Acta Scientiae Veterinariae, 2024. 52: 1949.

RESEARCH ARTICLE
Pub. 1949

ISSN 1679-9216

Haematological Status of Cows in Different Physiological Stages under Humid Tropic Conditions

Oswaldo Margarito Torres-Chablé[1], Nadia Florencia Ojeda-Robertos[2], Paulo Sergio Zamudio-Ortiz[2], Alfonso Juventino Chay-Canul[2], José Candelario Segura-Correa[3], Víctor Hugo Severino-Lendechy[4] & Jorge Alonso Peralta-Torres[2]

ABSTRACT

***Background*:** Baseline haematological data serve as reference for the evaluation of the health status of animals. In cows, physiological stages such as pregnant, calving and lactation represent challenges, which can affect their blood parameters. The prepartum and postpartum periods are important for the productive and reproductive efficiency of cows. There is a transition period involving several physiological adaptations in a short period of time that can lead to health problems, especially metabolic and infectious diseases. The aims of the present study were report haematological reference intervals and identify haematological changes in Gyr x Holstein cows from the humid tropics of Mexico during their prepartum, calving and postpartum stages.

***Materials, Methods & Results*:** Body weight, body condition and blood samples of 33 Gyr × Holstein cows were obtained every 30 days as follows: 60 and 30 days prepartum; calving day (0 day); and 30, 60 and 90 days postpartum. Cows were handled according to the production system and conditions established by owners. Feeding was based on intensive rotational grazing on the natural grass *Paspalum fasciculatum*, and 3 kg animal/day of commercial feed (16% CP), mineral salt and water ad libitum. Haematological variables were measured using an automated analyzer. The haematological reference intervals were obtained using the Reference Value Advisor V21 integrated into Microsoft Excel 2016. This facilitated the calculation of confidence intervals by evaluating the data dispersion and homogeneity. When data were considered with "No Gaussian" distribution, the reference interval and confidence intervals were obtained from the robust method with a Box-Cox transformation of the data. Confidence intervals of the haematological variables were calculated at 90% Variables with Gaussian distribution or transformed were evaluated in one-way analyses of variance using the statistical software IBM SPSS version 22, applying the Tukey test when significant differences were detected ($P < 0.05$). Additionally, Pearson correlation coefficients were estimated between variables. The body condition and body weight of pregnant cows were higher than after calving ($P < 0.05$), and these variables were positively correlated ($r = 0.4$, $P = 0.01$). However, the haematological variables were not associated with the productive variables. The erythrograms of the different physiological stages showed significant differences ($P < 0.05$) in the packed cell volume (PCV) and mean corpuscular haemoglobin concentration (MCHC) values, whereas the red blood cell (RBC), haemoglobin (HGB) and platelet (PLT) counts; mean corpuscular volume (MCV); and mean corpuscular haemoglobin (MCH) did not present differences among groups. The leukograms showed increases in band neutrophils and monocytes during the calving period ($P < 0.05$).

***Discussion*:** Cows showed a decrease in body condition and live weight after calving. This is attributable to the weight loss following the expulsion of calf as well as liquid and foetal membranes. After this point, cows did not present changes in live weight between 60 and 90 days postpartum. The RBC during all physiological stages was similar with the reported in dairy cows from central area of Mexico and Holstein cows raised in Canada. The RBC and PCV presented a gradual numeric decrease during the prepartum to postpartum periods, causing the increase in MCHC at 30, 60 and 90 days postpartum. Physiologically, it is understood that even when the number of erythrocytes decreases, their function is compensated by increasing their amount of hemoglobin. The leukograms showed statistical differences by increasing the band neutrophils and monocytes after calving, which can associated with calving and the migration of neutrophils to the uterine lumen and mammary glands. The haematological values reported herein can help to establish baseline values that would enable the detection of abnormalities in prepartum and postpartum Gyr x Holstein cows in the humid tropic of Mexico.

Keywords: blood values, erythrogram, leukogram, reference data.

DOI: 10.22456/1679-9216.138187

Received: 20 January 2024 Accepted: 30 March 2024 Published: 25 April 2024

[1]Laboratorio de Enfermedades Tropicales y Transmitidas por Vectores & [2]División Académica de Ciencias Agropecuarias, Universidad Juárez Autónoma de Tabasco (UJAT), Villahermosa, Tabasco, México. [3]Campus de Ciencias Biológicas y Agropecuarias. Universidad Autónoma de Yucatán (UADY), Mérida, Yucatán, México. [4]Centro de Estudios Etnoagropecuarios, Universidad Autónoma de Chiapas (UACH), San Cristóbal de las Casas, Chiapas, México. CORRESPONDENCE: J.A. Peralta-Torres [japt83@hotmail.com / jorge.peralta@ujat.mx]. División Académica de Ciencias Agropecuarias - UJAT. Carretera Villahermosa-Teapa Km 25. R/A La Huasteca. 86280 Villahermosa, Tabasco, México.

INTRODUCTION

Baseline haematological data are extensively used to evaluate health status and play an important role in the diagnosis and treatment of pathologies affecting domestic animals [18]. Several factors such as age, breed, gender, handling, nutritional status and physiological stage (empty, pregnant and lactating) can influence changes related to the red blood cell values (erythrogram) and leukocyte count (leukogram) of cattle [9,12,13].

The prepartum and postpartum periods are important for the productive and reproductive efficiency of cows. There is a transition period involving several physiological adaptations in a short period of time that can lead to health problems, especially metabolic and infectious diseases [8,19]. In pregnant and postpartum cows in Iran and Brazil, significant differences have been reported in packed cell volume, haemoglobin concentration and leukocyte count [9,12].

Dual-purpose cattle production is economically important in Mexico, producing 20% of milk and 44% of meat. Crossbred cattle (*Bos taurus* × *Bos indicus*) are commonly used and approximately 30% of livestock in Mexico are produced under this system [14]. However, only two studies have indirectly published data of reference haematological values of parasite-free cattle in local journals [1,5]. Therefore, the aims of the present study were report haematological reference intervals and identify haematological changes in Gyr x Holstein cows from the humid tropics of Mexico during their prepartum, calving and postpartum stages.

MATERIALS AND METHODS

Study area

The present study was carried out from March to July 2022 (dry season) on a dual-purpose cattle farm in the rural community of Estancia Vieja 1ra sección in the municipality of Centro, Tabasco, at 17°54'17.9 N and 93°06'07.9 W. The climate is tropical with rain falling year around (2,550 mm annually) and an average annual temperature of 26°C. The average elevation is approximately 10 m [6].

Animals and management

A total of 33 Gyr × Holstein (*Bos indicus* × *Bos taurus*) multiparous cows (with 2 to 4 parturitions) were evaluated in this study. Initially, 60 cows were subjected to a controlled breeding system for 60 days using two bulls. Animals were observed daily, and pro-estrous or estrous behaviours were registered. Gestation was confirmed by ultrasonography 45 days after estrous was detected (55% of pregnancy). Pregnant animals were periodically included in the study herd after pregnancy confirmation. Cows were handled according to the production system and conditions established by owners. Feeding was based on intensive rotational grazing (one day of paddock occupation and 12 days of pasture recovery), mainly on the natural grass *Paspalum fasciculatum*, which represented approximately 80% of the pasture mix, and diverse native grasses, which represented approximately 20%. All cows were supplemented with 3 kg animal/day of commercial feed (16% CP), mineral salt[1] and water *ad libitum*. Cows were mechanically milked twice a day (04:00 and 14:00 h), and calves received only residual milk. The lactation period lasted 210 days and subsequently cows were dried.

Body weight and body condition

Pregnant cows were evaluated 60 and 30 days Prepartum (expected); after calving (day 0); and 30, 60 and 90 days postpartum. Body weight and body condition were registered in each evaluation period. The 1st variable was calculated using a mechanical scale for livestock, and the 2nd was determined on a scale of 1 (emaciated) to 5 (fat) [11].

Blood sample collection

Blood samples were collected from the coccygeal vein of cows during each evaluation period using VacutainerTM tubes[2] containing ethylenediaminetetraacetic acid (EDTA) as an anticoagulant.

Haematological analysis

The haemoglobin (HGB), red blood cell (RBC), white blood cell (WBC) and platelet (PLT) counts in addition to the packed cell volume (PCV), mean corpuscular value (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were measured using an automated haematology analyser[3]. Blood smears were prepared and stained with Diff-Quick[4] to evaluate erythrocyte morphology and discard the presence of hemoparasites. Differential leukocyte counts were performed on the blood smears. All differential counts were performed in triplicate, and the means were expressed as an absolute value.

Statistical analysis

A descriptive statistical analysis of the productive (body condition and body weight) and haematological variables was performed using the statistical software IBM SPSS[5]. The haematological values with Gaussian distribution were analysed with one-way analyses of variance, and the Tukey test was applied when significant differences among groups ($P < 0.05$) were detected. Additionally, Pearson correlation coefficients between productive and haematological variables were individually estimated.

Since several studies have highlighted the importance of reporting confidence intervals for reference intervals, Veterinary Clinical Pathology indicates that according to the number of data (< 40), confidence intervals must be calculated at 90% [3]. In this study, the hematological reference intervals were obtained using the Reference Value Advisor V21 [4], integrated into Microsoft Excel 2016. This facilitated the calculation of confidence intervals by evaluating the data dispersion and homogeneity. When data were considered with "No Gaussian" distribution, the reference interval and confidence intervals were obtained from the robust method with a Box-Cox transformation of the data. The differential leukocyte count was reported as the mean + standard deviation of the data.

RESULTS

Body condition and live weight of cows unsurprisingly differed between cows when pregnant (higher values) and after calving (lower values), as shown in Table 1. Live weight and body condition were positively correlated ($r = 0.4$, $P = 0.01$). Despite of cows were milked twice a day and residual milk was intake by calves, they did not decrease their live weight since birth to 90 postpartum days. Similarly, the body condition score no shown differences among lactation days evaluated.

Table 2 shows the mean values, median, standard deviation of the data, 90% reference intervals, minimum, maximum, and confidence intervals for hematologic variables of Gyr x Holstein cows at 60 and 30 days prepartum. In this table, it can be observed that MCH did not have a Gaussian distribution; therefore, reference intervals and confidence intervals were obtained with a Box-Cox transformation of the data. The other variables had a Gaussian distribution, although outliers were deleted in several variables to enhance the homogeneity and normality of the data. Similarly, in Table 3, all hematological variables of Gyr x Holstein cows during the calving stage are presented; and Table 4 presents the hematological variables of Gyr x Holstein cows for 30, 60, and 90 postpartum days.

The haematological variables of the erythrogram (RBC, HGB, MCV, MCH and PLT) did not differ among prepartum, calving and postpartum groups evaluated in the present study (Table 5). The PCV and MCV presented a slight decrease in their values, indicating a decreasing in the erythrocyte size. However, the haematological variables were not associated with the productive variables (data not presented). With respect to the haematological values of the cows in different physiological stages, the PCV and MCHC values significantly ($P < 0.05$) differed among the groups.

The leukograms showed statistical differences in band neutrophils and monocyte count among the evaluated groups ($P < 0.05$), while the other leukocyte counts did not present statistical differences (Table 6).

Table 1. Body weight and body condition score in dual - purpose cows in different physiological stages (value ± Standard deviation).

Evaluation day	Body weight	Body condition score
	Prepartum	
60	400.21 ± 43.70^a	3.44 ± 0.53^a
30	417.93 ± 40.49^a	3.34 ± 0.60^a
	Calving	
0	367 ± 39.22^b	3.11 ± 0.64^a
	Postpartum	
30	355.96 ± 32.93^b	2.63 ± 0.44^b
60	356.80 ± 38.81^b	2.51 ± 0.32^b
90	356.64 ± 35.93^b	2.46 ± 0.41^b

[ab]Different literals in the same columns are statistically different with $P < 0.05$.

Table 2. Mean values, Median, standard deviation, 90% reference intervals, minimum, maximum and confidence intervals for hematologic variables of Gyr x Holstein cows 60 and 30 prepartum days.

Hematological variable	n	Mean	Median	SD	90% RI	Min	Max	Lower RI 90% CI		Upper RI 90% CI	
								Lower	upper	Lower	Upper
60 prepartum days											
RBC ($x10^{12}$L) G	32	5.76	5.98	0.72	4.22 - 7.30	4.38	7.12	3.81	4.67	6.84	7.75
HGB (g/dL) G	32	9.08	9.25	1.08	6.79 - 11.37	6.9	11	6.18	7.45	10.68	12.04
PCV (%) G	32	28.70	29.70	4.15	19.88 - 37.52	20.6	35.3	17.53	22.42	34.85	40.08
MCH (pg) NG†	32	15.75	15.50	1.20	13.77 - 18.91	13.7	18.9	13.40	14.27	17.64	20.73
MCHC (g/dL) G	32	31.77	32.10	1.90	27.74 - 35.81	27.7	34.8	26.67	28.90	34.58	36.98
MCV (fL) G	33	50.45	49.70	4.96	39.94 - 60.96	43	62.3	37.20	42.90	57.84	63.94
Platelets (x 10^9L) NG†	33	505.7	503	109.1	202.6 - 808.7	382	630	58.4	371	632.8	968.4
30 prepartum days											
RBC ($x10^{12}$L) G	32	5.80	5.81	0.77	4.20 - 7.40	4.44	7.58	3.84	4.58	7.00	7.79
HGB (g/dL) G	32	9.04	9.00	1.19	6.57 - 11.50	6.9	11.1	6.02	7.16	10.88	12.10
PCV (%) G	32	29.18	29.70	4.28	20.31 - 38.04	20.5	37.6	18.33	22.43	35.81	40.17
MCH (pg) NG†	32	15.56	15.40	1.01	13.33 - 17.59	12.08	17.50	13.00	13.96	17.12	18.15
MCHC (g/dL) G	29	31.21	30.90	1.91	27.24 - 35.18	27.5	35.9	26.30	28.33	34.13	36.18
MCV (fL) G	32	50.47	50.65	4.64	40.86 - 60.08	42.1	60.4	38.71	43.15	57.66	62.39
Platelets (x 10^9L) NG†	32	394	357.5	92.1	163.4 - 625.3	309	570	68.3	274.2	509	730

†RI and CI were obtained from the robust method with a Box - Cox transformation of the data. SD: Standard deviation; RI: Reference intervals; Min: Minimum; Max: Maximum; G: Gaussian distribution; NG: No Gaussian distribution.

Table 3. Mean values, median, standard deviation, 90% reference intervals, minimum, maximum and confidence intervals for hematologic variables of Gyr x Holstein cows during calving stage.

Hematological variable	n	Mean	Median	SD	90% RI	Min	Max	Lower RI 90% CI		Upper RI 90% CI	
								Lower	upper	Lower	Upper
RBC ($x10^{12}$L) G	31	5.57	5.53	0.79	3.93 - 7.22	4.08	7.49	3.55	4.33	6.79	7.63
HGB (g/dL) G	31	8.94	8.95	1.31	6.22 - 11.66	6.6	11.7	5.60	6.89	10.96	12.34
PCV (%) G	31	28.01	28.35	4.68	18.29 - 37.74	19.3	37.6	16.04	20.69	35.22	40.15
MCH (pg) G	31	16	15.95	0.97	13.98 - 18.02	14.3	17.5	13.51	14.48	17.50	18.52
MCHC (g/dL) G	30	31.85	31.40	2.20	27.27 - 36.42	28.6	37.2	26.20	28.42	35.22	37.58
MCV (fL) G	31	50.33	50.10	4.59	40.78 - 59.88	42	61.6	38.57	43.13	57.41	62.26
Platelets (x 10^9L) NG†	28	401.8	387	72.7	240.7 - 562.9	326	560	190.1	297.2	503.6	619.6

SD: Standard deviation; RI: Reference intervals; Min: Minimum, Max: Maximum; G: Gaussian distribution; NG: No Gaussian distribution. †RI and CI were obtained from the robust method with a Box - Cox transformation of the data.

Table 4. Mean values, Median, standard deviation, 90% reference intervals, minimum, maximum and confidence intervals for hematologic variables of Gyr x Holstein cows 30,60 and 90 postpartum days.

Hematological variable	n	Mean	Median	SD	90% RI	Min	Max	Lower RI 90% CI		Upper RI 90% CI	
								Lower	upper	Lower	Upper
30 postpartum days											
RBC ($x10^{12}L$) G	31	5.23	5.20	0.65	3.85 - 6.61	4.23	6.60	3.53	4.21	6.24	6.96
HGB (g/dL) G	31	8.41	8.65	1.11	6.08 - 10.73	6.4	10.3	5.53	6.68	10.11	11.33
PCV (%) G	31	25.43	25.15	3.58	17.95 - 32.91	20.8	33.5	16.17	19.86	30.90	34.83
MCH (pg) G	31	16.03	16.05	1.20	13.52 - 18.53	13.1	18.4	12.92	14.16	17.86	19.18
MCHC (g/dL) G	30	32.86	32.80	2.26	28.12 - 37.59	29	37.5	26.97	29.35	36.30	38.83
MCV (fL) G	29	47.92	48.45	3.52	40.54 - 55.31	40.3	53.9	38.72	42.50	53.25	57.28
Platelets (x 10^9L)NG†	29	420.2	386	166.4	210.2 - 1153.1	238	771	182.2	255.3	656.7	2614.5
60 postpartum days											
RBC ($x10^{12}L$) G	30	5.21	5.27	1.01	3.07 - 7.35	3.29	7.46	2.53	3.65	6.74	7.93
HGB (g/dL) G	29	8.55	8.50	1.24	5.90 - 11.20	6.5	11.6	5.18	6.68	10.38	11.98
PCV (%) G	28	25.24	26.05	3.11	18.50 - 31.98	20.7	29.6	16.54	20.65	29.72	34.14
MCH (pg) G	29	15.99	15.90	1.24	13.38 - 18.60	12.2	17.9	12.72	14.08	17.86	19.31
MCHC (g/dL) G	29	33.67	34	1.82	29.79 - 37.56	30.1	37.1	28.73	30.93	36.35	38.71
MCV (fL) G	30	47.58	48.30	3.13	41.00 - 54.17	42.4	52.2	39.35	42.78	52.29	55.96
Platelets (x 10^9L)NG†	29	410.9	357	133	282.5 - 1141.4	299	745	270.4	304.5	546	5693
90 postpartum days											
RBC ($x10^{12}L$) G	29	5.29	5.35	0.85	3.51 - 7.07	3.1	6.95	3.07	3.98	6.58	7.55
HGB (g/dL) G	30	8.23	8.35	0.86	6.42 - 10.03	6.8	9.5	5.96	6.92	9.51	10.53
PCV (%) G	30	25.50	26.10	4.92	15.21 - 35.79	15.8	37.8	12.71	17.88	32.97	38.48
MCH (pg) G	29	15.72	15.45	0.99	13.65 - 17.80	14	17.8	13.13	14.20	17.22	18.55
MCHC (g/dL) G	30	32.93	32.65	2.16	28.40 - 37.45	29.4	37.45	27.29	29.60	36.19	38.66
MCV (fL) G	30	47.39	47.20	3.92	36.19 - 55.60	39.9	56.1	37.20	41.32	53.35	57.75
Platelets (x 10^9L)NG†		336.4	314.5	106	163.6 - 657.3	202	546	131.4	212.7	491.7	872,8

†RI and CI were obtained from the robust method with a Box - Cox transformation of the data. SD: Standard deviation; RI: Reference intervals; Min: Minimum; Max: Maximum; G: Gaussian distribution; NG: No Gaussian distribution.

Table 5. Hematological values of clinically healthy dual - purpose cows in different physiological stages (value ± Standard deviation).

ED	RBC ($x10^{12}L$)	PCV (%)	HGB (g/dL)	MCV (fl)	MCH (pg)	MCHC (g/dL)	Platelets (x 10^9L)
Prepartum							
60	5.76 ± 0.72^a	28.70 ± 4.15^a	9.25 ± 1.08^a	50.45 ± 4.96^a	15.75 ± 1.20^a	31.77 ± 1.90^a	505.7 ± 109.1^a
30	5.80 ± 0.77^a	29.18 ± 4.28^a	9.04 ± 1.19^a	50.47 ± 4.64^a	15.56 ± 1.01^a	31.21 ± 1.91^a	394 ± 92.1^a
Calving							
0	5.57 ± 0.79^a	28.01 ± 4.68^{ab}	8.95 ± 1.31^a	50.33 ± 4.59^a	16.00 ± 0.97^a	31.85 ± 2.20^a	401.8 ± 72.7^a
Postpartum							
30	5.23 ± 0.65^a	25.43 ± 3.58^b	8.41 ± 1.11^a	47.92 ± 3.52^a	16.03 ± 1.20^a	32.86 ± 2.26^b	420.2 ± 166.4^a
60	5.21 ± 1.01^a	25.24 ± 3.11^b	8.55 ± 1.24^a	47.26 ± 5.08^a	15.99 ± 1.24^a	33.67 ± 1.82^b	410.9 ± 133^a
90	5.29 ± 0.85^a	25.50 ± 4.92^b	8.23 ± 0.861^a	47.58 ± 3.13^a	15.72 ± 0.99^a	32.93 ± 2.16^b	336.4 ± 106^a

ED: Evaluation day. [abc]Different literals in the same columns are statistically different with $P < 0.05$.

Table 6. Leukogram of clinically healthy dual - purpose cows in different physiological stages (value ± Standard deviation).

ED	WBC ($x10^3$ μL^1)	Basophils ($x10^3$ μL^1)	Eosinophils ($x10^3$ μL^1)	Segmented neutrophils ($x10^3$ μL^1)	Band neutrophils ($x10^3$ μL^1)	Lymphocytes ($x10^3$ μL^1)	Monocytes ($x10^3$ μL^1)
Prepartum							
60	8.26 ± 2.32^a	0.0^a	0.81 ± 0.48^a	2.96 ± 0.95^a	0.04 ± 0.07^{ab}	3.96 ± 1.20^a	0.43 ± 0.20^{ab}
30	8.02 ± 1.88^a	0.0^a	0.62 ± 0.41^a	3.36 ± 0.65^a	0.07 ± 0.09^{ab}	3.52 ± 0.73^a	0.35 ± 0.19^a
Calving							
0	8.81 ± 3.03^a	0.0^a	0.69 ± 0.55^a	3.48 ± 0.84^a	0.09 ± 0.15^b	3.82 ± 0.97^a	0.65 ± 0.45^b
Postpartum							
30	7.60 ± 2.18^a	0.0^a	0.62 ± 0.38^a	3.05 ± 0.61^a	0.05 ± 0.07^{ab}	3.42 ± 0.69^a	0.42 ± 0.28^{ab}
60	8.76 ± 4.24^a	0.0^a	0.68 ± 0.44^a	3.44 ± 0.71^a	0.03 ± 0.07^{ab}	4.27 ± 0.90^a	0.25 ± 0.20^a
90	7.14 ± 1.52^a	0.0^a	0.55 ± 0.31^a	2.86 ± 0.61^a	0.00 ± 0.03^a	3.41 ± 0.71^a	0.32 ± 0.27^a

ED: Evaluation day. [abc]Different literals in the same columns are statistically different with $P < 0.05$.

DISCUSSION

The present study is the 1st to describe haematological changes in Gyr x Holstein cows in different physiological stages under the humid tropical conditions of southeastern Mexico. With respect to the evaluated productive variables, the cows showed a decrease in body condition and live weight after calving. This is attributable to the weight loss following the expulsion of calf as well as liquid and foetal membranes. After this point, cows did not present changes in live weight between 60 and 90 days postpartum. This behaviour can be considered an adaptation of the Gyr × Holstein cows to this environmental condition and the production system. Specially, if is considered that studied cows were feeding in natural paddocks of *Paspalum fasciculatum* which is considered an invasive species in cultured paddocks due to their low crude protein content. Similar results were previously found for Holstein cows, whose live weight and body condition decreased until 4 weeks postpartum but subsequently remained constant [15].

On the other hand, the fertility evaluations of lactating cows have shown that animals with a body condition score < 2.5 present lower percentages of pregnancy than cows with scores above this value [2,15]. In this study, the BCS (2.63, 2.51 and 2.43 for 30, 60 and 90 postpartum days, respectively), require special attention mainly close to 90 postpartum. Therefore, feeding strategies to increase the body condition above 2.7 should be employed to improve the reproductive index of herds.

The haematological variables measured in the present study were similar to other data previously published for cattle in haematology books. Although, some breeds or conditions of the cattle were not specifically described for the authors. The RBC count during all physiological stages was within reference intervals (5 to 8 x1012 /L) reported in dairy cows from central area of Mexico and Holstein cows raised in Canada, respectively [10,20]. Similarly, González-Garduño *et al.* [5] reported a RBC count similar to the reported in present study (6 and 5.8 x10^{12} /L, respectively) in cattle raised in Tabasco state in southern of Mexico. Despite the RBC count not showing statistical differences herein, the PCV value was higher in pregnant cows and lower in lactating cows. Overall, these PCV values were close to the lower reference intervals reported by Nuñez & Bouda [10] in cattle raised in farms in central and northern of Mexico. Some factors such as high altitude (2,240 masl in the center of country), and low temperate could be associated to the physiological increase of RBC in the central and north areas of Mexico, while in Tabasco the region Centro have a mean of 20 masl (https://tabasco.gob.mx) [6]. Similarly, the RBC and PCV values of this study were within the reference intervals reported in Holstein cows from Canada [7], and Mexico [1], and agrees with reported for lactating Holstein cows in the Veterinary Haematology book [20]. Finally, the HGB, MCV, MCH, MCHC and platelet count did not significantly differ among the evaluated groups (Table 2). However, the MCHC did increase in cows at 30, 60 and 90 days postpartum. The RBC count and, correspondingly, the PCV presented a gradual numeric decrease during the prepartum to postpartum periods, causing the increase in MCHC at 30, 60 and 90 days postpartum due to the MCHC is the result of the division of haemoglobin by the PCV value. Physiologically, it is understood that even when the number of erythrocytes decreases, their function is compensated by increasing their amount of hemoglobin.

The leukograms showed values within the reference intervals previously reported in the veterinary books [10,20]. Statistical differences were only observed in band neutrophils and monocytes (Table 6). The highest values were observed in cows immediately after calving. Regarding this effect, several authors have reported variations in leukograms, mainly due to the stress associated with calving and the migration of neutrophils to the uterine lumen and mammary glands [9,16,17].

In general, the erythrograms showed similar reference intervals (closer to the lower confidence intervals), to whose reported in previous studies [10,20] and the body condition of cows at 30 days postpartum was close to 2.5, which is not desirable for reproductive performance [2, 15]. Whereby, these values should be preferably increased to improve the reproductive efficiency of the herd.

The haematological values reported in the present study can contribute to the reference values and diagnosis of diverse pathologies in pregnant and postpartum Gyr x Holstein cows and other crossbred *Bos indicus* × *Bos taurus* cows commonly used in production systems in Mexico and Latin American countries. In conclusion, productive variables, live weight and body condition were found to differ in prepartum and postpartum cows. However, at 30 days postpartum, these variables remained constant. It is important to monitor these variables to avoid productive and reproductive problems.

CONCLUSION

The haematological values reported herein contribute towards the establishment of baseline reference values for detecting abnormalities in prepartum and postpartum Gyr x Holstein cows raised in the humid tropics of Mexico.

MANUFACTURERS

[1]Nutec. El Marqués, Querétaro, Mexico.

[2]Vacutainer, BD Biosciences. Franklin Lakes, NJ, USA.

[3]Desego Laboratories. Morelia, Michoacán, Mexico.

[4]Hycel Laboratories. Jalisco, Mexico.

[5]IBM Corporation. Armonk, NY, USA.

***Acknowledgements*.** We are grateful for the veterinarian Jorge Priego Noguera, owner of the La Carolina Ranch, and his collaborators María Angela Torres Pérez and José del Carmen Alejo Álvarez, for providing animals and aiding in the field work. Also, we are grateful for the veterinary students Beatríz Tonantzin Hernández García, Brenda Méndez Córdova and Martha Carolina Pérez De la Cruz for their aid in the field and laboratory work.

***Ethical approval*.** All of the authors declare that during the experiment, the animals were handled in accordance with the experimental protocols approved by the Animal Care and Ethical Investigation Committee of the Universidad Juárez Autónoma de Tabasco (approval number: 0240), and biological waste was managed in accordance with official norms in Mexico (NOM-087-ECOL-SSA1-2002).

***Declaration of interest*.** All authors have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

REFERENCES

1 **Calzada-Calzada P., Morales-Salinas E., Quiróz-Rocha G., Salmerón-Sosa F., García- Ortiz C. & Hernández-Balderas J. 2002.** Hematological values in Holstein-Friesian *Neospora caninum* seropositive cows from the dairy cattle region of Tizayuca in the State of Hidalgo in Mexico. *Veterinaria México*. 33: 119-124. DOI:10.21753/vmoa.33.002.66.

2 **Carvalho P.D., Souza A.H., Amundson M.C., Hackbart K.S., Fuenzalida M.J., Herlihy M.M., Ayres H., Dresch A.R., Vieira L.M., Guenther J.N., Grummer R.R., Fricke P.M., Shaver R.D. & Wiltbank M.C. 2014.** Relationships between fertility and postpartum changes in body condition and body weight in lactating dairy cows. *Journal of Dairy Science*. 97: 3666-3683. DOI: 10.3168/jds.2013-7809.

3 **Friedrichs K.R., Harr K.E., Freeman K.P., Szladovits B., Walton R.M., Barnhart K.F. & Blanco-Chavez J. 2012.** ASVCP reference interval guidelines: determination of de novo reference intervals in veterinary species and other related topics. *Veterinary Clinical Pathology*. 41(4): 441-453. DOI: 10.1111/vcp.12006.

4 **Geffré A., Concordet D., Braun J.P. & Trumel C. 2011.** Reference Value Advisor: a new freeware set of macroinstructions to calculate reference intervals with Microsoft Excel. *Veterinary Clinical Pathology*. 40: 107-112. DOI: 10.1111/j.1939-165X.2011.00287.x.

5 **González-Garduño R., Hernández-Hernández J., Ortiz-Pérez D. & Torres-Hernández G. 2019.** Hematological performance of cattle infected by trematodes in a humid warm climate of Mexico. *Pastos y Forrajes*. 42: 197-201.

6 **INEGI 2022.** Instituto Nacional de Estadistica y Geografía-INEGI, Mexico. Disponível em: <https://www.inegi.org.mx>.

7 **Lumsden J.H., Mullen K. & Rowe R. 1980.** Hematology and biochemistry reference values for female Holstein cattle. *Candian Journal of Comparative Medicine and Veterinary Science*. 44: 24-31.

8 **Moreira T.F., Facury Filho E.J., Meneses R.M., Mendonça F.L.M., Lima J.A.M. & Carvalho A.U. 2015.** Energetic status of crossbreed dairy cows during transition period in two different seasons. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*. 67: 1327-1334. DOI:10.1590/1678-4162-8287.

9 **Nazifi S., Ahmadi M.R. & Gheisari H.R. 2008.** Hematological changes of dairy cows in postpartum period and early pregnancy. *Comparative Clinical Pathology*. 17: 157-163. DOI:10.1007/s00580-008-0730-6.

10 **Nuñez O. & Bouda J. 2007.** *Patología Clinica Veterinaria*. Facultad de Medicina Veterinaria y Zootecnia de la Universidad Nacional Autónoma de México. México: UNAM, pp.27-67.

11 **O'Hara L.A., Båge R. & Holtenius K. 2016.** The impact of body condition after calving on metabolism and milk progesterone profiles in two breeds of dairy cows. *Acta Veterinaria Scandinavica*. 58(1): 68. DOI: 10.1186/s13028-016-0251-2.

12 **Oliveira W.D.C., Dias e Silva T.P., Araújo M.J., Edvan R.L., Oliveira R.L. & Bezerra L.R. 2019.** Changes in hematological biomarkers of Nellore cows at different reproductive stages. *Acta Scientiarum. Animal Sciences*. 41(1): e45725. DOI:10.4025/actascianimsci.v41i1.45725.

13 **Roy S., Roy M. & Mishra S. 2010.** Hematological and biochemical profile during gestation period in Sahiwal cows. *Veterinary World*. 3: 26-28.

14 **Rojo-Rubio R., Vázquez-Armijo J.F., Albarrán-Portillo B., Hernández-Martínez J., Rebollar-Rebollar S., Cardoso-Jiménez D., Dorantes-Coronado E.J. & Gutierrez-Cedillo J.G. 2009.** Dual purpose cattle production in Mexico. *Tropical Animal Health and Production*. 41: 715-721. DOI 10.1007/s11250-008-9249-8.

15 **Sakaguchi M. 2009.** Differences between body condition scores and body weight changes in postpartum dairy cows in relation to parity and reproductive indices. *Canadian Veteterinary Journal*. 50: 649-656.

16 **Subandrio A.L. & Noakes D.E. 1997.** Neutrophil migration into the uterine lumen of the cow: The influence of endogenous and exogenous sex steroid hormones using two intrauterine chemoattractants. *Theriogenology*. 47: 825-835. DOI: 10.1016/s0093-691x(97)00038-1.

17 **Subandrio A.L., Sheldon I.M. & Noakes D.E. 2000.** Peripheral and intrauterine neutrophil function in the cow: the influence of endogenous and exogenous sex steroid hormones. *Theriogenology*. 53: 1591-1608. DOI: 10.1016/S0093-691X(00)00300-9.

18 **Torres-Chable O.M., Ojeda-Robertos N.F., Chay-Canul A.J., Peralta-Torres J.A., Luna-Palomera C., Brindis-Vazquez N., Blitvich B.J., Machain-Williams C., Garcia-Rejon J.E., Baak-Baak C.M., Dorman K.S. & Alegria-Lopez M.A. 2017.** Hematologic RIs for healthy water buffaloes (*Bubalus bubalis*) in southern Mexico. *Veterinary Clinical Pathology*. 46: 436-441. DOI: 10.1111/vcp.12508.

19 **Wankhade P.R., Manimaran A., Kumaresan A., Jeyakumar S., Ramesha K.P., Sejian V., Rajendran D. & Varghese M.R. 2017.** Metabolic and immunological changes in transition dairy cows: A review. *Veterinary World*. 10: 1367-1377. DOI: 10.14202/vetworld.2017.1367-1377.

20 **Weiss D.J., Wardrop K.J. & Schalm O.W. 2010.** *Schalm's Veterinary Hematology*. 6th edn. Ames: Wiley-Blackwell, pp.927-930.