table 2). NEFA values were slightly but not significantly higher on day 3 than on day 28 postpartum. Only the mean cholesterol concentration was slightly low (52.3 mg/dL). No significant differences in biochemical analytes were observed between cows with and without liver lipidosis (Table 3).

Table 2. Mean values and standard deviation of analytes on days 3 and 28 postpartum for cows with mild hepatic lipidosis (N = 5) in southern Brazil.

| Analyte (units) | Reference value* | Day 3 postpartum | Day 28 postpartum |
|---------------------|---------------------|----------------------------|----------------------------|
| Albumin (g/L) | 27-35 | 32.04 ± 2.06 | 32.78 ± 2.47 |
| BHB (mmol/L) | <1.4 | 0.51 ± 0.22 | 0.50 ± 0.21 |
| Bilirubin (mg/dL) | <0.54 | 0.13 ^a ± 0.03 | 0.08 ^b ± 0.03 |
| Cholesterol (mg/dL) | 80-120 ^b | 52.26 ^b ± 12.98 | 82.95 ^a ± 22.71 |
| AST (U/L) | <132 | 52.0 ± 15.12 | 49.60 ± 14.04 |
| ALP (U/L) | <196 | 114 ± 42.33 | 94.60 ± 35.59 |
| GGT (U/L) | <39 | 26.77 ± 11.44 | 27.35 ± 7.13 |
| NEFA (μmol/L) | <700 | 692 ± 391 | 386 ± 346 |

* Reference values from González et al. (2011) and Cozzi et al. (2011). ^{a,b} Different superscripts in the same row indicate significant difference ($P < 0.05$). AST, aspartate aminotransferase; BHB, β-hydroxybutyrate; ALP, alkaline phosphatase; GGT, gamma-glutamyl transferase; NEFA, non-esterified fatty acids.

Table 3. Mean values and standard deviation (SD) from all analytes measured on healthy cows and cows with liver lipodosis.

| Analyte (units) | Reference value* | Healthy cows | Cows with liver lipodosis |
|---------------------|------------------|----------------|---------------------------|
| N** | | 92 | 10 |
| Albumin (g/L) | 27-35 | 33.61 ± 5.77 | 32.41 ± 4.68 |
| BHB (mmol/L) | < 1.4 | 0.49 ± 0.03 | 0.50 ± 0.04 |
| Bilirubin (mg/dL) | < 0.54 | 0.08 ± 0.04 | 0.10 ± 0.01 |
| Cholesterol (mg/dL) | 80-120 | 83.83 ± 32.77 | 67.61 ± 26.92 |
| AST (U/L) | < 132 | 49.36 ± 39.99 | 50.80 ± 19.06 |
| ALP (U/L) | < 196 | 110.15 ± 56.91 | 104.30 ± 64.45 |
| GGT (U/L) | < 39 | 27.31 ± 6.48 | 27.06 ± 8.01 |
| NEFA (μmol/L) | < 700 | 463 ± 105 | 538 ± 125 |

* Reference values from González et al. (2011) and Cozzi et al. (2011); ** Number of samples (N) includes sampling at 3 and 28 days postpartum. AST, aspartate aminotransferase; BHB, β-hydroxybutyrate; ALP, alkaline phosphatase; GGT, gamma-glutamyl transferase; NEFA, non-esterified fatty acids.

Values of LFI close to or above zero are considered to indicate adequate liver function. The total mean LFI was -1.26. Cows with liver lipodosis had a significantly lower LFI (-3.46) than healthy ones (-1.02; $P < 0.01$). No significant correlation was observed between liver lipid infiltration and LFI.

Discussion

The transition period in dairy cows (3 weeks before calving and 3 weeks after calving) is the period of greatest metabolic challenge. For this reason, in the present study, the analysis was more concentrated in the initial postpartum period (4 weeks postpartum). Regarding the BCS evaluation techniques used in this study, both had similar mean values: 3.10, using the subjective method and 3.16 using the objective method on day 3. On day 28, the mean values were 2.91 and 2.99, respectively, with a mean BCS loss of 0.19 points with the subjective method and 0.17 points with the objective method between days 3 and 28 postpartum. The adequate BCS at parturition and the small loss of BCS may explain the low number of cows with hepatic lipodosis. Cows with a mean BCS of 3.5 or above have a higher incidence of hepatic infiltration (Graugnard et al., 2013). In the current study, cows presented a BCS of approximately 3.0 at calving and lost a few BCS points up to day 28 postpartum with both forms of BCS evaluation. To minimize peripartum risks, the ideal BCS is considered to be around 3.25 at calving (Garnsworthy, 2013). The mean BCS by both evaluation methods was close to the ideal BCS, reducing the risk of liver lipodosis. This might explain the low incidence of hepatic lipodosis in the current study since the main predisposing factor for hepatic lipodosis is high BCS loss (Bobe et al., 2004).

Subjective (visual) and objective (camera) BCS evaluation methods showed a good correlation on days 3 ($r = 0.72$) and 28 postpartum ($r = 0.76$), as has been previously observed (Vanrobays et al., 2015). According to Song et al. (2018), the objective method of BCS evaluation has a similar effect and purpose as the manual and semi-automatic methods available and presents good morphometric evaluation but lacks a more efficient data interpretation system to increase its accuracy.

Although high-yielding dairy cows are predisposed to hepatic lipodosis, and an incidence of up to 40% has been reported (Jorritsma et al., 2001; Bobe et al., 2004), the incidence observed was lower (3.92% and 5.88% on days 3 and 28 postpartum, respectively). The cows in the present study had a mean milk production of 38 L for 305 days, falling into the high-yielding category (Quiroz-Rocha et al., 2010). All cows presented adequate BCS at calving and did not lose more than one BCS unit; these are important factors influencing liver lipid infiltration. This finding was the result of providing a diet that guaranteed the nutritional needs of the cows accordingly with their production.

In all studied populations, there was a higher bilirubin concentration on day 3 than on day 28, while cholesterol values remained low on both days. Higher bilirubin and hypocholesterolemia

during early lactation (until day 3) physiologically occur in high-yielding dairy cows, in which high metabolic demand and low dry matter intake lead to NEB (Graugnard et al., 2012; Trevisi et al., 2012). Considering liver enzymes, AST values for all cows, including those with hepatic lipidosis, were within the reference range. AST is an acute-phase enzyme found in the mitochondria and, to a lesser extent, the hepatocyte cytosol (Divers & Peek, 2018). AST is released into the bloodstream due to liver injury, hepatic lipid accumulation, inflammation, or muscular lesions. AST levels can be useful to detect hepatocellular injuries, but it should be evaluated in conjunction with metabolites that indicate liver function to obtain a more accurate diagnosis (Allison, 2012).

In the present study, BHB and NEFA concentrations were slightly higher on day 3 postpartum than on day 28 in all cows. Reduction of dry matter intake during the peripartum period leads to a greater mobilization of NEFA from reserves to meet lactation demands, also increasing BHB (Piñeiro et al., 2019). NEFA has been reported as a good biomarker for prepartum energy metabolism and BHB as a good marker for postpartum energy metabolism (Mann et al., 2016), both of which are widely used today. In the present study, the lack of a significant difference between these indicators on days 3 and 28 postpartum indicated that NEB was not high enough to induce substantial BHB or NEFA elevations in the cows studied. As food consumption normalizes over time during the postpartum period, NEFA and BHB concentrations tend to stabilize (Quiroz-Rocha et al., 2010), as was observed in the current study, where both NEFA and BHB were lower on day 28 than on day 3 postpartum, suggesting energy demand stabilization and increasing food consumption. It should be noted that the first 4 weeks of lactation correspond to the greatest metabolic challenge. In addition to convenience reasons for being commercial farms, the study focused on this period. In the present observational study, it is noteworthy that the farm had an excellent feed management system, which certainly contributed to a low prevalence of hepatic lipidosis.

ALP is a non-specific membrane-associated enzyme with several isoforms. Most serum ALP corresponds to the hepatic isoform present in biliary epithelial cells and the canalicular membrane of hepatocytes (Allison, 2012). Early postpartum cows undergo intense lipid mobilization, which explains the higher ALP levels on day 3 than on day 28, when consumption and energy demand are already stabilized, considering that it is after the transition period. Lipid deposition compresses bile ducts, inducing ALP release. Furthermore, parenchymal swelling can obstruct small bile ducts and cause indirect ALP release, resulting in a wide reference range, often hindering its interpretation in ruminants (Divers & Peek, 2018). Moreover, ALP levels in serum are much higher in cases of liver lipidosis (González et al., 2011). This could be why a small difference was observed between ALP concentrations in cows with hepatic lipidosis. GGT is an enzyme found in the membranes and cytosol of different cells, especially the epithelial cells of the bile ducts and renal tubules (González et al., 2011). GGT activity remained within the reference values, with no difference between days 3 and 28, among all studied animals. ALP is a more sensitive enzyme than GGT for the detection of bile duct compression due to fat infiltration.

Diseases that impair liver or biliary function may lead to bile pigment accumulation and increased levels of total bilirubin. Moreover, bilirubin physiologically increases a week before calving and remains high for a few weeks after parturition (González et al., 2011). During the peripartum period, the liver usually undergoes an inflammatory process, leading to decreased production of some enzymes that conjugate bilirubin, increasing unconjugated bilirubin concentration during this period (Bertoni & Trevisi, 2013). Hyperbilirubinemia is associated with diffuse hepatic diseases such as lipidosis or chronic liver failure in ruminants (Allison, 2012). This supports the fact that cows presented higher bilirubin concentrations at the beginning of lactation, even if its values remained within reference levels. Lipid deposition in the liver and the consequent organ swelling could lead to hyperbilirubinemia of both hepatic and post-hepatic origin. These values could potentially influence LFI calculation.

Hypocholesterolemia was a consistent finding present in all cows on day 3 postpartum (Tables 1 and 2) and when obtaining all measurements of cows with liver lipidosis (Table 3). Cholesterol comes from the diet or metabolization of acetyl-CoA by the liver (Allison, 2012). A previous study on dairy cows during the transition period demonstrated that cholesterolemia had the same pattern of dry matter intake (Guretzy et al., 2006). Blood cholesterol levels reflect the concentration of hepatic cholesterol production and food consumption, which generally remains low from the last prepartum week to week 6 postpartum. Another study found that

cows with liver lipidosis had lower cholesterol concentrations than those without lipidosis. Hypocholesterolemia was also associated with liver lipidosis and low dry matter consumption in the immediate postpartum period, returning to normal levels over several weeks (Sepulveda-Varas et al., 2015).

Albumin remains high until the end of pregnancy, with a concentration of 36–37 g/L, decreasing slightly in the postpartum period, as it is a negative acute-phase protein (Bertoni & Trevisi, 2013). It is more probable that albumin concentration was affected by the inflammatory process than by impaired hepatic function, considering that albumin takes 21 days to be cleared (Allison, 2012). Additionally, decreased consumption in the period around parturition may be a cause of decreased serum albumin (González et al., 2000).

LFI results indicated adequate liver function as its mean value in all cows was close to zero (-1.26). Postpartum cows generally undergo a period of systemic and hepatic inflammation, impairing liver function (Leblanc, 2012). Postpartum cows with good liver function usually present with LFI around -1.5 or above; however, cows with hepatic inflammatory processes or pathologies tend to have an extremely low LFI (Trevisi et al., 2013). In the present study, postpartum cows with liver lipidosis presented lower LFI (-3.46) than those without lipidosis (-1.02). There was a strong relationship between liver lipidosis and LFI, as expected, because LFI is influenced by variations in albumin, cholesterol, and bilirubin concentrations caused by liver lipidosis. LFI could be a more sensitive indicator of liver function than the isolated values of each analyte in its formula. It is important to highlight that cholesterol was low and bilirubin was high in cows with lipidosis and that those metabolites did not have significant differences compared to those of the group without lipidosis.

The main limitation of this study is that the sampled cows belonged to a single property. It can be difficult to obtain permission to perform liver biopsies on lactating cows in a productive system. The results obtained in this study must be interpreted with caution when comparing them with those in other types of productive systems, feeding, or even geographic areas.

Conclusion

Cholesterol and bilirubin levels showed the most remarkable changes during the early postpartum period in healthy cows and cows with hepatic lipidosis. LFI was a potential indicator of postpartum liver function. The objective BCS evaluation method was well correlated with the subjective method, but adjustments are still necessary to improve its performance.

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Ethics statement

The study has been approved by the Ethics Committee on Animal Use (CEUA) of the Federal University of Rio Grande do Sul under protocol number 32692.

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Conflicts of interests

CPB, RSG, LVQC, SFV e FHDG - No conflict of interest.

Authors' contributions

CPB e RSG - Development of methodology; preparation and writing the initial draft . CPB - Application of statistical study data. SFV, FHDG - Review and Editing manuscript. LVQC - Writing, Review and Editing manuscript. FHDG - Acquisition of the financial support for the project leading to this publication.

Availability of complementary results

NCBI PubMed Central <https://www.ncbi.nlm.nih.gov/pmc/>

Histologic analysis of liver biopsies were carried out at Laboratório de Patologia Animal do Centro de Ciências Agroveterinárias, Universidade do Estado de Santa Catarina. Biochemical analysis were carried out at Laboratório de Análises Clínicas Veterinárias, Faculdade de Veterinária, Universidade Federal do Rio Grande do Sul.

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