Special Issue:
Emerging and Re-emerging Animal Health Challenges in Low and Middle-Income Countries

Coenzyme Q10 and Zinc Methionine Treatment Impact Productive and Hematological Traits in Awassi Lambs

Abdulkhaliq Ahmed Farhan Al-Janabi*, Nawar Bahaa Abduljabbar, Mohammed A. Amean

Animal Production Department, College of Agriculture, Tikrit University, Tikrit, Iraq.

Abstract | To determine the potential of Coenzyme Q10 and Zinc Methionine supplementation in affecting productive and hematological traits in Awassi lambs, this study was executed. In this study, a total of 20 Awassi lambs were used that ranged from 4 to 4.5 months old and weighed an average of 21.71± 0.34 kg. Animals were allocated into five different treatment groups randomly. The first group received distilled water, but animals in the second group drank Coenzyme Q10 mixed with water at 25 mg/5 ml and those in the third group consumed 50 mg/5 ml water mixture. The fourth group received 25 mg of Coenzyme Q10 mixed with 5 ml water per animal plus 150 mg zinc per animal while the fifth group received 50 mg of Coenzyme Q10 mixed with 5 ml water per animal together with 150 mg zinc per animal. The study presented statistically significant enhancements ($P \leq 0.05$) in final weight, total weight gain for animals receiving the third and fifth treatments when compared to animals in other groups. The fifth treatment group's animals demonstrated significant increases in red blood cell count as well as hemoglobin concentration and packed cell volume after 90 days compared to the control group. The values of red blood cell indices (MCV, MCH, MCHC) remained unchanged across all five groups. The data showed significantly lower total white blood cell counts along with neutrophil levels and stress indices in animals who received the fifth, fourth, and third treatments compared to the control group ($P \leq 0.05$). The lymphocyte percentage showed a significant increase ($P \leq 0.05$) in treated animals compared to the control group after 90 days but eosinophils, basophils and mononuclear white blood cells remained unchanged through Coenzyme Q10 and Zinc Methionine treatments.

Keywords | Coenzyme Q10, Zinc methionine, Productive and hematological traits, Awassi lambs

Received | October 28, 2025; **Accepted** | December 15, 2025; **Published** | December 22, 2025
***Correspondence** | Abdulkhaliq Ahmed Farhan Al-Janabi, Animal Production Department, College of Agriculture, Tikrit University, Tikrit, Iraq; **Email:** dr.abdalkhalid45@tu.eud.iq
Citation | Al-Janabi AAF, Abduljabbar NB, Amean MA (2025). Coenzyme Q10 and zinc methionine treatment impact productive and hematological traits in Awassi lambs. J. Anim. Health Prod. 13(s1): 945-953.
DOI | https://dx.doi.org/10.17582/journal.jahp/2025/13.s1.945.953
ISSN (Online) | 2308-2801

INTRODUCTION

The Awassi sheep breed has a broad distribution across multiple Middle Eastern nations (Tabbaa *et al*., 2006). Awassi sheep demonstrate prominent meat production quality while showing high resilience against tough environmental and dietary situations (Merchen and Titgemeyer, 1992). The decline of animal nutrition leads to diminished production capabilities which requires the implementation of various enriched nutritional options. These nutritional additions are intended to boost the animals' nutritional value while simultaneously improving productivity and strengthening their health and immune systems (Steen *et al*., 2008; Khan *et al*., 2010).

Researchers now study how adding antioxidants and mineral components to animal feed can protect cellular structures from free radicals while also improving animal

health alongside reproductive capabilities and production efficiency (Hassan et al., 2021; Balani *et al.*, 2018; El-Nagar and Wafa, 2021). Antioxidants maintain a crucial function by either stopping free radicals from forming due to biological processes in the body or moderating their harmful impacts (Videla *et al.*, 2004; Law *et al.*, 2018). Coenzyme Q10 functions as an antioxidant and is naturally found in living organisms including both macro and microorganisms. The body is capable of producing coenzyme Q10 which functions as a fat-soluble antioxidant (Littarru *et al.*, 2016). The mitochondrial energy production process depends on Coenzyme Q10 which functions as an electron and proton transporter during oxidative phosphorylation (Shukla and Dubey, 2018). This substance defends cellular membranes and plasma lipid proteins against lipid peroxidation damage and helps restore other antioxidants such as vitamins E and C (Gvozdjáková *et al.*, 2015).

Animal feed contains essential trace minerals whose bioavailability remains restricted and fails to fulfill the nutritional needs of animals according to Princewill *et al.* (2015). Rare minerals in animal feed become inaccessible for animal consumption because chemical compounds like phytates, oxalates, and tannins bind with them and prevent absorption which leads to nutritional deficiencies (Hummel *et al.*, 2020). The repetitive farming practices along with grazing and deforestation activities have made the soil deficient in essential minerals which causes forage crops to become deficient as well (Datt and Chhabra, 2005). Research demonstrates that supplementing animal feed with suitable quantities of rare trace minerals enhances nutritional metabolism and growth while supporting reproduction and eliminating free radicals from oxidative stress through their role in enzymatic functions or as enzyme cofactors. The research by Yatoo *et al.* (2013) demonstrates that these minerals strengthen immune response functions.

Zinc serves as a vital element for growth promotion, immune function enhancement, cell division processes, protein synthesis, surface tissue integrity maintenance, antioxidant activity and hormone secretion regulation (Krishnaiah *et al.*, 2019). Field animals rarely experience zinc toxicity because they can handle high amounts of zinc in their food sources according to studies by McDowell (1992) and NRC (1996). This investigation seeks to determine how Coenzyme Q10 and Zinc Methionine supplements affect productive and hematological traits in Awassi.

MATERIALS AND METHODS

The experiment took place at the University of Tikrit's College of Agriculture Animal Production Department animal field from March 8 to June 5, 2023. For this research, a total of 20 local Awassi animals were used which ranged in age between 4 and 4.5 months and had an average weight of 21.71 ± 0.34 kg. divided these animals into five treatment groups, where the first group received distilled water while the second and third groups received Coenzyme Q10 at 25 mg and 50 mg doses, respectively, in 5 ml of water per animal. Groups four and five received combined treatments with Coenzyme Q10 and Zinc Methionine at doses of 25 mg of Q10 plus 150 mg of zinc methionine per 5 ml water per animal and a second dose of 50 mg of Q10 plus 150 mg of zinc methionine per 5 ml water per animal, respectively.

Throughout a 14-day acclimatization period closely monitored these animals to prevent health problems. The animals received a concentrated feeding mixture made of crushed barley (50%), crushed yellow corn (25%), soybean meal (13%), bran (10%), limestone (1%), and table salt (1%). The diet contained 14.4125% crude protein content while delivering 287,305 kcal/kg of energy content. Each treatment group received their provender, which constituted 3% of its live weight, split between morning and evening meals. Every two weeks, feed quantities were modified according to weight changes while animals had unlimited access to roughage (straw). Each pen received a clean water supply along with mineral salt blocks placed throughout all pens. Blood samples were regularly collected every forty-five days at 7: During a 12-hour fasting period. Blood samples from the jugular vein in animal necks at 7:30 AM were collected into clean and sterilised plastic tubes using a 10 ml sterile syringe.

Blood tests

Red blood corpuscles count

The measurement of red blood cell count was conducted using a hemocytometer slide. by using a specialised pipette to draw blood until the 0.5 mark before reaching the 101 mark with Hyme's solution. prepared a counting slide after swirling the pipette contents gently for ten seconds. Three initial blood drops were discarded before depositing the fourth drop at the counting slide's edge and covering it with a cover slide. waited two minutes to let the cells settle and stabilise. Through a light microscope at 40x magnification counted the cells present in five standard squares. 16 smaller squares were present within each average square according to Hughes *et al.* (2004). The total red blood cell was counted by implementing this formula:

$$RBC\ (mm^3\ of\ blood) = Number\ of\ cells\ in\ five\ average\ squares \times 200\ (dilution\ correction\ factor) \times 50\ (volume\ correction\ factor)$$

The process to measure packed red blood cell volume involved using open-ended capillary glass tubes inclined

at a 45-degree angle without anticoagulants to determine the packed red blood cell volume percentage. Once the tube reached three-quarters of its capacity, sealed at the submerged ends with synthetic clay. The tubes were placed in a Micro-Hematocrit centrifuge and rotated at 10000 revolutions per minute for five minutes. A specialised Hematocrit reader was used to measure the blood sediment length in the capillary tube. The measurement recorded represents the percentage of packed red blood cell volume according to Hughes *et al*. (2004).

Blood hemoglobin concentration

Using an apel spectrophotometer type at 540nm measured blood hemoglobin concentration was measured through the Drabkin and Austin method 193,5 following Randox Laboratory Co. Ltd's guidelines from Antrim, United Kingdom, for their analysis kit as described by Coles (1986). computed blood hemoglobin levels by applying this specific equation.

The blood hemoglobin concentration in grams per 100 mL of blood equals the sample reading on the device divided by the standard solution reading, multiplied by the dilution factor, then multiplied by the standard hemoglobin solution concentration and divided by 1000.

Red blood cell indices

These were calculated using the following equations:

- The Mean Corpuscular Volume (MCV in cubic micrometres) is calculated by dividing the volume of packed red blood cells by the red blood cell count and multiplying the result by 10.
- The MCH value in picograms is calculated by dividing the Hemoglobin Concentration by the Red Blood Cell Count and multiplying the result by 10.
- The calculation for Mean Corpuscular Hemoglobin Concentration (MCHC% %) requires dividing the Hemoglobin Concentration by the Volume of Packed Red Blood Cells and multiplying the result by 100.

White blood cell count

To count white blood cells with a hemocytometer slide the blood sample was drawn up to the 0.5 mark using a specialised pipette, followed by filling up to the 11th mark with Turk's Solution. The sample was allowed to remain unstirred for three minutes to enable staining of the white blood cell nuclei after mixing its contents by hand for ten seconds. The counting slide preparation included discarding the first three drops and placing the fourth drop beside the counting chamber cover. The sample was left for two minutes until the cells settled and stabilised before examination through a light microscope at X40 magnification. The following formula allowed for calculating the total white blood cell count.

WBC (cells/mm^3 of blood) = Number of Cells in the Central Large Square × 20 (dilution correction factor) × 10 (volume correction factor)

The process for determining the differential white blood cell count involved making a blood smear. A small blood drop was positioned on the corner of a glass slide, and another slide spread it to form an even layer. The smear dried completely after ten minutes before being fixed by placing it into methyl alcohol (0.97 N). The slides underwent half an hour of staining through immersion with Gamsa stain, which was prepared beforehand and detailed. The slides were cleaned of excess stain with gentle tap water washing. Under a light microscope with an oil immersion lens (X 100 examined) white blood cells, including Lymphocytes, Monocytes, Neutrophils, Eosinophils and Basophils. moved the slide along a Z-shaped path to count 100 white blood cells (Sood, 1985).

Statistical analysis

The performed statistical analysis through Complete Randomised Design (CRD), which followed a one-way path. The statistical significance of treatment differences was evaluated using Duncan's multiple range test as reported by Duncan in 1955 and conducted statistical analysis through the SAS software version 2012. The following mathematical model served as the basis for data analysis.

$$Yij = \mu + Ti + eij$$

Where: Yij denotes the jth observational data point from treatment i. The effect of treatment i corresponds to index I, which includes control as 1, second as 2, third as 3, fourth as 4, and fifth as 5. Experimental error eij maintains normal distribution properties while being independent with a zero mean and variance of ∈2σ.

RESULTS AND DISCUSSION

Impact of enzyme COQ10 and zinc methionine on productive performance in Awassi lambs

As shown in the Table 1, there was no statistically significant differences (P≥0.05) in the body weight of Awassi lambs between treatments at the 28th day of study. At day 56, body weight measurements showed no significant differences between treatments, yet animals from the fifth treatment demonstrated significant improvement over treatments one, two, and four, along with improvements noted in the third and fourth treatments. Treatment three showed no significant variance when compared to other treatments. The final weight analysis revealed significant differences (P≤0.05) between the groups, showing that animals in the fifth treatment gained significantly more weight than those in treatments one, two, and four but displayed no significant weight difference when compared to treatment three.

Table 1: The effect of treatment with enzyme coenzyme Q10 and zinc methionine on productivity in Awassi lambs.

Significance level	Treatments					Traits
	Fifth (T5)	Fourth (T4)	Third (T3)	Second (T2)	First (T1)	
N.S	21.93 ± 0.55 a	22.25 ± 0.81 a	21.60 ± 0.53 a	21.18 ± 1.29 a	21.40 ± 0.61 a	Initial Weight (kg)
N.S	25.30 ± 0.36 a	25.45 ± 0.72 a	24.73 ± 0.38 a	24.35 ± 1.6 a	24.00 ± 0.67 a	Weight after 28 days (kg)
N.S	29.95 ± 0.63 a	29.28 ± 0.72 a	29.23 ± 0.17 a	28.70 ± 1.00 a	27.68 ± 0.88 a	Weight after 56 days (kg)
**	34.68 ± 0.28 a	32.65 ± 0.93 bc	33.55 ± 0.49 ab	31.83 ± 0.77 c	30.80 ± 0.89 c	Final Weight (kg)
**	151.79 ± 7.51 a	121.43 ± 5.30 bc	142.26 ± 7.93 ab	126.78±6.81 bc	111.90± 10.7 c	Total Weight Gain (kg)

The values represent means ± standard error. N.S. means no significant differences (P ≥ 0.05). Means significant differences (P ≤ 0.05). ** means highly significant differences (P ≤ 0.01). T1 = Control, T2 = Enzyme Coenzyme Q10 25 mg/animal, T3 = Enzyme Coenzyme Q10 50 mg/animal, T4 = Enzyme Coenzyme Q10 25 mg/animal + 150 mg/animal Zinc Methionine, T5 = Enzyme Coenzyme Q10 50 mg/animal + 150 mg/animal Zinc Methionine.

Table 1 illustrates that CoQ10, along with zinc methionine treatment, produced significant results in total weight gain among the five Awassi lamb groups. The fifth treatment group exhibited a significant weight gain (P≤0.05) when compared to treatment groups one, two, and four, but showed no significant difference when compared to treatment three. Zinc in the fifth treatment appears to promote body weight gain because it boosts ghrelin secretion from the stomach and gastrointestinal tract lining. The peptide Ghrelin opposes leptin's effects by triggering the release of appetite-inducing peptides Neuropeptide Y (NP-Y), Agouti-related peptide (AgRP), Orexin and Galanin from the arcuate nucleus within the hypothalamus. Adipose tissues produce less leptin when ghrelin is present, as shown in research by Zhang and Guo (2008) and Kharbanda *et al.* (2022).

Zinc protects pancreatic tissues from oxidative damage while enabling proper pancreatic functionality including digestive enzyme secretion which improves digestion and prevents an energy deficit that causes stress (Wang *et al.*, 2021). Animal weight gain results from zinc's ability to break down cellulose bonds in feed, which activates rumen microorganisms and improves microbial balance in the rumen environment. Enhanced feed conversion efficiency along with muscle tissue deposition during growth results from this (Ballantine *et al.*, 2002; Hilal *et al.*, 2016). The results align with the outcomes of research done by Mallaki *et al.* (2015) study discovered that Zandi animals fed with zinc- supplemented feed showed significant daily weight gain improvements compared to their control group counterparts. Similarly, Jafarpour *et al* (2015) and collaborators discovered that feeding sheep with various amounts of Zn-Met led to higher final weight and total weight gain, and daily weight gain than the control group.

The current study results are consistent with the found made by Towaje *et al.* (2018), goats experienced significant gains in final weight, total weight gain, and daily weight gain when fed diets supplemented with zinc at concentrations of 0, 15, 20, and 25 mg zinc/kg dry matter. The female goats in the four study groups achieved final weights of 27.75 kg, 28.44 kg, 29.84 kg, and 28.55 kg while their total weight gains amounted to 9.82 kg, 11.21 kg, 12.04 kg, and 11.15 kg, respectively with daily weight increases of 155 g/day, 177 g/day, 191 g/day, and 176 g/day, demonstrated substantial enhancements in final weight alongside daily and total weight gain in animals administered with Zn-Met relative to their control counterparts (Alimohamady *et al*, 2019). According to Mani *et al.* (2021), feeding calves zinc supplements at rates of 40 and 80 mg/kg dry matter over 90 days produced better growth performance metrics for body weight, daily weight gain, and body length compared to the control group. The study by Belewu and Adewumi (2021) demonstrated greater final body weight and daily weight gain in goats receiving 80 mg/kg zinc in their diet over 56 days versus other treatment groups.

The research by Al-Taie and Almahdawi (2021) demonstrated that Awassi animals receiving 50 mg of zinc per head three times weekly for 90 days showed significant increases in final body weight and daily and total weight gain when compared to control and selenium-treated groups. Ali *et al.* (2023) found that animals receiving nano-zinc at 6 and 12 mg/kg feed gained significant body weight, along with daily weight gain and total weight gain over 98 days, compared to the control group.

Effect of enzymatic co-treatment with Q10 and zinc methionine on some physiological blood parameters in Awassi lambs

Red blood cells, packed cell volume, and hemoglobin

The results showed no significant differences in red blood cell counts, packed cell volume and hemoglobin concentration of Awassi lambs between five treatments when enzymatic co-treatment with Q10 and zinc methionine was performed during the initial 45 days of treatment. The treatment showed a significant impact (P ≤ 0.05) on red blood cell counts in the second treatment phase that lasted 90 days. The animals undergoing the fifth treatment exhibited a significant rise (P ≤ 0.05) in red blood cell numbers when compared to those in the first two

Table 2: The effect of enzymatic co-treatment with Q10 and zinc methionine on some physiological blood parameters in Awassi lambs.

Significance	Treatments					Period	Traits
	Fifth (T5)	Fourth (T4)	Third (T3)	Second (T2)	First (T1)		
N.S	13.19±0.31a	12.54±0.21a	13.01±0.45a	12.39±0.48a	12.27±0.42a	First (after 45 days)	R.B.C count x 10^6
*	14.35±0.30a	13.59±0.23ab	14.14±0.38ab	13.23± 0.36b	13.10±0.36b	Second (after 90 days)	
N.S	31.75±0.85a	30.50±1.19a	31.25±0.75a	30.50± 1.32a	30.25±0.63a	First (after 45 days)	Packed cells volume
*	33.00±0.91a	32.25±1.11ab	32.75±0.63a	31.25±0.63ab	30.00±0.71b	Second (after 90 days)	
N.S	9.47±0.23a	9.39±0.33a	9.40±0.18a	9.24±0.36a	9.24±0.40a	First (after 45 days)	Blood hemoglobin gm/100 ml
*	10.70±0.28a	10.47±0.34ab	10.62±0.19a	10.17±0.19ab	9.79±0.21b	Second (after 90 days)	

The values represent means ± standard error. N.S. means no significant differences (P ≥ 0.05), means significant differences (P ≤ 0.05). Treatment Groups: T1 = Control, T2 = Enzymatic assistant Q10 25 mg/animal, T3 = Enzymatic assistant Q10 50 mg/animal, T4 = Enzymatic assistant Q10 25 mg/animal + 150 mg/animal zinc methionine, and T5 = Enzymatic assistant Q10 50 mg/animal + 150 mg/animal zinc methionine.

Table 3: Effect of enzymatic assistant Q10 and zinc methionine treatment on some red blood cell indices in Awassi lambs.

Significance	Treatments					Period	Traits
	Fifth (T5)	Fourth (T4)	Third (T3)	Second (T2)	First (T1)		
N.S	24.11 ± 0.76 a	24.35 ± 1.01 a	24.12 ± 1.10 a	24.67 ± 1.07 a	24.70 ± 0.55 a	First (after 45 days).	MCV (fl)
N.S	23.01 ± 0.67 a	23.74 ± 0.80 a	23.24 ± 0.93 a	23.65 ± 0.38 a	22.93 ± 0.37 a	(after 90 days)	
N.S	7.18 ± 0.06 a	7.49 ± 0.23 a	7.25 ± 0.27 a	7.50 ± 0.47 a	7.53 ± 0.13 a	Second (after 45 days)	MCH (Pg)
N.S	7.46 ± 0.21 a	7.71 ± 0.25 a	7.54 ± 0.29 a	7.70 ± 0.13 a	7.48 ± 0.12 a	(after 90 days).	
N.S	29.90± 1.16 a	31.02 ± 2.07 a	30.12 ± 0.98 a	30.49 ± 1.91 a	30.54 ± 1.05 a	First (after 45 days)	MCH (%)
N.S	32.42 ± 0.06 a	32.47 ± 0.08 a	32.44 ± 0.04 a	32.54 ± 0.04 a	32.63 ± 0.06 a	Second (after 90 days).	

The values represent the means ± standard error. N.S. means no significant differences (P ≥ 0.05). T1 = Control, T2 = Enzyme Co-Adjuvant Q10 25 mg/animal, T3 = Enzyme Co-Adjuvant Q10 50 mg/animal, T4 = Enzyme Co-Adjuvant Q10 25 mg/animal + 150 mg/animal Zinc Methionine, T5 = Enzyme Co-Adjuvant Q10 50 mg/animal + 150 mg/animal Zinc Methionine.

treatments but showed no statistical differences when compared to groups in the third and fourth treatment groups. The third and fifth treatments showed significant increases (P ≤ 0.05) in packed cell volume percentage and hemoglobin concentration over the control group, with no notable differences when compared to the second and fourth treatments (Table 2).

The higher red blood cell counts and packed cell volume, and hemoglobin concentration found in the fifth and third treated groups result from the enzymatic assistant Q10's effect on increasing testosterone hormone levels (Al-Samarai and Al-Janabi, 2021). The testosterone hormone controls red blood cell formation through two mechanisms: It triggers erythropoietin production in the kidney and increases red blood cell production in the bone marrow (Coles, 1986). The positive changes in blood properties likely stem from improved antioxidant status that could protect red blood cells from oxidative damage during their development or after they are produced in the bone marrow, which results in better stability and size of red blood cells (Kraus *et al*., 1997). Research shows that long-term zinc supplementation can improve blood properties because zinc deficiency leads to greater osmotic fragility of red blood cells and more oxidative harm, which reduces their size (Kraus *et al*., 1997).

Zinc plays a role in two stages of blood formation. The first function of zinc in blood formation involves stimulating erythropoietin synthesis, its effect on bone marrow cells through an unidentified process that likely activates growth hormone and IGF-1 to promote red blood cell production. The absence of this enzyme contributes to the development of anemia and the dysfunction of the respiratory system, according to Lukaski's Research (2005).

This study's findings match those reported by Shareef *et al.* (2019), Song and Shen (2020) and Abdelgayed *et al.* (2022), and Yusuf *et al.* (2023). All studies conducted in 2023 demonstrated substantial enhancements in counts of red blood cells alongside packed cell volume and hemoglobin levels following zinc supplementation in animals.

Red blood cell indices

Table 3 revealed that the treatments of enzymatic assistant Q10 combined with zinc methionine did not produce significant changes in red blood cell indices (MCV, MCH, MCHC) across all treatment groups during both the 45-day and 90-day intervals.

Table 4: The effect of treatment with the coenzyme Q10 and zinc methionine on white blood cell counts and their differential count in the blood of Awassi lambs.

Significance	Treatments					Period	Traits
	Fifth (T5)	Fourth (T4)	Third (T3)	Second (T2)	First (T1)		
N.S	5.93 ± 0.37 a	5.85 ± 0.35 a	6.33 ± 0.51 a	7.15 ± 0.57 a	7.20 ± 0.43 a	First (after 45 days)	WBC count (10^3/ml)
*	5.85 ± 0.35 b	5.85±0.35ab	5.93 ± 0.37 b	7.40 ± 0.46 a	7.43 ± 0.42 a	Second (after 90 days)	
N.S	35.25±1.11 a	6.65 ± 0.26 a	35.00±1.08 a	35.75±0.75 a	36.25±0.25 a	First (after 45 days)	Neutrophil (%)
*	32.00±0.70 c	35.25±0.75bc	35.00±0.58 b	35.75±0.75ab	37.25±0.75 a	Second (after 90 days)	
N.S	4.50 ± 0.50 a	4.75 ± 0.48 a	4.75 ± 0.47 a	5.00 ± 0.58 a	5.00 ± 0.41 a	First (after 45 days)	Acidophils (%)
N.S	5.00 ± 0.40 a	5.00 ± 0.48 a	5.00± 0.41 a	5.00 ± 0.58 a	5.25 ± 0.48 a	Second (after 90 days)	
N.S	1.00 ± 0.58 a	1.25 ± 0.25 a	1.50 ± 2.29 a	1.50 ± 0.28 a	1.50 ± 0.29 a	First (after 45 days)	Basophils
N.S	1.75 ± 0.25 a	1.00 ± 0.58 a	1.50 ± 0.29 a	1.50 ± 0.28 a	1.50 ± 0.29 a	Second (after 90 days)	
N.S	54.25±0.85a	53.50±0.65 a	53.75±0.85 a	52.75±0.25 a	52.25±0.25 a	First (after 45 days)	Lymphocytes
*	55.50±0.65a	55.00±0.41ab	53.25±0.75ab	52.75±0.25 b	50.50±0.19 c	Second (after 90 days)	
N.S	5.00 ± 0.58 a	5.25 ± 0.25 a	5.00 ± 0.58 a	5.00 ± 0.58 a	5.00 ± 0.57 a	First (after 45 days)	Mononuclear white blood cells
N.S	5.75 ± 0.25 a	5.00 ± 0.57 a	5.25 ± 0.25 a	5.00 ± 0.58 a	5.50 ± 0.29 a	Second (after 90 days)	

Findings from this research matched Song and Shen (2020) because they found no significant changes in red blood cell indices for goats that received zinc supplements at 30, 60, and 90 mg/kg dry matter over 30 days compared to those in the control group. Similarly, Research by Nematpoor *et al.* (2021) demonstrated that administering 1500 mg of zinc per dairy cow daily throughout a 42-day lactation period did not produce significant changes in red blood cell indices (MCV, MCH, MCHC).

White blood cells and differential count

Table 4 showed that treatment with Q10 enzyme co-adjuvant and zinc methionine did not affect white blood cell counts in Awassi lambs after 45 days of treatment (first period). The second period (after 90 days of treatment) showed significant differences (P ≤ 0.05) with treatments three and five having a significant reduction compared to treatments one and two but remained statistically similar to treatment four. The outcomes align with findings by Yusuf *et al.* (2023) observed that Dwarf goats in West Africa showed a significant reduction in total white blood cell count when fed with 300 mg/kg of nano zinc oxide. Manimaran *et al.* Research by Manimaran *et al.* (2022) found no significant changes in total white blood cell counts among Osmanabadi goats that received daily doses of 100 mg of copper sulphate and 40 mg of zinc oxide.

The values represent the means ± standard error. N.S. indicates that there are no significant differences (P ≥ 0.05). (*) denotes significant differences (P ≤ 0.05). T1 = Control, T2 = Enzyme Coenzyme Q10 25 mg/animal, T3 = Enzyme Coenzyme Q10 50 mg/animal, T4 = Enzyme Coenzyme Q10 25 mg/animal + 150 mg/animal Zinc Methionine, T5 = Enzyme Coenzyme Q10 50 mg/animal + 150 mg/animal Zinc Methionine.

The differential white blood cell count in Awassi sheep showed no significant treatment effects on neutral, basophilic, eosinophilic, and mononuclear cells after 45 days of treatment (Table 4). The second period, after 90 days of treatment (second period), showed significant differences (P ≤ 0.05) in neutral white blood cell percentages, which decreased significantly in animals receiving the fifth treatment compared to those receiving the first and second treatments but remained unchanged compared to those treated with the fourth treatment (Table 4).

Both the third and fourth treatments demonstrated marked reductions when compared to the control group,yet showed no statistically relevant change compared to the second treatment. The elevated levels of lymphocytic white blood cells in animals receiving the fifth treatment compared to both the control group and the second treatment (Table 4). could result from the combined effects of zinc and co-adjuvant enzyme Q10. Zinc significantly activates the immune system by supporting thymus development and bone marrow maturation, according to Goswami et al. (2005). Zinc activates thymulin from the thymus gland, which binds tightly to Tlymphocyte receptors and stimulates the growth and activity of T lymphocytes across different lymphoid tissues throughout the body (Prasad, 2008). Zinc serves as an antioxidant to shield cells against free radical toxicity while boosting mineral absorption essential for blood cell function (Sanchez *et al.*, 2009).

Table 4 demonstrates that there were no significant differences (P ≥ 0.05) between the five treatments for the stress index throughout the initial treatment period of 45 days. The fifth treatment, followed by the fourth and third treatments, displayed significant index value reductions (P ≤ 0.05) compared to controls throughout the second 90-day period, while the second treatment showed no significant stress index differences when compared to controls.

CONCLUSIONS

In conclusion, this study shows that treating Awassi lambs with a mixture of zinc methionine and coenzyme Q10 gave the best results related to production indicators and improved immune status through increasing the percentage of lymphocytes and decreasing the percentage of neutrophils. In addition, the long duration of treatment with coenzyme Q10 and zinc methionine had a positive effect on most of the studied traits.

ACKNOWLEDGMENTS

The researchers extend their sincere gratitude to the Department of Animal Production, College of Agriculture, Tikrit University, for their support in providing all the necessary materials to complete this study.

NOVELTY STATEMENT

The authors declare that no generative artificial intelligence or AI-assisted techniques were used in the preparation, analysis, or writing of this manuscript.

AUTHOR'S CONTRIBUTION

AAFA-J: Conceptualization, investigation, supervision, validation, writing review and editing. NBA: Formal analysis, methodology, investigation, writing original draft. MAA: Data curation, investigation, writing original draft, project administration.

Generative AI and AI-assisted technology statement

We, the authors, declare that we did not use any artificial intelligence tools in writing the manuscript

Conflict of interest

The authors declare no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

REFERENCES

Abdelgayed A, Sami H, El-Moghazy G, Saba FES, Ghanem MM, Abdel-Raoof Y (2022). Effect of Zinc oxide nanoparticles and zinc oxide on clinical, hemato-biochemical, body weight, trace elements and wool zinc changes in lambs. Benha Vet. Med. J., 42(2): 147-152. https://doi.org/10.21608/bvmj.2022.138119.1521

Ali M, El-Sheikh HA, Ahmed B, Nayel U (2023). Efficiency of Nano Zinc supplementation on growth performance, digestibility, rumen parameters, blood biochemistry and immunity status of barki sheep. Menoufia J. Anim. Poult. Fish Prod., 7(3): 37-46. https://doi.org/10.21608/mjapfp.2023.198972.1014

Alimohamady R, Aliarabi H, Bruckmaier RM, Christensen RG (2019). Effect of different sources of supplemental zinc on performance, nutrient digestibility, and antioxidant enzyme activities in lambs. Biol. Trace Element. Res., 189(1): 75-84. https://doi.org/10.1007/s12011-018-1448-1.

Al-Samarai, E., and Al-Janabi, A.K. (2021). The effect of using coenzyme Q10 and wheat germ oil on some blood characteristics of stressed rabbits. Mesopotamia Journal of Agriculture, 49(4), 35-0. 10.33899/magrj.2021.131859.1142

Al-Taie YA, Almahdawi MK (2021). Effect of selenium and zinc doses and interaction between them on production performance and some carcass traits of Awassi lambs. Ann. Roman. Soc. Cell Biol., 25(4): 2506-2520.

Balani ZMRK, Hameed IK, Faridon ASMA (2018). The effect of selenium and zinc supplements on some antioxidants and biochemical parameters in the serum of male Kurdish sheep. College of Agriculture, Tikrit University. College of Veterinary Medicine, Tikrit University. College of Veterinary Medicine, University of Sulaimaniyah, Iraq.

Ballantine HT, Socha MT, Tomlinson DAD, Johnson AB, Fielding AS, Shearer JK, Van Amstel SR (2002). Effects of feeding complexed zinc, manganese, copper, and cobalt to late gestation and lactating dairy cows on claw integrity, reproduction, and lactation performance. Prof. Anim. Sci., 18(3): 211-218. https://doi.org/10.15232/S1080-7446(15)31524-2

Belewu A, Adewumi D (2021). Effect of green syntheses nano zinc oxide on performance characteristics and haematobiochemical profile of West African dwarf goats. Anim. Res. Int., 18(1): 3938-3946.

Coles EA (1986). Veterinary clinical pathology. 4th ed. Sannders W. B. Co. Philadelphia. London. pp:124 – 127. https://doi.org/10.1136/jcp.39.12.1365

Datt C, Chhabra A (2005). Mineral status of Indian feeds and fodders: A review. Indian J. Dairy Sci., 58(5): 305-320.

Drabkin DL, Austin JH (1935). Spectrophotometric studies: II. Preparations from washed blood cells; nitric oxide hemoglobin and sulfhemoglobin. J. Biol. Chem., pp. 112-151. https://doi.org/10.1016/S0021-9258(18)74967-3

Duncan DB (1955). Multiple range and multiple F test. Biometrics, 11: 1-42. https://doi.org/10.2307/3001478

El-Nagar HA, Wafa WM (2021). Reproductive efficiency, milk production, health status, antioxidant capacity, lipid profile, and metabolic hormones of lactating cows treated with coenzyme q10 and l-carnitine. J. Anim. Health Prod., 9(4): 380-390. https://doi.org/10.17582/journal.jahp/2021/9.4.380.390

Feng HL, Chen YH, Jeng SS (2019). Effect of zinc supplementation on renal anemia in 5/6-nephrectomized rats and a comparison with treatment with recombinant human erythropoietin. Int. J. Mol. Sci., 20(20): 4985. https://doi.org/10.3390/ijms20204985

Goswami, T.K., Bhar, R., Jadhav, S.E., Joardar, S.N., Ram, G.C. (2005). Role of dietary zinc as a nutritional immunomodulator. Asian-Australasian journal of animal sciences, 18(3), 439-452.

Gvozdjáková A, Kucharská J, Dubravicky J, Mojto V, Singh RB (2015). Coenzyme Q10, α-Tocopherol, and oxidative stress could be important metabolic biomarkers of male infertility. Dis. Markers, 2015(1): 827941. https://doi.org/10.1155/2015/827941

Hassan FA, Kishawy AT, Moustafa A, Roushdy EM (2021). Growth performance, tissue precipitation, metallothionein and cytokine transcript expression and economics in response to different dietary zinc sources in growing rabbits. J. Anim. Physiol. Anim. Nutr., 105(5): 965-974. https://doi.org/10.1111/jpn.13550

Hean PJ (1995). Principle of hematology. Edited by: L.H. Yong; W.B. Publishers. London.

Hilal EY, Elkhairey MA, Osman AO (2016). The role of zinc, manganse and copper in rumen metabolism and immune function: A review article. Open J. Anim. Sci., 6(4): 304-324. https://doi.org/10.4236/ojas.2016.64035

Hou R, He Y, Yan G, Hou S, Xie Z, Liao C (2021). Zinc enzymes in medicinal chemistry. Eur. J. Med. Chem., 226: 113877. https://doi.org/10.1016/j.ejmech.2021.113877

Hughes NC, Wickramasinghe SN, Hatton C (2004). Lecture notes on haematology. Seventh edition. Blackwell Publishing. London.

Hummel M, Talsma EF, Taleon V, Londoño L, Brychkova G, Gallego S, Spillane C (2020). Iron, zinc and phytic acid retention of biofortified, low phytic acid, and conventional bean varieties when preparing common household recipes. Nutrients, 12(3): 658. https://doi.org/10.3390/nu12030658

Jafarpour N, Khorvash M, Rahmani HR, Pezeshki A, Hosseini GM (2015). Dose–responses of zinc–methionine supplements on growth, blood metabolites and gastrointestinal development in sheep. J. Anim. Physiol. Anim. Nutr., 99(4): 668-675. https://doi.org/10.1111/jpn.12286

Jia W, Jia Z, Zhang W, Wang R, Zhang S, Zhu X (2008). Effects of dietary zinc on performance, nutrient digestibility and plasma zinc status in Cashmere goats. Small Rumin. Res., 80(1-3): 68-72. https://doi.org/10.1016/j.smallrumres.2008.09.009

Khan ZI, Ashraf M, Ahmad K, Al-Qurainy F (2010). Seasonal assessment of selenium as a hazardous element in pasture and animal system: A case study of Kajli sheep in Sargodha, Pakistan. J. Hazard. Mater., 179(1-3): 1111-1114. https://doi.org/10.1016/j.jhazmat.2010.03.121

Kharbanda C, Bansal S, Aneja PS (2022). Role and significance of ghrelin and leptin in hunger, satiety, and energy homeostasis. J. Sci. Soc., 49(1): 12-16. https://doi.org/10.4103/jss.jss_126_21

Kraus A, Roth HP, Kirchgessner M (1997). Supplementation with vitamin C, vitamin E or β-carotene influences osmotic fragility and oxidative damage of erythrocytes of zinc-deficient rats. J. Nutr., 127(7): 1290-1296. https://doi.org/10.1093/jn/127.7.1290

Krishnaiah MV, Arangasamy A, Selvaraju S, Guvvala PR, Ramesh K (2019). Organic Zn and Cu interaction impact on sexual behaviour, semen characteristics, hormones and spermatozoal gene expression in bucks (*Capra hircus*). Theriogenology, 130: 130-139. https://doi.org/10.1016/j.theriogenology.2019.02.026

Law BA, Liao X, Moore KS, Southard A, Roddy P, Ji R, Cowart LA (2018). Lipotoxic very-long-chain ceramides cause mitochondrial dysfunction, oxidative stress, and cell death in cardiomyocytes. FASEB J., 32(3): 1403-1416. https://doi.org/10.1096/fj.201700300R

Littarru GP, Bruge F, Tiano L (2016). Biochemistry of coenzyme Q10. In Antioxidants in andrology. Cham: Springer International Publishing. pp. 23-34. https://doi.org/10.1007/978-3-319-41749-3_2

Lukaski HC (2005). Low dietary zinc decreases erythrocyte carbonic anhydrase activities and impairs cardiorespiratory function in men during exercise. Am. J. Clin. Nutr., 81(5): 1045-1051. https://doi.org/10.1093/ajcn/81.5.1045

Mallaki M, Norouzian MA, Khadem AA (2015). Effect of organic zinc supplementation on growth, nutrient utilization, and plasma zinc status in lambs. Turk. J. Vet. Anim. Sci., 39(1): 75-80. https://doi.org/10.3906/vet-1405-79

Mani V, Mir SH, Sharma A, Sarkar S (2021). Comparative effect of zinc supplementation by hydroxy and inorganic sources on nutrient utilisation, mineral balance, growth performance and growth biomarkers in pre-ruminant calves. Arch. Anim. Nutr., 75(6): 435-449. https://doi.org/10.1080/1745039X.2021.2007692

Manimaran S, Kekan PM, Daware SB, Wankar AK, Munde VK, Khose KK, Ghorpade SSAP (2022). Effect of copper and zinc supplementation on hematological parameters of Osmanabadi goats. Pharma Innov. J., SP-11(6): 837-840. https://doi.org/10.18805/IJAR.B-4926

McDowell LR (1992). Zinc. In: Minerals in animal and human nutrition. San Diego: Academic Press; pp. 265-293.

Merchen NR, Titgemeyer EC (1992). Manipulation of amino acid supply to the growing ruminant. J. Anim. Sci., 70(10): 3238-3247. https://doi.org/10.2527/1992.70103238x

National Research Council (NRC) (1996). Minerals In: National Research Council, editors. Nutrient requerements of beef cattle. Washington: National Academy Press; Pp.54-74.

Nematpoor M, Rezayazdi K, Ganjkhanlou M, Towhidi A (2021). Effects of zinc sources on cellular immune response, biochemical and hematological blood parameters in early lactation of Holstein dairy cows. Iran. Vet. J., 17(2): 116-124.

Praharaj S, Skalicky M, Maitra S, Bhadra P, Shankar T, Brestic M, Hossain A (2021). Zinc biofortification in food crops could alleviate the zinc malnutrition in human health. Molecules, 26(12): 3509. https://doi.org/10.3390/molecules26123509

Prasad AS (2008). Zinc in human health: Effect of zinc on immune cells. Mol. Med., 14(5-6): 353-357. https://doi.org/10.2119/2008-00033.Prasad

Princewill OI, Uchenna AE, Charles OI, Uwaezuoke IM (2015). Global Journal of Animal Scientific Research. Glob. J. Anim. Sci. Res., 3(2): 524-535.

Salman AD, Hadeel KI, Al-Khalisy AF (2009). Effect of body condition and supplementary feeding on the reproductive performance of Awassi animals. Iraqi J. Vet. Med., 33(2): 595-599. https://doi.org/10.30539/iraqijvm.v33i2.703

Sánchez C, López-Jurado M, Planells E, Llopis J, Aranda P (2009). Assessment of iron and zinc intake and related biochemical parameters in an adult Mediterranean population from southern Spain: Influence of lifestyle factors. J. Nutr. Biochem., 20(2): 125-131. https://doi.org/10.1016/j.jnutbio.2007.12.008

SAS (2012). SAS / STAT users guide for personal computers. Release. 9: 12. SAS Institute Inc., Cary, N.C., U.S.A

Shareef MA, Mohammed TR, Muneeb AH (2019). Effect of yeast (*Saccharomyces cerevisiae*) enhanced with selenium or zinc on the hematological characteristics in Iraqi does. Al-Anbar J. Vet. Sci., 12(2): 75-81. https://doi.org/10.37940/AJVS.2019.12.2.9

Shukla S, Dubey KK (2018). CoQ10 a super-vitamin: Review on application and biosynthesis. 3 Biotech, 8(5): 249. https://doi.org/10.1007/s13205-018-1271-6

Song C, Shen X (2020). Effects of environmental zinc deficiency

on antioxidant system function in Wumeng semi-fine wool sheep. Biol. Trace Element. Res., 195(1): 110-116. https://doi.org/10.1007/s12011-019-01840-1

Sood R (1985). Hematology for students and practitioners. Jaypee Brothers, India. pp. 243-320.

Steen A, Strøm T, Bernhoft A (2008). Organic selenium supplementation increased selenium concentrations in ewe and newborn lamb blood and in slaughter lamb meat compared to inorganic selenium supplementation. Acta Vet. Scand., 50(1): 7. https://doi.org/10.1186/1751-0147-50-7

Tabbaa M, Kridli R, Amashe M, Barakeh F (2006). Factors affecting scrotal circumference and semen characteristics of Awassi rams. Jordan J. Agric. Sci., 2(3): 243-250.

Towaje MAA, Kuttar AH, Hassan H (2018). Effect of adding different levels of zinc to the diets on performance and growth of local female goat. College of Veterinary Medicine/ Green University of Al-Qasim Agriculture Research Directorate/Ministry of Technology and Science. Al-Anbar J. Vet. Sci., 11(2): 27-32. https://doi.org/10.37940/AJVS.2018.11.2.5

Videla LA, Rodrigo R, Araya J, Poniachik J (2004). Oxidative stress and depletion of hepatic long-chain polyunsaturated fatty acids may contribute to nonalcoholic fatty liver disease. Free Radic. Biol. Med., 37(9): 1499-1507. https://doi.org/10.1016/j.freeradbiomed.2004.06.033

Wang Z, Chen Y, Chen M, Zhang Y (2021). Overexpression of Fgf8 in the epidermis inhibits hair follicle development. Exp. Dermatol., 30(4): 494-502. https://doi.org/10.1111/exd.14232

Yatoo MI, Saxena A, Deepa PM, Habeab BP, Devi S, Jatav RS, Dimri U (2013). Role of trace elements in animals: A review. Vet. World, 6(12): 963-967. https://doi.org/10.14202/vetworld.2013.963-967

Yusuf AO, Adeyi TK, Oni AO, Owalabi AJ, Sowande SO (2023). Nano zinc supplementation in ruminant's livestock, influence on physiological, immune functions and oxidative stability of West African dwarf goat bucks. Compar. Clin. Pathol., 32(4): 629-643. https://doi.org/10.1007/s00580-023-03471-4

Zhang B, Guo Y (2008). The growth-promoting effect of tetrabasic zinc chloride is associated with elevated concentration of growth hormone and ghrelin. Asian-Australas. J. Anim. Sci., 21(10): 1473-1478. https://doi.org/10.5713/ajas.2008.80057