EFFECT OF ZINC ADDITION TO DRINKING WATER ON PERFORMANCE AND BEHAVIOR OF GROWING LAMBS DURING HOT CLIMATE

Abbi & al.

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Keywords: Zinc; Weight gain; Lamb Behavior; Feeding time; Rumination.

ABSTRACT

The aim of the current study was to determine whether adding zinc to water will improve lamb performance and behavior during a hot climate. In this experiment, twenty seven lambs were housed indoor in individual pens (1.50 x 1.30m). Zinc was added to the fresh drinking water in three different levels namely T1 (0 mg Zn/day), T2 (36 mg Zn/day) and T3 (72 mg Zn/day). Rumination (m/h), feeding time (m/h), number of visiting feeds (n/h), standing time (m/h), lying time (m/h) and standing bouts (n/h) were recorded three times a day by visual observation. Dry matter intake (kg/d), drinking water intake (litter/day), daily live weight gain and feed conversion ratio were also recorded. The current results indicated that rumination, feeding duration, and the visiting feed number were significantly (P ≤ 0.05) higher in T2 than T1 and T3 groups. However, no-differences were noticed among T1, T2 and T3 groups regarding standing time, lying time, standing bouts, dry matter intake, water intake, daily live weight gain, and feed conversion ratio. In conclusion, adding zinc to fresh drinking water improved rumination, feeding duration and the feed visiting number.

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INTRODUCTION
It is well recognized that hot weather has a negative impact on lamb performance and behavior (3, 12 and 20); this could lead to a tremendous economic loss for lamb production. One of the major problems facing lamb performance and behavior during hot climate is the heat stress resulting from high ambient temperature and solar radiation, causing the effective environment temperature to exceed the thermo-neutral zone, particularly during the summer season (19). Heat stress reduces animal feed intake (37), rumination time, digestibility and changes in water intake, causing a reduction in their productivity, including body weight, reproductive performance and milk production (14, 16, 34 and 36). Heat stress can affect lamb's behavior and performance by reducing antioxidant defense or overproduction of free radicals and reactive oxygen species (6, 8 and 24). The metabolism process in the body is constantly generating the reactive oxygen species (ROS; 23), which considered as a major reason for causing oxidative stress (30). Reduction of oxidative stress could help lamb performance improvement (1 and 28). Several nutritional management approaches have been used to reduce heat stress and improve farm animals’ performance and behavior. The adverse effects of environmental stress can be decreased by antioxidant nutrient supplementation, mainly Zinc (28 and 30) and improve lamb behavior. In addition, zinc is known to affect animals’ growth and immune system by influencing enzyme activity (17). Zinc is also required for the structural and functional integrity of over 2000 transcription factors (31). Furthermore, studies on the effect of adding Zn on nutrients digestibility and ruminal fermentation is scarce (15), and, where available, results are inconsistent. However, in this regard, Salama et al. (25) revealed that dietary Zn increased the digestibility of dry matter (D.M.), organic matter and crude protein (C.P.) for goats. Previous studies used several methods for heat stress alleviation and improved farm animals' performance, including feeding strategies and management (35). However, there was lack information about using zinc supplement to reduce heat stress effect on performance and behavior of Iraqi native lamb. Therefore, the objective of the current study was to determine the influence of different levels of zinc added to drinking water to alleviate the impact of heat stress on lamb performance and behavior during hot climate.

MATERIALS AND METHODS
This study was conducted during the period 16th July 2020 and 3rd September 2020 at the Animals Farm Project, Department of Animal Production, College of Agricultural Engineering Sciences, University of Duhok. Ethical approval of the research protocol was obtained from the Ethics Committee of the Department of Animal Production, College of Agricultural Engineering Sciences, University of Duhok.

Experimental animals
Twenty seven lambs aged 8 ± 1.1 months with a 26.0 ± 3.0 kg live body weight were used at the farm pertaining to the Department of Animal Production. The lambs were housed indoor in individual pens (1.50 x 1.30m) in randomized blocks on sawdust. The lambs were moved into the study area one week before data collection for adaptation. After the adaptation period, two kg of a total mixed ration (TMR; see Table 1) was offered daily at approximately 08:30 a.m. and 5:00 p.m. for ad libitum availability using individual clean plastic buckets. The remaining feed was removed daily, and the plastic buckets were cleaned prior to RMR was allocated. Water was offered ad libitum daily using the plastic buckets. Samples of TMR (0.5 kg) were collected weekly for chemical composition analysis. The nutrient content of the ration composed of dry matter (88.5%), energy (280 kcal/kg DM), crude protein (16% DM), ether extract (2.5% DM), neutral detergent fiber (36.4% DM) and ash (4.8%).

Table 1. Dietary composition of the trial total mixed ration

| Ingredients                  | g/kg (%)  |
|------------------------------|-----------|
| Barley                       | 550 (55%) |
| Corn                         | 100 (10%) |
| Wheat barn                   | 150 (15%) |
| Soybean meal                 | 170 (17%) |
| Calcium Carbonate (CaCo3)    | 20.0 (2%) |
| Di Calcium Phosphate         | 4.00 (0.4%) |
| Salt                         | 5.00 (0.5%) |
| Multi Vitamin (ADE)          | 1.00 (0.1%) |
| **Total**                    | **1000 (100%)** |
Experimental design

The Zinc (Zinc sulphate, monohydrate (12 mg/ml)) was added to the fresh drinking water in three different levels namely T1 (0 mg/day), T2 (36 mg/day) and T3 (72 mg/day). Lambs were visually observed by three professional persons for one hour continuously two times a day at 13:00 and 18:00. During observation, rumination time (minutes per hour; m/h), feeding time (m/h), number of visiting feeds (number per hour; n/h), standing time (m/h), lying time (m/h) and standing bouts (n/h) were recorded. Drinking water (litter/day) was recorded by using a graduated cylinder. Lambs were weighed one time a week on Thursday then divided by seven days for daily body gain. Daily feed intake was recorded by digital weight balance for the daily feed conversion ratio. Data from T1, T2 and T3 lambs were collected during the study period. The six parameters analyzed were the rumination time (m/h), feeding duration (m/h), the number of visits to feed per day, time spent standing (m/h), time spent lying (m/h) and the number of standing bouts per hour. Prior to statistical analysis, the data for all parameters were summarized to one value per hour using Microsoft Excel. Drinking water (L/d), daily body weight (gm/kg), and feed conversion ratio were summarized to one value per day using Microsoft Excel.

Statistical analyses

Data were analyzed by factorial one way ANOVA using the Genstat statistical software package (Genstat V 20th edition, VSN International Ltd, U.K.). The datasets were analyzed to compare among the experimental groups for the rumination time (m/h), feeding duration (m/h), number of visits to feed per day, time spent standing (m/h), time spent lying (m/h) and the number of standing bouts per hour, drinking water (L/d), daily body weight (gm/kg) and feed conversion ratio. Repeated measure ANOVA analyses of datasets were also analyzed to compare among treated groups during different time (weeks) and the treatment x time interaction. Tukey test was used to compare different groups for all parameters. Differences were reported as significant at P <0.05, and trends were reported when P was between <0.1 and >0.05.

RESULTS AND DISCUSSIONS

Rumination and feeding behavior: There was an effect of time (P < 0.05) on rumination (m/h), feeding duration (m/h) and the number of visiting feed (n/h; Table 2, 3 and 4). Rumination, feeding duration and number of visiting feed were declined with the experiment progress; however, the lambs in T2 group had higher values of the above mentioned measurements. There was an effect of Zn addition to drinking water on rumination (m/h), feeding duration (m/h) and the number of visiting feed (n/h; Table 2, 3 and 4), respectively. The T2 group exhibited rumination (m/h; P < 0.001), feeding duration (m/h; P < 0.001) and the number of visiting feed (n/h; P < 0.010). The present study results revealed that zinc addition to drinking water had beneficial for the lamb rumination and feeding behavior during heat stress. Rumination time is a good feeding behavior marker to distinguish efficient and inefficient lambs (18). The present study found that the rumination period (m/h; P < 0.001) was greater in T2 lambs’ group than T1 and T3 groups at weeks 2, 3, 4 and trended to be higher at week 5. These results are in accordance with those reported by Jenkins and Hidiroglou (11) and Ott et al. (21), who found an increase in zinc intake with food increased rumination in ruminant lamb. Moreover, the present study revealed that feeding duration (m/h; P < 0.001) was also longer in the T2 lambs’ group compared to T1 and T3 groups. This result is consistent with the previous finding of Underwood et al. (33), who found that lamb's fed diet with zinc supplementation had longer a higher feed intake. Furthermore, the results show that the numbers of visiting feed (n/h; P = 0.010) were more in the T2 lambs’ group than T1 and T3 groups. Rice et al. (23) observed that the number of visiting feed was reduced during heat season and reported a positive relationship between the number of visiting feed and cortisol concentration in lamb. To the best of our knowledge, the present study is the first to report the effect of adding zinc to drinking water on lamb feeding duration the numbers of visiting feed during a hot climate. An increase in rumination period, feeding duration and the number of visiting feed may be due to that drinking zinc with
Standing time, lying time and standing bouts: There was an effect of time (P < 0.05) on Standing time (m/h), lying time (m/h) and standing bouts (n/h; Figure 1, 2 and 3). There was a fluctuation in standing time, lying time and standing bouts with experiment progress. There was no effect of adding zinc to drinking water on standing time, lying time and standing bouts (Figure 6 and Table 3 and 4). The results are inconsistent with the findings of Pent et al. (22), who reported that lambs were spent longer time, less standing with lower standing bouts during heat stress compared to the result of the current study. In a study conducted on a lamb behavior by Rice et al. (23) also found that heat stress reduced both lambs lying time (m/h) and increased sanding time (m/h) by 5-20%. Previously, Cook et al. (4), and Scaglia and Boland (27) found that standing up is a general response of the animal to heat stress. Spending greater time standing with inconstant standing bouts during hot climate designates the level of heat stress experienced by the lambs indicated to increase the efficiency of body heat loss through amended airflow (29). These results were also irrelevant to results observed by previous studies (17,26), which found lower activity levels in lambs than the present. These differences may be due that lamb activity was recorded by visual observation, and lambs were fed zinc addition to drinking water; however, other studies recorded lamb activity by small behavior monitoring devices called IceTags (IceTag sensor, IceR-robotics, Edinburgh, U.K.), which were more accurate and sensitive than visual observation (23). However, there was no published information on the effect of zinc addition to the drinking water on lamb sating bouts. The effect of hot climate on lamb behavior may be that heat stress changes lamb activities and intensifies stresses experienced by lambs during hot climate, which leads to increased time and energy spent in behaviours to stabilize body thermoregulation (13).

Dry matter intake, water intake, body weight gain and feed conversion ratio: There was an effect of time (P < 0.05) on feed dry matter intake (DMI), water intake, and lambs live weight (Figure 4, 5 and 6). There was a fluctuation in feed dry matter intake (DMI) and water intake, while lambs weight had increased with experiment progress. There was no effect (P > 0.05) of zinc addition to the drinking water on feed dry matter intake, water intake and lambs live weight (Figure 6 and Table 3 and 4). In addition, zinc addition to the drinking water had no effect on the average dry matter intake, water intake, daily body weight gain and feed conversion ratio (Table 5). Regarding dry matter intake (DMI; kg/d; P = 0.560). Similarly, Garg et al. (7) showed that dry matter intake was not different between lambs feed zinc supplementation and control. However, the current results of the current study was in contrast with those reported by Mallaki et al. (15), who found that dry matter intake was significantly higher for the lambs fed the diet supplemented with zinc. There was also no effect (P = 0.916) of Zinc addition on the average water intake (L/d) in the current study. In addition, there was no effect of zinc addition to the drinking water on the average daily body weight gain (g/d; P = 0.614) between T1, T2 and T3 lambs. These results disagree with the previous study (15), who reported that average daily weight gain increased significantly with Zn addition and was higher for the lambs fed with Zn than the control diet lambs. The results of the current study are also in contrast to those showed (Garg et al., 2008), who reported that the average daily gain of lambs during 150 days of experimental feeding zinc supplementation was significantly higher compared to the control. Furthermore, feed conversion ratio (FCR; kg feed/1kg gain; P = 0.389) was also not different between T1, T2 and T3 lambs. Although the number of feeding bouts in the present was higher in T2 than T1 and T3 lamb groups, feeding bouts may not be a direct measure of feed intake and conversion ratio (23). Similarly to the present study, Mallaki et al. (15) found that ZnS supplementation had no effect on feed conversion ratio compared to the control group.
Table 2. The effect of adding zinc (Zn) to the drinking water on lamb rumination during hot climate season

| Weeks | T1   | T2   | T3   | SED  | P-value |
|-------|------|------|------|------|---------|
| W1    | 13.5 | 12.9 | 11.5 | 1.699| 0.473   |
| W2    | 8.98 | 13.0 | 7.31 | 1.892| 0.019   |
| W3    | 7.69a| 14.4b| 5.55c| 1.566| <0.001  |
| W4    | 6.87a| 11.5b| 5.15a| 1.451| <0.001  |
| W5    | 5.09 | 8.75 | 4.61 | 1.853| 0.070   |
| W6    | 5.26 | 4.32 | 4.53 | 1.747| 0.853   |
| Rumination m/h | 7.86b| 10.8a| 6.24c| 0.770| <0.001  |

T1 = control (0 mg Zn/day), T2 (36 mg Zn/day) and T3 (72 mg Zn/day), Means with different superscript letters differ (P<0.05). SED = standard error of deviation, m=minutes, h=hours and n=number. Repeated measures analysis: SED values: T= 0.961, Time= 0.897, T×Time=1.714; P-values: T= <.001, Time= <.001, Time×T=0.008

Table 3. The effect of adding zinc (Zn) to the drinking water on lamb feeding time during hot climate season

| Weeks | T1   | T2   | T3   | SED  | P-value |
|-------|------|------|------|------|---------|
| W1    | 10.3 | 14.8 | 12.7 | 1.766| 0.055   |
| W2    | 8.20 | 12.2 | 11.8 | 1.730| 0.059   |
| W3    | 6.89a| 12.0b| 8.06ab| 1.930| 0.038   |
| W4    | 5.44 | 9.23 | 6.04 | 1.777| 0.094   |
| W5    | 5.06 | 6.33 | 4.84 | 1.232| 0.438   |
| W6    | 4.31a| 8.12b| 3.95a| 1.583| 0.027   |
| Overall mean m/h | 6.44b| 10.5a| 7.82b| 0.689| <0.001  |

T1 = treatment one (0 mg Zn/day), T2 (36 mg Zn/day) and T3 (72 mg Zn/day), Means with different superscript letters differ (P<0.05). SED = standard error of deviation, m=minutes, h=hours and n=number. Repeated measures analysis: SED values: T= 1.102, Time= 0.825, T×Time=1.708; P-values: T= 0.004, Time= <.001, Time×T=0.381.

Table 4. The effect of adding zinc (Zn) to the drinking water on lamb feeding bout during hot climate season

| Weeks | T1   | T2   | T3   | SED  | P-value |
|-------|------|------|------|------|---------|
| W1    | 2.15 | 2.06 | 2.00 | 0.273| 0.861   |
| W2    | 1.48 | 1.54 | 1.57 | 0.173| 0.866   |
| W3    | 1.37 | 1.50 | 1.26 | 0.254| 0.642   |
| W4    | 1.04a| 1.81b| 1.22a| 0.238| 0.009   |
| W5    | 1.20 | 1.20 | 1.10 | 0.240| 0.875   |
| W6    | 0.87a| 1.31b| 0.87a| 0.186| 0.037   |
| Overall mean n/h | 1.33b| 1.58a| 1.31b| 0.100| 0.010   |

T1 = control (0 mg Zn/day)), T2 (36 mg Zn/day) and T3 (72 mg Zn/day), Means with different superscript letters differ (P<0.05). SED = standard error of deviation, m=minutes, h=hours and n=number. Repeated measures analysis: SED values: T= 0.1454, Time= 0.112, T×Time=0.229; P-values: T= 0.222, Time= <.001, Time×T=0.150.
Figure 1. The effect of adding zinc to the drinking water on lamb standing time during hot climate season. Error bars indicate SED
T$_1$= control (0 mg Zn/day), T$_2$ (36 mg Zn/day) and T$_3$ (72 mg Zn/day). Repeated measures analysis: SED values: T = 3.09, Time = 1.812, T×Time=4.214; P-values: T = 0.751, Time = 0.028, Time×T=0.801

Figure 2. The effect of adding zinc to the drinking water on lamb laying time during hot climate season. Error bars indicate SED
T$_1$= control (0 mg Zn/day), T$_2$ (36 mg Zn/day) and T$_3$ (72 mg Zn/day). Repeated measures analysis: SED values: T= 3.048, Time= 1.819, T×Time=4.191; P-values: T= 0.752, Time= 0.032, Time×T=0.831.

Figure 3. The effect of adding zinc to the drinking water on lamb standing bout during hot climate season. Error bars indicate SED
T$_1$= control (0 mg Zn/day), T$_2$ (36 mg Zn/day) and T$_3$ (72 mg Zn/day). Repeated measures analysis: SED values: T= 0.2415, Time= 0.1705, T×Time=0.3619; P-values: T= 0.831, Time= 0.037, Time×T=0.618

Figure 4. The effect of adding zinc to the drinking water on lamb feed DMI intake during hot climate season. Error bars indicate SED
T$_1$= control (0 mg Zn/day), T$_2$ (36 mg Zn/day) and T$_3$ (72 mg Zn/day). Repeated measures analysis: SED values: T= 0.1017, Time= 0.0697, T×Time=0.1499; P-values: T= 0.56, Time= <.001, Time×T=0.613
Figure 5. The effect of adding zinc to the drinking water on lamb water intake during hot climate season. Error bars indicate SED T1= control (0 mg Zn/day), T2 (36 mg Zn/day) and T3 (72 mg Zn/day), Repeated measures analysis: SED values: T= 0.5979, Time= 0.165, TxTime=0.6523; P-values: T= 0.916, Time= <.001, Time×T=0.233

Table 5. Means of dry matter intake (DMI; kg/d), water intake (L/d) and body weight gain g/d, between different groups

| Parameters               | Treatments | SED   | P value |
|--------------------------|------------|-------|---------|
| DMI kg/d                 | T1         | 1.08  |         |
| Water intake L/d         | T2         | 1.06  |         |
| Bodyweight gain g/d      | T3         | 0.97  | 0.102   |
| FCR (kg feed/1kg gain)   | T3         | 0.07  | 0.060   |

SED = standard error of deviation and FCR = feed conversion ratio

In contrast to the current study, previous studies Underwood et al. (33) and Ott et al. (21) also found improved feed conversion ratio in finishing lambs fed organic Zn compared to the control group. It is documented that the bioavailability of organic zinc is higher than inorganic (7,9 and 15). The available source of zinc in the local markets that supplemented in the current experiment was inorganic. This could be the reason that there was no effect of zinc supplementation on dry matter intake, feed conversion ratio and daily weight gain.

Conclusion

Adding Zinc to the fresh drinking water was significantly improved rumination, feeding duration and the number of visiting feed in lambs during heat stress. However, this addition with water had no effect on standing time, lying time, standing bouts, dry matter intake, water intake, daily body weight gain and feed conversion ratio in lambs during hot climate. This means that inorganic zinc supplementation with water had no effect on lamb performance improvement during hot climate.

REFERENCES
1. Abbi, A. 2020. Factors affecting the response of pregnant and lactating ewes to vitamin E supplementation. (Doctoral dissertation, Harper Adams University)
2. Abdoun, K.A., Okab, A.B., El-Waziry, A.M., Samara, E.M. and Al-Haidary, A.A., 2013. Dietary supplementation of seaweed (Ulva lactuca) to alleviate the impact of heat stress in growing lambs. Pak. Vet. J., 34, 108-111
3. Baumgard, L.H. and Rhoads Jr, R.P., 2013. Effects of heat stress on postabsorptive metabolism and energetics. Annu. Rev. Anim. Biosci., 1(1), 311-337
4. Cook, N.B., R.L., Mentink, B.T. Bennett, and K.,Burgi, 2007. The effect of heat stress
and lameness on time budgets of lactating dairy cows. Journal of Dairy Science, 90(4), 1674-1682
5. Dezfoulian, A.H., H., Aliarabi, M.M., Tabatabaei, P., Zamani, D., Alipour, A. Bahari, and A., Fadyiifar, 2012. Influence of different levels and sources of copper supplementation on performance, some blood parameters, nutrient digestibility and mineral balance in lambs. Livestock Science, 147(1-3), 9-19
6. Di Trana, A., P., Celi, S., Claps, V. Fedele, and R., Rubino, 2006. The effect of hot season and nutrition on the oxidative status and metabolic profile in dairy goats during mid lactation. Animal Science, 82(5), 717-722
7. Garg, A.K., V. Mudgal, and R.S., Dass, 2008. Effect of organic zinc supplementation on growth, nutrient utilization and mineral profile in lambs. Animal Feed Science and Technology, 144(1-2), 82-96
8. Halliwell, B., and J.M.C. Gutteridge, 1990. Role of free radicals and catalytic metal ions in human disease: An overview. Methods Enzymol. 186:1–85.
9. HAYman Ahmed, H., A. Ghada Mostafa El, and S., Soliman Mohamed, 2011. Effect of supplementation of chelated zinc on milk production in ewes. Food and Nutrition Sciences, 2011
10. Hedgepeth, C.M., L.J.,Conrad, J., Zhang, H.C., Huang, V.M. Lee, and P.S., Klein, 1997. Activation of the Wnt signaling pathway: a molecular mechanism for lithium action. Developmental Biology, 185(1), 82-91
11. Jenkins, K.J. and M., Hidiroglou, 1991. Tolerance of the preruminant calf for excess manganese or zinc in milk replacer. Journal of Dairy Science, 74(3),1047-1053
12. Kak, H.F., S.H. Al-Doski, and V.J., Taha, 2020. Effect of implanting zeranol on growth and carcass characteristics of awassi lambs and goat kids raised under commercial condition. The Iraqi Journal of Agricultural Science, 51(5), 1321-1328
13. Karki, U. and M.S., Goodman, 2015. Microclimatic differences between mature loblolly-pine silvopasture and open-pasture. Agroforestry Systems, 89(2), 319-325
14. Maia, G.G., L.G.B., Siqueira, C.O., de Paula Vasconcelos, T.R.,Tomich, L.S., de Almeida Camargo, J.P.P., Rodrigues, R.A., de Menezes, L.C., Goncalves, B.F.,Teixeira, R., de Oliveira Grando, and L.A.G., Nogueira, 2020. Effects of heat stress on rumination activity in Holstein-Gyr dry cows. Livestock Science, 239, 104092
15. Mallaki, M., Norouzian, M.A. and Khadem, A.A., 2015. Effect of organic zinc supplementation on growth, nutrient utilization, and plasma zinc status in lambs. Turkish Journal of Veterinary and Animal Sciences, 39(1), 75-80
16. Marai, I.F.M., El-Darawany, A.A., Fadiel, A. and Abdel-Hafez, M.A.M., 2007. Physiological traits as affected by heat stress in sheep a review. Small Ruminant Research, 71(1-3), 1-12
17. McDonald, C.L., Norris, R.T., Speijers, E.J. and Ridings, H., 1990. Feeding behaviour of Merino wethers under conditions similar to lot-feeding before live export. Australian Journal of Experimental Agriculture, 30(3), 343-348
18. Montelli, L., N.L. Lins N.L., de Almeida A.K., Ribeiro C.R. de F., Grobe M.D., Abrantes M.A.F., Lemos G.S., Furusho Garcia I.F., and Pereira I.G. 2019. Performance, feeding behavior and digestibility of nutrients in lambs with divergent efficiency traits. Small Rumin. Res. 180:50–56.
19. Naji, H.A., 2017. The effect of zinc and copper deficiency on hematological parameters, oxidative stress and antioxidants levels in the sheep. Basra J. Vet. Res, 16(2), 344-355
20. Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S. and Bernabucci, U., 2010. Effects of climate changes on animal production and sustainability of livestock systems. Livestock Science, 130(1-3), 57-69
21. Ott, E.A., Smith, W.H., Stob, M. and Beeson, W.M., 1964. Zinc deficiency syndrome in the young lamb. The Journal of Nutrition, 82(1), 41-50
22. Pent, G.J., Greiner, S.P., Munsell, J.F., Tracy, B.F. and Fike, J.H., 2020. Lamb performance in hardwood silvopastures, II: animal behavior in summer. Translational Animal Science, 4(1), 363-375
23. Rice, M., Jongman, E.C., Butler, K.L. and Hemsworth, P.H., 2016. Relationships between temperament, feeding behaviour, social interactions, and stress in lambs.
adapting to a feedlot environment. Applied Animal Behaviour Science, 183, 42-50
24. Saker, K.E., Fike, J.H., Veit, H. and Ward, D.L., 2004. Brown seaweed-(TascoTM) treated conserved forage enhances antioxidant status and immune function in heat-stressed wether lambs. Journal of Animal physiology and animal nutrition, 88(3-4), 122-130
25. Salama, A.A., Caja, G., Albanell, E., Such, X., Casals, R. and Plaixats, J., 2003. Effects of dietary supplements of zinc-methionine on milk production, udder health and zinc metabolism in dairy goats. Journal of Dairy Research, 70(1), 9-17
26. Savage, D.B., Ferguson, D.M., Fisher, A.D., Hinch, G.N., Mayer, D.G., Duflou, E., Lea, J.M., Baillie, N.D. and Raue, M., 2008. Preweeding feed exposure and different feed delivery systems to enhance feed acceptance of sheep. Australian Journal of Experimental Agriculture, 48(7), 1040-1043
27. Scaglia, G. and Boland, H.T., 2014. The effect of bermudagrass hybrid on forage characteristics, animal performance, and grazing behavior of beef steers. Journal of Animal Science, 92(3), 1228-1238
28. Sefdeen, S.M., 2021. Effect of dietary iron in presence of sulphur on some liver mineral concentrations and performance of growing lambs. Iraqi Journal of Agricultural Sciences, 52(1), 1-9
29. Silanikove, N., 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. Livestock Production Science, 67(1-2), 1-18
30. Sunil Kumar, V.B., K. Ajeet, and K. Meena. 2011. Effect of Heat Stress in Tropical Livestock and Different Strategies for Its Amelioration. J. Stress Physiol. Biochem. 7:45–54
31. Suttle, N.F., 2010. The mineral nutrition of livestock-4-th ed. Wallingford, Oxfordshire: CABI Publishing, 2010, 600
32. Taher, K.N. and Ali, A.H., 2016. Determination of some heavy metals residues in raw milk of cows, sheep and goats in al-qadisiya governorate. Iraqi Journal of Agricultural Sciences, 47(4).
33. Underwood, E.J. and Somers, M., 1969. Studies of zinc nutrition in sheep. I. The relation of zinc to growth, testicular development, and spermatogenesis in young rams. Australian Journal of Agricultural Research, 20(5), 889-897
34. WBV, S.K., Ajeet, K. and Meena, K., 2011. Effect of heat stress in tropical livestock and different strategies for its amelioration. Journal of Stress Physiology & Biochemistry, 7(1).
35. Williams, J.E., Spiers, D.E., Thompson-Golden, L.N., Hackman, T.J., Ellersieck, M.R., Wax, L., Colling, D.P., Corners, J.B. and Lancaster, P.A., 2009. Effects of Tasco in alleviation of heat stress in beef cattle. The Professional Animal Scientist, 25(2), 109-117
36. Yadav, B., Singh, G., Wankar, A., Dutta, N., Chaturvedi, V.B. and Verma, M.R., 2016. Effect of simulated heat stress on digestibility, methane emission and metabolic adaptability in crossbred cattle. Asian-Australasian Journal of Animal Sciences, 29(11), 1585
37. Zebari, H.M. 2019. Investigations of factors that influence oestrus expression in dairy cattle. Harper Adams University.