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Monitoring blood biochemical indices during the lactogenesis and galactopoiesis stages in female dromedary camels (*Camelus dromedarius*)

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ABSTRACT

This study aims to investigate the changes of biochemical blood parameters in female dromedary camels during lactogenesis and galactopoiesis in Algeria. Therefore, 56 serum samples were collected from females (monthly) for last four months antepartum (AP) and the first four months postpartum (PP) and biochemical profiles were investigated. The data were statistically analyzed using General Linear Model with repeated measures and Benferroni test as post-hoc test. Glucose increased significantly at the third month PP, with sudden decrease after that. Triglycerides peaked significantly in second month PP compared to fourth month PP and first month AP. Cholesterol elevated significantly at the third month PP comparatively to the first months AP and PP. Low-density lipoprotein increased significantly substantially from the second to the fourth month PP. High-density lipoprotein lowered significantly in the first month AP to rise substantially at third month PP. Calcium increased considerably from second to third months PP. A significant difference of iron was marked between the third month AP and the fourth month PP. Urea dropped abruptly at first month PP and elevated considerably in the second month PP. Creatinine marked a substantial rise from third to first month AP to decrease afterward. It increased significantly at third months PP compared to antepartum period. ALT indices of second month AP decreased notably in the second month PP. These findings indicate that lactogenesis and galactopoiesis period have substantial impacts on metabolites, proteins, hepatic enzymes, and minerals in the blood of female camels.

Keywords: Antepartum, Camels, Metabolites, Postpartum

Lactation in mammals includes two essential stages namely, lactogenesis and galactopoiesis. Lactogenesis involves functional differentiation and limited structure of the secretory epithelium. However, galactopoiesis takes place during the immediate periparturient period, completing cellular differentiation as abundant milk synthesis and secretion begin (Akers and Capuco 2002, Pillay and Davis 2023). In camels, the duration of gestation was reported to last for 387 days and their lactation period extends between 6 to 19 months (Nagy and Juhász 2019). Lactogenesis typically initiates in the last trimester of pregnancy (Akers and Capuco 2002, Pillay and Davis 2023), which coincides in camels with the last four months of pregnancy. During lactation, an abundant quantity of protein, lipid and carbohydrate are synthesized and secreted by the secretory cells of the udder and this process needs coordination between the pathway of supplying biochemical metabolic intermediates and secretory pathways to produce these nutrients (Akers and Capuco 2002, Pillay and Davis 2023). Therefore, biochemical metabolites are crucial for maintaining maternal and offspring health during pregnancy and postpartum. The increased metabolic demands of gestation and lactation in ruminants lead to alterations in biochemical indices (Naji *et al.* 2024). Biochemical and hematological variables are key components of blood metabolic profiles (BMPs), widely used to assess animal health, production and nutritional status (Antunovic *et al.* 2011, Zhang *et al.* 2023, Chikha *et al*. 2024). The evolution and alterations of biochemical parameters during lactogenesis in female camels, as well as the potential impact of the latter on these parameters, have not been explored. Moreover, the variations in blood biochemical parameters during lactogenesis and galactopoiesis periods in female dromedary camels have never been investigated in Algeria.

As camel milk plays a multifaceted and significant role in contributing to sustainable development goals (Chikha and Faye 2025), understanding the physiological changes during lactation is crucial. This prospective study aims to assess variations in energetic metabolites, proteins, hepatic

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enzymes, and minerals in the blood of female dromedary camels (*Camelus dromedarius*) in southeastern Algeria. Focusing on the last four months of gestation and the first four months of lactation, the study explores key metabolic adaptations during lactogenesis and galactopoiesis. The findings will offer valuable insights to enhance maternal health, milk production, and the overall management of camels in arid regions.

MATERIALS AND METHODS

Animals: Seven multiparous female Sahraoui dromedary camels, aged 10-12 years, were randomly selected from a local semi-intensive herd in El Oued, Algeria. The camels were healthy, free of parasites, and housed in open stalls in a desert area far from residential buildings and roads. During the postpartum period, the camels were milked daily in the early morning and grazed on natural desert pasture. They were separated from their calves after midday and fed a mixture of barley, alfalfa, wheat bran, and olive pomace pellets in the morning. Watering occurred at the end of the day. No health issues or diseases were observed during the study, and all camels gave birth to full-term, viable calves without clinical dystocia.

Sampling procedure: Blood samples were collected from the left jugular vein of each animal at 14th, 10th, 6th and 2nd weeks before the expected parturition date, and at 2nd, 6th, 10th and 14th weeks after parturition. These sampling stages corresponding to the 4th, 3rd, 2nd and 1st months antepartum (4M-AP, 3M-AP, 2M-AP and 1M-AP, respectively) and at 1st, 2nd, 3rd and 4th months after parturition (1M-PP, 2M-PP, 3M-PP and 4M-PP, respectively). The sampling was carried out in the early morning before morning grazing or feeding. The serum was harvested by centrifuging at 3000 rpm for 10 minutes and then transferred directly to the laboratory for the analytical procedures. Verbal approval for the collection of biological samples was given by the livestock owner.

Analytical procedures: Serum biochemical parameters were measured by biochemistry automatic analyzer COBAS Integra 400 (Roche Diagnostics GmbH, Mannheim, Germany) using commercial assay kits (Biodiagnostic Company GmbH, Mannheim, Germany) for detection of the activities of aspartate transaminase (AST, IU/L) and alanine transaminase (ALT, IU/L), the concentration of urea (g/L), iron (mg/L), calcium (mg/L), glucose (g/L), creatinine (mg/L), cholesterol (g/L), triglyceride (g/L), high density lipoprotein (HDL, g/L) and low density lipoprotein (LDL, g/L).

Statistical analysis: The means and standard of error (SEM) of biochemical parameters were calculated by General Linear Model with repeated measures using IBM SPSS Statistics 25 (IBM Corp., NY, USA). Benferroni test was used as post-hoc test to examine the difference between the means. A significance level of $p< 0.05$ was applied to determine statistical significance. The distribution of the coefficient of variation (CV) for each parameter at different stages was visualized using box plots.

RESULTS AND DISCUSSION

The regulation of the metabolism of biochemical parameters is the most important physiological process during lactogenesis and galactopoiesis. Based on the statistical analysis, The glucose levels during the antepartum period ranged between 0.81 and 1.17 g/L, and no significant difference was observed between months during this period with decrease in glucose concentration at 3M-AP (fig. 1A). In contrast, Ahmadpour *et al.* (2019) found a significant difference in glucose concentration during the antepartum period. Glucose has a critical role in meeting the mammary demand for lactogenesis, where glucose is utilized for the synthesis of cellular components, serving as a supplier of carbons (Matthew 2016, Western Canadian Dairy Seminar). Similar to 3PP changes in the current study, significant differences in glucose concentration were observed during early lactation (El-Zahar *et al.* 2017, Ahmadpour *et al.* 2019) and across different stages of lactation (Hussein *et al.* 2012). Glucose turnover may be linked to its role in the synthesis of lactose in the mammary gland as the sole precursor (Faye and Bengoumi 2018). Concentrations of cholesterol rose considerably (p<0.05) at 3M-PP (0,68±0,14 g/L) in comparison to the numerical values reported at 1M-AP (0.30±0.10 g/L) and 1M-PP (0.36±0.11 g/L) (fig. 1B). The decrease of cholesterol concentration during antepartum period that reported in our study is in contrast with the results from previous research in camels (Ahmadpour *et al.* 2019). The reduction in cholesterol levels during the months surrounding parturition can be attributed to an increased demand for cholesterol in steroid hormone synthesis, particularly as predominant precursors in steroidogenic endocrine organs such as the ovaries and placenta (Kurpińska *et al.* 2015, Arfuso *et al.* 2016, Ahmadpour *et al.* 2019). Additionally, this decrease may be influenced by the cellular differentiation requirements of the mammary gland during lactogenesis. On the other hand, the lower cholesterol levels during the initial two months postpartum may be a result of the demands for milk production and the suppressed activity of Lecithin: Cholesterol Acyl-Transferase (Arfuso *et al.* 2016, Ahmadpour *et al.* 2019).

During antepartum period, HDL concentrations of 4M-AP (0.362±0.014 g/L) dropped significantly (p<0.05) until 1MPP. After that, it increased considerably (p<0.05) from 2M-PP (0.13± 0.01 g/L) to 3M-PP by more than 338 %. (fig. 1D). The decline in HDL levels can be attributed to the decrease in cholesterol levels, while the subsequent increase during the 3M-PP phase is linked to the rise in cholesterol levels. Consistent with our study, Ahmadpour *et al.* (2019) reported a significant decrease in HDL during the antepartum period. Our current findings highlight that the lowest significant HDL values were observed during the first two months of lactation. Similar results from Mazur *et al.* (1988) showed lower HDL values in cattle at the beginning of lactation compared to those at six weeks of lactation. The reduced HDL levels during this lactation

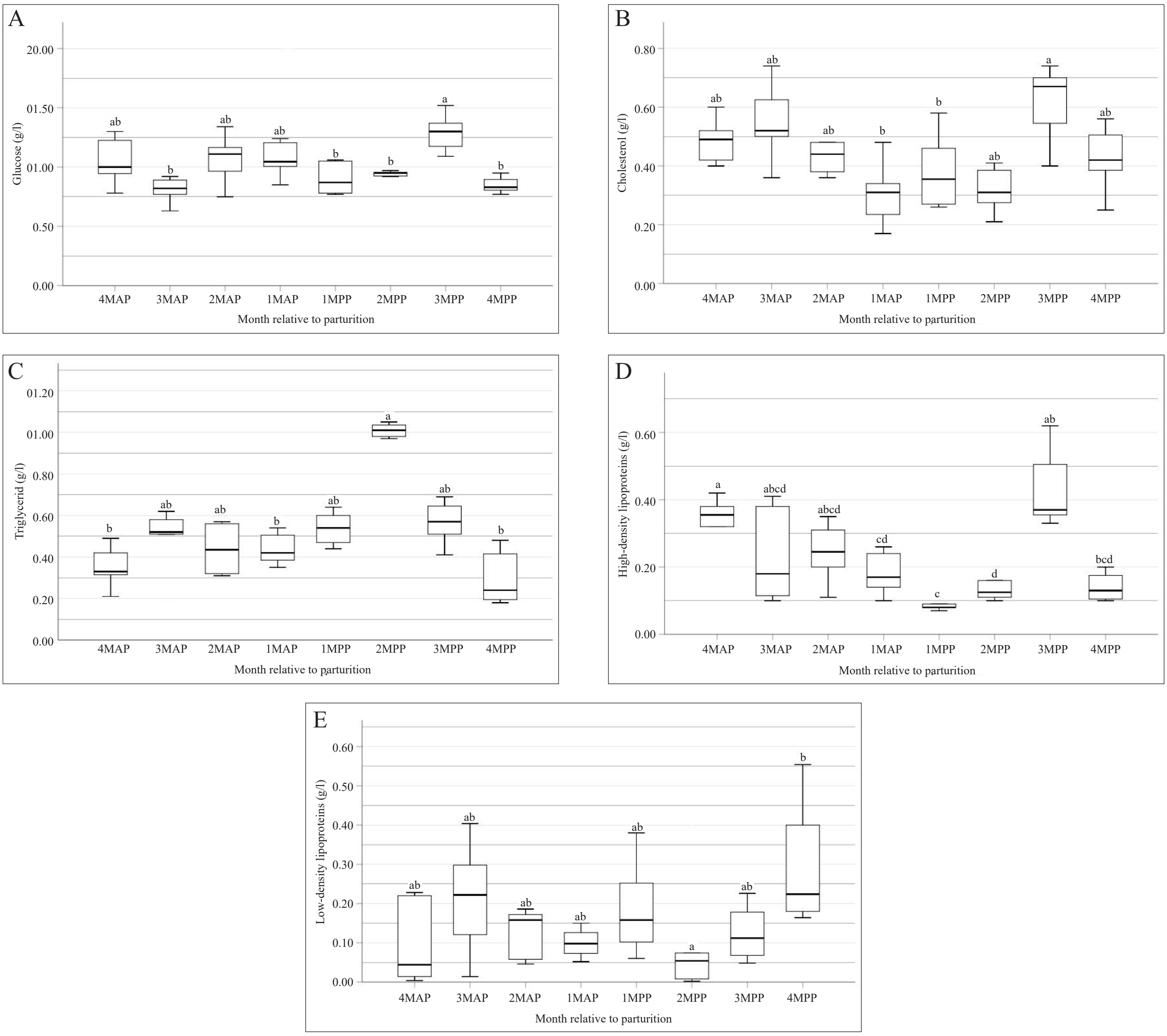


Fig. 1 Statistical significance of temporal changes of circulatory concentrations of glucose (A), total cholesterol (B), triglyceride (C), HDL (D), LDL (E) during lactogenesis and early galactopoiesis. a, b, c and d letters indicate that there are significant differences between months, where having the same letter/s mean no significant difference between months (P<0.05).

stage may be associated with low hepatic VLDL synthesis (Mazur *et al.*1988) and the mammary glands requirement for VLDL in milk fat synthesis (Grummer 1993).

In the present study, no significant difference in LDL values was observed during the antepartum period; however, a non-significant decrease was noted in the last two antepartum months, consistent with findings by Ahmadpour *et al.* (2019). Conversely, Miyamoto *et al.* (2006) reported a significant decrease in LDL levels in cattle approaching parturition. Similar to observations in camels (El-Zahar *et al.* 2017, Ahmadpour *et al.* 2019), a significant difference in LDL values was reported during the postpartum period in our study. Additionally, low LDL values were noted at the beginning of lactation compared to six weeks after calving, as reported by Mazur *et al.* (1988). Studies, such as that by Turk *et al.* (2004), have indicated lower LDL concentrations in the postpartum period compared to late non-pregnant lactation. The diminished LDL concentration in such cases may be attributed to low hepatic VLDL synthesis (Mazur *et al.* 1988) or the mammary glands requirement for VLDL for milk fat synthesis (Mazur *et al.* 1988).

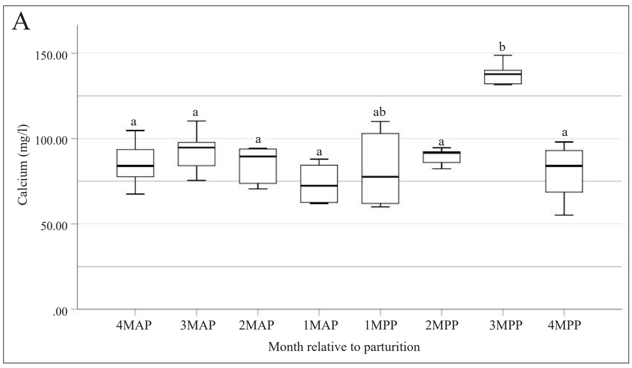
The no significant difference in triglyceride concentrations during the antepartum period is aligning with previous findings (Omidi *et al.* 2014). This increase is often attributed to the overproduction of very low-density lipoprotein cholesterol (Kirsten *et al*. 2003). Low triglyceride values during the lactogenesis period may be attributed to increased triglyceride catabolism, essential for providing energy for mammary gland cell differentiation and fetal requirements (Ghio *et al.* 2011). Changes of triglyceride patterns could be linked to the storage of excess triglycerides taken up by the mammary gland and used for milk fat synthesis, as they are major blood lipid precursors (Moorej and Christiwe 1988).

Despite the decrease tendency, no significant variations of sera calcium concentration were observed during the antepartum period (p>0.05). Previous studies have reported low calcium values during pregnancy (Saeed *et al.* 2009, Muhammad *et al.* 2011). The reduction in calcium concentration during pregnancy may be attributed to increased maternal demands and fetal requirements, possibly associated with low albumin levels (Singh *et al.* 2015, El-Zahar *et al.* 2017, Faye and Bengoumi 2018). Additionally, this decrease could be related to the utilization of calcium in cell differentiation and development during lactogenesis. In contrast, the current study revealed a significant difference in calcium concentration during the postpartum period at 3M-PP. Other studies (Hussein *et al.* 1992, Singh *et al*. 2015) have reported significant changes in calcium concentration during lactation. El-Zahar *et al*. (2017) documented an increase in calcium concentration during the postpartum period, considering it a normal physiological condition indicator and suggestive of normal uterine involution. However, Sajjan (2015) and Kuria *et al*. (2013) reported a decrease in calcium concentration along the stages of lactation, potentially attributed to the high utilization of calcium for milk synthesis. As for iron concentrations, an instable pattern was shown. However, a significant difference ($p<0.05$) was marked between the third month AP and the third month PP (0.95±0.13 mg/L and 0.49±0.13 mg/L, respectively) (fig. 2B). Similar results were reported in camels by Hussein *et al*. (2012), Faye *et al*. (2005), and El-Zahar *et al*. (2017). However, Saeed *et al*. (2009) found a significantly low value of iron in pregnant camels. A notable finding in our study was a significant decrease in iron concentrations at 3M-PP compared to that of 3M-AP. This decline may be attributed to the increased requirements of iron for milk production during the third month of lactation as camel milk contains high iron concentration (Wernery 2006).

Both decrease and increase of AST activities during antepartum and postpartum periods respectively, weren't statistically significant (Figure 3B). Similar findings were reported in earlier studies by Elias and Yagil (1984), Bengoumi *et al.* (1997), Osman and Al-Busadah (2000), Khadjeh (2002), Saeed *et al*. (2009), Omidi *et al.* (2014), and El-Zahar *et al*. (2017). However, El-Belely *et al*. (1988) reported that AST activity increased during pregnancy, specifically just before parturition (after 360 days of gestation).

No significant difference was observed in ALT activity during both antepartum and postpartum periods (Figure 3A). Consistent with our findings, previous studies have indicated that ALT activity does not show significant variations based on physiological status during pregnancy or lactation (Elias and Yagil 1984, Bengoumi *et al*. 1997, Osman and Al-Busadah 2000, Khadjeh 2002, Saeed *et al*. 2009, Omidi *et al*. 2014, El-zahar *et al*. 2017). However, a notable significant difference in ALT activity was reported in our study between 2M-AP and 2M-PP. Similarly, Seboussi *et al*. (2004) reported a significant difference in ALT between pregnant and lactating camels.

In the current study, a significant difference in creatinine concentration was observed during the antepartum period, with the creatinine level increasing and reaching its peak at 1M-AP (Figure 4B). This finding aligns with the observations of Omidi *et al*. (2015), who noted an increase in creatinine concentration during the last trimester of gestation. Ayoub *et al*. (2003) explained that higher creatininemia in pregnant camels, potentially attributed to decreased kidney filtration during this period. On the other hand, a significant difference in creatinine levels was noted between lactating and non-lactating she-camels in a study conducted by Osman and Al-Busadah (2000). There was an insignificant decrease in urea during the antepartum period; however, a significant increase was detected during 4M-AP and 3M-AP compared to that of 1M-PP (Figure 4A). High urea concentration was documented in pregnant she-camel (Bhargara *et al.* 1964, Rezakhani *et al*. 1997, Ayoub *et al*. 2003, Ben-Romdhane *et al*. 2003, Mohammed *et al.* 2007, Omidi *et al.* 2015). The higher urea concentration during pregnancy may be attributed to increased protein catabolism activities, higher energy requirements in the late stage of pregnancy, and the increased metabolism of the fetus (Muhammad *et al*. 2011, Omidi *et al.* 2015). However, no significant difference has been observed between pregnant and non-pregnant camels in other studies



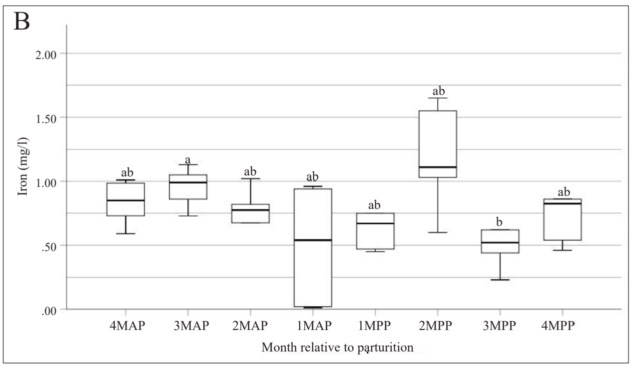


Fig. 2 Statistical significance of temporal changes of circulatory concentrations of calcium (A), iron (B) during lactogenesis and early galactopoiesis.

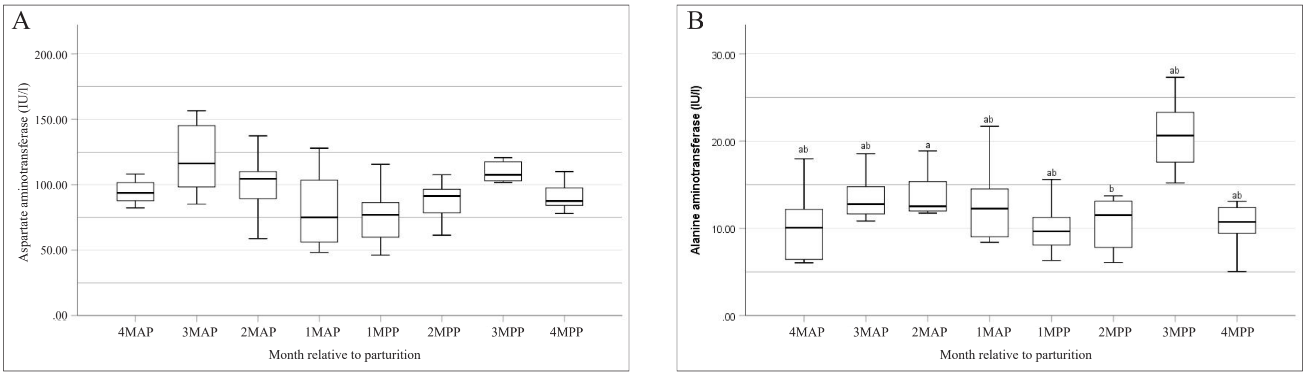


Fig.3 Statistical significance of temporal changes of circulatory concentrations of AST (A), ALT (B) during lactogenesis and early galactopoiesis.

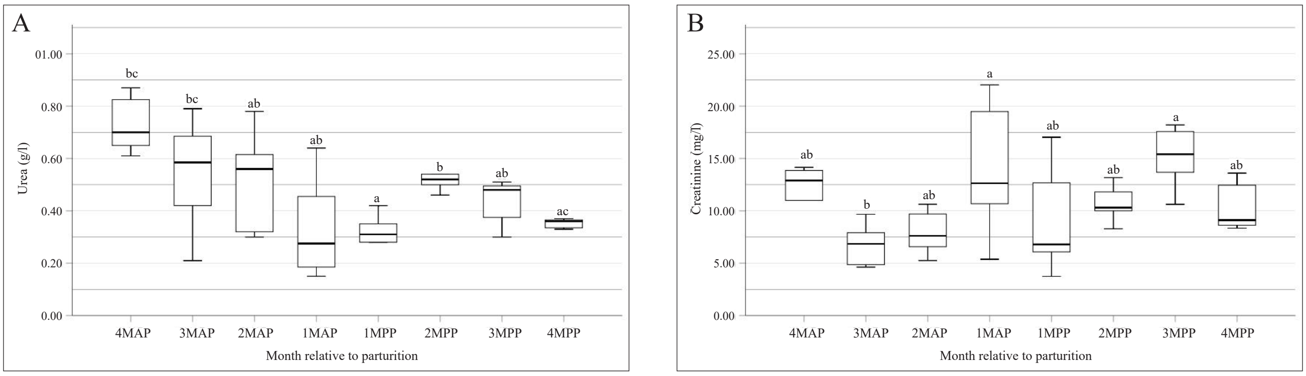


Fig. 4. Statistical significance of temporal changes of circulatory concentrations of urea (A), creatinine (B) during lactogenesis and early galactopoiesis.

(Saeed *et al*. 2009, Muhammad *et al*. 2011, Omidi *et al.* 2014).

These results underscore the substantial impact of lactogenesis and galactopoiesis on energetic metabolites, proteins, hepatic enzymes, and minerals. This research emphasizes the need for targeted health monitoring and tailored healthcare strategies to manage the metabolic and nutritional needs of female camels during these critical periods, contributing valuable knowledge to improve camel husbandry practices.

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