



THE IMPACT OF DIETARY ORGANIC FOOD ON THE HAEMATOLOGICAL PARAMETERS, BODY COMPOSITION AND GROWTH OF SILVER CARP RAISED IN RECIRCULATING AQUACULTURE SYSTEM

Ifrah Manzoor¹, Barira Zahid², Abeera Khan², Iram Parveen³, Iqra Qadeer², Maham Iftikhar⁴, Bareera Sarwar⁵, Rabia Yasmeen⁶

¹Department of Zoology, Cholistan University of Veterinary and Animal Sciences, Bahawalpur

²Department of Zoology, Wildlife & Fisheries, University of Agriculture, Faisalabad

³Department of Zoology, Government College University, Lahore

⁴Department of Zoology, Government College University, Faisalabad

⁵Department of Zoology, Government College Women University, Faisalabad

⁶Department of Biochemistry and Biotechnology, The Women University, Multan

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Corresponding Author:

Iqra Qadeer,

Zoology, Wildlife & Fisheries,
University of Agriculture,
Faisalabad

Email: iqraqadeer571@gmail.com

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ABSTRACT

The effects of different dietary doses of organic selenium (Se) on the growth, body composition, and haematological parameters of silver carp were evaluated in a feeding experiment. The basal diet was supplemented with selenium at levels of 0.0, 0.5, 1, and 2 mgkg⁻¹. A total of 25 fish were randomly stocked into 500 L tanks using Recirculating Aquaculture System (RAS) technology and fed for ten weeks. Fish fed diets containing 0.5 mgkg⁻¹, 1 mgkg⁻¹, and 2 mgkg⁻¹ Se showed significantly higher weight gain, final body weight, and specific growth rate ($p < 0.05$). The lowest growth values were observed in fish fed the basal diet. Survival rate was similar among all treatment groups, and no significant difference was observed in feed intake ($p > 0.05$). Whole-body composition analysis revealed that fish fed 1 mgkg⁻¹ Se had significantly higher body moisture and protein levels on a dry weight basis ($p < 0.05$). Fish receiving 2 mgkg⁻¹ Se had the highest fibre content, while those fed 0.5 mgkg⁻¹ had significantly higher ash content. Dietary selenium had no significant effect on fat content. Whole-body selenium concentrations increased significantly ($p < 0.05$) with increasing dietary Se levels. Haematological data indicated that fish fed 0.5 mgkg⁻¹ and basal diets exhibited significantly higher haemoglobin and red blood cell counts ($p < 0.05$). White blood cell counts were higher in fish fed basal and 2 mgkg⁻¹ diets, whereas lymphocyte percentages were higher in fish fed basal and 0.5 mgkg⁻¹ diets ($p < 0.05$). Overall, the study concludes that dietary selenium supplementation benefits silver carp. Supplementation with organic selenium, particularly at 0.5–1 mgkg⁻¹, improved growth performance, whole-body protein content, selenium deposition, and certain haematological indicators. Therefore, the optimal dietary selenium level for silver carp is suggested to be between 0.5 and 1 mgkg⁻¹.

1. INTRODUCTION

A trace mineral that has recently attracted a lot of attention in aquaculture nutrition, selenium (Se) is an essential component required for fish growth (Tabasian, H et al, 2021). It is crucial to biological systems since it is a component of the enzyme glutathione peroxidase. It transforms into selenoproteins, which are in charge of a number of biological processes within cells (Rotruck JT et al, 1980, Lall SP et al, 2021). Aquaculture feed is therefore required for physiological functions and typical growth. Dietary deficiency of Se affects development rate and promotes mortality (Rotruck JT et al, 1980, Zhou X et al, 2009). The most readily metabolised form of selenium is organic, and it is a mineral that occurs naturally in the environment. Selenates and selenites are the main forms in which it is found in trace levels in water (Kieliszek M. et al, 2019). The bioavailability of Se is influenced by several factors. One of the primary influencing factors is thought to be its chemical form (Kieliszek M. et al, 2016). When other components like vitamins E, D, and A are present, it is absorbed more efficiently (Rotruck JT et al, 1980). Furthermore, the bioavailability of Se is influenced by heavy metals, proteins, and lipids.

On the other hand, high concentrations of Se are harmful because they build up in fish tissue (Lemly AD et al, 1999, Hilton JW et al, 1980). Fish are fed a variety of chemical forms of selenium. Because organic selenium is more biologically active and accessible than inorganic forms, it is frequently utilised in aquaculture (Han D et al, 2013). Consequently, numerous studies have documented the effects of dietary selenium on different fish species using varying forms and amounts.

Fish species and culture conditions affect the incorporation rate of Se. Several species, including the channel catfish (*Ictalurus punctatus*) (Liu S et al, 2022), cobia (*Rachycentron canadum*), and Nile tilapia (*Oreochromis niloticus*) (Al-Din et al, 2022), as well as cyprinid species like crucian carp

(*Carassius carassius*) (Mushtaq M et al, 2022), gibel carp (*Carassius auratus gibelio*) (Zhou X et al, 2009, Han D et al, 2013), silver carp (*Hypophthalmichthys molitrix*) (Saffari S et al, 2017), and a small number of studies on silver carp (Ashouri S et al, 2015), have been conducted regarding the effects of selenium.

Saffari et al. discovered that nano-Se was more effective than both organic and inorganic forms (Ashouri S et al, 2015), whereas (Ashouri et al. 2010) revealed that employing 1 mg of nano-Se enhanced the growth and antioxidant status of Silver Carp. Using 0.03 mg/kg-1 organic Se, (Ani et al. 2010) discovered some beneficial effects of Se on Silver Carp performance, which is comparable to the current investigation (Gaber MM et al. 2009).

Few studies have been conducted on the optimal dietary Se requirements of silver carp, a fish with substantial economic significance and a global distribution. The goal of the current study was to find out how varying rates of organic Se inclusion in feed affected the juvenile silver carp's body composition, growth performance, and blood haematological indicators.

2. Materials and Methods

2.1. Experimental design

Juveniles of silver carp were obtained from a nearby fish hatchery in University of Agriculture. Fish were acclimated and given a control diet prior to the experiment. The experiment was carried out at the Agricultural Research Centre in University of Agriculture, using the RAS system. Polyethylene tanks, a drum filter, a protein skimmer, and a biological filter made up the 18 m³ system. In addition, the system had a UV steriliser and an ozone generator. Twenty-five fish were placed in each 12:500L polyethylene tank using a randomised complete block design for treatment allocation. Throughout the trial, the system was upheld and cleared.

2.2. Test Diets and experimental duration

During the two-week acclimatisation period, fish were fed the basal diet. Three test diets

were then prepared and put into use. For growing silver carp in RAS culture, a basic diet was created that included the necessary nutrients and had a balanced nutritional value. As a foundation for organic Se, Sel-plex (1000), which was acquired from Alltech Company, was added to three test diets. 0.5, 1, and 2 mgkg⁻¹ Se were added to each of the three test diets (Table 1). For ten weeks, fish were given a certain amount of 3% of the test diets twice a day.

2.3. Water quality

In the RAS system, the water's chemical and physical characteristics were kept within the ideal range for Silver Carp culture. Temperature, pH, and dissolved oxygen (DO) were measured daily. Every five days, measurements of ammonia (NH), nitrite (No-), and nitrate (No-) were made. A constant temperature of 22.45±0.90 °C (Mean±SD), DO 8.15±0.64 mgL⁻¹, PH 8.34±0.06, NH 0.22±0.01 mgL⁻¹, No- 1.66±0.69 mgL⁻¹, and No- 2.5±1.21 mgL⁻¹ were maintained throughout the experiment.

2.4 Growth performance

Weekly fish weights were taken in order to measure growth parameters. At the conclusion of the experiment, samples were taken for a variety of measurements. All fish were weighed at the conclusion of the experiment, or week 10, in order to evaluate growth metrics. The following formulas were used to compute and assess weight gain (WG), specific growth rate (SGR), survival rate, feed conversion efficiency (FCE), protein efficiency ratio (PER), and feed conversion ratio (FCR):

$$WG = \text{Final Weight (g)} - \text{Initial weight(g)}$$

$$SGR = \frac{(\ln \text{ final weight} - \ln \text{ initial weight})g \times 100}{\text{rearing days (days)}}$$

$$FCR = \frac{\text{Total feed given (g)}}{\text{Total weight gain (g)}}$$

$$PER = \frac{\text{Total wet weight gain(g)}}{\text{Dry weight of protein in diet (g)}}$$

Table 1. Formulation and proximate composition (% dry matter) of experimental diets containing different concentrations of organic selenium (Se).

Ingredients	Ingredient quantities in different dietary Se level			
	0	0.5	1	2
Fish meal 65% anchovy	29	29	29	29
Soybean 46% (expel)	33	33	33	33
Corn	15.6	15.6	15.6	15.6
Wheat bran	9	9	9	9
Wheat (10CP)	13	13	13	13
Oil	4	4	4	4
Vitamin premix free Se ^a	0.3	0.3	0.3	0.3
Sel-plex ^b	0.5	1	1.5	2.5
Proximate composition of test diets				
Protein (%)	36.80	36.79	34.50	37.30
Ash (%)	8.62	8.77	9.11	9.12
Fiber (%)	3.43	4.71	4.81	4.28
Moisture (%)	6.39	6.30	6.17	6.10
Lipid (%)	8.77	7.35	8.43	7.76
Energy al/kg ^{kc}	3063	3036	3039	3052

a: Vitamin premix contains the followings (mgkg⁻¹): vitamin B1, 20; vitamin B2, 20; vitamin B5, 25; vitamin B6, 10; vitamin B12, 3; vitamin A, 90; vitamin K3, 10 vitamin D3, 20; Iron, 12000; Copper, 4000; Zinc, 10000; Manganese, 12000.

b: Sel-plex[®] 1000 From Alltech Company, Branch of Turkey.

$$FCE = \frac{\text{Total weight gain(g)}}{\text{Total feed given (g)}} \times 100$$

$$\text{Survival rate\%} = \frac{\text{No. of initial fish stocked}}{\text{No. of fish harvested}} \times 100$$

2.5 Diets and whole-body composition

Prior to being sacrificed with an overdose of MS-222 (tricaine methanesulfonate), samples were chosen at random and weighed. They were ground and their approximate composition examined after being dried for 24 hours at 105°C in an oven. Additionally, the deposition of organic Se in test meals and fish samples was investigated. Standard proximate composition was used to analyse the moisture, ash, protein, and lipids. The moisture was determined by oven-drying samples at 105°C to a constant weight, and the ash was determined by burning them for 24 hours at 550°C. Protein was assessed using the Kjeldahl method, and lipid was identified by ether extraction using the Soxhlet method. The Atomic Absorption Spectroscopy (AAS) method, as described by (Tinggi et al. 1999), Ministry of Science and Technology, was used to measure the amount of selenium in fish samples and meals.

2.6 Hematological analysis

Fish samples were chosen at random, and 100 mgL⁻¹ of MS-222 was used to anaesthetise them. Caudal vein blood was drawn and put into tubes containing 5 mg of EDTA. Haematology Analyser (MCL 3800, China) was used to measure the haematological analysis of red blood cells (RBC), haematocrit (HCT), haemoglobin (HGB), platelet count (PLT), mean platelet volume (MPV), mean corpuscular haemoglobin concentration (MCHC), and mean corpuscular haemoglobin (MCH). As previously mentioned, a haematology analyser was used to measure additional haematological parameters, including monocyte percentage (MON%), lymphocyte percentage (LYM%), white blood cells (WBC), and granulocyte percentage (GRA%).

2.7 Statistical analysis

The Shapiro-Wilk test was used to check the data for homogeneity and normality of variance. A one-way analysis of variance (ANO-VA) was used to examine the data. A post-hoc test was used to determine further significance, followed by Tukey's and

Duncan's tests. Multiple comparisons and significances were evaluated at ($p < 0.05$). The descriptive statistics were displayed as mean \pm standard deviation.

3. Results

The addition of 0.5 mgkg⁻¹ of dietary selenium improved ($p < 0.05$) FBW, WG, and SGR in the current investigation (Table 2). The fish-fed basal diet had an FBW of 57.06 g, while the treatment with the greatest Se content had an FBW of 54.41 g. The fish-fed baseline diet had the lowest FBW. Additionally, the WG in the 0.5 mgkg⁻¹ treatment was 30.10g and considerably greater ($p < 0.05$) than the WG in the other treatments, which were followed by treatment three.

Furthermore, there were no discernible variations ($p > 0.05$) in feed utilisation metrics across the various treatment groups (Table 3). In every treatment group, FCR, PER, TFI, and FCE were comparable. Additionally, there were no discernible variations in survival rates between feeding treatments ($p > 0.05$). Fish fed a basal diet had a 92% survival rate, while the highest Se-fed fish had a 90% survival rate.

A dry weight basis was used to measure the whole-body composition. The protein, fibre, and ash content of fish fed 1, 2, and 0.5 mgkg⁻¹, respectively, showed significant differences ($p < 0.05$). Fish fed 1 mgkg⁻¹ had a body protein content of 56.46%, which was considerably greater ($p < 0.05$) than fish fed a basic diet of 48.00% (Table 4). The fibre content of fish fed 2 mgkg⁻¹ was substantially ($p < 0.05$) higher at 1.66% than that of fish fed a basal diet alone, which came in second at 0.97%. Fish fed only 0.5 mgkg⁻¹ had an ash level of 9.43%, which was substantially greater ($p < 0.05$) than the other treatment groups; nevertheless, the basal diet provided better digestible energy. Fish fed 2 mgkg⁻¹ Se had significantly ($p < 0.05$) more Se (0.97 mgkg⁻¹) than other fish, according to whole-body retention and deposition of Se (Table 4).

Table 2. Growth rate parameters of Silver Carp fed different levels of dietary organic.

Parameters	Dietary Selenium mg kg ⁻¹			
	0	0.5	1	2
IBW(g)	25.72 ± 0.48	26.86 ± 0.36	26.79 ± 0.52	27.84 ± 0.46
FBW(g)	50.82 ± 0.61 ^c	67.06 ± 2.85 ^a	54.09 ± 0.96 ^{bc}	55.41 ± 0.91 ^{ab}
WG(g)	34.20 ± 0.36 ^c	40.10 ± 2.73 ^a	36.40 ± 0.96 ^{bc}	37.57 ± 1.27 ^{ab}
SGR (%)	0.93 ± 0.016 ^c	1.17 ± 0.06 ^a	0.97 ± 0.04 ^{bc}	1.10 ± 0.04 ^{ab}
TWG	503.33±5.60	578.04±50.91	517.81±40.87	572.0.6±33.30
Survival rate %	93.0±0.00	88.0±6.82	89.33±4.61	91.0±2.40

Values are means ± SD (n = 3). Values with different superscript letters are significantly different (p < 0.05). Abbreviations: IBW, initial body weight; FBW, final body weight; WG, weight gain; SGR, specific growth rate; TWG; total weight gain.

Table 3. Feed utilization parameters of Silver Carp fed different levels of dietary Se.

Parameters	Dietary Selenium mg kg ⁻¹			
	0	0.5	1	2
FCR	3.35±0.07 ^a	3.08±0.24 ^a	3.32±0.32 ^a	3.13±0.13 ^a
TFI/g	1695.28±54.57 ^{0a}	1783.83±21.28 ^a	1718.15±44.31 ^a	1764.35±43.35 ^a
FCE (%)	29.67 ± 0.71 ^a	32.42 ± 2.49 ^a	30.15 ± 2.74 ^a	31.85 ± 1.4 ^a
PER (%)	0.81 ± 0.03 ^a	0.91 ± 0.06 ^a	0.83 ± 0.06 ^a	0.86 ± 0.02 ^a

Abbreviations: FCR; Food conversion ratio, TFI; Total feed intake, FCE; Feed conversion efficiency, PER, protein efficiency ratio; PI; production Index. Values are means ± SD (n = 3). Values with different superscript letters are significantly different (p < 0.05).

Table 4. Whole- Body Proximate Composition (as dry weight basis) of Silver Carp fed different levels of dietary Se.

Parameters	Dietary Selenium mg kg ⁻¹			
	0	0.5	1	2
Moisture	1.59 ± 0.22 ^c	1.65 ± 0.20 ^{bc}	2.6 ± 0.45 ^a	2.22 ± 0.34 ^b
Protein	48.10 ± 1.53 ^b	51.58 ± 3.68 ^{ab}	56.56 ± 3.32 ^a	52.84 ± 1.80 ^{ab}
Fat	30.68 ± 2.40 ^a	28.58 ± 2.99 ^a	26.84 ± 2.15 ^a	26.98 ± 1.67 ^a
Fiber	0.98 ± 0.13 ^b	0.74 ± 0.34 ^c	1.30 ± 0.23 ^{ab}	1.76 ± 0.52 ^a
Ash	7.72 ± 0.71 ^c	9.53 ± 0.61 ^a	8.98 ± 0.33 ^{ab}	8.59 ± 0.35 ^b
Energy	4676 ± 129.56 ^a	4520 ± 165.88 ^{ab}	4414 ± 94.30 ^b	4424 ± 78.13 ^b
Se*	0.72±0.12 ^c	0.74±0.13 ^c	0.89±0.14 ^b	0.87±0.13 ^a

Values are means ± SD (n = 3). Values with different superscript letters are significantly different (p < 0.05).

*Whole-body Se concentration determined using Atomic Absorption Spectroscopy (AAS).

Table 5. Hematological parameters of Silver Carp fed different dietary selenium levels.

Parameters	Dietary Selenium mg kg ⁻¹			
	0	0.5	1	2
RBC 10 ¹² L ⁻¹	39.67±2.58 ^a	39.18. ±3.90 ^a	32.33±4.04 ^b	30.01±4.60 ^b
HCT %	458.45±53.45	442.56±72.94	409.03±94.48	332.07±30.75
HGB gL ⁻¹	95.21±8.50 ^a	96.91±25.24 ^a	65.23±29.54 ^b	68.23±6.94 ^b
MPV fl	23.66±1.20 ^a	23.26±1.71 ^a	22.98±2.03 ^a	23.41±1.33 ^a
PLT 10 ⁹ L ⁻¹	8208±890.48 ^a	7782±2086.25 ^a	8081±308.85 ^a	8087±668.26 ^a
MHC pg	3.56±1.38 ^a	4.13±1.80 ^a	3.50±1.25 ^a	4.31±1.96 ^a
MCHC gL ⁻¹	30.66±3.84 ^a	35.33±7.02 ^a	35.16±6.75 ^a	27.16 ±8.37 ^a

Values are means ± SD (n = 3). Values with different superscript letters are significantly different (p < 0.05). Abbreviations: RBC; Red blood cells, HGB; Hemoglobin, HCT; Hematocrit, PLT; Platelet count, MPV; Mean platelet volume, MCH; Mean corpuscular hemoglobin, MCHC; Mean corpuscular hemoglobin concentration.

The current study found that the blood RBC and HGB of fish fed a basal and 0.5 mgkg⁻¹ diet increased significantly (p<0.05). Fish fed a basal diet had blood RBC and HGB of 29.67 gL⁻¹ and 85.21 gL⁻¹, respectively. Fish fed a diet with 0.5 mgkg⁻¹ had blood RBC and HGB of 29.18 10¹²L⁻¹ and 86.96 gL⁻¹, respectively (Table 5). Dietary Se addition had an impact on blood WBC and LYM percentages (p<0.05) (Figure 1). However, the proportion of blood LYM was substantially greater in the fish-fed basal diet than in the fish-fed just 0.5 mgkg⁻¹. The fish-fed diet 2 mgkg⁻¹ had the greatest level of blood WBC, followed by the fish-fed basal diet. All feeding treatments, however, showed no change in the percentages of blood MON and GRA.

4. DISCUSSION

The highest protein content was found in fish fed a diet of 1 mgkg⁻¹, followed by

diets of 2 and 0.5 mgkg⁻¹. Fish fed 2 mgkg⁻¹ had considerably more fibre. The current study's improvement of whole-body composition is in contrast to (Saffari et al. 2007) and (Ashouri et al. 2015), who found no effect of dietary Se nanoparticles on the proximate composition of silver carp. This could be because different forms of Se were used in these investigations. Furthermore, (Zhu et al. 2017) found no discernible variations in the gibel carp's body composition. (Zhu et al. 2017) and colleagues and (Han et al. 2011) and colleagues showed similar effects of Se on fish body composition.

Gibel carp that were fed 1.34 mgkg⁻¹ showed a noticeably greater whole-body Se content. Fish given 5 mgkg⁻¹ showed a markedly elevated Se concentration, according to (Han et al. 2011) and (Zhu et al. 2017). Se accumulation was higher throughout the body of fish given 2 mgkg⁻¹. Crustacean fish were discovered to have a high concentration of Se in their muscle. Fish muscle acquires selenium in a different way than tissue (Vinet et al. 2011). Variations in fish life phases, culture systems, and specific factors like temperature or feed quality may all be responsible for these discrepancies. Because organic selenium is transported to target tissues intact, it has a higher bioavailability (Lorentzen et al. 1994).

Studies have shown that both organic and inorganic forms of selenium improve fish health in general. Certain haematological parameters, including albumin, Hb, lysozyme, haematocrit parameters, blood serum, and blood cells, can be used to assess immunological health. Fish health may have improved as a result of higher total counts of red blood cells, haematocrit, and haemoglobin brought on by higher Se levels in their diet.

Significant effects of dietary selenium on HGB, RBC, HCT, and WBC were found in silver carp (Saffari et al. 2017). However, dietary Se had no effect ($p > 0.05$) on the levels of HCT, MPV, PLT, MHC, and

MCHC. Alternatively, (Durigon et al. 2019) found that dietary Se raised blood MHC but had no effect on blood MCHC in Nile tilapia-fed Se, while Mushtaq et al. found that silver carp-fed Se had a substantial effect on MCHC (Saffari et al. 2017). Therefore, varied fish species, culture circumstances, Se forms, and the degree of inclusion in test meals could all be contributing factors to the variation in haematological. In order to reduce the effects of Se and enhance interaction between feeding treatments, the current investigation was conducted in the RAS system, where water from all dietary treatments was filtered simultaneously.

5. CONCLUSION

The growth, body composition, and haematological parameters of silver carp were examined in relation to varying dietary quantities of organic selenium (Se). Fish fed selenium (Se) showed significant improvements in growth, protein content, selenium deposition, and haematological indices of silver carp. While fish-fed basal diets displayed the lowest growth rate values, fish-fed treatment meals containing 0.5 mgkg⁻¹, 1 mgkg⁻¹, and 2 mgkg⁻¹ Se demonstrated a considerable weight gain, final body weight, and specific growth rate. A Se concentration of 0.5 to 1 mgkg⁻¹ is optimal for a Silver Carp diet. The ideal Se requirement for silver carp in RAS cultivation should be investigated further.

REFERENCES

- Al-Din AS, Ibrahim S, Omar A, Refaey M (2022) Growth, Feed Efficiency, Hemato-Biochemical Indices, and Flesh Quality of Adult Nile Tilapia, *Oreochromis niloticus*, Fed a Diet Supplemented with Nano-Selenium. *Egypt J Aquat Biol Fish* 26:653–676. doi: 10.21608/ejabf.2022.275456
1. Ani AR, Şara A, Barbu A, Bentea M (2010) Organic Selenium (Sel-Plex) and its Impact on the Indices of Growth, Consumption and Meat Quality of Carp (Silver Carp), the Galitian Variety. *Sci Pap Anim Sci Biotechnol* 43:43.

2. Ashouri S, Keyvanshokooh S, Salati AP, Johari SA, Pasha-Zanoosi H. Effects of different levels of dietary selenium nanoparticles on growth performance, muscle composition, blood biochemical profiles and antioxidant status of Silver Carp (Silver Carp). *Aquaculture* 2015; 446:25-9.
3. Betancor MB, Caballero MJ, Terova G, Saleh R, Atalah E, Benítez-Santana T, et al (2012) Selenium inclusion decreases oxidative stress indicators and muscle injuries in sea bass larvae fed high-DHA microdiets. *Br J Nutr* 108:2115–2128. doi: 10.1017/S0007114512000311
4. Durigon EG, Kunz DF, Peixoto NC, Uczay J, Lazzari R (2019) Diet selenium improves the antioxidant defense system of juveniles Nile tilapia (*Oreochromis niloticus* L.). *Brazilian J Biol* 79:527–532. doi: 10.1590/1519-6984.187760
5. Gaber MM (2009) Efficiency of selenium ion inclusion into common carp (Silver Carp L.) diets. *African J Agric Res* 4:348–353.
6. Han D, Xie S, Liu M, Xiao X, Liu H, Zhu X, et al (2011) The effects of dietary selenium on growth performances, Oxidative stress and tissue selenium concentration of gibel carp (*Carassius auratus gibelio*). *Aquac Nutr* 17:e741–e749. doi: 10.1111/j.1365-2095.2010.00841.x
7. Hilton JW, Hodson P V., Slinger SJ (1980) The requirement and toxicity of selenium in rainbow trout (*Salmo gairdneri*). *J Nutr* 110:2527–2535. doi: 10.1093/jn/110.12.2527
8. Kieliszek M (2019) Selenium—fascinating microelement, properties and sources in food. *Molecules* 24:1298. doi: 10.3390/molecules24071298
9. Kieliszek M, Błazejak S (2016) Current knowledge on the importance of selenium in food for living organisms: A review. *Molecules* 21:609. doi: 10.3390/molecules21050609
10. Lall SP, Kaushik SJ (2021) Correction to: Nutrition and metabolism of minerals in fish (*Animals* 2021, 11, 2711). *Animals*. doi: 10.3390/ani11123510
11. Lemly AD (1999) Selenium impacts on fish: An insidious time bomb. *Hum Ecol Risk Assess* 5:1139–1151. doi: 10.1080/10807039.1999.10518883
12. Liu S, Yu H, Li P, Wang C, Liu G, Zhang X, et al (2022) Dietary nano-selenium alleviated intestinal damage of juvenile grass carp (*Ctenopharyngodon idella*) induced by high-fat diet: Insight from intestinal morphology, tight junction, inflammation, anti-oxidation and intestinal microbiota. *Anim Nutr* 8:235–248. doi: 10.1016/j.aninu.2021.07.001
13. Lorentzen M, Maage A, Julshamn K (1994) Effects of dietary selenite or selenomethionine on tissue selenium levels of Atlantic salmon (*Salmo salar*). *Aquaculture* 121:359–367. doi: 10.1016/0044-8486(94)90270-4
14. Mushtaq M, Fatima M, Shah SZH, Khan N, Naveed S, Khan M (2022) Evaluation of dietary selenium methionine levels and their effects on growth performance, antioxidant status, and meat quality of intensively reared juvenile *Hypophthalmichthys molitrix*. *PLoS One* 17:101182. doi: 10.1371/journal.pone.0274734
15. Rotruck JT, Pope AL, Ganther HE (1980) Selenium: biochemical role as a component of glutathione peroxidase. *Nutr Rev* 38:280–
16. Saffari S, Keyvanshokooh S, Zakeri M, Johari SA, Pasha-Zanoosi H (2017) Effects of different dietary selenium sources (sodium selenite, selenomethionine and nanoselenium) on growth performance, muscle composition, blood enzymes and antioxidant status of Silver Carp (Silver Carp). *Aquac Nutr* 23:611–617. doi: 10.1111/anu.12428
17. Tabasian, H. ., Abdoli, A. ., Valikhani, H. ., Khosravi, M. ., & Madiseh, S. f D. . (2021). An investigation into socio-economic impacts of invasive redbelly tilapia *Coptodon*

- fzillii (Gervais, 1848): A case study from the Shadegan Wetland, Iran. *Sci Rep Life Sci*, 2(3): 25–38. <https://doi.org/10.22034/srls.2021.245823>
18. Tinggi U (1999) Determination of selenium in meat products by hydride generation atomic absorption spectrophotometry. *J AOAC Int* 82:364–367. doi: 10.1093/jaoac/82.2.364
19. Vinet L, Zhedanov A (2011) A “missing” family of classical orthogonal polynomials. *J Phys A Math Theor* 44:21–75. doi: 10.1088/1751-8113/44/8/085201
20. Zhou X, Wang Y, Gu Q, Li W (2009) Effects of different dietary selenium sources (selenium nanoparticle and selenomethionine) on growth performance, muscle composition and glutathione peroxidase enzyme activity of crucian carp (*Carassius auratus gibelio*). *Aquaculture* 291:78–81. doi: 10.1016/j.aquaculture.2009.03.007
21. Zhu L, Han D, Zhu X, Yang Y, Jin J, Liu H, et al (2017) Dietary selenium requirement for on-growing gibel carp (*Carassius auratus gibelio* var. CAS III). *Aquac Res* 48:2841–2851. doi: 10.1111/are.13118.

