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ORIGINAL ARTICLE

Hematological and biochemical profiles in goats during the transition period

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Abstract The aim of the present study was to investigate changes in the hematobiochemical profiles in goats during the transition period. Blood samples were collected from 15 goats during the transition period (weeks −3, −2, −1, 0, +1, +2, and +3). Blood picture revealed neutrophilia 1 week after kidding and monocytopenia +2 and +3 weeks postpartum. A decrease in erythrocyte count was observed a week before parturition. Total protein increased dramatically from week −1 until week +3 postpartum. Globulin increased from week −2 until week +3. Albumin concentration decreased during week −2 until week +3. Calcium concentration decreased at weeks −1, 0, and +2 but returned to prepartum levels at week +3 postpartum. Phosphorus concentration increased significantly at weeks −2 and +2 but decreased at parturition and a week after. The serum activity of aspartate aminotransferase increased significantly from week −2 prepartum till week +2 postpartum. The activity of γ-glutamyl transferase increased significantly a week after parturition. Alkaline phosphatase activity showed decreases at parturition and 3 weeks later. The concentration of total cholesterol decreased significantly at weeks −1 and 0. The serum concentration of progesterone decreased sharply at parturition and thereafter, while the serum concentration of estrogen reached its maximum at parturition and then declined. Hyperglycemia was observed at weeks −2, +1, +2, and +3. The serum concentration of cortisol increased significantly at parturition. In conclusion, the hematobiochemical variables and lipid profiles reported in this study could be used as a reference for goats during the transition period.

Keywords Biochemistry · Goat · Hematology · Peripartum · Transition period

Place of the work The work was performed at the Veterinary Teaching Hospital, College of Agriculture and Veterinary Medicine, Qassim University.

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Introduction

The transition period, 3 weeks before to 3 weeks after parturition, is characterized by marked changes in an animal's endocrine status that are much more dramatic than at any other time in the lactation–gestation cycle, as well as by a reduction in feed intake when nutrient demand for the developing conceptus and the impending lactogenesis is increasing (Drackley 1999). During the transition phase in bovines, the animal has to adapt to a dramatic and several-fold increase in nutrient uptake by the mammary gland associated with lactogenesis compared with the much smaller nutrient requirement in late gestation by the growing conceptus (Tharwat et al. 2012).

Suboptimal transition from the late-gestation period to lactation can impair production and reproductive performance and cause economic losses (Drackley 1999; Overton and Waldron 2004). Therefore, the transition period is the most stressful time in the production cycle of a dairy cow because of depressed feed intake and endocrine and metabolic changes at parturition. Optimal transition requires a comprehensive understanding of the biochemical events occurring during the periparturient period (Guo et al. 2007).

In goats on the other hand, the transition period has gained little attention. Most of the available data describing metabolism during the transition phase are based on only a few measurements (Khan and Ludri 2002a, b; Skotnicka et al. 2011). More frequent sampling and measurement of blood metabolites should be used to capture the dynamic changes in the periparturient period. The present study was therefore designed to gain detailed information on other commonly measured biochemical and hematological analytes in goats during the transition period.

Materials and methods

Animals and clinical examination

Fifteen nonpregnant does (age 22.6±8.7 months; weight 42.3± 6 kg; parity 2.1±1.9) were purchased and reared at the Qassim University Farm. All animals underwent a thorough physical examination (Rosenberger 1990; Radostits et al. 2000), which included general behavior and condition; auscultation of the heart, lungs, rumen, and intestines; measurement of heart rate, respiratory rate, and rectal temperature; swinging auscultation; percussion auscultation of both sides of the abdomen; and rectal examination. The does were fed on a commercial concentrate and alfalfa hay. The amount of concentrate and hay was calculated according to the nutritional requirements for goats, dependent on the age and production status of the animals. Water and mineral supplement blocks were freely available to all animals.

The does were synchronized by inserting the controlled-release internal drug EAZI-BREED controlled internal drug release (CIDR; Pharmacia & Upjohn, Rydalmere, Australia) containing 0.3 g progesterone. These CIDRs were inserted vaginally and left for 12 days. At the time of CIDR removal, each doe was treated with 600 IU of equine chorionic gonadotropin. Two mature fertile bucks were used for breeding the does. All goats were maintained in a free-stall barn and kept under the *Laboratory Animal Control Guidelines* of Qassim University, which basically conform to the *Guide for the Care and Use of Laboratory Animals* of the National Institutes of Health in the USA (NIH publication nos. 86–23, revised 1996). The experimental protocol was approved by the Animal Ethical Committee, Deanship for Scientific Research, Qassim University, Saudi Arabia.

Hematological and biochemical analyses

Blood samples were collected, and each doe was weighed at seven points: 3, 2, and 1 week before parturition (weeks −3, −2, and −1); within 12 h of parturition (week 0); and 1, 2, and 3 weeks (weeks +1, +2, and +3) after parturition. At each time, two blood samples were collected by puncture of the jugular vein, one on ethylenediaminetetraacetic acid (EDTA) and the other without an anticoagulant. A complete blood count (CBC) [total and differential leukocytic count, erythrocyte, hematocrit, hemoglobin, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC)] was carried out on the EDTA sample using the VetScan HM5, Abaxis, California, USA. The second blood sample was centrifuged at 1200×*g* for 10 min, and the serum samples obtained were aliquoted in tubes and immediately stored at −20 °C pending the clinical chemistry analyses.

Using commercially available kits, we used the serum samples to determine the concentrations of total protein, albumin, globulin, blood urea nitrogen (BUN), creatinine, calcium, magnesium, phosphorus, total bilirubin, glucose, triglycerides (TG), total cholesterol, high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), and very-low-density lipoprotein cholesterol (VLDL). The serum activity of γ-glutamyl transferase (GGT), aspartate aminotransferase (AST), creatine kinase (CK), and alkaline phosphatase (ALP) is also measured. A fully automated open-system biochemistry analyzer was used for the biochemical analytes (Biosystems A15, Spain).

Estrogen, progesterone, and cortisol were determined in serum samples using electrochemiluminescent immunoassay kits (Roche Diagnostics, Indianapolis, Indiana, USA), with a measuring range of 5.00–4300 pg/ml, 0.030–60.00 ng/ml, and 0.018–63.4 μg/dl, respectively. The intra- and inter-assay coefficients of variance for estrogen, progesterone, and cortisol were 3.7 and 3.8 %, 2.2 and 5.0 %, and 1.22 and 1.54 %, respectively.

Statistical analysis

The data were analyzed for period effects using repeated-measure analysis of variance (ANOVA), with Fisher's protected least significant difference (LSD) as the post-ANOVA test. The level of significance was tested at $p < 0.05$. A statistical program (SPSS 2009) was used to perform the statistical analysis.

Results

At parturition, none of the 15 goats showed clinical disease. Compared with values at −3 weeks (61±12 kg), the body weight of the goats decreased dramatically at week 0 (47±13 kg; $p = 0.013$) and at +3 weeks postpartum (42±9 kg; $p = 0.0001$). Eight of the goats delivered a single kid, and the remaining seven delivered twins.

Table 1 summarizes the hematological variables in the 15 examined goats during the transition period. The CBC revealed neutrophilia 1 week after kidding ($p = 0.008$) and monocytopenia 2 and 3 weeks postpartum ($p = 0.04$). A

Table 1 Complete blood counts in goats ($n=15$) during the transition period

	Time (weeks)							p-value
	−3	−2	−1	0	+1	+2	+3	
WBC ($\times10^9$/l)	14.7±4.1	15.8±4.4	16.5±7.0	16.0±6.2	21.1±10.1	17.9±7.1	15.3±5.6	0.414
Lym ($\times10^9$/l)	7.0±2.9	8.5±2.9	9.5±4.9	5.7±2.2	6.0±4.1	7.2±5.2	4.6±2.0	0.08
Mon ($\times10^9$/l)	0.69±0.55	0.47±0.37	0.27±0.33	0.54±0.48	0.84±1.18	0.13±0.06*	0.17±0.07*	0.04
Neu ($\times10^9$/l)	6.8±2.9	6.7±3.2	5.8±3.5	9.4±5.7	14.2±8.5*	10.6±4.8	10.34.2	0.008
Eos ($\times10^9$/l)	0.01±0.00	0.02±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.00	0.05
Bas ($\times10^9$/l)	0.16±0.11	0.21±0.08	0.13±0.08	0.09±0.10	0.03±0.06	0.03±0.06	0.16±0.11	0.113
RBCs ($\times10^{12}$/l)	13.6±1.4	13.7±1.5	10.1±2.2*	14.6±2.7	14.1±2.3	14.8±2.9	14.6±1.9	0.0001
HGB (g/dl)	11.1±1.3	10.4±1.8	10.1±2.2	10.2±1.7	12.1±1.9	15.7±10.1	14.8±10.2	0.173
HCT (%)	22±3	16±0.7*	21±4	16±0.8*	23±3	23±5	22±3	0.0001
MCV (fl)	16.3±0.8	16.1±0.7	15.8±1.2	15.5±0.8	16.2±1.2	15.3±0.5	14.8±0.4*	0.04
MCH (pg)	7.0±1.5	6.3±0.4	6.6±0.8	6.4±0.5	6.5±0.1	12.8±11.8	13.6±8.3	0.09
MCHC (g/dl)	42.8±9.3	39.7±1.8	41.7±7.8	41.1±2.6	38.8±3.3	39.0±0.9	41.5±1.1	0.9

WBC white blood cells, *Lym* lymphocyte, *Mon* monocyte, *Neu* neutrophil, *Eos* eosinophil, *Bas* basophil, *RBCs* red blood cells, *HGB* hemoglobin, *HCT* hematocrit, *MCV* mean corpuscular volume, *MCH* mean corpuscular hemoglobin, *MCHC* mean corpuscular hemoglobin concentration

* Differ significantly at $p<0.05$

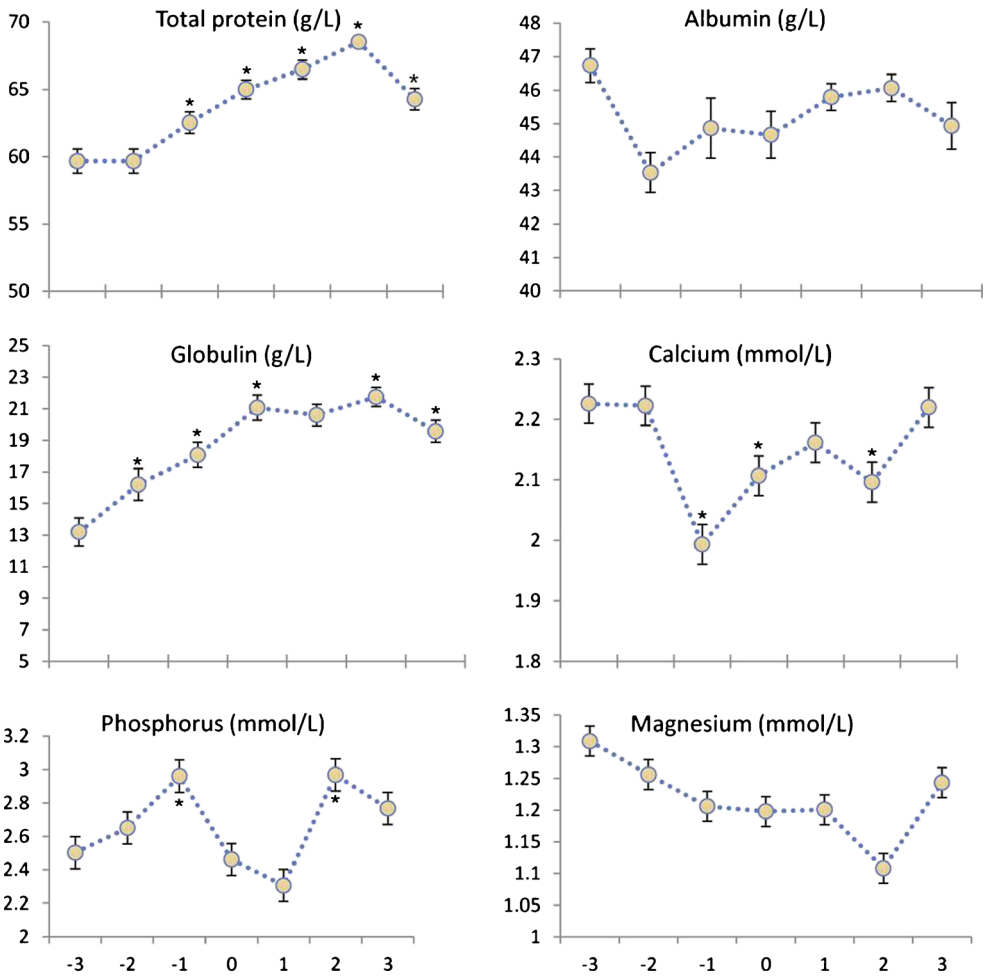

Fig. 1 Serum proteins and the macroelements calcium, phosphorus, and magnesium in goats ($n=15$) during the transition period. Blood samples were collected 3 weeks before parturition (−3, −2, and −1), within 12 h of parturition (0), and for the following 3 weeks after parturition (+1, +2, and +3)

decrease in the erythrocyte count was observed a week before parturition (week −1; $p=0.0001$). Similarly, a decrease in the hematocrit value was detected 2 weeks before (week −2) and just after parturition (week 0) ($p=0.0001$). Other hematological changes included a reduced MCV 3 weeks (week +3) after parturition ($p=0.04$). Lymphocytes, eosinophil, basophil, hemoglobin, MCH, and MCHC did not differ significantly among all the examined periods ($p>0.05$).

Figure 1 illustrates changes in serum proteins and the macroelements calcium, phosphorus, and magnesium in the goats during the transition period. Total protein increased dramatically from week −1 until week +3 ($p=0.0001$). In a similar trend, globulin increased from week 2 until week +3 ($p=0.0001$). In contrast, albumin concentration decreased, but not significantly, during week −2 until week +3 ($p=0.14$). Calcium concentration had decreased at weeks −1, 0, and +2 ($p=0.0001$) but returned to prepartum levels at week +3. Similarly, magnesium concentration decreased, but not significantly, from week −2 to week +3 ($p=0.654$). On the other hand, phosphorus concentration increased significantly at weeks −2 and +2 ($p=0.0001$) but decreased at parturition and a week after.

Figure 2 shows the hepatic and renal functions in the goats during the transition period. The activity of serum AST increased significantly from week −2 prepartum till week +2 postpartum ($p=0.0001$). The activity of GGT increased significantly only one week after parturition (week +1) ($p=0.0001$), whereas ALP activity showed increases prepartum and decreases at parturition and 3 weeks later (weeks 0 to +3) ($p=0.0001$). There were no significant differences in the serum concentration of bilirubin, BUN, and creatinine during the transition period in the goats ($p>0.05$). Similarly, the concentration of serum TG in the goats did not differ significantly during the transition period ($p=0.054$). However, the concentration of total cholesterol decreased significantly at weeks −1 and 0 ($p=0.027$), while the concentration of HDL, LDL, and VLDL did not differ significantly during the transition period in the goats ($p>0.05$), as illustrated in Fig. 3.

The serum concentration of progesterone decreased sharply at parturition and thereafter (weeks 0 to +3) ($p=0.0001$). On the other hand, the serum concentration of estrogen reached its maximum peak at parturition (week 0) and then declined ($p=0.0001$), as seen in Fig. 4. Figure 5 shows the serum concentration of glucose and the serum activity of CK.

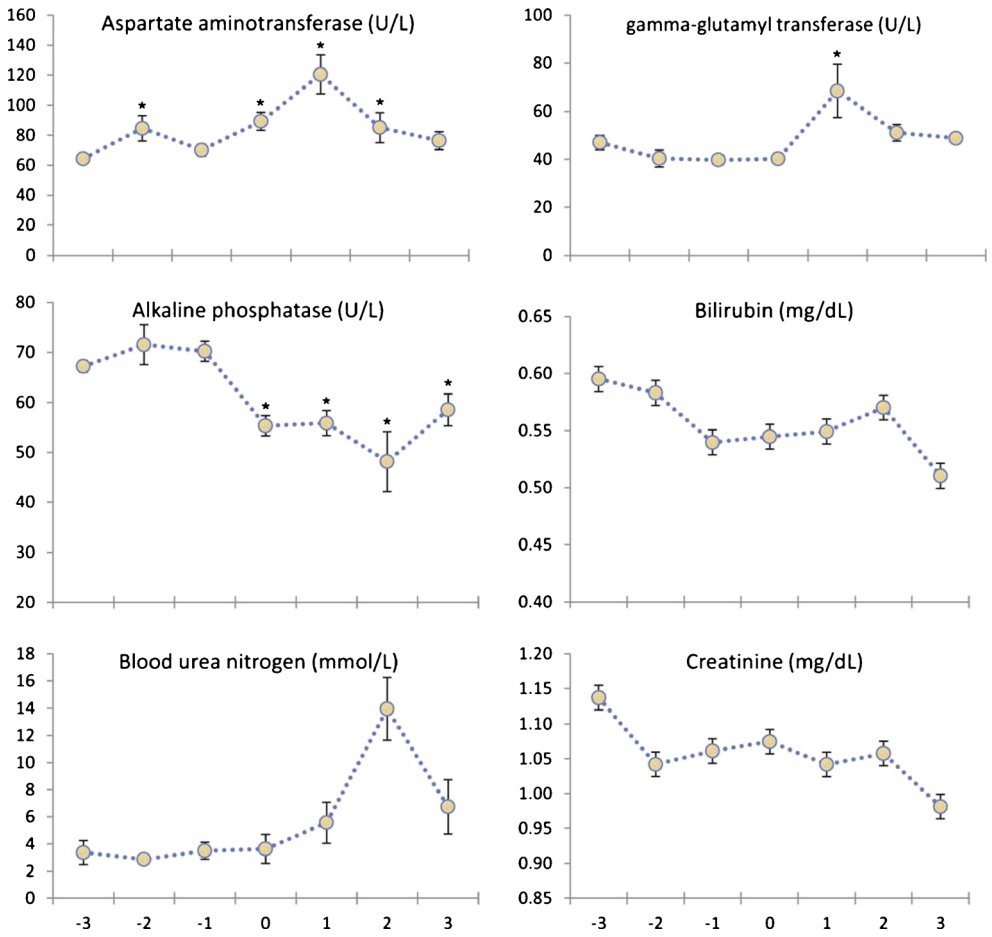

Fig. 2 Serum concentrations of aspartate aminotransferase, γ-glutamyl transferase, alkaline phosphatase, bilirubin, blood urea nitrogen, and creatinine in goats ($n=15$) during the transition period. Blood samples were collected 3 weeks before parturition (−3, −2, and −1), within 12 h of parturition (0), and for the following 3 weeks after parturition (+1, +2, and +3)

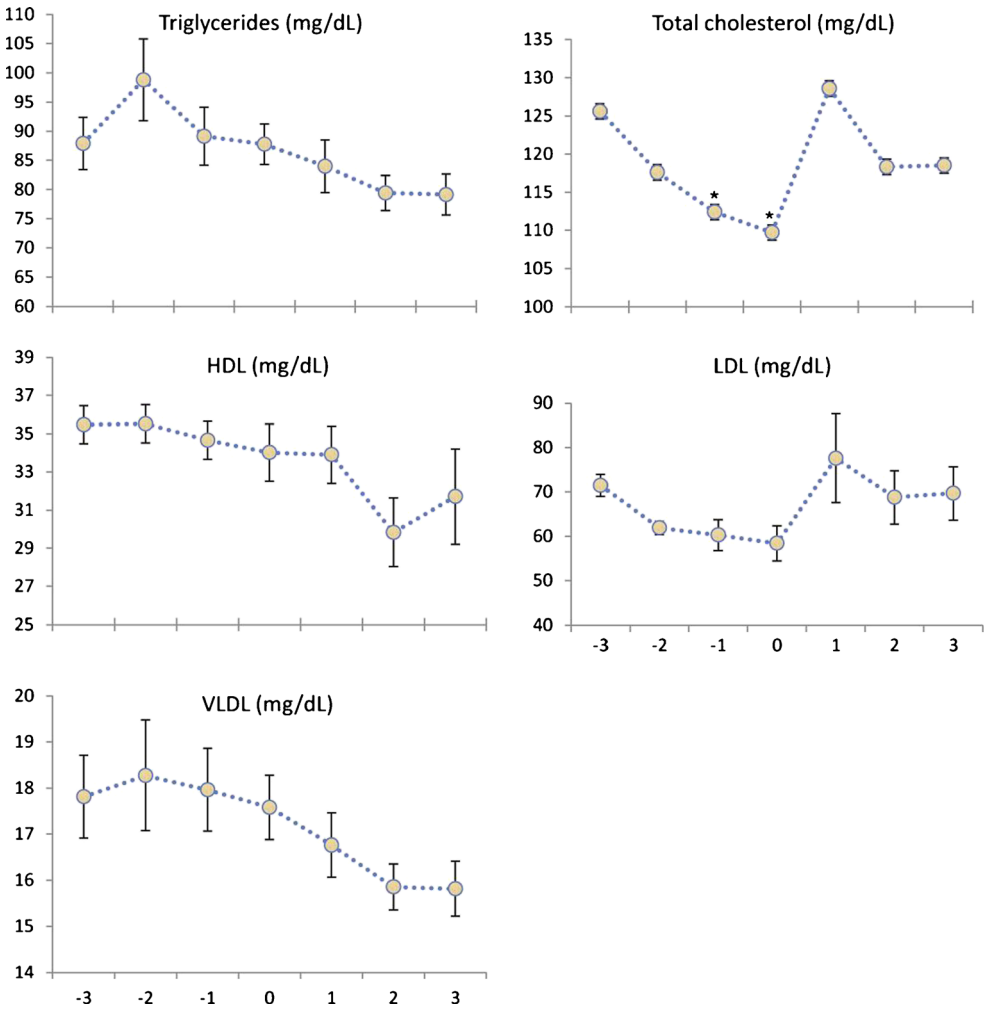

Fig. 3 Serum lipids in goats ($n=15$) during the transition period. Blood samples were collected 3 weeks before parturition (−3, −2, and −1), within 12 h of parturition (0), and for the following 3 weeks after parturition (+1, +2, and +3)

Hyperglycemia was observed at weeks −2, +1, +2, and +3 ($p=0.0001$). The serum activity of CK had declined at week −2 ($p=0.028$) but returned to normal during other points of examination. Compared with values at weeks −3 and +3, the serum concentration of cortisol during the transition period had increased significantly at parturition (week 0) ($p=0.004$), as shown in Fig. 6.

Discussion

Unlike the transition period in cattle, the transition period in goats has received very little attention. The effect of the transition period on a few metabolic parameters, including hormones, glucose, nonesterified fatty acid, and lipids, has been reported (Khan and Ludri 2002a, b; Skotnicka et al. 2011). Through laboratory profiling, not only can sick animals be detected, but also those herds at higher risk of developing metabolic, reproductive, or infectious diseases may be identified. Therefore, to capture the extensive pre- and post-parturient metabolic changes, we sampled 15 pregnant goats from 21 days before anticipated kidding to 21 days after parturition. In addition to the above published variables, the objective of this study was to evaluate other commonly measured biochemical and hematological analytes, especially serum proteins, hepatic and renal functions, the macro-minerals calcium, phosphorus, and magnesium, as well as the complete blood picture.

The most important hematological changes in the goats during the transition period were the neutrophilia, monocytopenia, and decreased erythrocyte count. These changes were also reported in cattle during the periparturient period and may have resulted from the stress associated with parturition and lactation (El-Ghoul et al. 2000). The total protein and globulin, but not albumin, increased post-kidding. Similar findings in dairy cows have been recently published (Tharwat et al. 2012). The increased total protein may have been observed because of the increased globulin resulting from the formation of immunoglobulins. Albumin is an indicator of liver function; it decreases in the peripartum period, and its reduction could be associated with

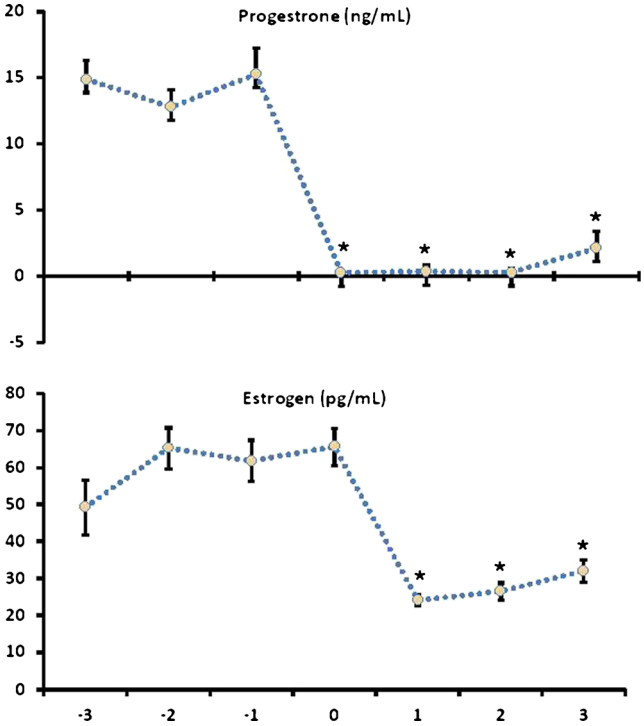

Fig. 4 Serum progesterone and estrogen in goats ($n=15$) during the transition period. Blood samples were collected 3 weeks before parturition (−3, −2, −1), within 12 h of parturition (0) and for the following 3 weeks after parturition (1, 2, ,3)

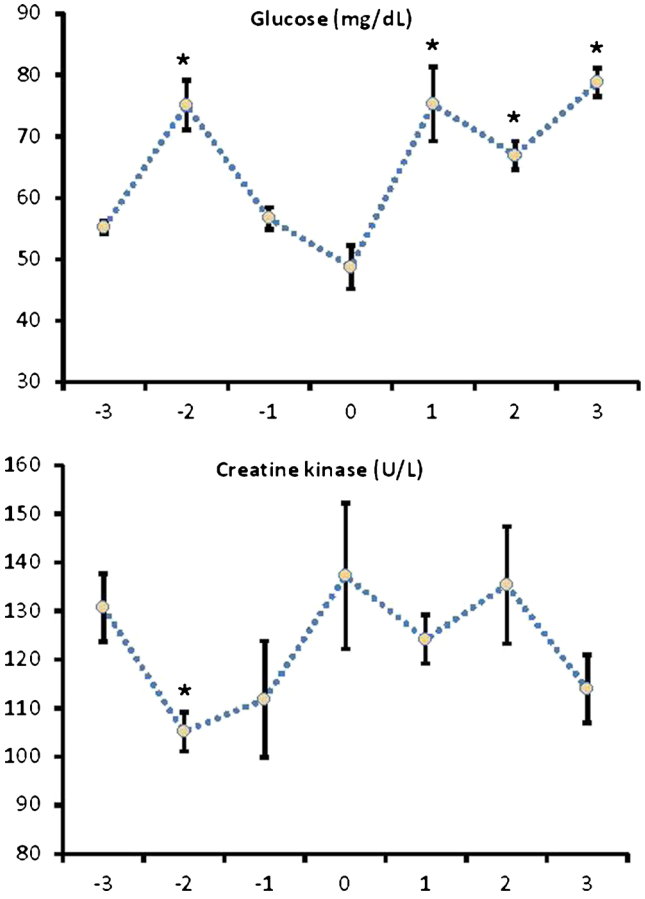

Fig. 5 Serum glucose and creatine kinase in goats ($n=15$) during the transition period. Blood samples were collected 3 weeks before parturition (−3, −2, and −1), within 12 h of parturition (0), and for the following 3 weeks after parturition (+1, +2, and +3)

hepatocellular liver diseases and fatty liver (Nehra et al. 2001). However, its reduction in this study was not significant.

It is well known that there are profound physiological changes in certain analytes pre- and post-parturition. These changes are not necessarily indicative of disease but reflect physiological variations. As an example, the decreased calcium concentration around parturition is physiological, reflecting the onset of colostrum/milk production. Decreased numbers of receptors for 1,25-dihydroxyvitamin D in the intestine cause a decrease in calcium absorption (Ramberg et al. 1970; Goff 2000). This situation might explain the low levels determined for calcium and phosphorus at parturition in the goats. There was a significant elevation in the serum activity of AST and GGT in the goats during the transition period. This may be attributed to triglyceride accumulation in the liver, as has been reported in cows (Tharwat et al. 2012). Unfortunately, in this study, we did not estimate the hepatic triglyceride accumulation to confirm the elevated AST and GGT. The elevated serum activity of ALP in the goats prepartum may be explained by the increased placental production of this enzyme, as has been reported for cows (Peter et al. 1987).

Two weeks before parturition, the concentration of serum TG in the goats had increased but later declined. A similar tendency has been observed in women (Alvarez et al. 1996), cows (Bell, 1995; Mohebbi-Fani et al., 2006), sheep (Nazifi et al. 2002), and recently goats (Skotnicka et al. 2011). In all these species, late pregnancy is characterized by an increase in the resistance of the female's peripheral tissues to insulin and by enhanced lipolysis in the liver and adipose tissue (Martin-Hidalgo et al. 2005). The observed decreases in cholesterol and its fractions (HDL, LDL, and VLDL) in the goats during the transition period may be physiological. These

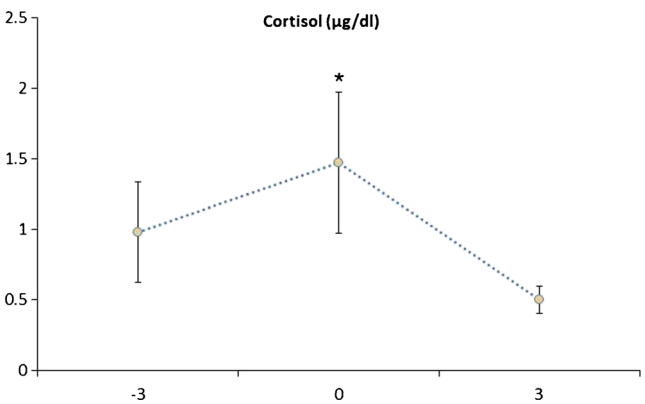

Fig. 6 Serum cortisol concentration in goats ($n=15$) during the transition period. Blood samples were collected at week 3 before parturition (−3), within 12 h of parturition (0), and at week 3 after parturition (+3)

changes are confirmed by the results of studies conducted in sheep (Nazifi et al., 2002a).

The serum concentration of progesterone decreased sharply at parturition and thereafter (weeks 0 to +3). This decline is physiological due to the destruction of the corpus luteum of pregnancy and the decreased level of progesterone released from the placenta (Khan and Ludri 2002b; Alwan et al. 2010). On the other hand, the serum concentration of estrogen reached its maximum peak at parturition (week 0) and declined thereafter. This increase is also physiological as it is required for uterine contractions during parturition (Khan and Ludri 2002b; Alwan et al. 2010).

The decreased glucose concentrations at parturition may be due to utilization by the growing fetuses and more by the stress of parturition (Khan and Ludri 2002a). The serum concentration of cortisol during the transition period increased significantly at parturition. During the late stage of pregnancy, there is an increase in the ACTH section from the fetal pituitary, which stimulates the rapid growth of the fetal adrenals, leading to a rise in the concentration of serum cortisol. The increased cortisol enters the maternal circulation and induces parturition by activating the production of prostaglandin F2α (Arthur et al. 1989; Suganya et al. 2000; Suganya and Gomathy 2009).

In conclusion, marked hematobiochemical changes were observed during the transition period in goats. Hematological abnormalities were found in the monocyte, neutrophil, RBC, HCT, and MCV. Significant biochemical changes were seen in the serum concentrations of total protein, globulins, calcium, phosphorus, AST, GGT, ALP, CK, glucose, cholesterol, estrogen, progesterone, and cortisol. These hematobiochemical variables may thus be used as references for goats during the periparturient period.

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