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

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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 T_1 (0 mg Zn/day), T_2 (36 mg Zn/day) and T_3 (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 ($P \leq 0.05$) higher in T_2 than T_1 and T_3 groups. However, no-differences were noticed among T_1, T_2 and T_3 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.

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

تأثير إضافة الزنك الى الماء في أداء وسلوك الحملان المرباة في المناخ الحار

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المستخلص
أجريت هذه التجربة لمعرفة فيما إذا كان اضافة الزنك الى مياه الشرب سيحسن من أداء وسلوك الحملان في المناخ الحار. تم إيواء 27 حملًا داخل حظائر فردية (1.50 × 1.30 م)، وتمت إضافة الزنك إلى مياه الشرب العذبة بثلاثة مستويات مختلفة T_1 (بدون اضافة زنك؛ 0 ملغم زنك / يوم) وT_2 (36 ملغم زنك / يوم) وT_3 (72 ملغم زنك / يوم). تم تسجيل الاجترار (دقيقة/ساعة)، ووقت التغذية (دقيقة/ساعة)، وعدد مرات الزيارة العلف (العدد/ساعة)، ووقت الوقوف (دقيقة/ساعة)، ووقت الأسترخاء (دقيقة/ساعة) والنوبات الوقوف (العدد/ساعة) ثلاث مرات في اليوم عن طريق المشاهدة البصرية. كما تم تسجيل كمية المادة الجافة المتناولة (كغم / يوم) وكمية مياه الشرب (لتر/ يوم) وزيادة الوزن الحي اليومي وكفاءة التحويل الغذائي .أشارت نتائج التجربة الحالية إلى أن الاجترار، وقت التغذية وعدد مرات زيارة العلف كانت أعلى معنويا في مجموعة T_2 مقارنة بالمجاميع T_1 و T_3، ومن جانب اخرانعدمت الفروق المعنوية بين مجاميع الحملان T_1 و T_2 و T_3 فيما يتعلق بوقت الوقوف، ووقت الأسترخاء، ونوبات الوقوف، والمادة الجافة المتناولة، وكمية الماء المتناول، وزيادة الوزن الحي اليومي، وكفاءة التحويل الغذائي. نستنتج بأنه إضافة الزنك لمياه الشرب العذبة أدى إلى تحسين الاجترار ومدة التغذية ورقم زيارة العلف.

الكلمات المفتاحية: الزنك؛ زيادة الوزن، سلوك الحمل، وقت الأكل، اجترار

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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 lake 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 T_1 (0 mg/day), T_2 (36 mg/day) and T_3 (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 T_1, T_2 and T_3 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 [20]th 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), 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 DISCUSSTIONS

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 T_2 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 T_2 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 T_2 lambs' group than T_1 and T_3 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 T_2 lambs' group compared to T_1 and T_3 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 T_2 lambs' group than T_1 and T_3 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 water reduces the impact of heat stress on the lamb (30).

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)and (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 T_1, T_2 and T_3 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 T_1, T_2 and T_3 lambs. Although the number of feeding bouts in the present was higher in T_2 than T_1 and T_3 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	7.69^{a}	14.4^{b}	5.55^{a}	1.566	<0.001
W4	6.87^{a}	11.5^{b}	5.15^{a}	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	7.86^{b}	10.8^{a}	6.24^{c}	0.770	<0.001

T_1= control (0 mg Zn/day), T_2 (36 mg Zn/day) and T_3 (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	6.89^{a}	12.0^{b}	8.06^{ab}	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	4.31^{a}	8.12^{b}	3.95^{a}	1.583	0.027
Overall mean m/h	6.44^{c}	10.5^{a}	7.82^{b}	0.689	<0.001

T_1= treatment one (0 mg Zn/day), T_2 (36 mg Zn/day) and T_3 (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	1.04^{a}	1.81^{b}	1.22^{a}	0.238	0.009
W5	1.20	1.20	1.10	0.240	0.875
W6	0.87^{a}	1.31^{b}	0.87^{a}	0.186	0.037
Overall mean n/h	1.33^{b}	1.58^{a}	1.31^{b}	0.100	0.010

T_1= control (0 mg Zn/day)), T_2 (36 mg Zn/day) and T_3 (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

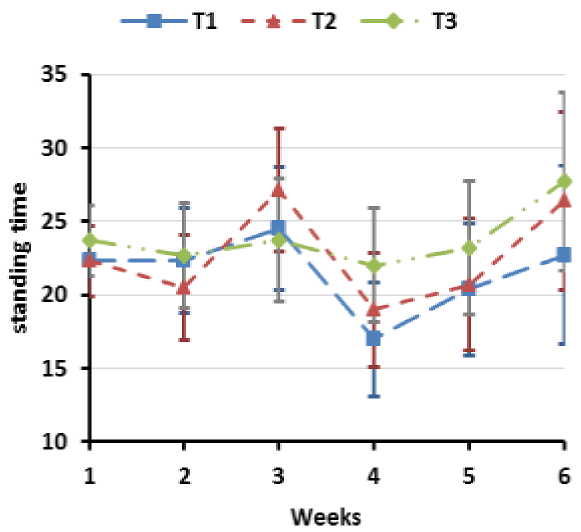

Figure 1. The effect of adding zinc to the drinking water on lamb standing time during hot climate season. Error bars indicate SED

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

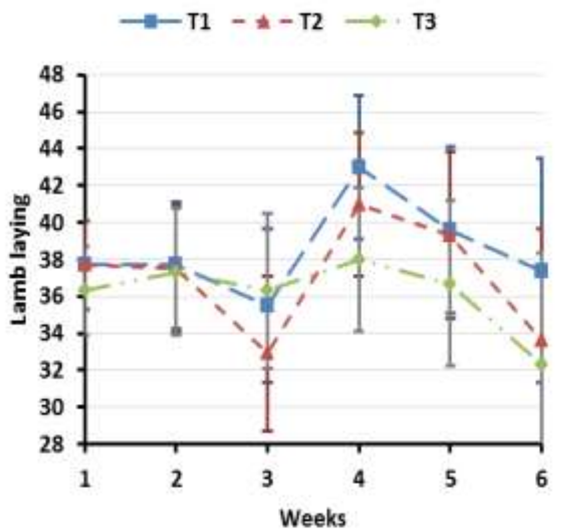

Figure 2. The effect of adding zinc to the drinking water on lamb laying time during hot climate season. Error bars indicate SED

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.

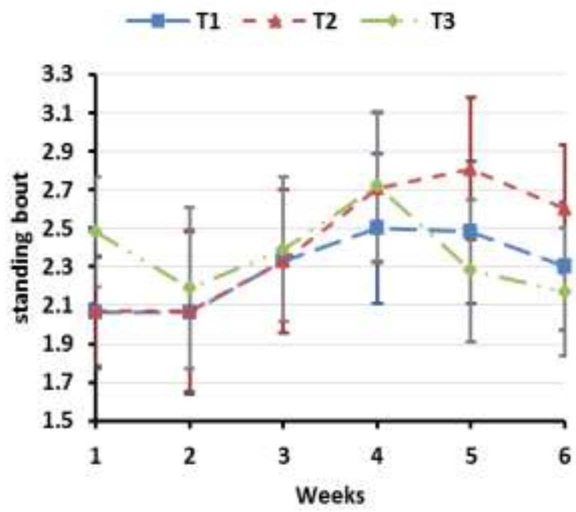

Figure 3. The effect of adding zinc to the drinking on lamb standing bout during hot climate season. Error bars indicate SED

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

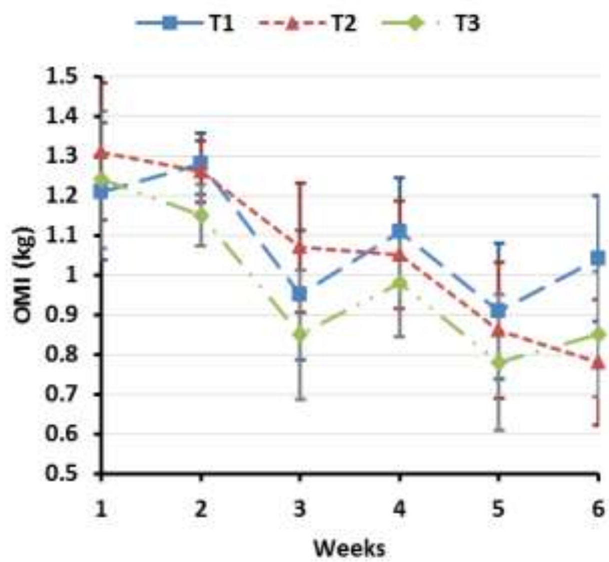

Figure 4. The effect of adding zinc to the drinking water on lamb feed DMI intake during hot climate season. Error bars indicate SED

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

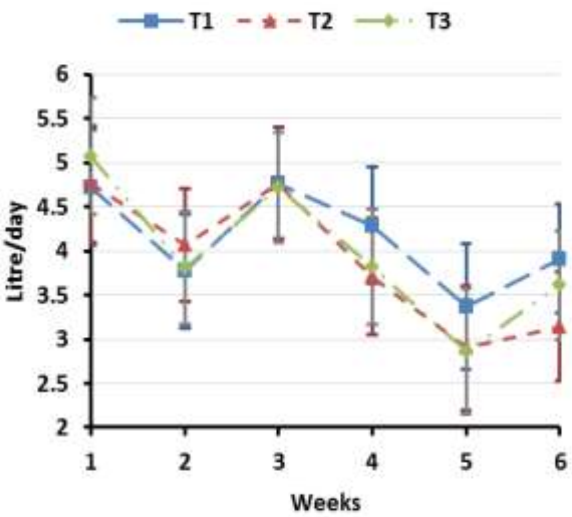

Figure 5. The effect of adding zinc to the drinking water on lamb water intake during hot climate season. Error bars indicate SED
T_1= control (0 mg Zn/day), T_2 (36 mg Zn/day) and T_3 (72 mg Zn/day), Repeated measures analysis: SED values: T= 0.5979, Time= 0.165, T×Time=0.6523; P-values: T= 0.916, Time= <.001, Time×T=0.233

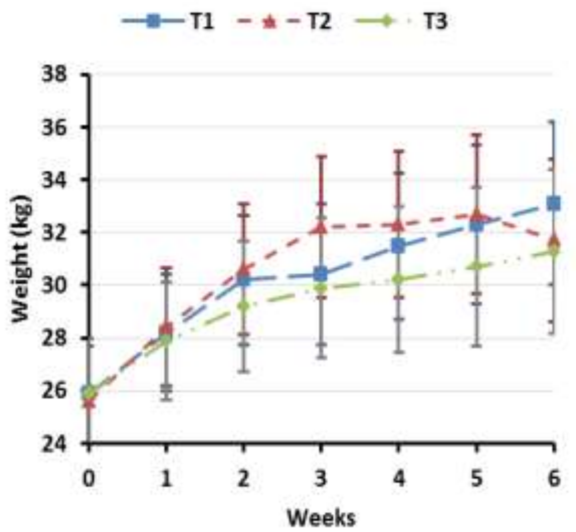

Figure 6. The effect of adding zinc to the drinking water on lamb live weight during hot climate season. Error bars indicate SED
T_1= control (0 mg Zn/day), T_2 (36 mg Zn/day) and T_3 (72 mg Zn/day), Repeated measures analysis: SED values: T= 2.546, Time= 0.456, T×Time=2.649; P-values: T= 0.889, Time= <.001, Time×T=0.28

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
	T1	T2	T3		
DMI kg/d	1.08	1.06	0.97	0.102	0.560
Water intake L/d	4.14	3.89	3.98	0.165	0.916
Bodyweight gain g/d	171	144	149	39.10	0.576
FCR (kg feed/1kg gain)	6.45	6.35	6.65	1.024	0.389

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.

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