Original Article

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Assessing the effects of dietary and waterborne commercial salt on the performance and welfare of common carp

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ABSTRACT. This study investigated the effects of salt additives in water and diet on the physiological and health parameters of common carp (*Cyprinus carpio* L.). Fingerlings (~50 g) were divided into seven groups: a control group (G1), three water treatment groups ($G2_{A}$–$_{C}$; 4, 8, and 12 g L^{-1} salt), and three diet treatment groups ($G3_{A}$–$_{C}$; 5, 10, and 15 g kg^{-1} dietary salt). All fish were fed a standard diet containing 28% crude protein at 3% body weight per day. Results revealed that G1 had the highest values for lymphocyte and monocyte counts, mean corpuscular hemoglobin (MCH), mean corpuscular volume (MCV), cholesterol, triglycerides, low-density lipoprotein cholesterol (LDL), albumin, total protein, and several somatic indices. $G2_{B}$ exhibited significantly higher potassium and sodium levels, while $G3_{A}$ showed elevated white blood cell (WBC), granulocytes, liver enzyme activities (Alanine aminotransferase activity (ALT), aspartate aminotransferase activity (AST)), creatinine, glucose, chloride, and various somatic indices. $G2_{A}$ and $G2_{B}$ groups had increased red blood cells (RBC), hemoglobin, hematocrit, and body weight index. The findings indicate that using 12 g L^{-1} salt in rearing water and 15 g kg^{-1} salt in the diet can enhance growth and health performance in *Cyprinus carpio*. This study provides important insights into salt-induced physiological responses in carp and offers practical recommendations for aquaculture practices.

Keywords: dietary salt, adding to rearing water, *Cyprinus carpio*, health, blood

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1. Introduction

The aquaculture and fisheries sectors play a crucial role in ensuring global food security and nutrition. Further improvement of this contribution requires faster implementation of key reforms in policy, management, innovation, and investment (FAO, 2022). Common salt (NaCl) is readily accessible and safe for humans and fish. It leaves no residue on the flesh of fish, making it a popular choice for aquaculture in many countries. Salt is a basic and economical material frequently used in handling freshwater fish. Its numerous beneficial applications and advantages include the capacity to mitigate handling stress, support osmoregulatory function, and contribute to the prevention and control of diseases, enhance fish health and survival both before and after transportation, reduce the effects of adverse environmental conditions, and promote the welfare of breeding fish throughout and following the spawning period (Kubitza, 2016).

The bulk of aquaculture farmers do not consider the use of salt to reduce fish losses. In fact, salt is frequently overused, administered too late, or used during very small periods or at extremely low and useless dosages. Furthermore, many fish farms lack proper facilities for timely fish handling and treatment. In addition to being a reliable and secure medication for controlling some external parasites, salt was also reported to lower the incidence of bacterial and fungal infections following fish handling by mitigating associated stress responses (Kubitza, 2016).

Due to increased GRs or shortened culture periods, adding growth-inducing chemicals to meals has the potential to be lucrative (Abdel-Tawwab et al.,

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2022; Abdulrahman, 2022; Abedalhammed et al., 2017; Nader and Abdulrahman, 2017). Supplementary additives such as sodium chloride are almost perfect for promoting growth when added to artificial feed. Using salt is not a recent development. Salt is one of the essential mineral elements needed by both animal and plant bodies for normal functioning. It improves the taste of food, controls the body's osmotic pressure, forms acid in the stomach mucous membrane (activating pepsin and salivary gland enzymes), and maintains normal digestive processes (Debnath et al., 2017).

Juvenile common carp reared in freshwater for fish farming may benefit from the addition of sodium chloride to the meal, since it affects body composition. Common carp juveniles raised in freshwater can greatly benefit from increased food consumption and growth performance when 1.5% salt is added to their diet. For young common carp raised in freshwater, the 1.5% diet had the best growth and biological performance (Nasir and Qusey, 2016).

This study aims to investigate the effect of salt addition in common carp as a way of precaution and treatment. This will be achieved by measuring certain physiological and health indices in six experimental groups, one control group, and three groups receiving different levels of salt added to the rearing water and mixed into their diets. There are three main objectives in this article: (a) to determine the effects of salt diets on some physiological aspects; (b) to determine if salt treatment can prolong the health indices; and (c) to examine the effect of salt additives in fish diets on health indices.

2. Material and methods

Fingerlings of common carp were obtained from a fish farm in Hilla, Iraq, and acclimatized to laboratory conditions for 21 days. During this period, the fish were fed a commercial diet with a 28% crude protein content. After acclimation, fish averaging ~51.9 g were separated into seven groups, with each group replicated three times, and placed in 21 tanks, each containing 70 liters (10 fish per tank). All tanks were equipped with air stones connected to an air pump for aeration. Fish were fed the control diet twice per day, with an amount equivalent to 3% of their body weight, and the tank's water was changed daily.

Each tank was fitted with air stones connected to an air pump for aeration. Fish were fed the control diet twice daily. Fish were reared for 10 weeks to study the effect of daily use of normal salt in rearing tanks with the following levels:

G1: the control group without salt;
$G2_A$: daily adding of 4 g L^{-1} rearing water;
$G2_B$: daily adding of 8 g L^{-1} rearing water;
$G2_C$: daily adding of 12 g L^{-1} rearing water;
$G3_A$: daily adding of 5 g kg^{-1} diet;
$G3_B$: daily adding of 10 g kg^{-1} diet;
$G3_C$: daily adding of 15 g kg^{-1} diet.

Table 1 summarizes the chemical composition of aquarium water (including temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), and total alkalinity), which was assessed at the start, mid-point, and end of the trial under the protocols established by APHA (2017). All parameters remained within accept-

Table 1. The chemical composition of aquarium water (mg L^{-1})

Water parameters	Time	Control	4 g salt 1L rearing water	8 g salt 1L rearing water	12 g salt 1L rearing water	5 g salt kg diet	10 g salt kg diet	15 g salt kg diet
Temperature	Start	25 ± 0.35	25 ± 0.35	25 ± 0.35	25 ± 0.35	25 ± 0.35	25 ± 0.35	25 ± 0.35
	Mid	24.37 ± 0.34	25.05 ± 0.35	24.95 ± 0.35	25.27 ± 0.36	25.17 ± 0.35	25.04 ± 0.35	24.83 ± 0.35
	End	24.18 ± 0.33	24.99 ± 0.35	25.94 ± 0.36	25.92 ± 0.36	24.91 ± 0.35	24.87 ± 0.35	25.18 ± 0.35
DO	Start	4.23 ± 0.05	4.54 ± 0.06	4.31 ± 0.06	4.44 ± 0.06	4.05 ± 0.05	4.93 ± 0.07	4.59 ± 0.06
	Mid	4.33 ± 0.06	3.19 ± 0.04	3.88 ± 0.05	4.07 ± 0.05	4.13 ± 0.05	4.05 ± 0.05	3.87 ± 0.05
	End	4.27 ± 0.06	4.12 ± 0.05	4.23 ± 0.05	3.99 ± 0.05	4.17 ± 0.05	4.28 ± 0.06	3.23 ± 0.04
pH	Start	7.1 ± 0.09	7.11 ± 0.09	7.18 ± 0.09	7.94 ± 0.11	7.92 ± 0.11	7.17 ± 0.09	7.11 ± 0.09
	Mid	7.65 ± 0.1	8.62 ± 0.12	8.07 ± 0.11	7.99 ± 0.11	7.23 ± 0.09	7.19 ± 0.09	7.2 ± 0.09
	End	7.67 ± 0.1	8.26 ± 0.12	8.26 ± 0.12	8.27 ± 0.12	7.27 ± 0.1	7.79 ± 0.11	7.87 ± 0.11
TDS	Start	212.18 ± 2.99	215.27 ± 3.04	211.15 ± 2.98	213.21 ± 3.01	216.3 ± 3.06	218.36 ± 3.09	214.24 ± 3.02
	Mid	206 ± 2.91	209 ± 2.95	205 ± 2.89	207 ± 2.92	210 ± 2.96	212 ± 2.99	208 ± 2.94
	End	214.24 ± 3.02	217.36 ± 3.07	213.2 ± 3.01	215.28 ± 3.04	218.4 ± 3.09	220.48 ± 3.11	216.32 ± 3.06
Total Hardness	Start	188.9 ± 2.67	195.7 ± 2.76	189.82 ± 2.68	191.58 ± 2.7	197.76 ± 2.8	196.83 ± 2.78	193.84 ± 2.74
	Mid	183.4 ± 2.59	190 ± 2.68	184.3 ± 2.6	186 ± 2.63	192 ± 2.71	191.1 ± 2.7	188.2 ± 2.65
	End	190.73 ± 2.69	197.6 ± 2.79	191.67 ± 2.7	193.44 ± 2.73	199.68 ± 2.82	198.74 ± 2.81	195.72 ± 2.77
Total Alkalinity	Start	133 ± 1.88	144.2 ± 2.03	140.1 ± 1.97	140 ± 1.97	128.2 ± 1.81	127.3 ± 1.8	127.9 ± 1.81
	Mid	136.99 ± 1.93	148.52 ± 2.09	144.3 ± 2.03	144.2 ± 2.03	132.04 ± 1.86	131.11 ± 1.85	131.73 ± 1.86
	End	142.46 ± 2.01	154.46 ± 2.18	150.07 ± 2.12	149.96 ± 2.11	137.32 ± 1.94	136.36 ± 1.92	137 ± 1.93
Turbidity	Start	0.51 ± 0.01	1.23 ± 0.01	2.47 ± 0.03	2.78 ± 0.03	1.13 ± 0.01	1.44 ± 0.02	1.64 ± 0.01
	Mid	0.5 ± 0.01	1.2 ± 0.01	2.4 ± 0.03	2.7 ± 0.03	1.1 ± 0.01	1.4 ± 0.02	1.6 ± 0.02
	End	0.52 ± 0.01	1.26 ± 0.02	2.52 ± 0.03	2.83 ± 0.03	1.15 ± 0.01	1.47 ± 0.02	1.68 ± 0.02

Water parameters	Time	Control	4 g salt 1L rearing water	8 g salt 1L rearing water	12 g salt 1L rearing water	5 g salt kg diet	10 g salt kg diet	15 g salt kg diet
Sulphates (SO4-)	Start	15.4 ± 0.21	15.8 ± 0.22	16.3 ± 0.23	16.1 ± 0.22	15.9 ± 0.22	17.1 ± 0.24	16 ± 0.22
	Mid	15.86 ± 0.22	16.27 ± 0.22	16.78 ± 0.23	16.58 ± 0.23	16.37 ± 0.23	17.61 ± 0.24	16.48 ± 0.23
	End	16.01 ± 0.22	16.43 ± 0.23	16.95 ± 0.24	16.74 ± 0.23	16.53 ± 0.23	17.78 ± 0.25	16.64 ± 0.23
Nitrates (NO_3^-)	Start	33 ± 0.46	41.9 ± 0.59	44.11 ± 0.62	45.5 ± 0.64	42.1 ± 0.59	44.15 ± 0.62	46.5 ± 0.65
	Mid	34.65 ± 0.48	43.99 ± 0.61	46.31 ± 0.65	47.77 ± 0.67	44.2 ± 0.62	46.35 ± 0.65	48.82 ± 0.68
	End	33.99 ± 0.48	43.15 ± 0.61	45.43 ± 0.64	46.86 ± 0.66	43.36 ± 0.61	45.47 ± 0.63	47.89 ± 0.67
Phosphates (PO_4^-)	Start	0.3 ± 0.01	0.37 ± 0.01	0.38 ± 0.01	0.36 ± 0.01	0.32 ± 0.01	0.35 ± 0.01	0.36 ± 0.01
	Mid	0.3 ± 0.01	0.36 ± 0.01	0.37 ± 0.01	0.35 ± 0.01	0.32 ± 0.01	0.34 ± 0.01	0.35 ± 0.01
	End	0.31 ± 0.01	0.37 ± 0.01	0.38 ± 0.01	0.36 ± 0.01	0.33 ± 0.01	0.35 ± 0.01	0.36 ± 0.01
Chlorides (Cl^-)	Start	20 ± 0.28	22.3 ± 0.31	23.5 ± 0.33	24 ± 0.33	22.8 ± 0.32	24.2 ± 0.33	23.8 ± 0.33
	Mid	20.6 ± 0.28	22.96 ± 0.32	24.2 ± 0.34	24.72 ± 0.34	23.48 ± 0.33	24.92 ± 0.35	24.51 ± 0.34
	End	21 ± 0.29	23.41 ± 0.32	24.67 ± 0.35	25.2 ± 0.35	23.94 ± 0.33	25.41 ± 0.36	24.99 ± 0.35

able thresholds for carp culture, indicating stable environmental conditions throughout the experiment. All physicochemical properties of water were assessed at the Environment Directorate laboratory in Sulaimani.

Physiological and health indicators were assessed to investigate the impact of daily salt usage. At the end of the experiment, three fish per tank were randomly selected, sedated using buffered clove powder (2.5 g L^{-1}), and sampled to take blood from the caudal vein. Fish weight and length were measured, and the fish were subsequently dissected. The liver, spleen, gills, kidney, and viscera were removed and weighed.

Condition factor (CF), hepatosomatic index (HSI), gill somatic index (GSI), visceral somatic index (VSI), spleen somatic index (SSI), and kidney somatic index (KSI) were calculated according to (Hama et al., 2025).

The blood samples obtained were divided into two sets of Eppendorf tubes. The first set contained sodium heparin at a concentration of 20 U L^{-1} as an anticoagulant. It was used to measure various blood parameters, including white blood cells (WBCs), granulocytes (%), lymphocytes (%), monocytes (%), RBCs (counted as 10^{12} L^{-1}), hemoglobin (HGB) (g dL^{-1}), hematocrit test (HCT), MCH, mean corpuscular hemoglobin concentration (MCHC) (g dL^{-1}), and platelets (counted as 10^3 uL^{-1}). The second set was not treated with any coagulant and was kept at 4°C until it clotted. After clotting, the second set was centrifuged at room temperature at 5,000 RPM for 20 minutes to obtain serum for measuring biochemical parameters.

Serum biochemical analyses were performed using an automatic chemical analyzer with commercial kits from Spinreact, S.A. (Gerona, Spain). The parameters measured included glucose (GL) (mmol L^{-1}), total protein (TP) (g dL^{-1}), albumin (ALB) (g dL^{-1}), total cholesterol (mmol L^{-1}), low-density lipoprotein cholesterol (LDL, mmol L^{-1}), high-density lipoprotein cholesterol (HDL, mmol L^{-1}), triglycerides (mmol L^{-1}), creatinine (µmol L^{-1}), aspartate aminotransferase (AST, U L^{-1}), alanine aminotransferase (ALT, U L^{-1}), creatine kinase isoenzyme (CKI, U L^{-1}), C-reactive protein (CRP), and electrolytes (sodium (Na), potassium (K), calcium (Ca), and chloride (Cl)). Scheme 1 summarizes the experimental design and different measurements.

3. Results

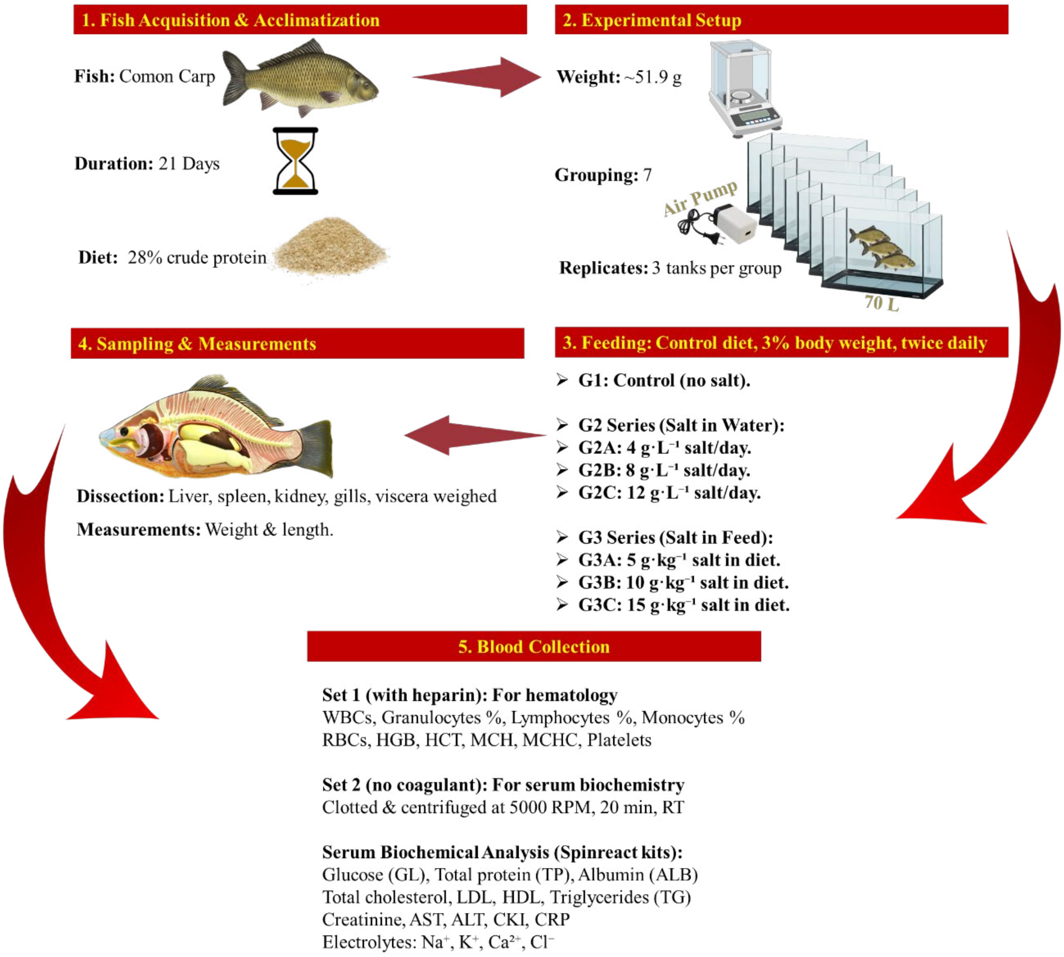
Fig. 1a shows no significant differences in the initial weight of common carp. However, by the end of the study, the $G2_B$, $G2_C$, $G3_A$, and $G3_B$ groups had significantly higher weights compared to the other groups. Furthermore, the daily growth rate (GR) and feed efficiency ratio (FER) were significantly higher in all groups compared to the control (G1) and $G2_A$ groups (Fig. 1g and Fig. 1e, respectively). No significant variations were noted in specific GR (Fig. 1f). The data in (Fig. 1h) indicate a clear and statistically significant drop in feed conversion ratio (FCR) ($p < 0.05$) for the $G2_B$, $G2_C$, $G3_A$, $G3_B$, and $G3_C$ groups compared to the control (G1) and low-salt water group ($G2_A$). This suggests that adding salt, whether through water or diet, at moderate levels can enhance how efficiently common carp convert feed into body mass.

There are significant differences in the RBC, HGB, and HCT levels of the G2A and G2B groups compared to the other groups (Fig. 2a, Fig. 2b, and Fig. 2c, respectively). Notably, the G1 demonstrated significantly higher MCH, MCHC, and MCV levels than the treatment groups (Fig. 2d, Fig. 2e, and Fig. 2f, respectively). Moreover, the platelet levels displayed a significant increase in the treatment groups that received salt additives in their fish diets.

Data in Fig. 3a and Fig. 3b revealed a significant increase in the WBC levels and granulocytes in the $G3_c$ group after adding 15 g kg^{-1} diet. The lymphocyte and monocyte levels in the G1 increased significantly compared to other groups (Fig. 3c and Fig. 3d).

Cholesterol, triglyceride, and LDL levels in the G1 group increased significantly compared to the additive groups (Fig. 4a, Fig. 4b, and Fig. 4c, respectively). Additionally, the HDL level was significantly higher in the $G3_C$ group when salt was added to the diets (Fig. 4d).

According to Fig. 5, the results indicated a significant increase in ALT, AST, and CKI levels in the $G3_C$ group that received a 15 g kg^{-1} diet compared to other groups (Fig. 5c, Fig. 5d, and Fig. 5e, respectively). The addition of salt to water in the $G4_A$, $G4_B$, and $G4_C$ groups led to a significant increase in globulin levels (Fig. 5a). However, only the G1 group showed a con-



Scheme 1. Experimental design and measurements

siderable increase in ALB levels (Fig. 5b). The level of TP showed a significant increase in the G1 group compared to other groups (Fig. 5f). GL, creatinine, and CRP were significantly higher in the $G3_C$ with a 15 g kg^{-1} (Fig. 5g, Fig. 5h, and Fig. 5i, respectively).

Condition factor and intestine weight index were significantly higher in the G1 group compared to the treatment groups (Fig. 6a and Fig. 6c), while the intestine length index increased in all treatment groups compared to the G1 group (Fig. 6b), and intestine length index (To fish length) increased in $G3_C$ compared to other treatments, as seen in (Fig. 6d). There is also a significant increase in HSI of G1 compared to other groups (Fig. 6e). The spleen somatic, kidney somatic, and gill somatic indices were higher in $G3_C$ (Fig. 6f, Fig. 6g, and Fig. 6h, respectively).

The potassium (Na) level increased significantly in $G4_C$ with 14 g L^{-1} water, as well as chloride (Cl) in $G3_C$, compared to other groups (Fig. 7a and Fig. 7d). K also increased in $G4_B$ compared to different groups, as well as Ca in the water additive's groups $G4_A$, $G4_B$, and $G4_C$ as shown in Fig. 7b and Fig. 7c.

Fig. 8 conclude that the weight level without head index revealed a significant increase in $G4_A$ and $G4_B$ compared to other groups (Fig. 8a), while G1 only displayed a significant increase in the weight level without head and visceral compared to other treatment groups (Fig. 8b).

4. Discussion

This study examined how different concentrations of sodium chloride (NaCl), delivered either through rearing water or the diet, affect the physiology and biochemistry of common carp (*Cyprinus carpio*) over 10 weeks. The results demonstrate that moderate levels of salt, specifically 8 and 14 g L^{-1} in water and 5 and 10 g kg^{-1} in the diet, can improve growth and metabolic performance. However, high salt levels, particularly in the diet at 15 g kg^{-1}, led to signs of physiological stress, as reflected in blood parameters and organ health.

Scientists cannot agree on the proper amount of NaCl in fish diets. Identifying Cl^- and Na^+ deficiencies in fish is challenging, since these ions are abundant in food and water. Consequently, metabolic deficiencies are rarely noticed. The study indicated that, although the likelihood of a deficit is minimal, excessive levels might have a detrimental impact on fish performance, resulting in aberrant behavior and shortened lifespans in the tanks (NRC, 2011).

This study found no significant differences in specific GR, and significant differences in FCR ($p < 0.05$) were observed between the control group (G1) and group $G4_A$ compared to the other groups. In contrast, *Labeo rohita* displayed the lowest FCR and the highest specific GR per day when supplemented with choline (Das et al., 2022). Higher salt concentrations in salted

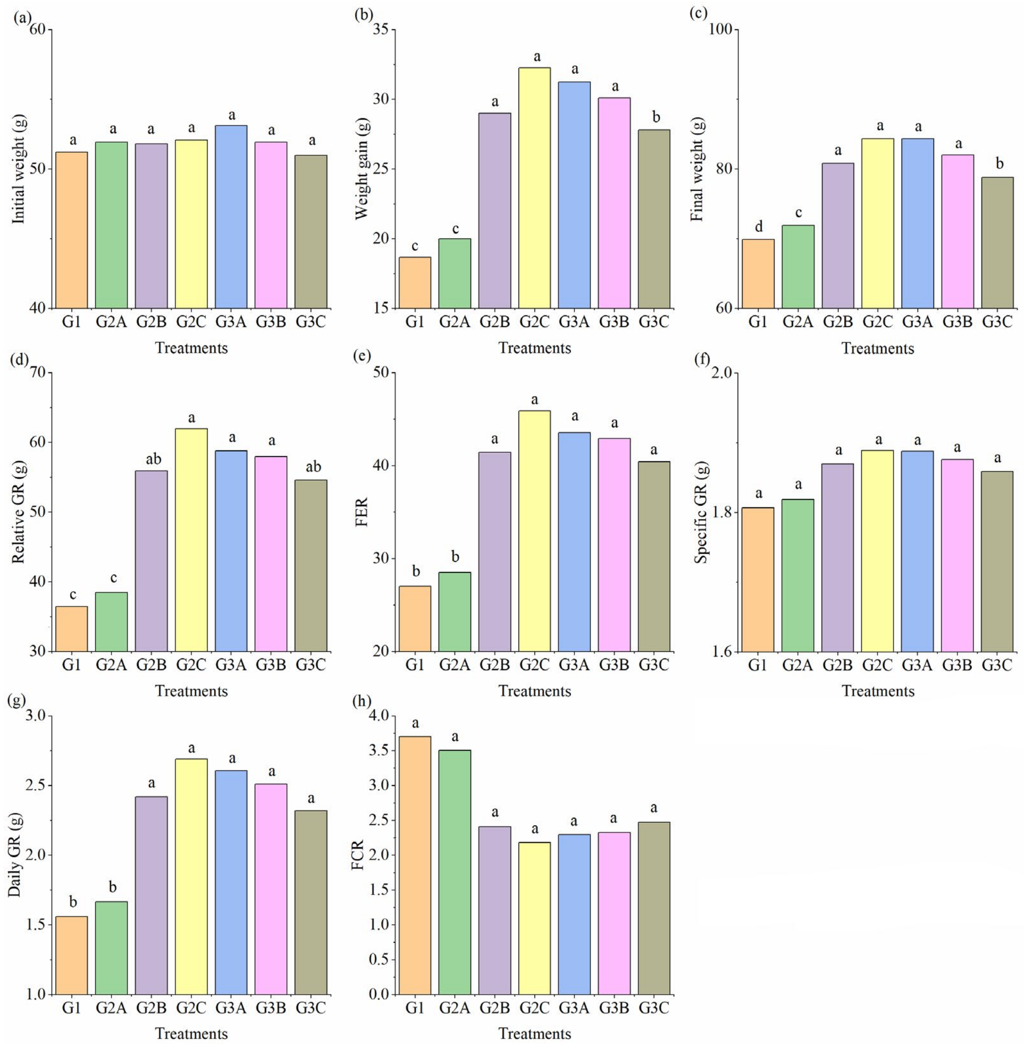


Fig.1. Evaluation of the common carp performance after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p<0.05$ level.

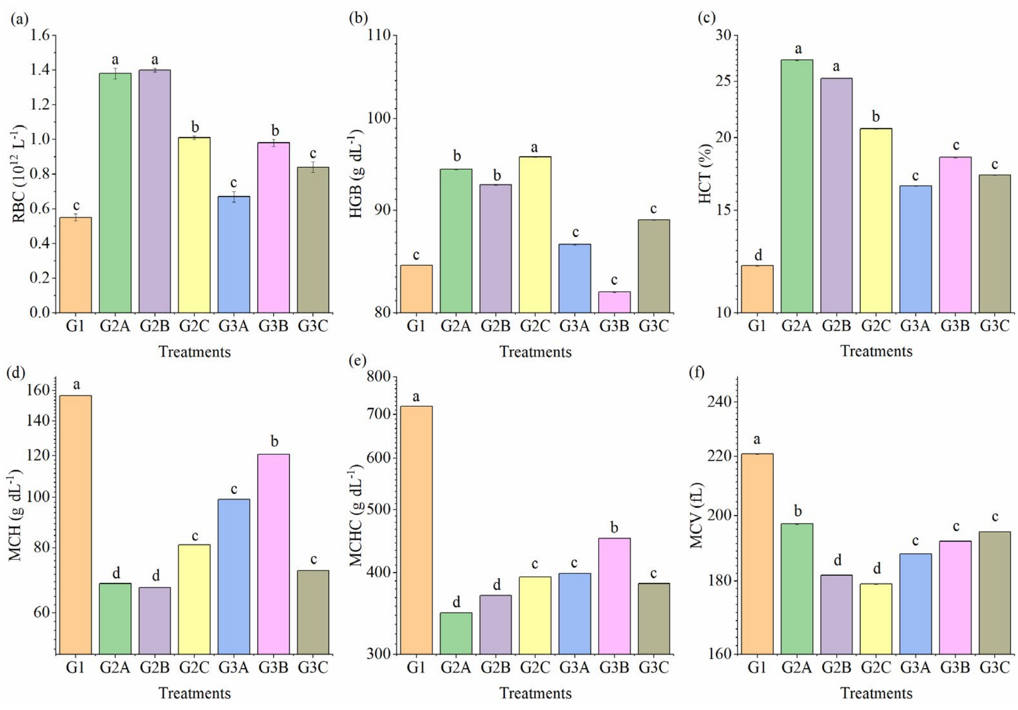


Fig.2. Evaluation of the common carp blood profile after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p<0.05$ level. Note that the y-axes for most of the panels are on a logarithmic scale, and some of the standard deviations are not visible because of small values.

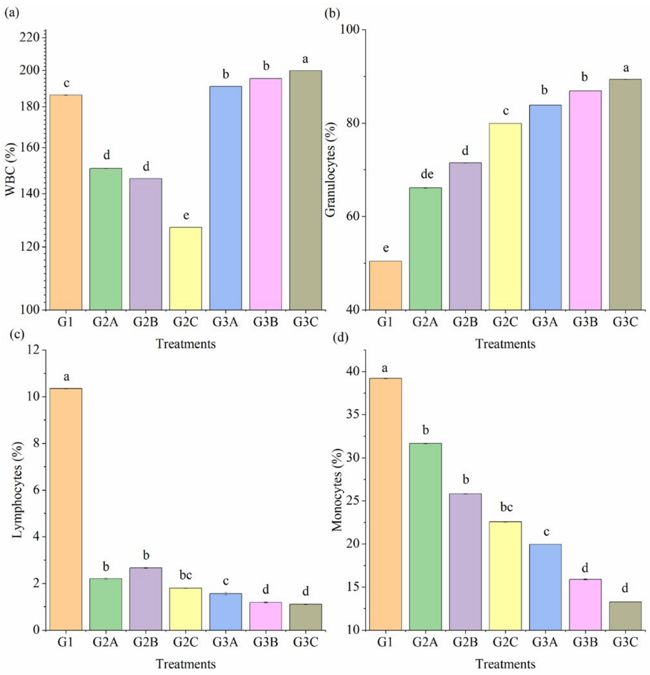


Fig.3. Evaluation of the common carp WBC counts after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p < 0.05$ level. Note that some of the standard deviations are not visible because of small values.

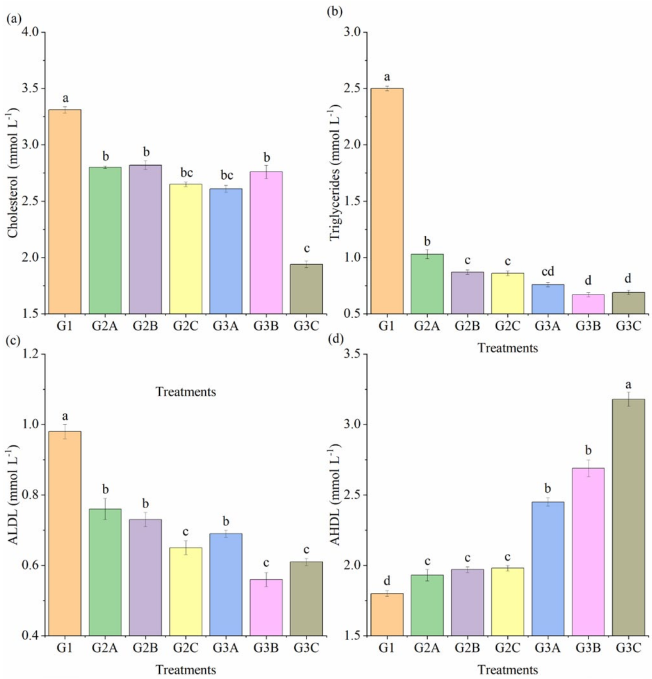


Fig.4. Evaluation of the common carp lipid profile after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p < 0.05$ level.

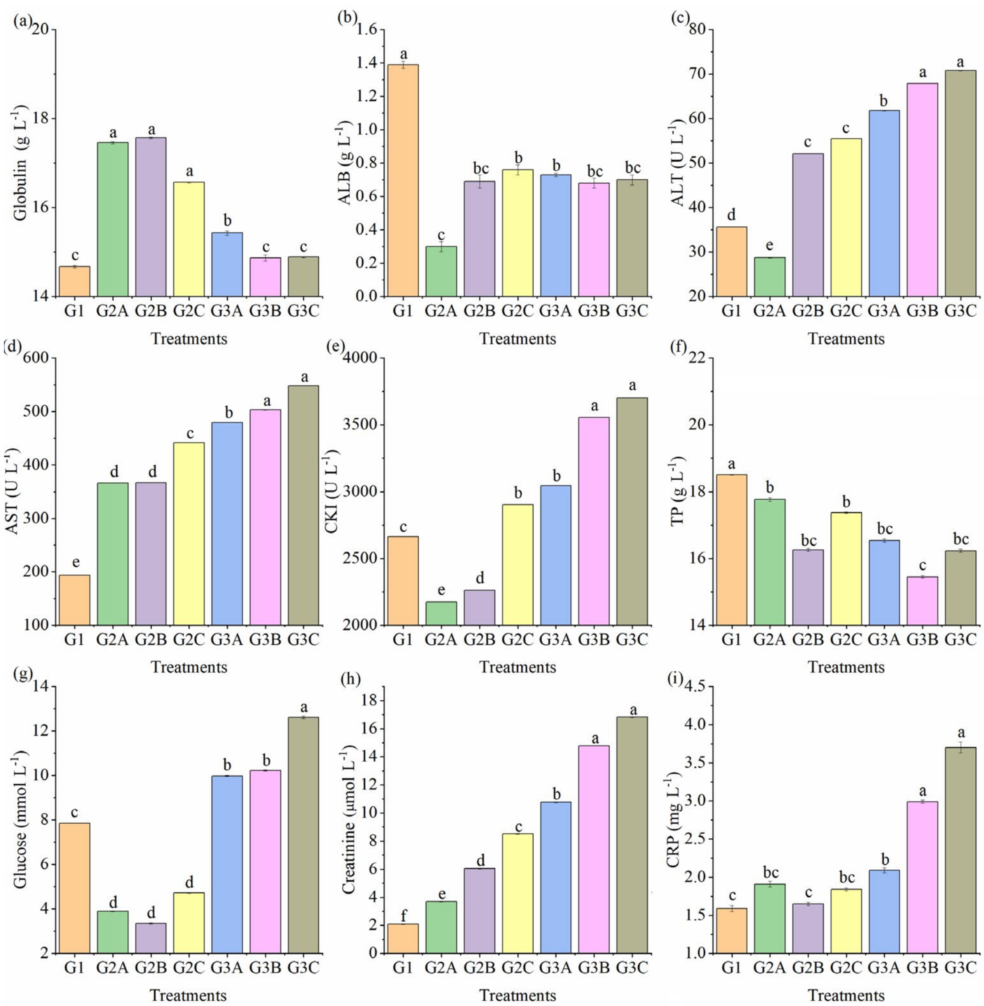


Fig.5. Evaluation of the common carp blood biochemical parameters after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p < 0.05$ level.

Note that some of the standard deviations are not visible because of small values.

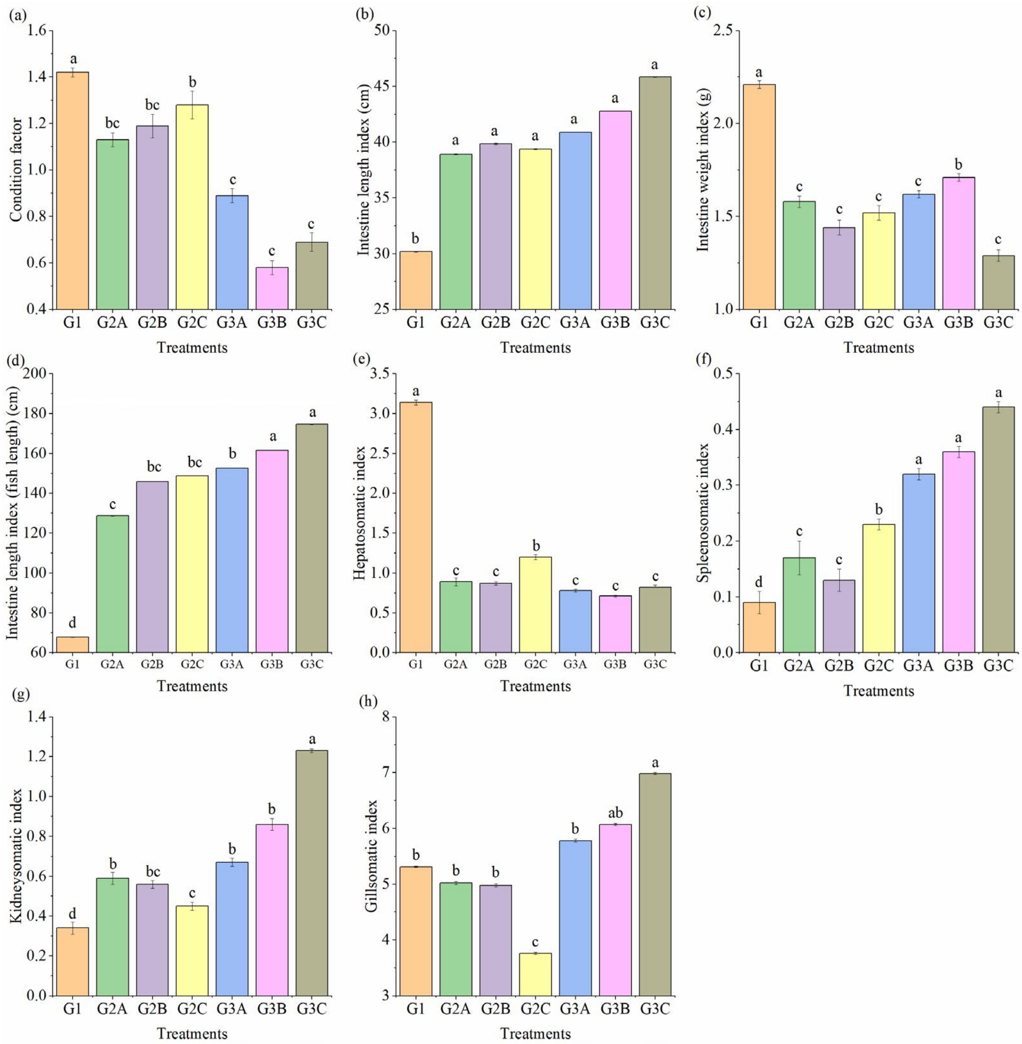


Fig.6. Evaluation of the common carp health indices after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p<0.05$ level. Note that some standard deviations are not visible because of small values.

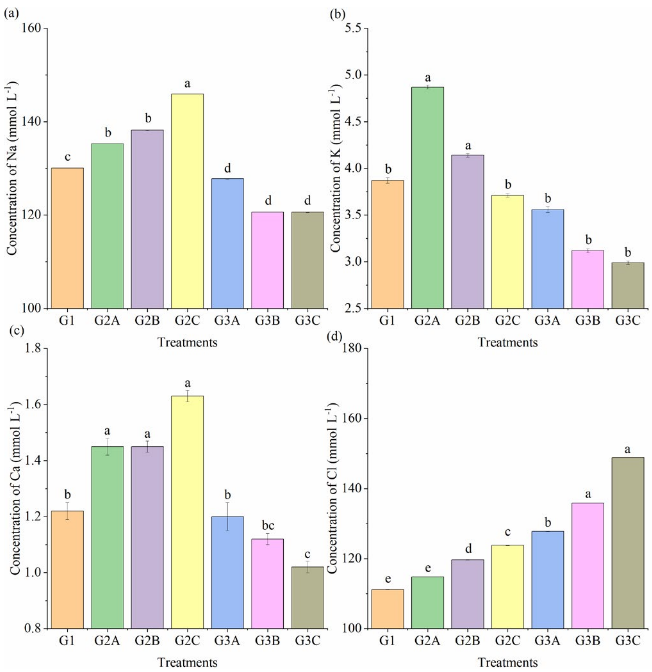


Fig.7. Evaluation of the common carp alkali metal level after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p<0.05$ level. Note that the y-axes for most of the panels are on a logarithmic scale, and some of the standard deviations are not visible because of small values.

viscera meal mixtures adversely affected the palatability and digestibility of the diets, reducing fish growth and diet utilization (He et al., 2023). This is diminished due to reduced palatability resulting from an imbalance of essential nutrient substances (Hasan et al., 2019; Pratoomyot et al., 2011).

4.1. Growth and feed efficiency

Most salt-treated groups, except $G4_A$, showed significantly better growth compared to the control group (G1). Fish in $G4_B$, $G4_C$, $G3_A$, and $G3_B$ gained more weight, suggesting that adding moderate salt can improve nutrient absorption and promote growth. This suggests that the presence of potassium chloride reduced the energy expenditures for osmotic regulation in fish that were not fed on it, as was the case in the treatment control (Albadran et al., 2022). Enhanced daily GR and FER across all treated groups (except $G4_A$) further support the idea that salt helps reduce the energy fish expend on osmoregulation, allowing more energy to be directed toward growth. However, the lack of changes in specific GR indicates that growth improvements may not have been consistent on an individual basis, due to differences in how fish responded to salt or absorbed nutrients. This discrepancy might be attributed to variations in feeding behavior or metabolic partitioning (V. Kumar et al., 2011).

According to Debnath et al. (2017), adding salt to the feed can significantly enhance the growth of tilapia fry. Among the different salt levels tested, the group with 1.5% salt showed the best performance in terms of weight, length, specific GR, and survival rate. The optimum salt level for incorporating in *Oreochromis niloticus* diets is 1.5%. Both 1% and 1.5% salt inclusion levels resulted in better feed utilization. However, increasing the salt level beyond a certain optimum level can render the feed unsuitable for consumption and negatively affect growth (Mubarik et al., 2019; Muhsan and Al-Shawi, 2017).

The daily GR and FER were significantly higher in all groups compared to the G1 and $G4_A$ groups. The study of Pratoomyot et al., (2011) completely disagrees with our finding, where dietary salted viscera meal mixtures did not significantly influence FER or PER in Atlantic salmon. Nile tilapia fingerling PER decreased significantly ($p < 0.05$) with increasing NaCl levels (De Aguiar et al., 2020). These findings were the opposite of the results in our experiment.

4.2. Blood cell responses

Over the last century, it has been reported that brackish water or seawater plays a significant role in various biological and physical traits. Recent studies show that blood parameters are reliable indicators of fish health and welfare, and monitoring these parameters provides valuable insights into fish health status (Acar et al., 2019; Fazio, 2019).

According to the present study's findings, RBC, HGB, and HCT in the $G4_A$ and $G4_B$ groups were significantly increased above the other groups. Buyukates

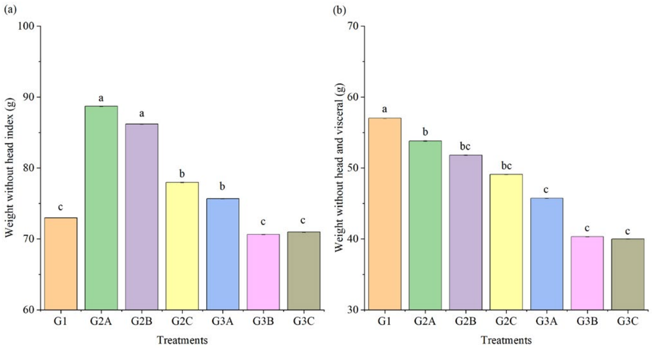


Fig.8. Evaluation of the common carp meat indices after salt supplementation in water and diet. Columns represent mean data, and bars above the columns represent data variability SDs (n = 9). Columns with different letters indicate statistical differences at the $p < 0.05$ level. Note that the y-axes for most of the panels are on a logarithmic scale, and some of the standard deviations are not visible because of small values.

et al. (2023) found that acclimating fish to seawater significantly increased hematological parameters ($P < 0.05$). The G1 group also exhibited a markedly higher MCH, MCHC, and MCV levels than the treatment groups, Buyukates et al. (2023) showed a significant decline ($P < 0.05$) in MCH, MCHC, and MCV of rainbow trout during the gradual transfer from freshwater to seawater. Additionally, the platelet levels showed a significant increase in the treatment groups that received salt additives in their fish diets. Leukocyte count (WBC) is essential for evaluating immune status in vertebrates and is composed of different cell types, including lymphocytes, monocytes, neutrophils, eosinophils, and basophils (Fazio, 2019). The data demonstrated an elevation in WBC and granulocyte levels accompanied by a significant reduction in lymphocyte and monocyte ranges in the treated groups.

The highest salt-fed group ($G3_C$) showed increased WBCs and granulocytes, which often signals an immune system response to stress or inflammation. Meanwhile, the control group had significantly higher lymphocyte and monocyte levels, which could indicate a compensatory immune response in less optimal conditions (Hrubec et al., 2000). These findings suggest that salt can influence the immune system; moderate levels may support immune function, while high levels can trigger stress-related immune responses. Salt, in moderate levels, is known to modulate immune parameters in freshwater fish, potentially through improved osmoregulation and reduced cortisol levels (Emeish, 2019). The common carp can withstand salinities of up to 6 ppt without compromising their ability to survive or their osmoregulatory, immunological, or stress responses (Emeish, 2019).

4.3. Lipid metabolism and liver function

Salt supplementation also had a noticeable effect on lipid metabolism. Control fish had the highest levels of cholesterol, triglycerides, and LDL, which are often associated with fat buildup and metabolic stress.

In contrast, fish in the high-salt diet group ($G3_C$) had increased levels of HDL, which is generally considered beneficial. These shifts suggest that salt can positively influence fat metabolism when used in moderation. Choline supplementation reduced cholesterol and triglycerides in fish (He et al., 2023). The reduction in triglyceride levels can be attributed to the role of choline in preventing the accumulation of excess lipids, which are associated with the development of fatty liver (NRC, 2011). Decreased cholesterol levels may result from a reduction in hepatic lipid content, thereby mitigating the risk of liver dysfunction in fish receiving choline supplementation (Li et al., 2014; Luo et al., 2016).

Elevated liver enzymes (ALT and AST) and (CKI) in the $G3_C$ group point to potential liver and muscle stress, which could reflect liver and muscle stress or damage due to excessive dietary salt (Hoseini et al., 2018). These enzymes are sensitive biomarkers of hepatic and muscular injury (Palanivelu et al., 2005), and their increase in high-salt diet groups aligns with Nassar et al. (2021) findings in carp under osmotic stress.

Our results indicated a significant increase in ALT, AST, and CKI levels in the $G3_C$ group compared to other groups. In contrast with our finding, fish under choline supplementation, AST, ALT, and cholesterol displayed a drastic reduction (He et al., 2023). The decreased levels of ALT and AST in the bloodstream suggest the presence of a defatted liver, which is attributed to exposure to choline chloride as well as its associated lipotropic metabolites (Das et al., 2022). Conversely, elevated ALT and AST activity in plasma was observed in the common carp following treatment with diazinon (Banaei et al., 2008; Takeuchi-Yorimoto et al., 2013). Additionally, elevated levels of ALT and AST were observed in the liver and muscle of *L. rohita* following exposure to endosulfan. These levels returned to normal after treatment with choline and its metabolites (N. Kumar et al., 2012). The addition of salt to water in the $G4_A$, $G4_B$, and $G4_C$ groups led to a significant increase in globulin levels. Unexpectedly, only the control group showed a significant increase in ALB levels. Nevertheless, the elevation in ALB and GL in seawater trout, in comparison with freshwater samples, was statistically significant ($P < 0.05$). Moreover, the rise in ALB was observed until the end of the experiment (Buyukates et al., 2023).

4.4. Protein levels, inflammation, and kidney function

The control group had the highest TP and ALB, while fish exposed to salt, the higher TP activity was observed during the breeding season with choline (Das et al., 2022). Additionally, seawater-acclimated fish showed higher serum TP levels than those from freshwater samples; however, this increase was not statistically significant ($P < 0.05$) (Buyukates et al., 2023). It had increased globulin levels, which may relate to enhanced immune activity. Notably, fish in the $G3_C$ group also showed higher GL, creatinine, and CRP levels, indicating possible kidney strain and systemic inflammation. As a result of increasing salinity in the environment, an increase in plasma GL levels is anticipated (Emeish, 2019), and elevated serum GL levels were observed when fish were transferred to seawater conditions. These results are consistent with previous studies that linked high salt intake to stress and reduced kidney function in freshwater species (Sampaio and Bianchini, 2002).

4.5. Organ health and intestinal changes

The control group also had higher condition factors and liver size (HSI) due to increased fat storage and lower feed utilization efficiency. The HSI is an indicator of the systemic health status of fish, reflecting hepatic energy stores and metabolic functions (Pyle et al., 2005). In contrast, fish in the $G3_C$ group had larger spleen somatic, kidney somatic, and gill somatic indices, potentially as a result of increased immune activation and osmoregulatory demand (Aalamifar et al., 2020). Interestingly, all salt-treated groups exhibited increased intestinal length, particularly in $G3_C$, indicating an adaptive response that enhances digestion and nutrient absorption in response to the altered environment (Ural and Sağlam, 2005).

4.6. Mineral balance and ion regulation

As expected, salt treatments affected the balance of ions in the fish blood. Na levels were significantly higher in $G4_C$; potassium levels were significantly higher in $G4_A$, and Cl levels were the highest in $G3_C$. These changes indicate the active regulation of ions and mineral uptake, particularly in groups exposed to salt through water. Katuli et al. (2014) found that exposure to diazinon affected the regulation of plasma sodium, chloride, and potassium in Caspian roach (*Rutilus caspicus*) after they were exposed to saltwater. The $Na+$ level in plasma, muscles, and erythrocytes of goldfish decreases in the total water content, which indicates the development of initial signs of tissue dehydration (Andreeva et al., 2022). The increase in calcium in water-treated groups may be related to improved mineral absorption or changes in gill function (Barton and Iwama, 1991). However, excessive ion accumulation, especially at high salt levels, could disrupt cellular balance if not properly regulated. Fish must actively use energy to enter ions via their gills and digestive system against the concentration gradient in freshwater, which is a hypotonic environment (Hallali et al., 2018). The findings of the current experiment are consistent with other research on euryhaline species that demonstrated the benefits of salt-enriched diets for both food efficiency and development (Salman, 2009).

Additionally, the level of K increased in $G4_A$ compared to different groups, as well as Ca in the water treated groups $G4_A$, $G4_B$, and $G4_C$. *L. rohita* revealed the maximum concentration of Ca among the studied species (Das et al., 2022). Conversely, a decreasing trend in Ca content was also observed in *Anabas testudineus* following anthracene exposure, likely due to increased Ca elimination (Dey et al., 2019). Sulfhydryl concentration decreased at higher NaCl concentrations, possibly due to increased protein solubility and unfolding under elevated salt conditions (He et al., 2023).

4.7. Body composition and somatic development

Fish in the $G4_A$ and $G4_B$ groups had higher "weight without head" indices, indicating that moderate salt in water may support lean body growth. Meanwhile, the G1 only displayed a significant increase in weight without head and visceral compared to other treatment groups. HSI and visceral are commonly employed as biological indicators (Ha et al., 2021). These observations support the role of controlled salinity in directing energy toward muscle development rather than fat accumulation.

5. Conclusion

In conclusion, we studied the effects of different salt additives in fish diets and water on the hematological and biochemical parameters, and organ indices of common carp in Sulaimaniyah province, Iraq. Overall, the results of the present experiment suggested that different additives of salt in fish diets and water can have significant effects on the growth, blood-related and biochemical parameters, and organ indices of common carp. These findings may be beneficial for fish farmers in identifying the most suitable and effective salt additives for both fish diets and rearing water. Furthermore, this study demonstrated that the application of 14 g L^{-1} of salt in rearing water and 15 g kg^{-1} of salt in the diet represents the optimal concentrations for enhancing fish growth and health in practical applications. Further investigation is required to elucidate the mechanisms behind the observed effects and to enhance the application of salt additives in aquaculture practices.

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Availability of data and materials

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Conflict of Interest

The authors declare no conflicts of interest.

References

Aalamifar H., Soltanian S., Vazirzadeh A. et al. 2020. Dietary butyric acid improved growth, digestive enzyme activities and humoral immune parameters in Barramundi (*Lates calcarifer*). Aquaculture Nutrition 26 (1): 156-164. DOI: 10.1111/anu.12977

Abdel-Tawwab M., Abdulrahman N.M., Ahmad V.M. et al. 2022. Effects of dietary oak (*Quercus aegilops L.*) acorn on growth performance, somatic indices, and hemato-biochemical responses of common carp, *Cyprinus carpio L.*, at different stocking densities. Journal of Applied Aquaculture 34 (4): 877–893. DOI: 10.1080/10454438.2021.1902450

Abdulrahman N.M. 2022. Effect of Germinated Barely and Earth Apple (Helianthus tuberosus) Powders in Some Physio-biological Indices of Common Carp (*Cyprinus carpio L.*). Iranian Journal of Veterinary Medicine 16 (2): 119–125.

Abedalhammed H.S., Abdulrahman N.M.A., Sadik H.L. 2017. Comparative study of the effect of natural planting, hydroponic germination and barley sprout powder as prebiotic in common carp *Cyprinus carpio L.* blood indices. Iraqi journal of Veterinary Sciences 31: 7-11.

Acar U., Saoca C., Kesbic O. et al. 2019. Comparative study on haematological and biochemical parameters of two wild sparid fish species. Cahiers de Biologie Marine 60 (1): 51-57. DOI: 10.21411/cbm.a.39a890f1

Albadran M., Sultan F., Najim S. 2022. Effect of potassium chloride and growth hormone supplementation on survival, nutrition and growth in juvenile Common carp fish *Cyprinus carpio* exposed to salinity. Neuro Quantology 20: 1226-1241. DOI: 10.14704/nq.2022.20.12.nq77102

Andreeva A.M., Martemyanov V., Vasiliev Ilya A.S. et al. 2022. Goldfish as a model for studying the effect of hypernatremia on blood plasma lipoproteins. Bratisl Lek Listy 123 (3): 172-177. DOI: 10.4149/bll 2022 028

APHA A.P.H.A. 2017. Standard methods for the examination of water and wastewater. (23 Ed.). Washington DC: American public health association.

Banaei M., Mir V.A., Rafei G. et al. 2008. Effect of sub-lethal diazinon concentrations on blood plasma biochemistry. Intenational Journals Environment Resource 2 (2): 189–198.

Barton B.A., Iwama G.K. 1991. Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids. Annual Review of Fish Diseases 1: 3-26. DOI: 10.1016/0959-8030(91)90019-G

Buyukates Y., Kesbiç O., Yigit M. et al. 2023. Temporal Variations in Hematological, Immunological and Serum Biochemical Parameters of Rainbow Trout (*Oncorhynchus mykiss*) Acclimated to High-Saline Water in the Northern Aegean Sea. Annals of Animal Science 23 (1): 97-106. DOI: 10.2478/aoas-2022-0047

Das S., Patra A., Mandal A. et al. 2022. Choline Chloride Induces Growth Performance of Indian Major Carps and Air-Breathing Fish Species with an Outcome of Quality Food-Fish under a Semi-Intensive Culture System: A Biochemical Investigation. ACS Omega 7 (17): 14579-14590. DOI: 10.1021/acsomega.1c06533

De Aguiar N.C., Dias P.S., Balen R.E. et al. 2020. Dietary sodium chloride effect in Nile tilapia fed with fish meal-free diets. Spanish Journal of Agricultural Research 18 (3): e0610. DOI: 10.5424/sjar/2020183-15753

Debnath P., Chowdhury S.K., Roy N.C. 2017. Effect of dietary slat supplementation on growth and feed utilization of tilapia (*Oreochromis niloticus*). International J. of Fisheries Aquatic Studies 5 (6): 275-280.

Dey S., Samanta P., Mondal N.S. et al. 2019. Dose specific responses of *Anabas testudineus* (Bloch) to anthracene (PAH): Haematological and biochemical manifestation. Emerging Contaminants 5: 232-239. DOI: 10.1016/j.emcon.2019.07.001

Emeish W. 2019. Adaptation of common carp to salinity. Assiut Veterinary Medical Journal 65 (162): 101-110. DOI: 10.21608/avmj.2019.168957

FAO. 2022. The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation. FAO 1 (1): 266. DOI: 10.4060/cc0461en

Fazio F. 2019. Fish hematology analysis as an important tool of aquaculture: A review. Aquaculture 500: 237-242. DOI: 10.1016/j.aquaculture.2018.10.030

Ha M.S., Lee K.W., Kim J. et al. 2021. Dietary substitution effect of fish meal with chicken by-product meal on growth, feed utilization, body composition, haematology and non-specific immune responses of olive flounder (*Paralichthys olivaceus*). Aquaculture Nutrition 27 (2): 315-326. DOI: 10.1111/anu.13176

Hallali E., Kokou F., Chourasia T.K. et al. 2018. Dietary salt levels affect digestibility, intestinal gene expression, and the microbiome, in Nile tilapia (*Oreochromis niloticus*). PLoS One 13 (8): 0202351. DOI: 10.1371/journal.pone.0202351

Hama S.R., Abdulrahman N.M., Mohammed H.F. et al. 2025. Enhancing Common Carp (*Cyprinus carpio*) Health Aspects and Performance with Garden Cress (*Lepidium sativum*) Seed Powder. Journal of Fisheries and Environment 49 (2): 200-215. DOI: 10.34044/j.jfe.2025.49.2.15

Hasan B., Putra I., Suharman I. et al. 2019. Growth performance and carcass quality of river catfish *Hemibagrus nemurus* fed salted trash fish meal. Egyptian Journal of Aquatic Research 45 (3): 259-264. DOI: 10.1016/j.ejar.2019.07.005

He X., Zhao H., Xu Y. et al. 2023. Synergistic effects of oat β-glucan combined with ultrasound treatment on gel properties of silver carp surimi. Ultrasonics Sonochemistry 95: 106406. DOI: 10.1016/j.ultsonch.2023.106406

Hoseini S.M., Hoseinifar S.H., Doan H.V. 2018. Effect of dietary eucalyptol on stress markers, enzyme activities and immune indicators in serum and haematological characteristics of common carp (*Cyprinus carpio*) exposed to toxic concentration of ambient copper. Aquaculture Research 49 (9): 3045-3054. DOI: 10.1111/are.13765

Hrubec T.C., Cardinale J.L., Smith S.A. 2000. Hematology and plasma chemistry reference intervals for cultured tilapia (*Oreochromis hybrid*). Vet Clin Pathol 29 (1): 7-12. DOI: 10.1111/j.1939-165x.2000.tb00389.x

Katuli K.K., Amiri B.M., Massarsky A. et al. 2014. Impact of a short-term diazinon exposure on the osmoregulation potentiality of Caspian roach (*Rutilus rutilus*) fingerlings. Chemosphere 108: 396-404. DOI: 10.1016/j.chemosphere.2014.02.038

Kubitza F. 2016. Common salt a useful tool in aquaculture–Part 1. Global Aquaculture Advocate. URL: https://www.globalseafood.org/advocate/common-salt-a-useful-tool-in-aquaculture-part-1/

Kumar N., Jadhao S.B., Chandan N.K. et al. 2012. Dietary choline, betaine and lecithin mitigates endosulfan-induced stress in *Labeo rohita* fingerlings. Fish Physiology and Biochemistry 38 (4): 989–1000. DOI: 10.1007/s10695-011-9584-y

Kumar V., Sinha A., Makkar H. et al. 2011. Phytate and phytase in fish nutrition. Journal of animal physiology and animal nutrition 96: 335-364. DOI: 10.1111/j.1439-0396.2011.01169.x

Li J.Y., Zhang D.D., Xu W.N. et al. 2014. Effects of dietary choline supplementation on growth performance and hepatic lipid transport in blunt snout bream (*Megalobrama amblycephala*) fed high-fat diets. Aquaculture 434: 340–347. DOI: 10.1016/j.aquaculture.2014.08.006

Luo Z., Wei C.-C., Ye H.-M. et al. 2016. Effect of dietary choline levels on growth performance, lipid deposition and metabolism in juvenile yellow catfish *Pelteobagrus fulvidraco*. Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology 202: 1-7. DOI: 10.1016/j.cbpb.2016.07.005

Mubarik M.S., Asad F., Zahoor M.K. et al. 2019. Study on survival, growth, haematology and body composition of *Cyprinus carpio* under different acute and chronic salinity regimes. Saudi J Biol Sci 26 (5): 999-1002. DOI: 10.1016/j.sjbs.2018.12.013

Muhsan A.M., Al-Shawi S.A. 2017. Effect of salts addition of some organic acids on growth performance of Common Carp Juvenile *Cyprinus carpio L*. The Iraqi Journal of Veterinary Medicine 40 (2): 131-134. DOI: 10.30539/iraqijvm.v40i2.124

Nader P.J., Abdulrahman N.M. 2017. Impact of Black Grape byproducts on Blood Picture in Common Carp (*Cyprinus carpio L*.). Basrah Journal of Agricultural Sciences 30 (1): 32-37. DOI: 10.37077/25200860.2017.15

Nasir N.A.-N., Qusey H. 2016. Growth development of young common carp *Cyprinus carpio* through dietary sodium chloride supplementation. Mesopotamia Environmental Journal (mesop. environ. j) 2 (2): 12-18.

Nassar S., Hassan A., Badran M. et al. 2021. Effects of salinity level on growth performance, feed utilization, and chromatic deformity of the hybrid Red tilapia, *Oreochromis niloticus* x *O. mossambicus*. Egyptian Journal of Aquatic Biology and Fisheries 25: 49-61. DOI: 10.21608/ejabf.2021.158248

NRC N.R.C. 2011. Nutrient requirements of fish and shrimp, Washington D.C., USA: National Academies Press,.

Palanivelu V., Vijayavel K., Balasubramanian S.E. et al. 2005. Influence of insecticidal derivative (cartap hydrochloride) from the marine polycheate on certain enzyme systems of the fresh water fish *Oreochromis mossambicus*. Journal of Environment and Biology 26 (2): 191-195.

Pratoomyot J., Bendiksen E.Å., Campbell P.J. et al. 2011. Effects of different blends of protein sources as alternatives to dietary fishmeal on growth performance and body lipid composition of Atlantic salmon (*Salmo salar L*.). Aquaculture 316 (1): 44-52. DOI: 10.1016/j.aquaculture.2011.03.007

Pyle G.G., Rajotte J.W., Couture P. 2005. Effects of industrial metals on wild fish populations along a metal contamination gradient. Ecotoxicol Environ Saf 61 (3): 287-312. DOI: 10.1016/j.ecoenv.2004.09.003

Salman N. 2009. Effect of dietary salt on feeding, digestion, growth and osmoregulation in teleost fish. Society of Experimental Biology 1: 109–150.

Sampaio L.s.A., Bianchini A. 2002. Salinity effects on osmoregulation and growth of the euryhaline flounder *Paralichthys orbignyanus*. Journal of Experimental Marine Biology and Ecology 269 (2): 187-196. DOI: 10.1016/S0022-0981(01)00395-1

Takeuchi-Yorimoto A., Noto T., Yamada A. et al. 2013. Persistent fibrosis in the liver of choline-deficient and iron-supplemented l-amino acid-defined diet-induced nonalcoholic steatohepatitis rat due to continuing oxidative stress after choline supplementation. Toxicology and Applied Pharmacology 268 (3): 264-277. DOI: 10.1016/j.taap.2013.01.027

Ural M.Ş., Sağlam N. 2005. A study on the acute toxicity of pyrethroid deltamethrin on the fry rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792). Pesticide Biochemistry and Physiology 83 (2): 124-131. DOI: 10.1016/j.pestbp.2005.04.004