Hematological and ionic parameters in Holstein dairy cows according to the different physiological stage: first report in Algeria

Meriem Mekroud
University of Constantine: Universite Constantine 1

Nadjet Amina Ouchene-Khelifi
Universite Saad Dahlab Blida

Amel Titi
University of Constantine: Universite Constantine 1

N. ARZOUR-LAKEHAL
University of Constantine: Universite Constantine 1

Nassim Ouchene (ouchenenaa@gmail.com)
Universite Saad Dahlab Blida

Abdessalam Mekroud
University of Constantine: Universite Constantine 1

Research Article

Keywords: Algeria, dairy cows, hematological parameters, ions, physiological stage

Posted Date: May 9th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1565124/v1

Abstract

This study aims to investigate, for the first time in Algeria, the variations of hematological and ionic parameters of Holstein dairy cows according to the physiological stage, as an indicator of its health status. The survey was conducted between January and March 2020 and carried out on 4 lots of 15 dairy cows each. The analysis of blood parameters concerned: red blood cells (RBC), hematocrit (HCT), hemoglobin (HGB), mean corpuscular volume (MCV), mean corpuscular hemoglobin content (MCH), mean corpuscular hemoglobin concentration (MCHC), platelets (PLT), the white blood cells (WBC), lymphocytes (LYM), monocytes (MONO), neutrophils (NEU), eosinophils (EOS), basophils (BASO) and ionic parameters such as potassium (K), chlorine (Cl), calcium (Ca), phosphorus (P) and sodium (Na).

The RBC level was lowest in the 2nd third of gestation (6.0 ± 0.8 x 10^6/µL) and in postpartum period (5.6 ± 0.8 x 10^6/µL), in comparison to the 1st third (6.6 ± 0.6 x 10^6 / µL) and 3rd third (dry period) of gestation (6.7 ± 0.5 x 10^6 / µL) ($p<0.0001$). The same observation was noted for HCT ($p<0.0001$). MCV was highest in dry cows ($p<0.01$). MCH and MCHC were highest in cows that were in the postpartum period ($p<0.001$). For WBC, the count was higher in the 1st third of gestation compared to the other stages, (11.3 ± 2.2 x 10^3 / µL) versus (6.4 ± 4.1 x 10^3 / µL), (5.2 ± 1.3 x 10^3 / µL), and (8.0 ± 4.9 x 10^3 / µL) for the 2nd third, 3rd third of gestation, and postpartum, respectively ($p<0.001$).

In postpartum cows, the ionic parameters had the lowest values of potassium (K), calcium (Ca) and phosphorus (P) compared to the other stages ($p<0.001$).

This investigation can be used as a basis for information on the hematological and ionic profile of dairy cattle in order to determine the health status before the onset of clinical signs.

Introduction

Through the various phases of the production cycle, dairy cows are confronted with changes in diet, management and environment, as well as changes in physiological parameters. These changes are reflected by hematological analyses (Herdt, 2000). Therefore, the evaluation of the hematological profile at the herd level can help in the diagnosis and prognosis of diseases, and provide an overview of the feeding and management strategies adopted in dairy farms, allowing the rapid assessment of animal responses to the different phases of the lactation cycle (Bezerra et al., 2017, Roland et al., 2014; Herdt, 2000). It is also useful for the classification of certain anemias (Brockus, 2011).

The hematological parameters can be influenced by several factors including age, breed, sex, physiological phases of the animal, season and farming system (Brucka-Jastrzebska et al., 2007; Farooq et al., 2012; 2017; Shehab-El-Deen et al., 2010).

Throughout the different physiological phases, dairy cows are confronted with multiple subclinical disorders (like subclinical hypocalcemia, subclinical ketosis) that are often associated with severe changes in several blood parameters (Mezzetti et al., 2019; Goff, 2008; Duffield, 2000). Variations in the

hematological parameters of dairy cows during different physiological phases have been investigated in several studies (Moretti et al., 2017; Brscic et al., 2015; Cozzi et al., 2011). However, to the best of our knowledge, this study is the first in Algeria.

In Algeria, the cattle herd represents about 6% of the total livestock population (sheep, goats, cattle, camels, and horses) with a total of 1.9 million cattle of which 52% are dairy cows (MADR, 2018). To date, no studies have been carried out in Algeria to investigate the hematological profile of dairy cows according to their physiological stage.

To the best of our knowledge, this study is the first in Algeria. It aims to investigate the variations of the hematological and ionic parameters of Holstein dairy cows, according to the physiological stage (first and second thirds of gestation, dry period and post-partum) as an indicator for physiological status assessment. The results obtained for the first time in Algeria, could be used as reference data.

Material And Methods

Study area

The study was conducted between January and March 2020, on a dairy cattle farm covering an area of 1500 hectares in the wilaya of Mila, northeast Algeria (36°20'47" N 6°20'19" E). This region has an altitude of 486 m, known for its warm Mediterranean climate with dry summers. January is the coldest month, with an average temperature of 6.5°C and precipitation of 61 mm. The average annual precipitation of this region is 501.7 mm.

Animals

The study was conducted on Holstein cows aged between 2 and 5 years. The milk production varies from 30 to 40 liters/cow/day. The dry period is at the end of the 7th month of gestation. Cows are artificially inseminated.

For the purpose of the study, the cows were divided into lots in a homogeneous way with regard to health status, age groups and season of study in order to keep only one factor of variation, which is the physiological stage. Clinically sick cows were excluded from our study.

The breeding system of the farm is intensive. The animals receive their feed (hay, barley, concentrate, silage and straw) in situ. The watering is ad-libitum. Milking is done in the milking room twice a day (morning and evening).

Blood samples

Four lots of 15 cows each were selected in the: 1st third period of gestation (1T), 2nd third period of gestation (2T), 3rd third period of gestation or dry period (3T) and postpartum (PP). Each animal was sampled only once.

Blood samples were taken from the coccygeal vein. Animals should be calm to avoid stress-related changes of the hemogram (Jones and Allison, 2007). The samples were transported under isothermal conditions respecting the cold chain and the time frame for analysis (within 24 hours) were respected, to ensure accurate and reliable results, (Adewoyin, 2014; Warren et al., 2013).

Blood samples were collected in the morning and divided into two tubes: one has EDTA for blood count formula and another heparinized for ion analysis. Blood smears for weight blood cells were made at the farm and dried then placed in boxes for later staining.

Laboratory analysis

The following hematological analyses were performed: Red blood cell count (RBC, $X10^6/\mu L$), hemoglobin concentration (HGB, g/dL), hematocrit (HCT, %), mean corpuscular volume (MCV, µm3), mean corpuscular hemoglobin content (MCH, pg), mean corpuscular hemoglobin concentration (MCHC, g/dL), platelets (PLT, $X10^3/\mu L$), and white blood cell count (WBC, $X10^3/\mu L$).

All these parameters were measured using a hematology automat (MINDRAY BC3000 Plus, Ref SKU-BC-3000Plus, China) and (BIOTA, Ref VABIO 360, Turkey).

Relative WBC values (neutrophils (NEU), eosinophils (EOS), basophils (BAS), lymphocytes (LYM), and monocytes (MON) were determined on the basis of microscopic observation of blood smears stained by May-Grunwald Giemsa staining technique (RAL 555 kit, RAL diagnostic, Martillac, France).

For ions, the dosage of sodium (Na), potassium (K), chlorine (Cl), calcium (Ca) and phosphorus (P) was carried out by:

- The EasyLyte electrolyte analyzer (EasyLyte plus ANALYZER, USA) which is an automated system that was used to make measurements of Na, K, Cl ions.

- The colorimetry for Ca and P ions.

For each physiological stage, average values of each blood parameter were calculated.

Data analysis

The statistical program used was R i386 3.0.2 for Windows Front-end GUI. The ANOVA test supplemented by the Chi-square test and multiple range tests (multiple range) were used for statistical analysis. The threshold value of different tests was $p<0.05$.

Results

The data concerning changes in hematological and ionic parameters according to physiological stage in dairy cows are presented in Tables 1, 2 and 3.

Table 1
Variations of red blood cell parameters and erythrocyte indices according to the cows' physiological stage

Parameters	1T (CI, 95%)	2T (CI, 95%)	3T (CI, 95%)	PP (CI, 95%)	P value
RBC ($x10^6$/µL)	6.6^a (6–7.2)	6.0^b (5.2–6.8)	6.7^a (6.2–7.2)	5.6^c (4.8–6.4)	0.0001
HGB (g/dL)	10.6^a (10–11.2)	10.2^a (9.3–11.1)	10.6^a (9.9–11.3)	10.2^a (10.1–10.3)	-
HCT (%)	30.6^b (28.6–32.6)	28.1^b (23.4–32.8)	33.6^a (31.4–35.8)	26.8^c (22.4–31.2)	0.0001
MCV (µm^3)	46.4^b (43.7–49.1)	47.0^b (43.4–50.6)	49.9^a (47.5–52.3)	47.7^b (45.5–49.9)	0.01
MCH (pg)	16.0^c (14.7–17.3)	17.2^b (16.1–18.3)	15.8^c (14.6–17)	18.2^a (17.5–18.9)	0.0001
MCHC (g/dL)	34.5^a (33.7–35.3)	36.8^a (32.6–41)	31.7^b (30.3–33.1)	37.1^a (31.5–42.7)	0.001
PLT ($x10^3$/µL)	332.7^a (250–415.4)	319.6^a (191.4–447.8)	288.4^a (207.5–369.3)	347.9^a (225.1–470.7)	-
1T: 1st third of gestation, 2T: 2nd third of gestation, 3T: dry, PP: postpartum					
Values that have different letters in the same line are significantly different ($p < 0.05$)					

Table 2
Variations in the parameters of the WBC according to the cows' physiological stage

Parameters	1T (CI, 95%)	2T (CI, 95%)	3T (CI, 95%)	PP (CI, 95%)	P values
WBC (x10^3/µL)	11.3^a (9.1–13.5)	6.4^{bc} (2.3–10.5)	5.2^c (3.9–6.5)	8.0^b (3.1–12.9)	0.001
LYM (x10^3/µL)	5.10^a (4.08–6.12)	2.69^{bc} (0.96–4.42)	2.33^c (1.59–3.07)	3.80^b (1.67–5.93)	0.0001
MONO (x10^3/µL)	0.51^a (0.14–0.88)	0.20^c (0.04–0.36)	0.32^{bc} (0.02–0.62)	0.45^b (0.20–0.70)	0.05
NEU (x10^3/µL)	5.28^a (3.79–6.77)	3.10^{bc} (0.87–5.33)	2.11^c (1.44–2.78)	3.63^b (0.81–6.45)	0.001
EOS (x10^3/µL)	0.42^a (0.02–0.82)	0.34^{bc} (0.00–0.78)	0.40^b (0.14–0.66)	0.11^c (0.00–0.25)	-
BASO (x10^2/µL)	0.0	0.0	0.0	0.0	-
1T: 1st third of gestation, 2T: 2nd third of gestation, 3T: dry, PP: postpartum					
Values that have different letters in the same line are significantly different (p < 0.05)					

Table 3
Variations in ion concentrations according to the cows' physiological stage

Parameters	1T (CI, 95%)	2T (CI, 95%)	3T (CI, 95%)	PP (CI, 95%)	P values
Na (mmol/L)	139.9^a (138.1–141.7)	140.6^a (138.9–142.3)	139.0^a(137.1–140.9)	139.8^a (138–141.6)	-
K (mmol/L)	4.2^a (4.0–4.4)	4.2^a(3.8–4.6)	4.3^a(4.1–4.5)	3.8^b(3.5–4.1)	0.001
Cl (mmol/L)	98.7^c(97.2–100.2)	100.5^{ab}(98.4–102.6)	102.1^a(100.5–103.7)	100.3^{bc}(96.5–104.1)	0.01
Ca (mg/L)	97.9^a(95.6–100.2)	99.0^a(94.7–103.3)	96.5^a(93.4–99.6)	86.3^b(78.8–93.8)	0.001
P (mg/L)	62.4^b(54.2–70.6)	70.2^a(62.9–77.5)	68.7^b(60.6–76.8)	48.2^c(37.5–58.9)	0.001
1T: 1st third of gestation, 2T: 2nd third of gestation, 3T: dry, PP: postpartum					
Values that have different letters in the same line are significantly different (p < 0.05)					

The results showed that the changes were not significant for HGB and LTP (Table 1). However, the changes were significant for RBC, HCT, MCV, MCH and MCHC.

RBC were lower in 2T (6.0 ± 0.8 x 10^6/µL) and PP (5.6 ± 0.8 x 10^6/µL) compared to 1T (6.6 ± 0.6 x 10^6/µL) and 3T (6.7 ± 0.5 x 10^6/µL) ($p < 0.0001$) (Table 1).

HCT was lower in PP (26.8 ± 4.4%), compared to 1T, 2T and 3T, (30.6 ± 2.0%) (28.1 ± 4.7%), (33.6 ± 2.2%) respectively ($p < 0.0001$) (Table 1).

Dry cows had the highest MCV values (49.9 ± 2.4 µm^3) ($p < 0.01$). MCH (18.2 ± 0.7 pg) and MCHC (37.1 ± 5.6 g/dL) were highest in PP ($p < 0.001$) (Table 1).

The dendrogram presented in Fig. 1, shows that the changes of the hematological parameters of red blood cells according to the physiological stage, are distributed on 2 groups, of which the first includes 1T and 3T and the second includes 2T and PP (Fig. 1).

Hematological analysis of white blood cells presented in Table 2, showed no significant variation for EOS and BASO. The highest values of WBC, LYM, MONO and NEU were observed in 1T ($p < 0.001$).

The neutrophil/lymphocyte ratio (NEU/LYM) was equal to 1.04, 1.15, 0.91, 0.96 at 1T, 2T, 3T and PP respectively

The dendrogram shows that the changes of WBC hematological parameters according to the physiological stage were divided into three groups (Fig. 2). The first group is represented by 1T, which is significantly different from the other two groups. The second is composed by the 2T and 3T, which are very close to the third group, which is PP (Fig. 2).

Regarding the ionic elements presented in Table 3, there was no significant difference for Na.

For K, Ca, and P, cows showed the lowest values in PP (3.8 ± 0.3 mmol/L), (86.3 ± 7.5 mmol/L), and (48.2 ± 10.7 mmol/L), respectively ($P < 0.001$). Cl was highest in 2T and 3T ($P < 0.01$) (Table 3).

It appears that the mineral content varies in three groups (Fig. 3). The first group is represented by 1T and 2T, whose values are quite close. The second group, composed of dry cows, differs significantly from the previous group and from the group that follows, composed of cows from the PP (Fig. 3).

Discussion

Performing a hematological profile of clinically normal cattle must take into account many factors such as age, physiological status of the animal, season and climate (Brucka-Jastrzebska et al., 2007; Farooq et al., 2017; Dzavo et al., 2020).

RBC count should include the total number of RBCs, hematocrit (HCT), hemoglobin (HGB) and erythrocyte indices which are mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean

corpuscular hemoglobin concentration (MCHC) (Brockus, 2011). All these parameters were investigated in this survey.

The results of the investigated blood parameters reported in the present survey, were within the range of reference values for healthy dairy cattle (Krimer, 2011; Bellier and Cordonnier, 2010).

In this study, RBC, HGB and HCT contents were high in the beginning of gestation (1T). This may be associated with increased erythrocyte release from the spleen due to the stress of gestation (Kumar and Pachauri, 2000). It may also be related to changes in the release of erythrocyte stimulating factor (ESF), that is regulated by the relationship between tissue oxygen demand and the amount of oxygen transported by the blood (Jain, 1996).

The lowest RBC and HCT values were reported in cows in PP. This finding could be due to anemia caused by calving (Brockus, 2011) and to increased production of pro-inflammatory cytokines that could cause a reduction in erythropoiesis (Chikazawa and Dunning, 2016).

The findings of this investigation are consistent with others (Paiano et al., 2020; Herman et al., 2018; Pelletier et al., 1985; Rowlands et al. 1979).

For MCV, dry cows have the highest values, while lactating cows (PP) have the lowest values. This is consistent with the results of Sattar and Mirza (2009). This observation, suggests a change in plasma volume induced by the cessation of milk production (Shalit et al., 1991; Wohlt et al., 1984).

MCH and MCHC contents in parturient cows were the highest. The same observations were found by Sattar and Mirza (2009).

The total number of platelets is influenced by the quantity of consumption, production, sequestration, and loss (Russell, 2010). The change in platelet count during the four stages investigated in this study was not significant. The same finding was made by Mirzadeh et al. (2010).

The WBC count is higher in early pregnancy cows (1T) compared to the other groups. Our results are consistent with Abdelatif and Alameen (2012) and Ouahrani and Bordjah (2016).

The increase in the number of WBC in PP compared to 3T observed in this survey is due to the increase in antepartum cortisol (Preisler et al., 2000). In addition, cows must satisfy the needs of their fetus at the end of gestation, which increases the energy demand reaching the peak around one month before parturition, to synthesize colostrum and milk (Esposito et al., 2014).

In the present study, NEU and LYM levels were higher in early lactation (PP) than in the third trimester of gestation (3T) and EOS, BASO and MONO were not affected by the periparturient period. This is consistent with the results of Ate et al. (2009), Sattar and Mirza (2009) and Klinkon and Zadnik (1999).

Regarding ions, K, Ca and P, recorded the lowest levels in postpartum cows (PP). This is explained by the occurrence of hypocalcemia coupled with hypophosphatemia during calving due to the high demand by

the mammary gland, a few days before calving. In the absence of any health problems, this hypocalcemia is physiological (Goff, 2014; Goff, 2008; Horst et al., 2005). This finding is in accordance with Cerutti et al. (2018).

Ca and P concentration is regulated by parathormone, which stimulates Ca reabsorption from the urine and bone and stimulates P absorption from the intestine (Cavestany et al., 2005; Peterson et al., 2005; Goff et al., 2014). The sudden high mobilization of circulating Ca and P by the mammary gland at the onset of lactation, however, leads to a decrease in their blood concentration (Goff and Liesegang, 2014).

However, the Na level was not significantly different between the different stages investigated. This observation is consistent with that of Pelletier et al. (1985).

An increase in plasma electrolyte concentration in the postpartum period has been reported in cattle affected by renal dysfunction or related to stress conditions caused by adrenocorticotropin hormone release and inflammatory conditions occurring around calving (Harshfield et al., 2009; Weeth and Lesperance, 1965). In our study, all cows were healthy and were raised under optimal conditions of which the lowest ion values were observed in PP.

Conclusion

The hematological data obtained in this study are comparable to the reference values for dairy cattle. They can be used as reference values in Algeria.

Significantly strong variation was noted for the majority of hematological parameters according to the physiological stage (RBC, HCT, MCV, MCH, WBC, and number of LYM, MONO and NEU) and ionic (K, Cl, Ca and P). The most marked variations were noted around part (peripartum period), by a decrease in red line and ion values, while white line cells show an increase.

Consequently, this study may be useful in providing baseline information on the hematological profile of dairy cattle for the assessment of physiological status. This survey requires additional investigation concerning the differences in hematological parameters with age and sex.

Declarations

Funding

Not applicable

Conflict of interest

The authors declare that they have no conflict of interest.

Ethics approval

Not applicable

Author contributions

All authors read and approved the final manuscript.

References

1. Abdelatif, A.M., & Alameen, A.O., 2012. Influence of season and pregnancy on thermal and haemotological responses of crossbred dairy cows in a tropical environment. Global Veterinaria, 9(3):334–340. https://doi.org/10.5829/idosi.gv.2012.9.3.65130
2. Adewoyin, A.S., (2014). Peripheral blood film-a review. Annals of Ibadan postgraduate medicine, 12(2):71–79.
3. Ate, I. U., Rekwot, P. I., Nok, A. J., & Tekdek, L. B., 2009. Haematological values of cows during third trimester of pregnancy and early lactation in settled cattle herds in Zaria, Northern Nigeria. African Journal of Biomedical Research, 12(3), 225–231.
4. Bellier, S., & Cordonnier, N., 2010. Usual values in veterinary haematology. Revue francophone des laboratoires: RFL, 2010(420), 27–42. https://doi.org/10.1016/S1773-035X(10)70419-6
5. Bezerra, L.R., Oliveira, W.D.C., Silva, T.P.D., Torreão, J.N.C., Marques, C.A.T., Araújo, M.J. & Oliveira, R.L., 2017. Comparative hematological analysis of Morada nova and Santa Inês ewes in all reproductive stages. Pesquisa Veterinária Brasileira, 37, 408–414. https://doi.org/10.1590/s0100-736x2017000400017
6. Brockus, C.W. 2011. Erythrocytes. In: Duncan and Prasse's veterinary laboratory medicine: clinical pathology (ed. K.S. Latimer), 5th ed., pp. 3–44, Wiley, Chichester, UK.
7. Brscic, M.; Cozzi, G.; Lora, I.; Stefani, A.L.; Contiero, B.; Ravarotto, L.; & Gottardo, F. 2015. Reference limits for blood analytes in Holstein late-pregnant heifers and dry cows: Effects of parity, days relative to calving, and season. Journal of Dairy Sciences. 98, 7886–7892. https://doi.org/10.3168/jds.2015-9345
8. Brucka-Jastrzębska, E., Kawczuga, D., Brzezińska, M., Orowicz, W., & Lidwin-Kaźmierkiewicz, M. 2007. Dependence of hematological parameters in Simmental breed cattle on physiological conditions. Medycyna Weterynaryjna, 63, 1583–1586.
9. Cavestany, D.; Blanc, J.E.; Kulcsar, M.; Uriarte, G.; Chilibroste, P.; Meikle, A.; Febel, H.; Ferraris, A.; & Krall, E. 2005. Studies of the transition cow under a pasture-based milk production system: Metabolic profiles. Journal of Veterinary Medicine. A. Physiology Pathology, Clinical Medicine. 52, 1–7. https://doi.org/10.1111/j.1439-0442.2004.00679.x
10. Cerutti, R.D., Scaglione, M.C., Arfuso, F., Rizzo M., & Piccione G. 2018. Seasonal variations of some hematochemical parameters in Holstein bovine under the same livestock conditions. Veterinarski Arhiv, 88(3):309–321. https://doi.org/10.24099/vet.arhiv.170404

11. Chikazawa, S. & Dunning, M.D. 2016. 'A review of anaemia of inflammatory disease in dogs and cats', Journal of Small Animal Practice 57(7), 348–353. https://doi.org/10.1111/jsap.12498
12. Cozzi, G.; Ravarotto, L.; Gottardo, F.; Stefani, A.L.; Contiero, B.; Moro, L.; Brscic, M.; & Dalvit, P. 2011. Reference values for blood parameters in Holstein dairy cows: Effects of parity, stage of lactation, and season of production. Journal of Dairy Science. 94, 3895–3901. https://doi.org/10.3168/jds.2010-3687
13. Duffield, T.F. 2000. Subclinical ketosis in lactating dairy cattle. Veterinary Clinics of North America: Food Animal Practice, 16, 231–253.
14. Dzavo, T., Zindove, T.J., Dhliwayo, M., Chimonyo, M., & Tivapasi, M.T., 2020. Do haematological profiles of cows in drought prone areas differ with conformation?. Spanish Journal of Agricultural Research, 18(2):e0604. https://doi.org/10.5424/sjar/2020182-16029
15. Esposito, G., Irons, P.C., Webb, E.C., & Chapwanya, A. 2014. Interactions between negative energy balance, metabolic diseases, uterine health and immune response in transition dairy cows. Animal Reproduction Science, 144(3–4):60–71. https://doi.org/10.1016/j.anireprosci.2013.11.007
16. Farooq, U., Ahmad, N., Ahmad, I., Mahmood, S.A., Andrabi, S.M.H., & Idris, M. 2017. Effect of seasonal variations on the haematochemical profile of Cholistani service bulls. Journal of Applied Animal Research, 45, 85–89. https://doi.org/10.1080/0 9712119.2015.1125351
17. Farooq, U., Ijaz, A., Ahmed, N., Rehman, H., & Zaneb, H. 2012. Haematologic profilere visited: Adult Cholistani breeding bulls as a model. Journal of Animal Plant Science, 22:835–839.
18. Goff, J.P.; Liesegang, A.; & Horst, R.L. 2014. Diet-induced pseudo-hypo-parathyroidism: A hypocalcemia and milk fever risk factor. Journal of Dairy Science. 97, 1520–1528. http://dx.doi.org/10.3168/jds.2013-7467
19. Goff, J.P. 2008. The monitoring, prevention, and treatment of milk fever and subclinical hypocalcemia in dairy cows. The Veterinary Journal, 176 (1), 50–57. http://dx.doi.org/10.1016/j.tvjl.2007.12.020
20. Goff, J.P. 2014. Calcium and magnesium disorders. Veterinary Clinics: Food Animal, 30(2):359–381. http://dx.doi.org/10.1016/j.cvfa.2014.04.003
21. Harshfield, G.A.; Dong, Y.; Kapuku, G.K.; Zhu, H.; & Hanevold, C.D. 2009. Stress-induced sodium retention and hypertension: A review and hypothesis. Current Hypertension Reports, 11, 29–34. https://doi.org/10.1007/s11906-009-0007-8
22. Herdt, T.H. 2000. Variability characteristics and test selection in herdlevel nutritional and metabolic profile testing. Veterinary Clinics of North America: Food Animal Practice, 16, 387–403.
23. Herman, N., Trumel, C., Geffre, A., Braun, J.P., Thibault, M., Schelcher, F., Bourges-Abella, N. 2018. Hematology reference intervals for adult cows in France using the Sysmex XT-2000iV analyzer. Journal of Veterinary Diagnosis and Investigation, 30(5):678–687. https://doi.org/10.1177/1040638718790310
24. Horst, R.L., Goff, J.P., Reinhardt, T.A. (2005). Adapting to the transition between gestation and lactation: differences between rat, human and dairy cow. Journal of Mammary Gland Biology and

Neoplasia, 10(2):141–156. https://doi.org/10.1007/s10911-005-5397-x

25. Jain, C.N. (1996). Schalm's Veterinary Haematology. 5th edn. Lee and Febiger, Philadelphia.
26. Jones, M.L., & Allison, R.W. (2007). Evaluation of the ruminant complete blood cell count. Veterinary Clinics of North America: Food Animal Practice, 23:377–402, v.
27. Klinkon, M., & Zadnik, T. (1999). Dynamics of red and white blood picture in dairy cows during the periparturient period. Comparative Haematology International, 9(3), 156–161.
28. Krimer, P.M. (2011). Generating and interpreting test results: test validity, quality control, reference values, and basic epidemiology. *In* Duncan and Prasse's veterinary laboratory medicine: clinical pathology. ed. Latimer, KS, 5th ed., pp. 365–382. Wiley, Chichester, UK.
29. Kumar, B., & Pachauri, S.P. 2000. Haematological profile of crossbred dairy cattle to monitor herd health status at medium elevation in central Himalayas. Research in Veterinary Sciences, 69: 141–145.
30. MADR, 2018. Statistiques agricoles. http://madrp.gov.dz/ agriculture/statistiques-agricoles/.
31. Mezzetti, M.; Minuti, A.; Piccioli-Cappelli, F.; Amadori, M.; Bionaz, M.; & Trevisi, E. 2019. The role of altered immune function during the dry period in promoting the development of subclinical ketosis in early lactation. Journal of Dairy Sciences. 102, 9241–9258. https://doi.org/10.3168/jds.2019-16497
32. Mirzadeh, K., Tabatabaei, S., Bojarpour, M., & Mamoei, M. (2010). Comparative study of haematological parameters according straon, age, sex, physiological status and season in Iranian cattle. Journal of Animal Veterinary Advances, 9 (16) 2123–2127. https://doi.org/10.3923/javaa.2010.2123.2127
33. Moretti, P.; Paltrinieri, S.; Trevisi, E.; Probo, M.; Ferrari, A.; Minuti, A.; & Giordano, A. (2017). Reference intervals for hematological and biochemical parameters, acute phase proteins and markers of oxidation in Holstein dairy cows around 3 and 30 days after calving. Research in Veterinary Sciences. 114, 322–331. https://doi.org/10.1016/j.rvsc.2017.06.012
34. Ouahrani, A.R., & Bordjah, S. (2016). Paramètres hématologiques et biochimiques durant le premier trimestre de la gestation chez la vache. Thèse Master, Université de Béjaia, 34p.
35. Paiano, R.B., Birgel, D.B., & Birgel Junior, E.H. (2020). Influence of peripartum on the erythrogram of Holstein dairy cows. Journal of the South African Veterinary Association, 91(0):e1-e6 https://doi.org/10.4102/jsava.v91i0.1975
36. Pelletier, G., Tremblay, A.V., & Helie, P. (1985). Facteurs influençant le profil métanologie des vaches laitières. Canadian Veterinary Journal, 26(10):306–311.
37. Peterson, A.B.; Orth, M.W.; Goff, J.P.; & Beede, D.K. (2005). Periparturient responses of multiparous holstein cows fed different dietary phosphorus concentrations prepartum. Journal of Dairy Sciences. 88, 3582–3594. https://doi.org/10.3168/jds.s0022-0302(05)73043-5
38. Preisler, M.T., Weber, P.S., Tempelman, R.J., Erskine, R.J., Hunt, H., & Burton, J.L. (2000). Glucocorticoid receptor down-regulation in neutrophils of periparturient cows. American Journal of Veterinary Research. 61, 14–19.

39. Roland, L., Drillich, M., & Iwersen, M. (2014). Hematology as a diagnostic tool in bovine. medicine Journal of Veterinary Diagnostic Investigation. 26(5):592–598. https://doi.org/10.1177/1040638714546490
40. Rowlands, G.J., Little, W., Stark, A.J., Mantson, R. (1979). The blood composition of cows in commercial dairy herds and its relation with season and lactation. Brazilian Veterinary Journal, 135(1):64–74. https://doi.org/10.1016/s0007-1935(17)32990-1
41. Russell, KE: 2010, Platelet kinetics and laboratory evaluation of thrombocytopenia. In: Schalm's veterinary hematology, ed. Weiss, DJ, Wardrop, KJ, 6th ed., pp. 576–585. Wiley, Ames, IA.
42. Sattar, A., & Mirza, R.H. 2009. Haematological parameters in exotic cows during gestation and lactation under subtropical conditions. Pakistan Veterinary Journal, 29(3):129–132.
43. Shalit, U.; Maltz, E.; Silanikove, N.; & Berman, A. 1991. Water, sodium, potassium, and chlorine metabolism of dairy cows at the onset of lactation in hot weather. Journal of Dairy Sciences. 74, 1874–1883
44. Shehab-El-Deen, M.A.M.M, Fadel, M.S., Ann Van Soom, Saleh, S.Y., Maes D., & Leroy, JL.MR. 2010. Circadian rhythm of metabolic changes associated with summer heat stress in high-producing dairy cattle. Tropical Animal Health and Production, 42:1119–1125. http://dx.doi.org/10.1007/s11250-010-9534-1
45. Warren, A.L., Stokol, T., Hecker, K.G., & Nydam D.V., 2013. Storage-associated changes in the bovine hemogram with the ADVIA 120 hematology analyzer. Comparative Clinical Pathology, 22:1235–1240. http://dx.doi.org/10.1007/s00580-012-1556-9
46. Weeth, H.J.; & Lesperance, A.L. 1965. Renal function of cattle under various water and salt loads. Journal of Animal Science. 1965, 24, 441–447
47. Wohlt, J.E.; Evans, J.L.; & Trout, J.R. 1984. Blood constituents in lactating holstein cows influenced by hematocrit, sampling site, and diet protein and calcium. Journal of Dairy Sciences. 67, 2236–2246.

Figures

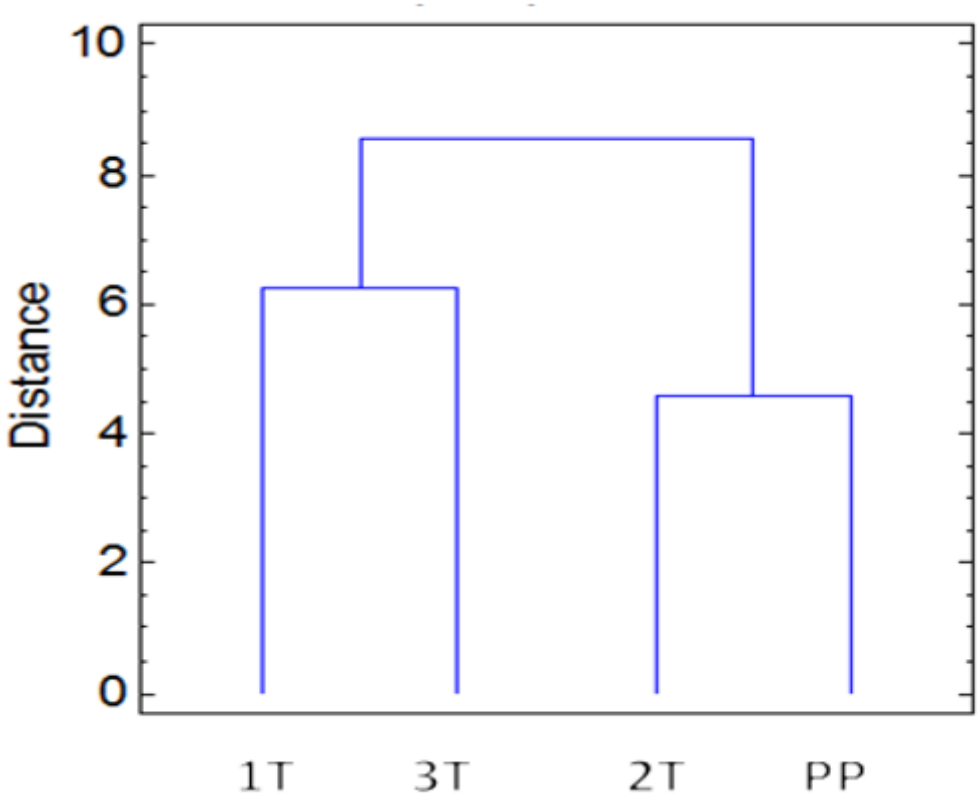

Figure 1

Red blood cell dendrogram and erythrocyte indices according to cow's physiological stage

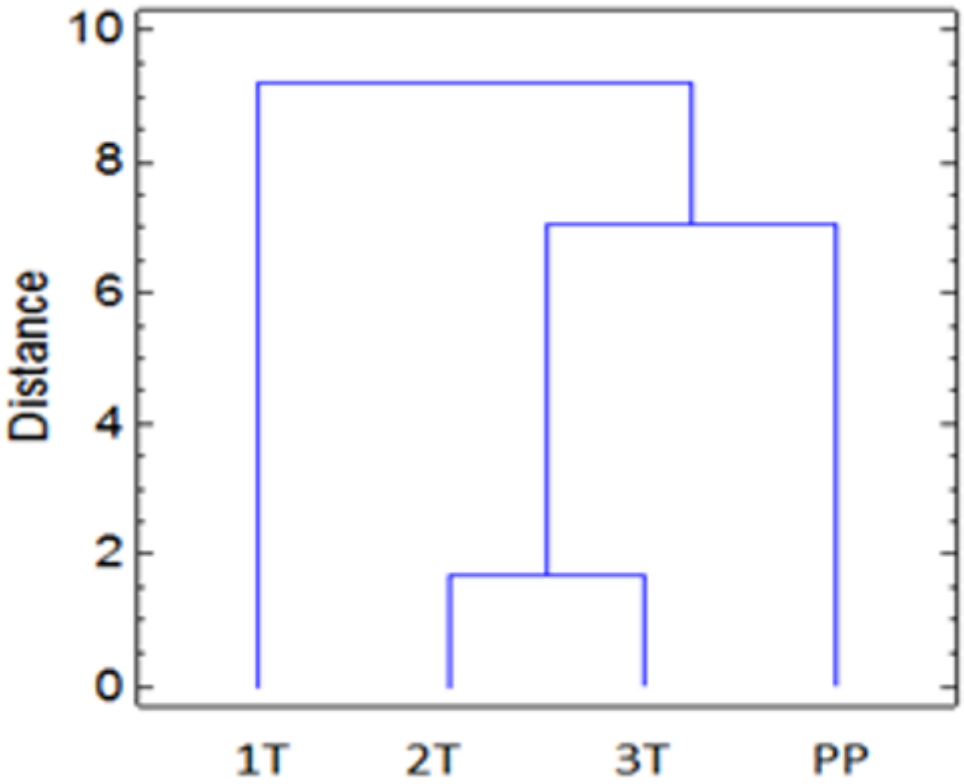

Figure 2

Dendrogram of the variation of WBC according to the cows' physiological stage

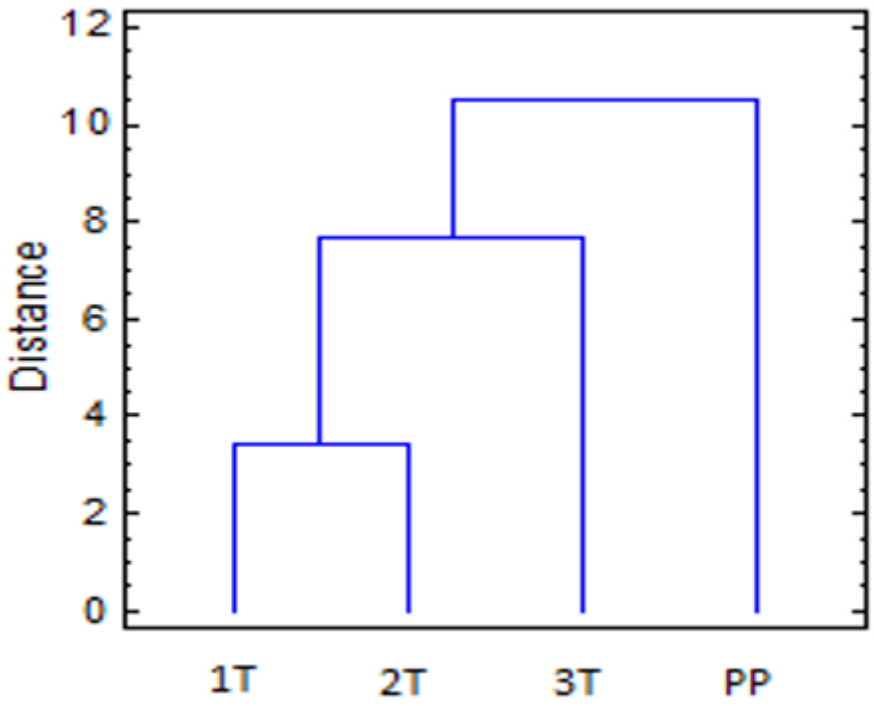

Figure 3

Dendrogram of the ions according to the cows' physiological stage