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Effect of Water Quality and Vitamin C on the Growth Performance and Haematological Parameters of Broiler Chickens

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Abstract: The goal of this study was to investigate the effect of varying water quality with and without vitamin C on the growth performance and some haematological parameters of broiler chickens. A total of 252 one day old, unsexed chicks of broiler chickens (ROSS 308), average body weight 42 g were used in this study. For 35 days, the chicks were divided into 7 treatments (each treatment thirty six chicks), with 3 replicate per each (twelve chicks per replicate). The first group drank reverse osmosis (R.O) without any addition containing 28.16 total dissolved solids mg.l^{-1} (TDS), whereas the second, third and fourth groups (Safwan, Qurna and Fao tap water) drank water containing 1849.6, 1452.8 and 1356.8 TDS mg.l^{-1} respectively. The fifth, sixth and seventh group drank water containing 1849.6, 1452.8 and 1356.8 TDS mg.l^{-1} with 100 mg.l^{-1} vitamin C respectively. The highest body weight, weight gain, feed intake and the better feed conversion ratio were observed at the seventh group. The highest cumulative water intake was observed at the second, third and fourth groups. Higher red blood cells (RBC), haemoglobin concentration (Hb), packed cells volume (PCV) and lymphocytes ratio were recorded at the seventh group. Higher heterophils and heterophils/lymphocytes ratio were observed at the second group. Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were not affected by different water quality. It can be concluded that the increase of TDS in the drinking water to 1849.6 mg.l^{-1} led to a decline in the growth performance and haematological parameters, while the addition of vitamin C (100 mg.l^{-1}) improved the growth parameters and physiological status of broilers.

Keywords: Ascorbic acid, Blood, Broiler chickens, Growth performance, TDS.

Introduction

In the poultry industry, water is crucial. It is an essential nutrient that is involved in many aspects of poultry metabolism, including digestion, feed absorption, and reproduction. Achieving a high productivity of poultry and plants requires the provision of high quality water (Kirkpatrick & Fleming, 2008; Obead & Jerry, 2019). Chickens have the ability to survive considerably longer without feed than they do without water (Watson *et al.*, 2020). A general rule of thumb for water consumption is that the bird consumes 1.5 to 2 times the amount of feed it consumes (Kellems & Church, 2002). As a result, it is projected that variations in water content will have a greater impact on broiler performance than variations in feed content. Crompton (1997) explained that water pollution is an undesirable change in the physical and chemical properties of water, and its pollution results in health damage to human, animal and plant.

The main problem currently facing water purity is the high salinity in it, especially in the waters of swamps, depressions and rivers, due to the high temperatures and the increase in evaporation. The World Health Organization WHO (2008) indicated that pollutants that reduce the quality of water suitable for human, animal and plant consumption include various salts that may be toxic when they reach high levels. Minerals and salts, if it was in high levels in the drinking water of animals, cause physiological disturbances to the animal, which in turn leads to the deterioration of the animal's health and immune status (Blumenthal *et al.*, 2001). Total dissolved solids (TDS) are a key index in water quality that defines whether or not water is suitable for animals to drink (Honarbakhsh *et al.*, 2007; Vosooghi-Postindoz *et al.*, 2018). TDS are commonly measured using electrical conductivity (EC) as a water salinity index (Atekwana *et al.*, 2004). TDS estimation is an excellent way to measure the quality and suitability of water (Watson *et al.*, 2020). It is known that high total dissolved solids pose stress on birds, therefore, as a way of improving performance, herbs or its extract and ascorbic acid could be administered to birds at drinking water to reduce the stress on poultry (Al-Mosawy & Al-Salhie, 2021; Mahjar & Al-Salhie, 2022).

Ascorbic acid often known as vitamin C, synthesis anti stress hormones that assist animals cope with the effects of stress. Vitamin C is a water soluble antioxidant that is generally synthesis in sufficient amounts by birds' metabolism when it is not stressed (Bains, 1996; Fails, & Magee, 2018). Vitamin C is a powerful endogenous antioxidant. Various animal studies have found that supplementing with vitamin C reduces oxidative stress in animals raised under a variety of stressful situations (Ahmadu *et al.*, 2016; Wei *et al.*, 2016). Several studies have found that vitamin C supplements, whether consumed orally or in drinking water, have favorable effects. Supplements improved physiological status of broiler chickens (Hashem *et al*, 2021), enhanced growth performance (Saiz del Barrio *et al.*, 2020).

The objective of the current study is to investigate the effect of different water quality with and without vitamin C on the growth performance and some haematological parameters of broiler chickens.

Materials & Methods

Period and study area

During the months of November and December 2021, this study was conducted at a poultry farm in the College of Agriculture, University of Basrah, Basrah city, Iraq.

Water samples and physio-chemical-microbial analyses

Four different sources of tap water were used in the current study. Water samples were reverse osmosis (RO), Safwan tap water, Qurna tap water and Fao tap water. Water samples were collected from these places for one time and stored in 1-ton tanks. Water physio-chemical parameters were measured in marine science center laboratories, university of Basrah, Basrah city, Iraq. The measured parameters include pH, electrical conductivity (EC), total dissolved solids (TDS), sodium (Na), chloride (Cl), sulfate (So4), copper (Cu) and Lead (Pb). Water microbial tests were measured in animal production department laboratories. The measured tests included total bacteria and *Escherichia coli* (*E. coli*). Water physio-chemical-microbial analysis were presented in table (1).

Table (1): Water physio-chemical- microbial analysis of study samples.

Parameters	Reverse osmosis water	Safwan	Qurna	Fao
pH	8.39	7.49	7.53	7.71
EC($mS.cm^{-1}$)	0.04	2.89	2.27	2.12
TDS ($mg.l^{-1}$)	28.16	1849.6	1452.8	1356.8
Na ($mg.l^{-1}$)	0	263	210	184
Cl ($mg.l^{-1}$)	12.2	641.1	549.5	458.0
So4 ($mg.l^{-1}$)	8.5	127.0	145.6	119.6
Cu ($mg.l^{-1}$)	0.015	0.007	0.009	0.009
Pb ($mg.l^{-1}$)	N.D	0.006	0.002	N.D
Total bacteria (CFU×10^3 ml^{-1}	19.33	1.36	2.00	1.06
E. coli (CFU×10^3 ml^{-1}	2.43	0.30	0.16	0.02

pH: power of hydrogen, EC: electrical conductivity, TDS: total dissolved solids, Na: sodium, Cl, chloride, So4: sulfate, Cu: copper, Pb: lead.

Study treatments and animals

Seven treatment groups were used in the current study. A total 252 of one day old, unsexed broiler chicks (ROSS 308), weighted 42 g were used in this study. The chicks were randomly distributed into 7 treatments (each group 36 birds), with three replicates per each (12 birds per replicate). The first group drank reverse osmosis (R.O) without any addition (28.16 TDS $mg.l^{-1}$), whereas the second, third and fourth groups (Safwan, Qurna and Fao tap water) drank water containing 1849.6, 1452.8 and 1356.8 TDS $mg.l^{-1}$ respectively. The fifth, sixth and seventh groups (Safwan, Qurna and Fao tap water) drank water containing 1849.6, 1452.8 and 1356.8 TDS $mg.l^{-1}$ with 100 $mg.l^{-1}$ vitamin C respectively.

Animals' management

The chicks were reared for five weeks (35 days) under similar conditions, according to the Ross 308 broiler management manual. The chicks were housed and raised in a closed broiler house. The chicks were reared in a littered floor sawdust. There were twenty one replicates, each replicate had (length: 200 cm; width: 80 cm; height: 54 cm), 12 chicks for each. The temperature was set at 33°C for the first week, then gradually decreased by 3°C each week until the end of the fifth week. The temperature thereafter remained steady at 21°C till the experiment ended. On the first day to the 35th day, the lighting schedule was 23 hours of light and 1 hour of darkness. The chicks fed two different basal diets. The chemical composition of the diets was estimated using NRC (1994). The chicks fed a pellet diets and *ad libitum* water access. The study diets and its chemical composition presented in table (2).

Table (2): Diets nutritional and chemical compositions.

Ingredient %	Starter diet (1-21 days) (%)	Grower diet (22-35 days)
Yellow corn	43	52
Wheat	17	13
Soybean meal (48%)	35.5	24.5
*Protein concentrate (40 %)	4	4
Plant oil	0.5	3.5
Limestone	1	1.5
NaCl	0.2	0.2
** Premix (29 %)	1.5	1
L-Lysine	0.2	0.2
Methionine	0.1	0.1
Total	100	100
Calculated chemical composition		
Metabolizable energy	2876.5	3148.5
Crude protein (%)	23.68	20.05
Calorie: protein ratio	121.47	157.03
Ether extract (%)	3.25	6.45
Crude fibre (%)	3.66	3.18
Calcium (%)	0.67	0.84
Available Phosphorus (%)	0.29	0.26
Lysine (%)	1.31	1.11
Methionine + Cysteine (%)	0.28	0.76

*The protein concentrate for broiler feeding produced by the company (Wafi B.V. Holland). Chemical composition: 40% crude protein, 5% crude fat, 2.20% crude fiber, 7.10% Moisture, 28.30% crude ash, 4.20% Calcium, 4.65% Phosphorus, 2107 Met. energy (kcal.g^{-1}).

**Premixes, chemical composition: 10% crude protein, 2.1% crude fat, 0.34% crude fiber, 2.66% Moisture, 51.02% crude ash, 20.08% Calcium, 10.83% Phosphorus, 753.82 kcal kg Met. Energy.

Data collection

Live body weight (g), average weight gain (g), cumulative feed intake (g), feed conversion ratio (g feed intake/ g weight gain) and cumulative water intake (ml) were recorded from all replicate at the end of the study. After the broiler chickens had fasted for 3 hours, blood samples were taken at the end of the study. Using a 3ml syringe (23G needle) and an EDTA-filled tube, blood was extracted 2-3 ml from a shank vein that had been cleaned with alcohol. Red blood cells (RBC x10^6 mm^3), haemoglobin concentration (Hb g.dl^{-1}), packed cells volume (PCV%), Mean Corpuscular Volume (MCV fl), Mean

Corpuscular Haemoglobin (MCH pg), Mean corpuscular haemoglobin concentration (MCHC g.l^{-1}), heterophils (%), lymphocytes (%), and heterophils/lymphocytes ratio were measured. All blood parameters were determined based on Campbell (1995).

Statistical analyses

A completely randomized design (One –way ANOVA) was applied to analyze experimental data using the program SPSS (2016) and Duncan's multiple range tests (Duncan's, 1955) were also used to assess significant differences between means at a 0.05 percent level of significance.

Results & Discussion

Productive performance of broiler chickens supplemented different water quality with or without vitamin C was presented in Table 3. There was a significant difference ($p \leq 0.05$) in final body weight, final weight gain, cumulative feed intake, cumulative water intake and final feed conversion ratio among different treatment groups. The seventh group recorded a significant increase ($p \leq 0.05$) in the final body weight, final weight gain, cumulative feed intake and improvement final feed conversion ratio compared to other groups. Increasing body weight with a lower TDS level in drinking water at seventh group may be due to the role of vitamin C. Vitamin C enhance antioxidant properties in the body systems, which preserve cell membranes from oxidative damage (Cinar *et al.*, 2014). Our findings are in agreement with those of Lohakare *et al.* (2005), who investigated the effects of supplementary ascorbic acid (10, 50, 100 and 200 ppm) on broiler chicken performance and found that the supplemented groups had significantly higher body weight at higher levels than the control groups. Rajput *et al*. (2009) found that supplementing broiler chickens with vitamin C enhanced their live body weight. According to Sahin & Kucuk (2001), vitamin C has an important role in the weight gain of Japanese quails reared under chronic heat stress. The second group recorded a significant decrease ($p \leq 0.05$) in these parameters and worse final feed conversion ratio. The relationship between decreasing body weight and increasing water salinity (more than 1000 ppm TDS) could be explained by an increase in TDS, which causes diarrhea and weight loss (Kirkpatrick & Fleming, 2008). Decreasing body weight with an increasing TDS level may be due to an apparent stress in the vital systems, particularly the kidney, which causes a delay in broiler growth (Kirkpatrick & Fleming 2008). Kirkpatrick & Fleming (2008) reported an increased TDS in drinking water (1000-3000 ppm) may cause a lower weight gain or death in poultry. Our findings are in agreement with those of Khalilipour *et al*. (2019), who found that higher TDS levels in drinking water resulted in lower pre-slaughter weight and carcass yield of Japanese quails. According to table (3), different levels of TDS in drinking water decreased feed intake in broiler chicken of second group compared to other groups. In contrast to our findings, Chen & Balnave (2001) found that increasing the amount of NaCl in drinking water (2, 3 and 4 g.L^{-1}) had no effect on feed intake of laying hen. Mahmud *et al*. (2010) in broiler chickens and Erener *et al*. (2002) in Japanese quails both revealed similar results. Furthermore, Alahgholi *et al*. (2014) discovered that water salinity (250, 1500, 3000 and 4500 ppm TDS) had no effect on feed intake of broiler chicken. They have stated, however, that animal reactivity or resistance to water salinity and its impact on performance may be based on the animal species, age, and water requirements, as well as physiological status, period of the year, and overall food salt content. Increased TDS in drinking water has a negative impact on feed conversion ratio. The best (lowest coefficient) feed conversion ratio was found in the seventh group, while the poorest (highest coefficient) was found in the second. Honarbakhsh *et al*. (2007) found that increasing the salinity of drinking water raises feed conversion ratio and lowers performance of broiler chickens due to poor cation-anion balance, which affects a variety of physiological status and metabolic activities of the body. The highest cumulative water intake was observed at the second, third and fourth groups. The increase in water intake seen in birds as salinity rises can be seen as an osmoregulatory mechanism for avoiding significant changes in extracellular fluid sodium concentration via the dynamic balance of consumption of water and excretion (Geerling & Loewy, 2008).

Table (3): Effect of varying water quality with and without vitamin C on productive performance (Mean± SE)

Treatments Parameters	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
Initial body weight (g)	42.00^{a} ± 0.00	42.00^{a} ± 0.00	42.00$^{.a}$ ± 0.00	42.00 ^{a} ± 0.00	42.00^{a} ± 0.00	42.00^{a} ± 0.00	42.00^{a} ± 0.00
Overall body weight (g)	1880.33^{bc} ± 33.41	1830.66^{c} ± 14.31	1859.66^{bc} ± 28.48	1890.33^{bc} ± 25.98	1859.33^{bc} ± 18.85	1909.16^{b} ± 6.50	2003.00^{a} ± 14.79
Final weight gain (g)	1838.33^{bc} ± 33.41	1788.66^{c} ± 14.31	1817.66^{bc} ± 28.48	1848.33^{bc} ± 25.98	1817.33^{bc} ± 18.85	1867.16^{b} ± 6.50	1961.00^{a} ± 14.79
Cumulative feed intake(g)	3414.26^{ab} ± 69.96	3336.71^{b} ± 39.29	3465.65^{ab} ± 65.01	3544.49^{ab} ± 76.76	3448.87^{ab} ± 56.22	3445.20^{ab} ± 54.67	3578.83^{a} ± 92.11
Feed conversion ratio (g.g)	1.85^{ab} ± 0.01	1.86^{ab} ± 0.02	1.90^{a} ± 0.01	1.91^{a} ± 0.02	1.89^{ab} ± 0.01	1.84^{ab} ± 0.02	1.82^{b} ± 0.03
Cumulative water intake (ml)	7563.03^{b} ± 89.94	8501.05^{a} ± 42.74	8474.25^{a} ± 48.52	8221.59^{a} ± 229.85	7622.42^{b} ± 16.10	7608.86^{b} ± 131.15	7663.76^{b} ± 129.22

Different letters in the same row mean there are significant different at $p \leq 0.05$.

The greater osmotic pressure, which activates the rennin angiotensin system, could explain the rise in water consumption. Rennin, which is generated by the kidneys, transforms angiotensinogen into angiotensin II, which stimulates the brain's thirst regulating region, causing an increase in water intake (Scanes & Dridi 2021). The link between sodium ingestion and increased water intake is well established, and has been documented in the literature (Watkins *et al*., 2005).

Haematological parameters of broiler chickens supplemented different water quality with or without vitamin C were showed in table (4). Different water quality had no significant effect ($p > 0.05$) on MCV, MCH, MCHC. There was a significant difference ($p \leq 0.05$) in RBC, PCV, Hb, Heterophils ratio, Lymphocytes ratio and H/L among different treatment groups. The seventh group recorded a significant increase ($p \leq 0.05$) in RBC, PCV, Hb and Lymphocyte's ratio compared to other groups. The haematological values improved after supplementation with vitamin C. Positive effect of vitamin C could be related to their antioxidant properties, which preserve RBC cell membranes from oxidative damage (Cinar *et al*, 2014). Antioxidant activity of vitamin C can be linked to its ability to maintain the integrity of the erythrocyte membrane by scavenging free radicals from the cellular environment, resulting in excessive malondialdehyde production (Adenkola & Angani, 2017). On the other hand, the second group recorded a significant decrease ($p \leq 0.05$) in these parameters. The reason for the reduction in RBC is that the high salt content in the water damages the renal tissue, resulting in a decrease in the secretion of the erythropoietin hormone, which is secreted into the bloodstream and transferred to the bone marrow to stimulate the formation of RBC, resulting in a reduction in RBC formation (Scanes & Dridi 2021). Increasing TDS level in drinking water may be resulting broiler stress, which lead to the secretion of corticosterone hormone from the adrenal gland which leads to the increase of the heterophils and decrease lymphocytes cells (Scanes & Dridi 2021).

Table (4): Effect of varying water quality with and without vitamin C on some blood parameters (Mean± SE)

Treatments Parameters	T1	T2	T3	T4	T5	T6	T7
RBC ($x10^6.mm^3$)	$3.15^{ab} \pm 0.14$	$3.02^{b} \pm 0.07$	$3.10^{b} \pm 0.04$	$3.35^{ab} \pm 0.29$	$3.40^{ab} \pm 0.14$	$3.52^{ab} \pm 0.14$	$3.64^{a} \pm 0.07$
Hb (g.dl)	$10.00^{ab} \pm 0.38$	$9.66^{b} \pm 0.19$	$9.88^{b} \pm 0.11$	$10.55^{ab} \pm 0.77$	$10.66^{ab} \pm 0.38$	$10.99^{ab} \pm 0.38$	$11.33^{a} \pm 0.19$
PCV (%)	$30.00^{ab} \pm 1.15$	$29.00^{b} \pm 0.57$	$29.66^{b} \pm 0.33$	$31.66^{ab} \pm 2.33$	$32.00^{ab} \pm 1.15$	$33.00^{ab} \pm 1.15$	$34.00^{a} \pm 0.57$
MCV (fl)	$95.23^{a} \pm 2.88$	$96.02^{a} \pm 3.46$	$95.67^{a} \pm 2.88$	$94.50^{a} \pm 3.21$	$94.11^{a} \pm 3.21$	$93.75^{a} \pm 2.30$	$93.40^{a} \pm 2.30$
MCH (pg)	$31.74^{a} \pm 2.88$	$31.98^{a} \pm 4.04$	$31.87^{a} \pm 4.04$	$31.49^{a} \pm 4.61$	$31.35^{a} \pm 5.19$	$31.22^{a} \pm 2.30$	$31.12^{a} \pm 2.88$
MCHC ($g.l^1$)	$33.32^{a} \pm 0.01$	$33.31^{a} \pm 0.01$	$33.31^{a} \pm 0.01$	$33.31^{a} \pm 0.00$	$33.31^{a} \pm 0.01$	$33.30^{a} \pm 0.01$	$33.32^{a} \pm 0.01$
Heterophils (%)	$18.00^{cd} \pm 0.57$	$32.66^{a} \pm 0.88$	$25.66^{b} \pm 2.33$	$20.00^{cd} \pm 0.57$	$21.00^{c} \pm 0.57$	$19.00^{cd} \pm 0.57$	$16.66^{d} \pm 0.88$
Lymphocytes (%)	$59.33^{ab} \pm 3.38$	$53.66^{b} \pm 1.85$	$57.33^{ab} \pm 1.45$	$63.33^{ab} \pm 3.33$	$57.00^{b} \pm 1.52$	$67.66^{a} \pm 3.93$	$67.66^{a} \pm 3.93$
H/L ratio	$0.30^{cd} \pm 0.01$	$0.60^{a} \pm 0.01$	$0.44^{b} \pm 0.04$	$0.32^{cd} \pm 0.01$	$0.36^{c} \pm 0.01$	$0.28^{d} \pm 0.01$	$0.25^{d} \pm 0.02$

Different letters in the same row mean there are significant different at $p \leq 0.05$.

The sixth and seventh groups recorded a significant decrease ($p \leq 0.05$) in heterophils ratio and H/L compared to other groups. According to the results of the current study, supplementing broiler drinking water with a high level of TDS caused a significant decrease ($p \leq 0.05$) in lymphocytes and a significant increase ($p \leq 0.05$) in heterophils, resulting in a higher heterophils/lymphocyte ratio than normal, whereas supplementing drinking water with vitamin C caused a significant increase ($p \leq 0.05$) in lymphocytes and a significant decrease ($p \leq 0.05$) in heterophils, resulting in a lower H/L ratio. The role of vitamin C is thus reflected by limiting the consequences of salt stress by inhibiting the impact of corticosterone hormone by preventing heterophils from being transported from their storage into the bloodstream, resulting in a reduction in their ratio in the bloodstream (Guyton & Hall, 2021).

Conclusion

Increase the TDS level to 1849.6 mg.l^{-1} of drinking water causes a decrease in broiler body weight, weight gain, feed intake, lymphocytes ratio and worse feed conversion ratio. High TDS causes an increase in water intake, heterophils ratio and H/L ratio. Addition vitamin C (100mg.l^{-1}) to drinking water increases broiler body weight, weight gain and feed intake. Supplementing drinking water with vitamin C caused an increase in lymphocytes and a significant decrease in heterophils, resulting in a lower H/L ratio.

Contributions of authors

S.J. Hussain: Collected the data and wrote the paper.

K.C.K. Al-Salhie: Wrote the paper and performed the analysis.

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Conflict of interest

The authors have no possible conflict of interest.

Ethical approval

All ethical guidelines related to poultry breeding and care issued by national and international organizations were implemented in this report.

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تأثير نوعية المياه وفيتامين ج في اداء النمو ومعايير الدم الخلوية لفروج اللحم

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المستخلص: صممت الدراسة الحالية لمعرفة تأثير نوعية المياه المختلفة مع او بدون فيتامين ج على أداء النمو وبعض معايير الدم الخلوية لفروج اللحم. تم استخدام 252 فرخاً من فروج اللحم (ROSS 308) بعمر يوم واحد، متوسط وزنها 42 غم. وزعت الطيور عشوائياً على سبع مجموعات (كل مجموعة 36 طائراً)، بثلاث مكررات لكل مجموعة (12 طائراً لكل مكرر) باستخدام التصميم العشوائي الكامل لمدة 35 يوماً. قُدم الى المجموعة الأولى مياه الشرب بالتناضح العكسي (RO) بدون إضافة وبمستوى 28.16 إجمالي المواد الصلبة الذائبة ملغم لتر$^{-1}$ بينما زُودت المجموعات الثانية والثالثة والرابعة بمياه الحنفية من (صفوان و القرنة و الفاو) تحتوي على 1849.6 و 1452.8 و 1356.8 TDSملغم.لتر$^{-1}$ على التوالي. كما زُودت المجموعة الخامسة والسادسة والسابعة بمياه شرب تحتوي على 1849.6 و 1452.8 و 1356.8 TDS ملغم.لتر$^{-1}$ مع 100 ملغم.لتر$^{-1}$ فيتامين ج على التوالي. غذيت الطيور عليقة بادئ لمدة 21 يومًا وبعد ذلك، عليقة نمو. اظهرت النتائج ان اعلى وزن للجسم، وزيادة وزنية، وكمية العلف المتناول وكفاءة تحويل غذائي افضل كانت في المجموعة السابعة. وظهرت زيادة معنوية في الاستهلاك التراكمي للمياه في المجموعات الثانية والثالثة والرابعة. سُجل ارتفاع في خلايا الدم الحمراء (RBC)، وتركيز الهيموغلوبين (Hb)، وحجم الخلايا المرصوصة (PCV) ونسبة الخلايا الليمفاوية في المجموعة السابعة. لوحظت نسبة اعلى من الخلايا المتغايرة ونسبة الخلايا المتغايرة الى الخلايا الليمفاوية في المجموعة الثانية. لم يتأثر متوسط حجم الخلايا (MCV)، ومتوسط هيموغلوبين الخلية (MCH) ومتوسط تركيز هيموغلوبين الخلية (MCHC) بنوعية المياه المختلفة. يمكن الاستنتاج بأن زيادة إجمالي المواد الصلبة الذائبة في مياه الشرب إلى 1849.6 ملغم.لتر$^{-1}$ يؤدي إلى انخفاض أداء النمو ومعايير الدم الخلوية، بينما أدت إضافة فيتامين C (ملغم.لتر$^{-1}$) إلى تحسين معايير النمو والحالة الفسيولوجية لفروج اللحم.

الكلمات المفتاحية: حامض الأسكوربيك، الدم، فروج اللحم، أداء النمو ، المواد الصلبة الذائبة الكلية.