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ORIGINAL ARTICLE

Impact of lactation stage on milk composition and blood biochemical and hematological parameters of dairy Baladi goats

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Abstract The objective of this study was to elucidate the impact of lactation stage on milk composition, hematological and biochemical parameters of dairy Baladi goats under Egyptian conditions. Forty-eight Baladi goats (32.8 ± 2.9 kg of BW) were enrolled in the current study. The lactation period has been divided into three stages; early (DIM less than 80 days), Mid (DIM 80–140 days), and Late (DIM over 140 days). Baladi goats had decreased daily-MY at a rate of 18.4% and 31.9% at mid and late stages of lactation, compared with early stage, respectively ($p = 0.001$). Furthermore, lactose% decreased significantly with progress of lactation ($p = 0.017$). Total solids%, however, decreased significantly at early stage of lactation in comparison with mid and late stages ($p = 0.022$). On the contrary, no significant differences were found in protein, fat and SNF percentages at different stages of lactation ($p = 0.836$, 0.625 and 0.281, respectively). Serum glucose and total protein were significantly reduced at late stage of lactation in comparison with early and mid stages ($p = 0.001$ and 0.001, respectively). On the contrary, no significant differences were found for erythrocytes count, hemoglobin, serum cholesterol, catalase and triiodothyronine at different stages of lactation. There were high and positive correlations between daily-MY and serum total protein ($r = 0.87$, $P < 0.01$) and triiodothyronine ($r = 0.41$, $P < 0.01$). However, negative estimates were reported between daily-MY and triglycerides ($r = -0.55$, $P < 0.01$) and cholesterol ($r = -0.33$, $P < 0.05$). Our results indicate that dairy Baladi goats produce milk with relatively stable protein, fat and solid not fat (SNF) contents at the

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different stages of lactation, encouraging the continuous utilization of their milk in processing. Also, dairy Baladi goats seem able to maintain the most vital biochemical parameters.

1. Introduction

On a global scale, developing countries produce the majority of goat milk, where goat's milk plays a notable function in the sustenance of millions of human beings (FAO, 2013). It was recently concluded that goats will continue to have a vital role in hard circumstances, subtropics and tropics, as well as desert and Mediterranean environments (Silanikove and Koluman, 2015). Regarding the tropical and desert environments, goats are considered the most efficient ruminants that adjust to such areas, where an adaptive capacity of a species is defined by its ability to cope with climate change by expressing adaptive strategies (Silanikove, 2000).

Earlier research has shown that reproductive and milk production traits of cow, sheep and goat are influenced by a number of factors, such as genetic type, age, lactation stage, parity and management, including the method of milking (Al-Saiady, 2006; Oravcova et al., 2007; El-Tarabany and El-Bayoumi, 2015). It has been evident that lactation stage affects the chemical composition of produced milk (Gonzalo et al., 1994); however, this effect has been influenced by the genetic type of the animal (Fenyvessy and Javor, 1999). Moreover, the variations in chemical properties of milk depend on production conditions and the individual merits of particular animals (Fuertes et al., 1998). A large portion of goat milk produced is processed into cheese; however, uneven quality of milk also reflects on cheese quality (Pavic et al., 2002).

Blood biochemical parameters including total protein, glucose, triglycerides, catalase, thyroid hormones and the antioxidant capacity are important criteria in determining the energy metabolism status of lactating animals (Hatfield et al., 1999). The thyroid hormones preserve the homeostasis of energy and protein metabolism, thermoregulation and production parameters (Huszenicza et al., 2002). Moreover, former trials have indicated that thyroid hormones have an essential role to play in the development of the mammary gland and the synthesis of important milk proteins (Bhattacharjee and Vonderhaar, 1984). Therefore, the objective of the present study was to establish the influence of the lactation stage on milk yield and composition, blood hematological and biochemical parameters in dairy Baladi goats, and furthermore to estimate the correlation coefficients among the milk composition traits and blood parameters.

2. Materials and methods

The current work was approved by the Committee of Animal Care and Welfare, Zagzaig University, Egypt (ANWD-215). The experiment was carried out at the experimental farm of the Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt.

2.1. Animals and management

Forty-eight Baladi goats (32.8 ± 2.9 kg of BW) were selected from an experimental farm of the Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt. The elected dairy goats were multiparous (2nd parity) with healthy and symmetrical udders at first period of lactation (33 ± 2.4 days in milk (DIM); 1.29 ± 0.12 L/d). The lactation period has been divided into three stages; Early (DIM less than 80 days), Mid (DIM 80–140 days), and Late (DIM over 140 days). Goats were housed in an open shelter all over the experimental period (six months), providing 3.8 m^2 of shaded slatted floor and 4 m^2 of concrete-surfaced yard/goat. The temperature humidity index (THI) over the experimental period (6 months) ranged from 66 to 74. Goats were fed on a balanced total mixed ration (TMR) composed of alfalfa hay, wheat straw and concentrate according to their requirements (NRC, 2007). On a weight basis, the hay, straw and concentrate were in a 35:20:45 ratio. The concentrate comprised yellow corn, soybean meal (solvent-extracted), corn gluten, undecorticated cake of cottonseed, rice bran, sugarcane molasses, and a premix containing minerals and vitamins. The dry matter (DM) chemical composition was calibrated by standard protocol (AOAC, 1990) and involves 16.6% crude protein, 2.2% fat (by ether extraction), 38.5% neutral detergent fiber (NDF), 8.8% ash and 10.2 MJ/kg of metabolizable energy. Feed was given in mangers (feeder space per animal = 0.42 m), and water was obtainable at all time in the shade.

2.2. Milk yield and composition

Daily examination was conducted for all dairy goats to explore the presence or emphasize the absence of clinical signs of mastitis, such as fever, painful reaction or gland swelling. Furthermore, dairy goats suffering from such criteria as mastitis were eliminated. Daily milk yield of individual goats was recorded throughout the experiment; however, milk composition was estimated weekly. Animals were hand milked once daily (0800 h) with two skillful milkers having comparable efficiency. After hand milking, yield of each doe was determined by weighing the milk. Milk samples (approximately 100 ml) were collected, preserved by means of Broad Spectrum Microtabs II and stored at 4 °C until analysis of the milk gross composition, including fat, protein, and lactose contents (MilkoScan 6000; Foss Electric A/S, Hillerød, Denmark). Milk total solids (TS) and solid not fat (SNF) were estimated according to Cipolat-Gotet et al. (2013).

2.3. Biochemical and hematological parameters

Before the morning feeding two blood samples were collected biweekly from each animal via the jugular vein puncture. The first blood sample (3 ml) was collected into an EDTA tube. In order to determine the hematological parameters, an automated analyzer (Autolyser AL 820, Swiss) was utilized to measure Red blood cell (RBC) counts, hemoglobin (Hb) concentration and the total leucocytes count (WBC). The second blood sample was handled to harvest serum samples and persevered at −20 °C. Serum total protein was determined via Biuret method (Armstrong and Carr, 1964). Serum cholesterol concentration was calibrated colorimetrically as described by Watson (1960). Glucose was determined according to Barham and Trinder (1972). The RBC hemolysate was used to estimate the activity of total antioxidant capacity (TAC), and was expressed as mmol/dl (El-Deeb and Younis, 2009). The activity of catalase was assessed by colorimetric method using Catalase Assay Kit, Oxford Biochemical Research, Inc., USA (Asri-Rezaei and Dalir-Naghadeh, 2006), however, the activities of such enzymes were expressed as U/g Hb. The concentrations of triiodothyronine (T_3) in preserved serum samples were calibrated by means of RIA using coated tubes kit; DSL, Inc. (Webster, Texas, USA). The lower limit of detection [95% binding/0 binding (B/B°)] was 0.17 ng/ml of serum, and the intra- and interassay CV were 6.2% and 5.3%, respectively.

2.4. Statistical analysis

All statistical steps were performed using the statistical system Package of SAS, V9.1 (SAS, 2003). The Kolmogorov–Smirnov test was applied to examine the data for non-normality. The analytical procedures of data distribution indicated that no parameters differed significantly from normal distribution ($P > 0.05$). The MIXED procedure of SAS was used to analyze the repeatedly measured variables (milk yield and composition, biochemical and hematological parameters). The statistical model included the fixed effects of lactation stage [Early (DIM less than 80), Mid (DIM 80–140), and Late (DIM over 140)], and the random effect of the dairy animal. Least squares means (LSM) were calculated for all milk compositions and blood biochemical and hematological traits to ensure the adjustment of the statistical model for the multiple factors. Proc COR was used to estimate the Pearson's correlations between milk composition traits with hematological and biochemical parameters.

3. Results

3.1. Effect of lactation stage on milk yield and composition in Baladi goats

Data summarizing significant results for the effect of lactation stage on milk production traits are included in Table 1. Baladi goats had decreased daily-MY at a rate of 18.4% and 31.9% at mid and late stages of lactation, compared with early stage, respectively. Furthermore, lactose% decreased significantly at late stage of lactation in comparison with early and mid stages. Total solids%, however, decreased significantly at early stage of lactation in comparison with mid and late stages. On the contrary, protein, fat and SNF percentages were stable at different stages of lactation.

3.2. Effect of lactation stage on biochemical and hematological parameters in Baladi goats

Data summarizing significant results for the effect of lactation stage on biochemical and hematological parameters in Baladi goats are presented in Table 2. Serum glucose and total protein in early and mid stages of lactation were significantly greater than that reported at the late stage of lactation. Total leucocytes count, serum triglycerides and total antioxidant capacity were significantly reduced at early stage of lactation in comparison with late stage. On the contrary, erythrocytes count, hemoglobin, serum cholesterol, catalase and triiodothyronine were stable at different stages of lactation.

3.3. Phenotypic correlation among the milk composition traits, biochemical and hematological parameters

Significant correlation estimates among the milk composition traits and biochemical and hematological parameters were summarized in Table 3. There were high and positive correlations between daily-MY and milk protein, fat, lactose, TS and SNF. There were significant positive correlations between daily-MY and hemoglobin concentration ($r = 0.37$), serum total protein ($r = 0.87$), catalase ($r = 0.51$), TAC ($r = 0.23$) and triiodothyronine ($r = 0.41$). However, negative estimates were reported between daily-MY and total leucocytes count

Table 1 Least square means (LSM) for the effect of lactation stage on milk yield and composition in Baladi goats.

Traits	Stage of lactation			
	Early[1]	Mid[2]	Late[3]	p-Value
Daily-MY[4] (kg)	1.63 ± 0.04	1.33 ± 0.03	1.11 ± 0.03	0.001
Protein (%)	3.60 ± 0.06	3.62 ± 0.04	3.65 ± 0.07	0.836
Fat (%)	3.27 ± 0.04	3.26 ± 0.03	3.30 ± 0.05	0.652
Lactose (%)	4.09 ± 0.04	4.06 ± 0.02	3.85 ± 0.03	0.017
Total solids (%)	10.99 ± 0.06	11.18 ± 0.05	11.29 ± 0.06	0.022
SNF[5] (%)	7.74 ± 0.05	7.80 ± 0.03	7.76 ± 0.04	0.281

[1] Early: DIM less than 80 days.
[2] Mid: DIM, 80–140 days.
[3] Late: DIM over 140 days.
[4] MY: milk yield.
[5] SNF: solids not fat.

Table 2 Least square means (LSM) for the effect of lactation stage on biochemical and hematological parameters in Baladi goats.

Traits	Stage of lactation			
	Early[1]	Mid[2]	Late[3]	*p*-Value
RBC ($\times10^6/\mu l$)[4]	10.19 ± 0.15	10.45 ± 0.09	10.28 ± 0.13	0.237
Hb(g/dl)[5]	9.71 ± 0.07	9.50 ± 0.08	9.45 ± 0.12	0.144
WBC ($\times10^3/\mu l$)[6]	8.45 ± 0.11	8.83 ± 0.08	8.96 ± 0.09	0.008
Glucose(mg/dl)	71.16 ± 0.49	67.76 ± 0.43	59.81 ± 0.41	0.001
TP (g/dl)[7]	7.38 ± 0.06	7.05 ± 0.05	6.46 ± 0.07	0.001
TG (mg/dl)[8]	126.9 ± 1.88	128.8 ± 1.46	132.9 ± 1.91	0.050
CH (mg/dl)[9]	131.9 ± 2.15	131.2 ± 2.06	126.4 ± 2.31	0.225
CAT (U/gHb)[10]	113.2 ± 4.61	115.4 ± 4.34	114.9 ± 4.69	0.856
TAC(mmol/dl)[11]	6.48 ± 0.37	6.67 ± 0.52	6.78 ± 0.43	0.046
T_3 (ng/ml)[12]	1.42 ± 0.06	1.49 ± 0.05	1.61 ± 0.07	0.148

[1] Early: DIM less than 80 days.
[2] Mid: DIM, 80–140 days.
[3] Late: DIM over 140 days.
[4] Red blood cells.
[5] Hemoglobi.
[6] White blood cells.
[7] TP: serum total protein.
[8] TG: triglycerides.
[9] CH: cholesterol.
[10] CAT: catalase.
[11] TAC: total antioxidant capacity.
[12] T_3: triiodothyronine.

Table 3 Correlation coefficients among the milk composition traits and blood parameters in Baladi goats.

Traits	MY[1]	MP[2]	MF[3]	ML[4]	TS[5]	SNF[6]	RBC[7]	Hb[8]	WBC[9]	SG[10]	TP[11]	TG[12]	CH[13]	CT[14]	TAC[15]
MP[2]	0.29[a]														
MF[3]	0.33[a]	0.49[a]													
ML[4]	0.52[a]	0.11	0.10												
TS[5]	0.53[a]	0.79[a]	0.76[a]	0.53[a]											
SNF[6]	0.52[a]	0.79[a]	0.42[a]	0.69[a]	0.91[a]										
RBC[7]	0.08	0.22[b]	0.36[a]	0.03	0.31[a]	0.28[a]									
Hb[8]	0.37[a]	0.09	0.42[a]	0.14	0.32[a]	0.40[a]	0.12								
WBC[9]	−0.44[a]	−0.15	−0.49[a]	−0.05	−0.34[a]	−0.38[a]	−0.16	−0.27[a]							
SG[10]	0.15	−0.18	−0.16	0.33[a]	−0.03	0.08	−0.05	−0.11	0.02						
TP[11]	0.87[a]	0.31[a]	0.27[a]	0.62[a]	0.55[a]	0.58[a]	0.16	0.32[a]	−0.36[a]	0.10					
TG[12]	−0.55[a]	−0.61[a]	0.19[b]	−0.06	−0.62[a]	−0.46[a]	−0.23	−0.37[a]	0.46[a]	0.05	−0.44[a]				
CH[13]	−0.33	−0.69[a]	0.06	−0.08	−0.59[a]	−0.38[a]	−0.30[a]	−0.11	0.32[a]	0.22	−0.43[a]	0.52[a]			
CT[14]	0.51[a]	0.71[a]	0.58[a]	0.18	0.71[a]	0.53[a]	0.43[a]	0.21	−0.35[a]	−0.14	0.51[a]	−0.69[a]	−0.78[a]		
TAC[15]	0.23	0.79[a]	0.62[a]	0.05	0.72[a]	0.42[a]	0.37[a]	0.16	−0.24	−0.23	0.30[a]	−0.54[a]	−0.79[a]	0.80[a]	
T_3[16]	0.41[a]	0.69[a]	0.65[a]	0.07	0.69[a]	0.52[a]	0.33[a]	0.25	−0.36[a]	−0.24	0.38[a]	−0.68[a]	−0.73[a]	0.91[a]	0.78[a]

[1] MY: daily milk yield.
[2] MP: milk protein%.
[3] MF: milk fat%.
[4] ML: milk lactose%.
[5] TS: total solids.
[6] SNF: solid not fat.
[7] Red blood cells.
[8] Hemoglobin.
[9] White blood cells.
[10] SG: serum glucose.
[11] TP: serum total protein.
[12] TG: triglycerides.
[13] CH: cholesterol.
[14] CT: catalase.
[15] TAC: total antioxidant capacity.
[16] T_3: Triiodothyronine.
[a] $P < 0.01$.
[b] $P < 0.05$.

(r = −0.44), triglycerides (r = −0.55) and cholesterol (r = 0.33). Milk protein and fat were positively correlated with erythrocytes count (r = 0.22 and 0.36, respectively), serum total protein (r = 0.31 and 0.27, respectively), catalase (r = 0.71 and 0.58, respectively), TAC (r = 0.79 and 0.62, respectively) and triiodothyronine (r = 0.69 and 0.65, respectively). Furthermore, lactose percentage was positively correlated with serum glucose and total protein (r = 0.33 and 0.62, respectively). Total solids was positively correlated with serum total protein, TAC (r = 0.72) and triiodothyronine (r = 0.55 and 0.69, respectively); but negatively correlated with triglycerides and cholesterol (r = −0.62 and −0.59, respectively). Serum total protein has high and positive correlations with catalase, TAC and triiodothyronine. On the contrary, serum total protein had high and negative correlations with serum triglycerides and cholesterol.

4. Discussion

In recent years, interest in commercializing goat milk production for human consumption and cheese manufacture is attracting producers due to growing demand (Mestawet et al., 2012; El-Tarabany et al., 2016). In the current study, the average daily-MY in Baladi goats was comparable to former trials, where the peak was attained at the early stage of lactation, and then a steady decline was observed thereafter until the end of lactation. These findings were consistent with Louca et al. (1975) who reported that the lactation peak of Damascus goats were located between 5 and 6 weeks postpartum. Moreover, Abd El Gadir and El Zubeir (2005) reported that the peak daily milk yield was reached during 40–50 days of lactation. Some researchers reported high persistency of Egyptian goat breeds (Baladi, Zaraibi and Damascus), with a slightly higher yield during the initial part of lactation (Laes-Fettback and Peters, 1995). Similarly in Damascus goats, Katanos et al. (2005) recorded no significant differences between the average daily milk yield (1.26 ± 0.06) at weaning (7–8th week) and that at mid stage of lactation.

Dairy Baladi goats produce milk with a relatively stable protein and fat contents at the different stages of lactation. This may be attributed to the ability of native goat breeds to preserve body condition at different stages of lactation. Furthermore, this prompts the steady and continuous utilization of their milk in processing at different stages of lactation. During the early stage of lactation, dairy goats may suffer a negative energy balance and variable degree of lipolysis in the fatty tissue, increasing the level of free fatty acids that have a negative effect on the palatability traits of milk (Strzałkowska et al., 2009). Former trials have conflicting results for protein and fat contents at different stages of lactation. Some researchers reported that protein contents were higher in early and late lactation (Mestawet et al., 2012; Ibnelbachyr et al., 2015). However, others found that protein contents decreased significantly from early to late lactation (Olechnowicz and Sobek, 2008; Mahmoud et al., 2014). Despite the relatively lower protein% recorded by Strzałkowska et al. (2009) at early and mid lactation stages, they support the increment of protein contents with the progress of lactation. Ibnelbachyr et al. (2015) reported that fat content increased as the lactation progressed. However, Mestawet et al. (2012) found that fat contents were significantly higher at the early and at the late stages of lactation. Other authors found that fat contents decreased significantly with the progress of lactation (Strzałkowska et al., 2009; Mahmoud et al., 2014). This suggests that fat present in the milk during the late stage of lactation is likely more liable to lipolysis, which may be caused by bacterial enzymes or even natural enzymes present in the mammary gland (Gajdusek et al., 1993).

In accordance with most related studies, the contents of total solids in Baladi goats have been increased significantly toward the end of the lactation, probably as a result of decrease in milk yield. These results are in agreement with those reported in other breeds, including the Draa goats (Noutfia et al., 2014), the Polish White Improved goats (Olechnowicz and Sobek, 2008) and Najdi ewes (Ayadi et al., 2014). In a former trial that reported comparable total solids contents, Soryal et al. (2004) stated that total solids content of milk from Alpine goats was highly correlated with lactation stages with the peak that occurred at the last month of lactation. However, Mestawet et al. (2012) found that total solids were significantly higher at the beginning and at the end of lactation. Quite a contrary trend was established for lactose content in the current study; as its content was significantly reduced at the late stage of lactation in comparison with early and mid stages. Consistent with these findings, other researchers reported that lactose contents decreased significantly from early to late lactation (Olechnowicz and Sobek, 2008; Mahmoud et al., 2014). In a previous trial reported comparable lactose percentages, Pavic et al. (2002) recorded the highest lactose content at the beginning (4.97%) and lowest at the end (4.09%) of the lactation period. In Leccese ewes, Dario et al. (1996) also reported a higher lactose content at the beginning (5.32%) in relation to the end (4.93%) of the lactation period. However, others reported that lactose contents were higher in the early and late lactation (Noutfia et al., 2014; Ibnelbachyr et al., 2015).

The current results revealed stability in most hematological parameters of Baladi goats at different stages of lactation. However, total leucocytes were decreased at the early stage of lactation in comparison with mid and late stages. This reduction at the early stage may be attributed to the increment in cortisol level (as a result of increased milk yield toward peak level), which probably is responsible for the impairment of the cellular immune response (Caroprese et al., 2012). In the current work, the significant higher serum glucose level at early stage of lactation may be considered as compensatory mechanism to meet the great demand of energy for milk synthesis (Abdelrahman et al., 2002). However, a reduced energy supply during the early lactation period leads to a greater risk of metabolic disorders (Bremmer et al., 2000). Consistent with results of this study, Casamassima et al. (2007) reported a significant decrease of serum glucose level at the late stage of lactation (210 days) in Montefalcone dairy goats. On the contrary, other researchers stated that blood glucose level was significantly higher in middle and late lactation than the early lactation stage (Slanina et al., 1992). However, others reported no significant variation of blood glucose at different stages of lactation in Valfortorina goats (Casamassima et al., 2007). The substantial decreases in the level of serum total protein with the progress of lactation agreed with previous studies (Cavestany et al., 2005; Casamassima et al., 2007). These decreases may reflect the maternal requirements of proteins for milking and providing immunoglobulins (Roubies et al., 2006; Mohri et al., 2007). Meanwhile, other trials reported no significant differences in serum total protein at different stages of lactation in Montefalcone goats (Casamassima et al., 2007).

In the current study, triglycerides showed a significant increase at the late stage of lactation in Baladi goats. Former trials support these results (Casamassima et al., 2007; Abd-El Naser et al., 2014). Probably because, at the late stage of lactation, there is an increase in the demands for regulatory mechanisms, responsible for all the processes involved with preparation for milking in the next season (Roche et al., 2009). On the contrary, other studies reported no significant differences in serum triglycerides at different stages of lactation in Valfortorina goats (Casamassima et al., 2007). The current trial indicates a non significant decrease of serum cholesterol level at late stage of lactation in comparison with early stage; however, other researchers estimated a significant reduction of serum total cholesterol at the late stage of lactation in Montefalcone and Valfortorina goats (Noè et al., 2004; Casamassima et al., 2007). Thyroid hormones have an important role to play in the development of the mammary gland (Ramos et al., 2000); however, dairy Baladi goats in the current study reported a non significant increase of triodothyronin at the late stage of lactation. Consistent with these findings, Pezzi et al. (2003) reported lower blood T3 concentration at the initiation of lactation.

Our results revealed a significant positive correlation between daily-MY and hemoglobin concentration, serum total protein and triiodothyronine. These findings are in conflict with other estimates reported by Gabris et al. (1985). They reported significant negative relation between milk yield and plasma protein ($r = -0.34$). However, our negative correlation estimate between milk yield and cholesterol was conflicted with Mohebbi-Fani et al. (2009) and Jóźwik et al. (2012). They found positive correlations between cholesterol with uncorrected or corrected milk yield during several periods of lactation. The significant positive correlation between daily-MY with catalase and total antioxidant capacity explained their antioxidant defense role and maintenance of normal cell function and metabolism (Spurlock and Savage, 1993). The significant positive correlation between lactose percentage and serum glucose level seems to be logical as 80–85% of glucose in blood is used by the mammary gland for lactose synthesis in goats (Sano et al., 1985). Total solids were negatively correlated with triglycerides and cholesterol; however, other researchers reported no significant relation between cholesterol level and total solid percentage (Jóźwik et al., 2012).

In conclusion, dairy Baladi goats produce milk with a relatively stable protein, fat and SNF contents at the different stages of lactation; however, significant increase of total solids contents was recorded at mid and late stages. Accordingly, this encourages the steady and continuous utilization of their milk in processing at different stages of lactation. Furthermore, they were able to maintain most hematological and biochemical parameters; however, variations reduction in few biochemical (serum total protein, glucose and triglycerides) and hematological (leucocytes count) indices have been reported at different stages of lactation.

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