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Haemato-chemical and immune variations in Holstein cows at different stages of lactation, parity, and age

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Abstract: Physiological components are influenced by various factors. However, little is comprehensively understood about lactation, parity, and age-related blood profile changes in dairy cows. Thus, we investigated significant variables associated with haemato-chemical and immune changes in healthy dairy cows. Blood was collected from 246 Holstein cows to analyse the physiological changes at different stages of lactation, parity, and age. The white blood cells (WBCs) and monocytes were influenced by the parity or age. Cows over three years of age showed a decreased WBC and monocyte count when compared to cows under three years of age. The lactation stage affected the red blood cell (RBC) profiles and metabolism, liver function-related components, and immunoglobulin A (IgA). A decrease in the haemoglobin (Hb) and haematocrit (HCT) were associated with peak lactation. The blood urea nitrogen (BUN) and total cholesterol (T-CHOL) concentrations, and alanine aminotransferase (ALT) and gamma-glutamyltransferase (GGT) activities increased in peak or mid lactation and remained high up to late lactation. An increased serum IgA concentration was observed in early and mid-lactation compared to that in late gestation. Many components of the haemato-chemical and immunological profiles changed (Hb, HCT, BUN, T-CHOL, ALT, GGT, and IgA) at a specific lactation stage under the physiological conditions. These data revealed that the lactation stage was a major variable contributing to the physiological variations in the dairy cows. Therefore, the lactation stage should be considered when determining haemato-chemical and immunological abnormalities.

Keywords: blood profile; cholesterol; dairy cows; immunoglobulins; physiological components

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Haematological and biochemical data are reliable indicators reflecting not only the physiological condition, but also the health state of cows (Roland et al. 2014). Blood components may be influenced by various factors such as age, parity, days relative to calving, milk production, and season, even in normal lactating cows (Cozzi et al. 2011; Brscic et al. 2015). Additionally, different decades, locations, management, species, breed, and laboratory factors can affect the haematological reference intervals (George et al. 2010). These factors must be considered when establishing criteria for the disease and physiological status. Identifying which variables specifically affect the value of a certain blood component will be an important strategy in uncovering health problems and the therapeutic intervention.

Due to the dramatic physiological changes, it is difficult to apply general reference values of blood components to dairy cows in the transition period (Kida 2002). The transition period, which is defined as an interval from three weeks before to three weeks after calving, is the most critical phase with respect to sudden metabolic, endocrine, and immune disorders in dairy cows (Mordak and Stewart 2015; Trevisi and Minuti 2018). Therefore, most studies that describe changes for commonly measured blood components have been focused on the periparturient period in dairy cows (Quiroz-Rocha et al. 2009). However, physiological imbalances that may cause health problems can occur during all stages of lactation (Bjerre-Harpoth et al. 2012). Thus, an understanding of the comprehensive physiological changes during all the stages of lactation is needed.

Several studies have reported that age and parity may underlie the differences in the haematological and biochemical variables in dairy cows (Cozzi et al. 2011). Older cows tend to show a low concentration of calcium (Horst et al. 2005) and a high concentration of the total protein (Cozzi et al. 2011). Parity is also of interest in interpreting the physiological variations in healthy cows, and biochemical differences were found in cows in a different number of parities (Cozzi et al. 2011). Exploring the effects of the relevant variables on the physiological variation could improve the detection efficiency of health abnormalities in dairy cows.

Dairy cows experience repeated delivery and diet management for milk production throughout their lives (Humer et al. 2018). We hypothesise that dairy cows have different profiles in their blood components according to the various physical conditions, which is not a disease status. Thus, the objectives of this study were 1) to investigate whether the haematological, biochemical, and immunological components were influenced by the variables such as the lactation stage, parity, and age in healthy Holstein dairy cows, 2) to determine which variables were related to the changes in the blood components in healthy Holstein dairy cows, 3) to analyse the coefficient of the significant variables on the changes in the blood values, and 4) ultimately, to understand the normal physiological changes in dairy cows with different a lactation, parity, an age status as a major relevant variable. The study would be helpful in providing information regarding physiological changes for early diagnosis and prevention of diseases.

MATERIAL AND METHODS

Animals

A total of 246 Holstein cows from a farm in the Republic of Korea were selected for the study from June 2016 to December 2017. This study was conducted through four seasons: spring (March–May, n = 116), summer (June–July, n = 35), fall (September–October, n = 43), and winter (December, n = 52). The calving date, lactation, parity, age, health status, milk production, body condition score (BCS; Edmonson et al. 1989), vaccination, and disease history were individually recorded for each cow. This study included adult cows that were considered healthy with no incidence of diseases by veterinarians. The cows were less than in the 5th parity, ranging in age from 2 to 10 years. The average milk production and BCS were 33.93 kg/cow/day (range 7.3 kg/cow/day to 84.4 kg/cow/day) and 3.3 (range 2.5 to 4.5), respectively. The lactation stages were divided into 5 groups according to a previous publication (Kayano and Kida 2015) as follows: late gestation (30 days before calving, n = 36), early [calving to 49 days in milk (DIM), n = 18], peak (50–109 DIM, n = 50), mid (110–219 DIM, n = 75), and late lactation (220 DIM to before dry-off, n = 67). The cows were also allotted into 3 groups by parity and age as shown in Table 4. All the procedures were carried out according to the ethical guidelines for the use of animal samples, as ap-

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proved by the National Institute of Animal Science [Institutional Animal Care and Use Committee (IACUC) decision No. NIAS 2016-180].

Blood sample collection

Blood was extracted from the jugular vein into ethylenediaminetetraacetic acid and plain tubes. The serum was separated from the blood samples from the plain tubes and was stored at –70 °C pending analysis.

Haematological and serum biochemical analysis

The haematological evaluation, including white blood cell (WBC) and red blood cell (RBC) profiles and platelets, was performed using a ProCyte Dx haematology analyser (IDEXX Laboratories, Westbrook, MA, USA). The serum biochemical components were measured using a Hitachi 7180 auto-analyser (Hitachi, Ltd., Tokyo, Japan). The chemistry profile included the total protein, albumin, blood urea nitrogen (BUN), creatine kinase (CK), creatinine, glucose, total cholesterol (T-CHOL), non-esterified fatty acids (NEFA), triglyceride (TG), beta hydroxybutyrate (BHBA), aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyltransferase (GGT), lactate dehydrogenase (LDH), total bilirubin (T-BIL), calcium, phosphorus, and magnesium.

Measurement of serum immunological components

Commercial ELISA (enzyme-linked immunosorbent assay) kits (Cusabio Biotech Co., Ltd., Hubei, P. R. China) were used to determine the serum cortisol, interferon-γ (IFN-γ), tumour necrosis factor-α (TNF-α), interleukin-6 (IL-6), interleukin-18 (IL-18), and immunoglobulin A (IgA) concentrations in the serum.

Statistical analysis

A logarithmic or square root transformation was applied to several physiological values to stabilise the variance in the data. The normally distributed and transformed data were statistically processed by a generalised linear mixed model of SPSS v24.0 (SPSS, Chicago, IL, USA) to analyse the data in which both fixed and random factors were included. The lactation stage, parity, age, and their interactions were included as the fixed factors and the season (visiting time) was included as a random factor. Models were built to statistically assess the significant effects of the fixed variables on the following physiological outcomes: milk yield, BCS, haematological, biochemical, and immune values. The mean, standard error mean (SEM), 95% confidence interval (CI), and coefficient were generated based on the outcomes of the model, taking the lactation stage, parity, age, interactions, and season into account. A P-value of < 0.05 was considered significant.

RESULTS

The lactation stage, parity, and age considerably affected the haematological variations in the clinically healthy dairy cows (Table 1). The lactation stage affected the variations in the milk yield, BCS, RBC counts, haemoglobin (Hb) concentration, haematocrit (HCT) value, and platelets ($P < 0.05$). The age had a significant effect on the WBC and monocyte counts. In particular, the Hb and HCT values were not only influenced by the lactation stage, but were influenced by the parity and age ($P < 0.05$). Among the serum biochemical indicators, variations in most biochemical components related to the protein and energy metabolism (total protein, BUN, creatinine, glucose, T-CHOL, NEFA, TG, and BHBA) and liver function (ALT, GGT, and LDH) were associated with the lactation stage ($P < 0.05$; Table 2). However, the parity and age did not significantly affect the other biochemical indicators. Meanwhile, the lactation stage, parity, and age did not show significant effects on the variations in the mineral concentrations such as calcium, phosphorus, and magnesium.

When we investigated the lactation stage, parity, and age effects in relation to the stress-related hormone, pro-inflammatory cytokines, and immunoglobulin production, the lactation stage had a significant effect on the variations in the TNF-α and IgA concentrations among the healthy dairy cows ($P < 0.05$; Table 3). However, the cortisol, IFN-γ, TNF-α, IL-6, and IL-18 concentrations were not af-

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Table 1. The effect of the lactation stage, parity, and age on the milk yield, body condition score, and haematological changes in the dairy cows

Indicator	Measured values			Fixed effect, *P*-value					
	mean	SEM	95% CI	lactation stage	parity	age	L × P	L × A	P × A
Milk yield (kg/d)	33.93	4.89	24.21–43.67	0.003	0.203	0.577	0.285	0.459	0.630
Body condition score	3.34	0.11	3.13–3.55	0.000	0.249	0.795	0.025	0.040	0.004
WBCs (10^3/µl)	8.42	0.73	6.97–9.87	0.456	0.218	0.017	0.912	0.282	0.403
Neutrophil (10^3/µl)	3.21	0.40	2.43–3.99	0.257	0.199	0.591	0.482	0.871	0.952
Lymphocyte (10^3/µl)	3.82	0.52	2.79–4.85	0.395	0.386	0.097	0.593	0.623	0.388
Monocyte (10^3/µl)	0.79	0.23	0.34–1.24	0.375	0.643	0.000	0.916	0.267	0.211
RBCs (10^6/µl)	5.85	0.11	5.64–6.07	0.008	0.059	0.044	0.506	0.676	0.324
Hb (g/l)	99.72	3.53	92.74–106.69	0.000	0.003	0.013	0.496	0.974	0.028
HCT (%)	30.23	1.25	27.76–32.71	0.000	0.003	0.004	0.379	0.970	0.012
Platelet (10^3/µl)	331.87	37.48	257.86–405.88	0.047	0.318	0.296	0.402	0.865	0.523

A = age; Hb = haemoglobin; HCT = haematocrit; L = lactation stage; P = parity; RBCs = red blood cells; WBCs = white blood cells

Table 2. The effect of the lactation stage, parity, and age on the biochemical changes in the dairy cows

Indicator	Measured values			Fixed effect, *P*-value					
	mean	SEM	95% CI	lactation stage	parity	age	L × P	L × A	P × A
Protein and energy metabolism									
Total protein (g/l)	87.50	16.27	55.38–119.62	0.015	0.563	0.536	0.329	0.727	0.619
Albumin (g/l)	41.14	9.49	22.43–59.85	0.391	0.844	0.688	0.579	0.792	0.392
Urea nitrogen (mmol/l)	4.64	0.99	2.69–6.60	0.000	0.186	0.245	0.117	0.262	0.851
CK (µkat/l)	3.61	1.14	1.36–5.87	0.086	0.766	0.078	0.911	0.042	0.833
Creatinine (µmol/l)	105.79	15.40	75.38–136.20	0.000	0.576	0.412	0.062	0.914	0.722
Glucose (mmol/l)	3.38	0.29	2.81–3.96	0.012	0.100	0.683	0.040	0.001	0.103
Total cholesterol (mmol/l)	4.29	0.37	3.56–5.01	0.000	0.560	0.248	0.676	0.533	0.332
NEFA (mmol/l)	0.153	0.093	0.00–0.34	0.000	0.556	0.551	0.298	0.077	0.504
Triglyceride (mmol/l)	0.13	0.02	0.10–0.16	0.000	0.277	0.580	0.473	0.092	0.748
BHBA (µmol/l)	661.68	74.74	514.39–808.97	0.009	0.970	0.601	0.969	0.635	0.296
Enzyme and liver function									
AST (µkat/l)	1.35	0.17	1.01–1.69	0.068	0.494	0.138	0.652	0.861	0.671
ALT (µkat/l)	0.42	0.04	0.34–0.50	0.000	0.421	0.873	0.964	0.326	0.336
GGT (µkat/l)	0.44	0.04	0.37–0.52	0.003	0.967	0.977	0.844	0.766	0.509
LDH (µkat/l)	17.77	0.37	17.05–18.50	0.041	0.179	0.314	0.141	0.025	0.241
Total bilirubin (µmol/l)	1.08	0.26	0.57–1.59	0.080	0.437	0.674	0.692	0.849	0.355
Mineral									
Calcium (mmol/l)	2.53	0.25	2.04–3.03	0.320	0.777	0.194	0.093	0.525	0.155
Phosphorus (mmol/l)	1.94	0.06	1.82–2.05	0.100	0.120	0.286	0.793	0.272	0.194
Magnesium (mmol/l)	1.08	0.08	0.92–1.24	0.304	0.863	0.309	0.456	0.453	0.573

A = age; ALT = alanine aminotransferase; AST = aspartate aminotransferase; BHBA = beta hydroxybutyrate; CK = creatine kinase; GGT = gamma-glutamyltransferase; L = lactation stage; LDH = lactate dehydrogenase; NEFA = non-esterified fatty acids; P = parity

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Table 3. The effect of the lactation stage, parity, and age on the pro-inflammatory and immune responses in the dairy cows

Indicator	Measured values			Fixed effect, *P*-value					
	mean	SEM	95% CI	lactation stage	parity	age	L × P	L × A	P × A
Cortisol (ng/ml)	78.73	24.96	29.54–127.93	0.494	0.431	0.711	0.743	0.539	0.733
IFN-γ (pg/ml)	948.78	353.60	251.83–1 645.73	0.825	0.772	0.666	0.254	0.198	0.660
TNF-α (ng/ml)	2.20	0.61	1.00–3.39	0.035	0.023	0.532	0.931	0.861	0.320
IL-6 (pg/ml)	122.72	89.52	53.72–299.16	0.196	0.088	0.679	0.932	0.393	0.568
IL-18 (pg/ml)	110.38	31.95	47.40–173.37	0.580	0.105	0.974	0.557	0.552	0.595
IgA (μg/ml)	260.41	122.08	19.78–501.03	0.038	0.540	0.170	0.910	0.308	0.354

A = age; IFN-γ = interferon-γ; IgA = immunoglobulin A; IL-18 = interleukin-18; IL-6 = interleukin-6; L = lactation stage; P = parity; TNF-α = tumour necrosis factor-α

Table 4. Changes in the haematological values depending on the different categories of the lactation stage, parity, and age

Variable category		Coefficient					
	n	milk yield	BCS	WBCs	MON	Hb	HCT
Intercept		33.73	4.28	12.38	1.48	107.16	32.59
Lactation stage							
Late gestation (Ref.)	36	–	0	0	0	0	0
Early lactation	18	0	–0.56**	–2.67	–0.38	–7.98	–2.92
Peak lactation	50	1.84	–1.51**	–3.53	–0.50	–12.74*	–4.96*
Mid lactation	75	–4.42	–0.80**	–2.65	–0.50	–9.97	–2.99
Late lactation	67	–12.11*	–1.32**	–1.86	–0.12	–10.32	–3.99
Parity							
≤ 1 (Ref.)	115	0	0	0	0	0	0
2	67	5.23	0.51	–0.66	–0.14	–4.20	–1.52
≥ 3	64	8.15	0.81	–2.29	–0.31	12.85	4.26
Age (years)							
< 3 (Ref.)	40	0	0	0	0	0	0
3–5	113	3.78	–0.70	–3.36**	–0.62**	–4.07	–1.13
> 5	93	0.86	–0.26	–3.92**	–0.77**	9.39	3.64

BSC = body condition score; Hb = haemoglobin; HCT = haematocrit; LYM = lymphocyte; MON = monocyte; WBCs = white blood cells

*$P < 0.05$, **$P < 0.005$ vs Ref. (reference category)

fected by the lactation stage as well as the parity and age among the healthy dairy cows. No significant interactions among the lactation stage, parity, and age factors were observed for the immunological variables under study.

A further analysis was conducted to determine which categories of lactation, parity, and age were associated with changes in the haemato-chemical and immune parameters. The decreased number of circulating WBCs and monocytes were associated with the increased ages ($P < 0.005$, Table 4). The WBC and monocyte counts decreased in the dairy cows over 3 years of age when compared to the dairy cows under 3 years of age. The Hb and HCT counts significantly decreased during the peak lactation period compared to the late gestation period ($P < 0.05$). No significant haematological differences were observed in the multiparous dairy cows with two or more parturitions when compared to the primiparous dairy cows.

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Table 5. The biochemical and immunological changes depending on the different categories of the lactation stage, parity, and age

Variable category	Coefficient										
	BUN	Cre	glucose	T-CHOL	NEFA	TG	BHBA[a]	ALT	GGT	TNF-α[a]	IgA[a]
Intercept	3.64	130.57	3.70	2.49	0.35	0.16	6.34	0.20	0.35	1.46	4.06
Lactation period											
Late gestation (Ref.)	0	0	0	0	0	0	0	0	0	0	0
Early lactation	0.36	–25.93*	–0.37	0.63	–0.14	–0.09*	0.25	0.14	0.03	–0.66*	1.41*
Peak lactation	0.41	–31.94**	–0.46*	1.95*	–0.11	–0.05	0.07	0.17	0.14*	–0.41	0.64
Mid lactation	2.08**	–31.99**	–0.34*	3.34**	–0.28**	–0.05	0.31*	0.33**	0.13*	–0.28	1.23*
Late lactation	2.95**	–39.10**	–0.42*	3.96**	–0.29**	–0.02	0.34	0.34**	0.13*	–0.40	0.15
Parity											
≤ 1 (Ref.)	0	0	0	0	0	0	0	0	0	0	0
2	–0.24	13.12	0.12	–0.23	–0.04	0.01	–0.03	0.09	–0.00	–0.06	0.13
≥ 3	0.76	19.61	0.24	–0.02	–0.09	0.01	–0.10	0.19	–0.09	0.12	–0.44
Age (years)											
< 3 (Ref.)	0	0	0	0	0	0	0	0	0	0	0
3–5	–0.54	–0.35	–0.37	0.14	–0.10	0.01	–0.04	0.02	0.03	0.32	1.06
> 5	–0.86	4.96	–0.34	–0.64	–0.23	0.05	–0.15	0.02	0.01	–0.17	–0.02

ALT = alanine aminotransferase; BHBA = beta hydroxybutyrate; BUN = blood urea nitrogen; Cre = creatinine; GGT = gamma-glutamyltransferase; IgA = immunoglobulin A; NEFA = non-esterified fatty acids; T-CHOL = total cholesterol; TG = triglyceride; TNF-α = tumour necrosis factor-α

[a]Superscript indicates the log or square root transformed data and values; *$P < 0.05$, **$P < 0.005$ vs Ref. (reference category)

In Table 5, the increased T-CHOL and GGT concentrations were associated with the peak lactation period, and the increased BUN and BHBA concentrations, and the ALT activities were associated with the mid lactation period ($P < 0.05$). Of these, the BUN, T-CHOL, ALT, and GGT concentrations remained high up to late lactation ($P < 0.05$). Conversely, the creatinine, glucose, NEFA, and TG concentrations were negatively associated with the lactation period compared to the late gestation period ($P < 0.005$). Moreover, the TNF-α concentration decreased in early lactation compared to late gestation ($P < 0.05$). The IgA concentrations fluctuated during the different lactation periods. An increase in the serum IgA concentration was observed from early and mid-lactation period when compared to late gestation period ($P < 0.01$), meanwhile the serum IgA concentration of the peak and late lactation period did not significantly differ from that of the late gestation period. No significant association was detected for the serum biochemical and immune components among the different categories of parity and age.

DISCUSSION

This study intended to identify the influence of the lactation stage, parity, and age as the major variables on the changes in the blood components. To the best of our knowledge, this study was the first to comprehensively investigate the haematochemical and immunological changes that are observed during the production cycle in healthy dairy cows. The blood values before parturition can be potentially used to predict the physiological or pathological conditions during the subsequent stages of lactation after parturition in dairy cows. It would help to understand the physiological responses and avoid the misdiagnosis of a pathological condition in dairy cows by analysing the changes in the blood components for each lactating stage based on the pre-calving values.

Different reference limits for various lactation stages need to be determined for certain physiological components to appropriately interpret the results. This study suggests that particular attention should be paid to the haematological

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analytes such as the Hb and HCT, the biochemical analytes such as the BUN, creatinine, glucose, T-CHOL, NEFA, TG, BHBA, ALT, and GGT and the immunological analytes such as the TNF-α and IgA, which showed significant differences in various lactation periods. Early lactation is well known to be related to metabolic changes (Kida 2002; Cozzi et al. 2011; Joksimovic Todorovic and Davidovic 2012). However, in the current study, the peak to late lactation period also had an influence on the significant changes in the metabolic and liver damage markers. Marked physiological changes were also present in the other lactation periods as well as around the transition period.

It is known that age has a major effect on several blood indicators (Herman et al. 2018). However, compared to the lactation stage factor, age and parity were not critical factors that influenced the physiological variations. The parity and age factors appeared to have minor effects on the blood profile of the healthy dairy cows in the current study. According to other reports that surveyed the blood profile of cows ranging in age from one to six years; over the age of two years, the age effect may not be critical (Roussel et al. 1982). The results of this present study agree with the previous reports. We did not identify the association in the other blood components except for the WBC and monocyte counts among the age groups of 2 to 10 years. In addition, unlike a study that reported higher creatinine and glucose in heifers than in primiparous and multiparous cows (Brscic et al. 2015), the minor or non-significant effect of the parity on the biochemical changes in the current study might be explained by the different grouping. In the present study, the heifer and primiparous cows were merged into one group of parity of ≤ 1.

There may be a wide difference in the blood profile in feeding and housing systems at different farms and locations (George et al. 2010). These differences may sometimes be observed among cows in the same herd (Kida 2002). The reference ranges in the current study showed narrower ranges, but were almost similar to previously reported data (George et al. 2010), supporting that the cows were within their expected physiological value. However, further studies on several farms are required to assess the physiological changes under various environmental and management conditions to more accurately adjust the results.

Transient leukopenia has been observed during the transition period in Holstein cows (Kehrli et al. 1989; Detilleux et al. 1995). In the current study, a decrease in the total WBCs was observed during the lactation periods compared to before calving, although the decrease in the WBC counts was not significant. One reason for the decrease in the immune cells is that it is thought to be due to the extensive influx of leukocytes into the reproductive tract after calving (Gunnink 1984). Similar to the findings by Herman et al. (2018), the HCT and Hb concentration remained low for the peak lactation period.

Of the 18 biochemical components listed, ten components showed a significant association with specific stages of lactation, defined as early, peak, mid and late lactation. Unlike another report, where the BUN level increased during the peak lactation stage in beef cattle (Doornenbal et al. 1988), the increase in the BUN was associated with the mid and late lactation stage in the healthy dairy cows in the present study. The cholesterol, which is attributed to the changes in the serum lipoprotein concentrations during the lactation (Kessler et al. 2014), markedly increased during the peak, mid and late lactation stages. The fluctuation in the cholesterol concentrations during the calving and lactation period can be found in cows with no clear signs of lipid metabolic disturbances (Pysera and Opalka 2000). In contrast, low concentrations of total lipids and cholesterol may be related to an impaired liver function (Pysera and Opalka 2000).

In accordance with the previous results that reported an increasing trend in the cholesterol (Cozzi et al. 2011; Kessler et al. 2014), the increased patterns in the ALT and GGT were observed as the lactation stage progressed. Meanwhile, similar to results to other studies (Pysera and Opalka 2000), a decreased TG concentration was seen during lactation. However, there are several discrepancies in the increasing or decreasing trends of these indicators in the healthy status of the dairy cows. Verification for the changes needs to be performed in more cows with a detailed investigation for the lipid composition of the lipoproteins.

Cytokines play a pivotal role in the development of a functional immune system as well as in the host response to infections. The overall pro-inflammatory cytokine profile was lower in the early lactation than the late gestation period (Trevisi et al. 2015). Consistent with a previous report that

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explained variations in the pro-inflammatory cytokine secretion around parturition (Trevisi and Minuti 2018), significantly decreased changes in the TNF-α was observed in the early lactating period. It is known that the immune system depresses in cows around parturition and alterations in the cortisol are induced at calving (Mordak and Stewart 2015). Although significant changes in the cortisol and other pro-inflammatory cytokines were not detected in the healthy condition around calving, the cortisol and IL-6 levels appeared to be decreasing during lactation when compared to late gestation (data not shown). Based on this data, the immune-related factors, in particularly TNF-α, would be useful in evaluating risky disease conditions in dairy cows.

The function of immunoglobulins in bovine milk is to protect the mammary gland against pathogens. Secretory IgA plays a major role in the innate immunity. We could not clearly explain the serum IgA changes during the different stages of lactation because of the limited information on serum IgA in dairy cows.

Although there are reports that IgA in milk is associated with the stage of lactation (Zhao et al. 2010), which presented a high concentration of IgA in the peak and late period, it is uncertain whether the milk IgA can represent the serum IgA. Evaluation of the milk IgA needs to accompany the serum IgA simultaneously to find out the reason for the IgA changes in the serum of the healthy lactating cows.

In conclusion, the stage of lactation was a major contributor in the various physiological variations. These data indicated that the specific stages of lactation can have an effect on the changes associated with the RBC profiles, energy metabolites and liver enzymes as well as several immunological changes such as the IgA production among clinically healthy dairy cows. Different reference values for lactating dairy cows should be determined forcertain haematological, biochemical, and immunological analytes in all the specific stages of lactation. This study provides valuable information in monitoring and predicting the health of a lactating cow.

Conflict of interest

The authors declare no conflict of interest.

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