Global Agronomy Research Journal

Effect of Potassium and Magnesium Chloride Dosing to Holstein Cows before and after Calving During the summer on Physiological Performance

Ghufran Tahseen Hussein [1*], Mohammed Ahmed Shwayel [2], Qays Abduljaleel Khalaf [3]

[1] Master's student, Iraq

[2] College of Agriculture, University of Diyala Iraq, Iraq

[3] Al Khalis Cow Station Manager, Iraq

* Corresponding Author: **Ghufran Tahseen Hussein**

Article Info

ISSN (online): 3049-0588

Volume: 02

Issue: 04

July - August 2025

Received: 25-05-2025

Accepted: 29-06-2025

Published: 06-07-2025

Page No: 61-66

Abstract

The aim of the experiment is to demonstrate the effect of potassium and magnesium chloride in reducing heat stress in Holstein cows in the summer by measuring body temperature, respiratory rate, pulse rate and heat tolerance coefficient starting from 1/7/2024 until 1/11/2024, where potassium and magnesium chloride are dosed every 48 hours per cow. 16 multi-season Holstein cows were used and divided into four treatments, each of which includes four replicates. The first treatment, T1, is the control treatment without dosing. The second treatment, T2, is dosed with 10g/48 hours per cow of potassium chloride. The third treatment, T3, is dosed with 2.5g/48 hours per cow of magnesium chloride. The fourth treatment, T4, is dosed with 10g/48 hours per cow and 2.5g/48 hours per cow of potassium chloride and magnesium chloride, respectively, to study the effect of these treatments on Holstein cows suffering from heat stress in the summer. The temperature and humidity index (THI) was calculated during the experiment and the results showed that the cows were under The effect of heat stress during the experiment period negatively affected its physiological performance, as the highest THI value reached 81.88 during the eighth week of August, and the lowest THI value reached 71.56 during the seventeenth week of October. The results of the statistical analysis of physiological characteristics on 13/7/2024 showed that there were no significant differences between the treatments. As for 16/8/2024, the results showed that treatment T4 led to a significant decrease ($P \leq 0.05$) in the respiratory rate, which reached 74.00 times/minute compared to treatment T2, which was 94.75 times/minute. On 24/8/2024, the results showed a significant increase ($P \leq 0.05$) in the thermal tolerance coefficient of treatment T4, which reached 92.00 compared to treatment T3, which was 83.75. As for 8/30/2024, the results showed a significant increase ($P \leq 0.05$) in the pulse rate of treatment T4, which reached 71.00 beats/minute compared to treatment T1, which was 76.00 beats/minute. On 27/9/2024, the results showed a significant decrease ($P \leq 0.05$) in the respiration rate in treatment T4. As it reached 48.70 times/minute compared to treatment T3, which reached 64.25 times/minute. As for 25/10/2024, the results showed a significant decrease ($P \leq 0.05$) in the respiratory rate in treatment T4, as it reached 37.00 times/minute compared to treatment T1, which was 39.75 times/minute. There was also a significant decrease ($P \leq 0.05$) in the pulse rate in treatment T4, as it reached 61.00 beats/minute compared to treatments T1 and T3, which were 68.00 and 71.00 beats/minute, respectively. On 31/10/2024, the results showed a significant decrease ($P \leq 0.05$) in the rectal temperature in treatment T3, as it reached 36.82°C compared to treatment T1, which was 38.01°C. Adding 10g of potassium chloride and 2.5g of magnesium chloride during the period of cows being exposed to heat stress had a significant effect on some physiological characteristics, as it reduced the number of respirations, pulse, and rectal temperature, and increased the heat tolerance coefficient during some periods of the experiment.

DOI: https://doi.org/10.54660/GARJ.2025.2.4.61-66

Keywords: Summer, Significant, Characteristics

1. Introduction

Heat stress is a major problem among breeders because it causes significant economic losses, as it affects cow production through a combination of environmental factors such as temperature and relative humidity [1, 2]. Heat stress affects dairy cattle production by reducing milk production, protein, fat, solids, and lactose content [3, 4]. Heat stress also affects fermentation processes within the rumen, which affects physiological processes [5]. As indicated [6], heat stress affects milk production because milk production leads to increased metabolic heat production, which leads to greater stress on the animal. High-producing cows are characterized by increased heat resulting from metabolic processes, which causes greater heat stress compared to less productive animals [7]. The temperature-humidity index (THI) is considered the most appropriate measure to determine the extent of heat stress on dairy cows because it calculates the temperature and relative humidity of the atmosphere into a single index [8, 9]. In some areas, relative humidity and temperature increase during the summer inside barns, which affects the ability of dairy cows to get rid of excess heat produced by the body through evaporation, which negatively affects production and health performance. For cows, in hot, dry regions such as central Iraq, for example, cows secrete potassium through sweat and saliva, causing a deficiency of this element in the body [10, 11]. The best treatment for potassium deficiency in dairy cows is to give potassium supplements orally to alleviate the effects of heat stress [12, 13]. Potassium plays a role in biological processes such as osmotic pressure within cells, transmission of nerve signals, enzyme reactions in cells, metabolism, kidney and heart functions. Magnesium is also an essential element and plays a vital role in the animal body, as the animal needs many minerals that work to activate the work of enzymes in all parts of the body. Magnesium is involved in building muscles and teeth, and muscle contraction and relaxation. Any deficiency in these mineral elements in feed causes a decrease in milk production and many diseases such as rickets and muscle weakness. It also causes miscarriage in pregnant women, death after birth, or a decrease in fertility rates. Therefore, magnesium is one of the mineral elements that should also be added to dairy cow feed [14]. The aim of the current experiment is to demonstrate the extent of the effect of potassium chloride and magnesium in reducing heat stress in Holstein cows in the summer by measuring body temperature, pulse, respiration, and heat tolerance coefficient in central Iraq.

2. Materials and Methods

This experiment was carried out at the Khalis cattle station located in the Habhab district of Diyala. Sixteen Holstein cows, raised in the field and with multiple births, were used. They were divided into four treatments, each containing four replicates, as follows:

Treatment 1: Control treatment without dosing.

The second treatment, T2, was given 10g/48h/cow of potassium chloride. The third treatment, T3, was given 2.5g/48h/cow of magnesium chloride. The fourth treatment, T4, was given 10g/48h/cow and 2.5g/48h/cow of potassium chloride and magnesium chloride, respectively.

The cows were kept in clean, enclosed pens measuring 75 m in length and 25 m in width. Each pen contained feed troughs and water troughs for the cows to drink from. Air temperature and relative humidity were measured using an electronic device that measures both temperature and humidity simultaneously and was placed inside the pen where the cows were kept. The device's readings were recorded daily to record the lowest and highest temperature and humidity levels during the day to calculate the temperature-humidity index (THI) throughout the experiment. The heart rate of each cow was measured weekly via the caudal vein per minute, and the number of respirations was measured by counting the number of flank movements per minute. The rectal temperature of each cow was also measured weekly using an electronic thermometer placed in the rectum for one minute. All measurements began at 1:00 PM. The THI was calculated using the method of Mader *et al*. (2006) [15] according to the following equation

$$THI=(0.8\times D.B.T.C^{o})+[(RH/100)\times(D.B.T.C^{o}-14.4)]+46.4$$

Temperature Humidity Index. =THI
D.B.T.C=Dry-Bulb.Temp = Average air temperature in °C..
RH/100: Relative Humidity = Relative humidity expressed as a percentage.

Constants. =0.8, 14.4, 46.4

The heat tolerance coefficient (HTC) for cows was calculated according to the following equation (Rhoad 1944) [16]:
$HTC = 100 - 10(ART - 38.3)$.
HTC: Heat tolerance coefficient.
ART: Average rectal temperature

Constants = 100, 10

3. Statistical Analysis

A completely randomized design (CRD) was used to study the effect of the studied factors (potassium and magnesium chloride) on the traits. The differences between the treatments were compared using the Tukey (1949) multinomial test. The SPSS (2011) program was used for statistical analysis, according to the following mathematical model:

$$Yij=M+ti+eij$$

Yij = observation effect
M = overall mean for the trait
ti = treatment effect
Eij = normally distributed random error
The number of treatments for cows is four.

4. Results and Discussion

The results of the temperature and humidity index (THI) values showed that the cows were under the influence of heat stress, which negatively affected their physiological performance through increased respiratory rate, pulse, and rectal temperature. Table (1) indicates that the highest recorded value of the temperature and humidity index was during the third, eighth, ninth, tenth, and eleventh week of the experiment, respectively, as shown in the following table.

Table 1: Average temperatures, relative humidity, and temperature and humidity index during the summer of 2024 in central Iraq within the cowshed

Weeks	Temperature c°	Humidity %	THI
The first week	34.6	15.5	77.02
The second week	36.3	17.6	79.29
The third week	36.6	23.8	80.96
The fourth week	35.7	23.1	79.88
The fifth week	36.2	18.4	79.37
Sixth week	35.6	18	78.69
The seventh week	35.7	22.1	77.6
The eighth week	36.8	22.5	80.88
The ninth week	37.2	23.2	81.44
The tenth week	36.7	27.4	81.87
The eleventh week	36.2	23.9	80.57
The twelfth week	33	29	78.19
The thirteenth week	34.5	26.1	79.24
The fourteenth week	29.8	24.7	74.04
The fifteenth week	30.2	21.5	73.95
The sixteenth week	28.8	29.7	73.71
The seventeenth week	26.8	30	71.56

Table 2: The effect of dosing potassium and magnesium chloride before and after birth to Holstein cows during the summer on some physiological performance of the body at the beginning of the experiment 9/7/2024 (mean ± standard error).

Transactions	Breathing (times/minute)	Pulse (beats/minute)	Rectal temperature (°C)	Thermal tolerance coefficient
T1 control treatment without dosing	101.50±4.11	91.00±5.44	38.78±0.14 B	92.75±3.47
T2 dose: 10g potassium chloride	94.50±2.27	90.50±4.34	39.75±0.25 AB	88.00±2.88
T3 dose: 2.5 g magnesium chloride	100.50±4.42	95.00±5.44	39.75±0.25 AB	85.50±2.50
T4 dosage 10 g Potassium chloride And 2.5 g of magnesium chloride	87.50±2.63	90.25±3.70	40.25±0.47 A	80.50±4.78
Moral level	N.S	N.S	*	N.S

N.S=indicates that there are no significant differences between the treatments.
*Different letters within one column indicate the presence of significant differences between the coefficients vertically at the level of P≤0.05.

The results in Table 2 show a significant decrease (P≤0.05) in the rectal temperature of treatment T1, as the rectal temperature reached 38.78°C compared to treatment T4, which reached 40.25°C. The reason for the higher rectal temperature of treatment T4 compared to treatment T1 may be due to the higher milk production of treatment T4, and the higher milk production causes a greater heat burden for the cow due to the higher metabolic heat [7], which leads to a higher rectal temperature for cows. As for the rest of the characteristics, the results show no significant differences between the treatments, as the respiratory rate reached 101.50, 94.50, 100.50, and 87.50 times/minute, the pulse 91.00, 90.50, 95.00, and 90.25 beats/minute, and the thermal tolerance coefficient 92.75, 88.00, 85.50, and 80.50 for treatments T1, T2, and T3. T4 respectively.

Table 3: The effect of dosing potassium and magnesium chloride before and after birth to Holstein cows during the summer on physiological performance 16/8/2024 (mean ± standard error)

Transactions	Breathing (times/minute)	Pulse (beats/minute)	Rectal temperature (°C)	Thermal tolerance coefficient
T1 control treatment without dosing	83.25±2.13 AB	90.00±3.00	39.25±0.25	89.50±2.59
T2 dose 10g potassium chloride	94.75±2.17 A	99.00±3.41	40.25±0.25	80.50±2.50
T3 dose2.5 g magnesium chloride	88.25±4.08 AB	92.00±4.32	39.75±0.25	85.50±2.50
T4 dosage 10 g Potassium chloride And2.5 g of magnesium chloride	74.00±4.08 B	91.00±3.41	39.75±0.25	85.50±2.50
Moral level	*	N.S	N.S	N.S

N.S=indicates that there are no significant differences between the treatments.
*Different letters within one column indicate the presence of significant differences between the coefficients vertically at the level of P≤0.05.

The results of Table 3 after more than a month of the experiment showed a significant decrease (P≤0.05) in the number of respirations in treatment T4, which reached 74.00 times/minute compared to treatment T2, which reached 94.75 times/minute, while the pulse, rectal temperature, and thermal tolerance coefficient were not significantly different between the treatments, as the pulse reached 91.00, 99.00, 92.00, and 91.00 beats/minute, and the rectal temperature was 39.25, 40.25, 39.75, and 39.75°C, and the thermal tolerance coefficient was 89.50, 80.50, 85.50, and 85.50 for treatments T1, T2, T3, and T4, respectively. A decrease in the number of respirations in the T4 treatment may be an indication of increased resistance to heat stress in that treatment due to the dose of potassium and magnesium chloride, which are needed more during that period of heat stress to ensure the normal functioning of the body's functions, including breathing, as potassium and magnesium play a major role in the process of regulating breathing. Potassium also helps regulate the balance of acids and bases in the blood, as it is considered one of the important processes during heat stress to dissipate excess heat from the body [10].

Table 4: Effect of dosing potassium and magnesium chloride before and after birth to Holstein cows during the summer on physiological performance 24/8/2024 (mean ± standard error)

Transactions	Breathing (times/minute)	Pulse (beats/minute)	Rectal temperature (°C)	Thermal tolerance coefficient
T1 control treatment without dosing	84.50±0.86	92.00±2.82	39.67±0.18	86.25±1.88 AB
T2 dose 10g potassium chloride	82.75±1.75	90.00±4.16	39.62±0.16	86.50±1.50 AB
T3 dose2.5 g magnesium chloride	85.25±0.62	90.00±0.18	39.92±0.28	83.75±2.89 B
T4 dosage 10 g Potassium chloride And2.5 g of magnesium chloride	83.50±1.55	85.00±3.00	39.10±0.10	92.00±1.00 A
Moral level	N.S	N.S	N.S	*

N.S=indicates that there are no significant differences between the treatments.
*Different letters within one column indicate the presence of significant differences between the coefficients vertically at the level of $P \leq 0.05$.

The results of Table 4 show a significant decrease in the thermal tolerance coefficient in treatment T3, which reached 83.75 compared to treatment T4, which reached 92. As for the rest of the characteristics, no significant differences were observed between the treatments, as the respiratory rate reached 84.50, 82.75, 85.25, and 83.50 times/minute, and the pulse was 92.00, 90.00, 90.00, and 85.00 beats/minute, and the rectal temperature was recorded at 39.67, 39.62, 39.92, and 39.10 °C for treatments T1, T2, T3, and T4, respectively. These results are consistent with a study conducted by the researcher [19] when adding potassium in three different ways. The experiment lasted for 7 months, as the first group was given in the form of potassium chloride, 100 ml every 12 hours, and the second group received it in the form of 500 ml of a gel containing 52 g of potassium in the form of Potassium propionate every two hours, and the third group added 100 grams of potassium chloride dissolved in one liter of drinking water directly available. There was no significant effect on respiratory rate, pulse rate, and rectal temperature. [20] It was mentioned that adding mineral supplements reduces the negative impact of heat stress on cows during the summer, as it regulates physiological processes.

Table 5: The effect of dosing potassium and magnesium chloride before and after birth to Holstein cows during the summer on some physiological traits 30/8/ 2024 (mean ± standard error)

Transactions	Breathing (times/minute)	Pulse (beats/minute)	Rectal temperature (°C)	Thermal tolerance coefficient
T1 control treatment without dosing	75.00±2.04	76.00±1.63 A	38.95±0.32	93.00±2.85
T2 dose 10g potassium chloride	76.25±0.62	73.00±1.00 AB	38.42±0.16	97.25±0.85
T3 dose2.5 g magnesium chloride	76.50±0.86	72.00±0.00 AB	38.12±0.40	91.75±3.66
T4 dosage 10 g Potassium chloride And2.5 g of magnesium chloride	75.75±1.03	71.00±1.00 B	38.45±0.35	94.00±1.22
Sig	N.S	*	N.S	N.S

N.S=indicates that there are no significant differences between the treatments.
*Different letters within one column indicate the presence of significant differences between the coefficients vertically at the level of $P \leq 0.05$.

The results of Table 5 show a significant decrease ($P \leq 0.05$) in the pulse rate in treatment T4, which reached 71.00 beats/min compared to the control treatment T1, which reached 76.00 beats/min, while there were no significant differences in the remaining characteristics between the treatments, as the respiratory rate reached 75.00, 76.25, 76.50, and 75.50 beats/min, and the rectal temperature reached 38.95, 38.42, 38.12, and 38.45 °C, and the thermal tolerance coefficient was 93.00, 97.25, 91.75, and 94.00 for treatments T1, T2, T3, and T4, respectively. The reason for the decrease in the pulse rate in treatment T4 may be due to the role of magnesium in regulating heart functions [21]. Potassium participates in many vital processes, as it has a major role in regulating smooth cardiac muscles [22].

Table 6: Effect of dosing potassium and magnesium chloride before and after birth to Holstein cows during the summer on some physiological traits 27/9/2024 (mean ± standard error)

Transactions	Breathing (times/minute)	Pulse (beats/minute)	Rectal temperature (°C)	Thermal tolerance coefficient
T1 control treatment without dosing	57.00±3.93 AB	65.00±2.58	38.07±0.04	95.25±1.54
T2 dose 10g potassium chloride	53.00±4.14 B	66.00±1.15	37.07±0.19	95.00±1.47
T3 dose2.5 g magnesium chloride	64.25±1.84 AB	68.00±0.00	38.52±0.04	97.75±0.47
T4 dosage 10 g Potassium chloride And2.5 g of magnesium chloride	48.70±2.09 A	65.00±1.00	37.57±0.33	92.00±2.92
Sig	*	N.S	N.S	N.S

N.S=indicates that there are no significant differences between the treatments.
*Different letters within one column indicate the presence of significant differences between the coefficients vertically at the level of $P \leq 0.05$.

The results of Table 6 show a significant decrease ($P \leq 0.05$) in the respiratory rate of treatment T4, which reached 48.70 times/minute compared to treatment T3, which reached 64.25 times/minute, and there were no significant differences between the treatments in the pulse, which was 65.00, 66.00, 68.00, and 65.00 beats/minute, and the rectal temperature reached 38.07, 37.07, 38.52, and 37.57 °C, and the thermal tolerance coefficient was 95.25, 95.00, 97.75, and 92.25 for treatments T1, T2, T3, and T4, respectively

Table 7: Effect of dosing potassium and magnesium chloride before and after birth to Holstein cows during the summer on some physiological traits 25/10/2024 (mean± standard error)

Transactions	Breathing (times/minute)	Pulse (beats/minute)	Rectal temperature (°C)	Thermal tolerance coefficient
T1 control treatment without dosing	39.75±0.25 A	71.00±1.00 A	38.50±0.26	96.00±1.78
T2 dose 10g potassium chloride	38.75±1.10 AB	65.00±1.00 AB	37.67±0.34	96.00±3.34
T3 dose2.5 g magnesium chloride	37.25±0.47 AB	68..00±1.63 A	37.55±0.18	97.00±1.68
T4 dosage 10 g Potassium chloride And2.5 g of magnesium chloride	37.00±0.40 B	61.00±1.91 B	37.05±0.55	87.50±5.50
Sig	*	*	N.S	N.S

N.S=indicates that there are no significant differences between the treatments.
*Different letters within one column indicate the presence of significant differences between the coefficients vertically at the level of P≤0.05.

The results of Table 7 show a significant decrease (P≤0.05) in the respiratory and pulse rates, as the respiration rate of treatment T4, which received potassium and magnesium chloride, decreased significantly by 37.00 times/min compared to the control treatment T1, which reached 39.75 times/min. The results also showed a significant decrease in the pulse rate of treatment T4, which recorded 61.00 beats/min compared to the control treatment T1, which recorded 71.00 beats/min, and treatment T3, which recorded 68.00 beats/min. As for the rectal temperature and thermal tolerance coefficient, there were no significant effects, as the rectal temperature recorded 38.50, 37.67, 37.55, and 37.05 °C, and the thermal tolerance coefficient recorded 96.00, 96.00, 97.00, and 87.50 for treatments T1, T2, T3, and T4, respectively. The reason for the decrease in the number of respirations and heartbeats in the T4 equation may be due to the role of potassium, as it participates in many vital processes, as it has a major role in regulating the smooth heart muscles [22] Magnesium is considered an inhibitory factor for norepinephrine, which helps reduce the number of respirations and heartbeats when cows are exposed to heat stress [23, 24].

Table 8: Effect of dosing potassium and magnesium chloride before and after birth to Holstein cows during the summer on some physiological traits (31/10/2024) (mean ± standard error)

Transactions	Breathing (times/minute)	Pulse (beats/minute)	Rectal temperature (°C)	Thermal tolerance coefficient
T1 control treatment without dosing	38.50±0.86	67.00±3.00	38.10±0.22 A	96.00±1.08
T2 dose 10g potassium chloride	35.00±1.00	61.25±1.00	37.10±0.21 AB	88.00±2.12
T3 dose2.5 g magnesium chloride	35.25±0.85	61.25±0.94	36.82±0.26 B	87.50±4.36
T4 dosage 10 g Potassium chloride And2.5 g of magnesium chloride	36.75±1.25	59.00±5.00	37.15±0.42 AB	88.50±4.29
Sig	N.S	N.S	*	N.S

N.S=indicates that there are no significant differences between the treatments.
*Different letters within one column indicate the presence of significant differences between the coefficients vertically at the level of P≤0.05.

The results of Table 8 show a significant decrease (P≤0.05) in the rectal temperature of treatment T3, which recorded 36.82°C compared to the control treatment T1, which recorded 38.10°C. As for the rest of the characteristics, there were no significant differences between the treatments, as the respiratory rate reached 38.50, 35.00, 35.25, and 36.75 times/minute, the pulse 67.00, 61.25, 61.25, and 59.00 beats/minute, and the thermal tolerance coefficient 96.00, 88.00, 87.50, and 88.50 for treatments T1, T2, T3, and T4, respectively.

5. Conclusions

Dosing 10g of potassium chloride and 2.5g of magnesium chloride separately or in combination with each other contributed slightly to improving some physiological characteristics associated with heat stress at certain times, such as respiratory rate and pulse.

6. References

1. Patel B, Purwar V, Jain V, Gupta D, Wankhede PR, Diwakar, Kumar N, Singh M. Heat stress in dairy cows – its impact and management: A short note. Int J Sci Environ Technol. 2018;7(1):225-31.
2. Al-Khafaji MAQ, Shwayel MA, Al-Azzawi AM. Effect of spraying water on the body of Holstein cows under heat stress conditions in milk production and components. IOP Conf Ser: Earth Environ Sci. 2023;1225(1):012044.
3. Pragna P, Archana PR, Aleena J, Sejian V, Krishnan G, Bagath M, *et al*. Heat stress and dairy cow: impact on both milk yield and composition. Int J Dairy Sci. 2017;12(1):1-11.
4. Mahmoud EQ, Shwayel MA. Effect of adding choline chloride to the diet in milk production of Holstein cows. IOP Conf Ser: Earth Environ Sci. 2023;1259(1):012076.
5. Wang Z, Liu L, Pang F, Zheng Z, Teng Z, Miao T, *et al*. Novel insights into heat tolerance using metabolomic and high-throughput sequencing analysis in dairy cows rumen fluid. Animal. 2022;16(3):100478.
6. Hansen PJ. Exploitation of genetic and physiological determinants of embryonic resistance to elevated temperature to improve embryonic survival in dairy cattle during heat stress. Theriogenology. 2007;68 Suppl 1:S242-9.
7. Al-Haidari AB, Aqab AB, Abdoun KA, Samara IM. Techniques to mitigate the negative effects of heat stress on the productive performance of dairy cattle. 2013.
8. Dikmen S, Hansen PJ. Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment? J Dairy Sci. 2009;92(1):109-16.
9. Shwayel MA. Effect of water spray in heat tolerance and

some biochemical parameters of Holstein cow under heat stress. Biochem Cell Arch. 2020;20(2).
10. Preston RL, Pratt JN, Cates J, Sanders JL. Hot days... Cool cows: Potassium helps make the difference. [Extension publication]. 1993.
11. West JW. Effects of heat-stress on production in dairy cattle. J Dairy Sci. 2003;86(6):2131-44.
12. Schneider PL, Beede DK, Wilcox CJ, Collier RJ. Influence of dietary sodium and potassium bicarbonate and total potassium on heat-stressed lactating dairy cows. J Dairy Sci. 1984;67(11):2546-53.
13. Santimalla VSR, Rajavolu SR, Dabbir BKR. Oral treatment of hypokalemia with potassium chloride and propylene glycol in cows. Int J Pharm Chem Anal. 2023;10(3):202-4.
14. Mahmoud NFH. Magnesium deficiency in dairy cows and methods of treatment. Animal Health Research Institute - Sohag Branch. 2021.
15. Mader TL, Johnson LJ, Gaughan JB. A comprehensive index for assessing environmental stress in animals. J Anim Sci. 2010;88(6):2153-65.
16. Rhoad AO. The Iberia heat tolerance test for cattle. Trop Agric. 1944;21:162-4.
17. Tukey JW. Comparing individual means in the analysis of variance. Biometrics. 1949;5(2):99-114.
18. SPSS. Statistical Package for Social Science version 26 for Windows. LEAD Technologies, Inc.; 2011.
19. Wittek T, Müller AE, Wolf F, Schneider S. Comparative study on 3 oral potassium formulations for treatment of hypokalemia in dairy cows. J Vet Intern Med. 2019;33(4):1814-21.
20. Del Río-Avilés MA, Gonzalez-Vizcarra VM, Ríos-Rincón FG, Ramos-Méndez JC, Zúñiga-González T. Effects of an injectable mineral supplement on physiological responses and milk production of heat-stressed Holstein cows. Trop Anim Health Prod. 2021;53(1):1-8.
21. Babinszky L. Latest Scientific Findings in Ruminant Nutrition-Research for Practical Implementation. 2024.
22. Suttle N, editor. Mineral nutrition of livestock. 4th ed. Wallingford: CABI; 2010.
23. Salgado DD, Nardone A, Lacetera N, Bernabucci U, Ronchi B. Effect of potassium and magnesium supplementation on physiological parameters of heat-stressed dairy cows. J Dairy Sci. 2002;85(4):1115-20.
24. Goff JP. Mineral disorders in dairy cattle. Vet Clin North Am Food Anim Pract. 2008;24(1):153-76.