

## Research Article

# Dietary supplementation of garlic (*Allium sativum* L.) extract enhances haematological, humoral immune responses and disease resistance of *Mugil cephalus* Linnaeus 1758, larvae against *Photobacterium damsela*

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## Abstract

This study was carried out to investigate the effect of dietary supplementation of garlic (*Allium sativum*) extract on growth parameters and hematological parameters and immune system response of *Mugil cephalus* larvae encountered with *Photobacterium damsela*. Two hundred and forty *M. cephalus* larvae with a mean weight of 5g were randomly divided into 12 equal groups, each containing 3 replicates. Fish were fed with diets containing 50, 100 and 200mg garlic extract/Kg of food for 8 weeks. Based on the results, significant difference was observed comparing final weight, specific growth rate (SGR), daily growth rate (DGR), protein efficiency ratio (PER) and feed conversion ratio (FCR) of 100 and 200mg garlic extract/Kg of food treatments and other treatments ( $p < 0.05$ ). Also, in 100 mg garlic extract/Kg treatment, red and white blood cells, hemoglobin, PCV counts, globulin, total protein and albumin were significantly higher than those of control and 200mg garlic extract/Kg of food ( $p < 0.05$ ). The immune indices (lysozyme activity, serum total immunoglobulin (Ig) content, phagocytic activity and respiratory burst activity) significantly increased in 100mg garlic extract/Kg treatment compared to those of other treatments, especially control ( $p < 0.05$ ). The results revealed that treatments containing 50 and 100mg garlic extract/Kg food had the highest survival after challenging with *P. damsela* compared to survival of other treatments ( $p < 0.05$ ). In conclusion, results suggested that dietary administration of garlic extract; especially in 100mg garlic extract/Kg concentration is recommended for enhancing growth performance, nutritional function, immunity and resistance of *M. cephalus* larvae against the bacterium *P. damsela*.

**Keywords:** *Allium sativum*, *Mugil cephalus*, Hematological parameters, Immune response, *Photobacterium damsela*.

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## Introduction

*M. cephalus* is a commercially valuable and popular species that has growing market potential in Iran as well as Europe, East and South Asia (Fereidouni *et al.*, 2015). *M. cephalus* feeds on animal and plant residues (detritus) and plays an important role in the refinement of organic matter resulting from decomposition and maintenance of ecosystem balance.

The innate immune system of fish is improved by many immunostimulant such as levamisole (Ispir and Dörücü, 2005), glucan, and glucan with vitamin C, lipopolysaccharide (Dalmo and Seljelid, 1995) or chitosan (Siwicki *et al.*, 1994). Many plants, such as garlic, are used in treatment and control of diseases of human and animals (Adel *et al.*, 2016). Most of the previous studies focused on the anti-oxidant and anti microbial properties of garlic and its derivatives such as garlic oil and Allison. Most immune stimulants are not used because of high prices and adverse effects, therefore, numerous herbal plants have been examined on aquatic animals (Dugenci *et al.*, 2003). The use of herbal plants as a medicine has been considered in recent years and is used in aquatic animals due to its availability, reasonable price, environmental degradation, lack of environmental impacts and effectiveness against a wide range of pathogens. Many of these plants have immune stimulating properties (Galina *et al.*, 2009).

Garlic (*Allium sativum*) is originated from central Asia. It is one of the main foods of ancient Egyptians which are

found in the grave of pharaoh because it was believed to be transmitted to the other world (Harris *et al.*, 2001). Garlic contains more than 200 chemical compounds including sulfur containing volatile oils (allicin, allin, and ajoene) and important enzymes such as myrosinase, peroxidase, allinase. Garlic is properly called one of the wonders of nature, contains important nutritional compounds such as vitamins and minerals, and the antibacterial (Harris *et al.*, 2001), antifungal (Irkin and Korukluoglu 2006), antiparasitic (Fromtling and Bulmer, 1978), antiviral (Corzo-Martinez *et al.*, 2007), immunostimulant (Kyo *et al.*, 1998) and antioxidant (Lee and Gao, 2012) properties.

In previous studies, beneficial effects of *A. sativum* L on growth performance, immunity and disease resistance has been reported in several fish species such as rainbow trout (Fazlolahzadeh *et al.*, 2011), beluga, *Huso huso* (Nobahar *et al.*, 2014), sterlet sturgeon, *Acipenser ruthenus* (Lee *et al.*, 2012), goldfish, *Carassius auratus* (Dadgar *et al.*, 2019), common carp fingerlings (Karimi Pashaki *et al.*, 2018) and benni fish, *Mesopotamichthys sharpeyi* (Maniat *et al.*, 2014). Also, in the study of Akbari *et al.* (2016) positive effects of *A. sativum* L on feed utilization, carcass composition and survival rate of *M. cephalus* larvae are reported. The aim of this study was to evaluate the effect of dietary supplementation of garlic (*A. sativum* L.) on haematological parameters, humoral immune response and disease resistance of *M. cephalus*

Linnaeus, 1758 larvae against *Photobacterium damsela*.

## Materials and methods

### Fish

This study was carried out at the Research Institute of Fisheries, Chabahar (Chabahar, Iran). Two hundred and forty *M. cephalus* larvae with average initial weight of  $0.75 \pm 0.02$ g and average length of  $4.4 \pm 0.81$ cm were distributed randomly into 4 groups, each one with 60 fish (20 fish per tank) before fed by the experimental diets for 8 weeks. Fish were acclimatized for 2 weeks in plastic tanks (60 L). The health condition of fish was checked visually through their movements, infectious diseases symptoms and physical appearance all over the body and fins of the fish. The water was maintained at  $28.2 \pm 0.5^\circ\text{C}$  temperature,  $7.1 \pm 0.87$  mg L<sup>-1</sup> dissolved oxygen and  $7.8 \pm 0.4$  pH during this study. The fish were subjected to a 14L: 10 D photoperiod regime.

### Experimental diets and feeding trial

*A. sativum* dried extract was obtained from the Department of Fisheries, Chabahar Maritime University, Chabahar, Iran. It dried and stored at  $-20^\circ\text{C}$  until use (Harikrishnan *et al.*, 2003). Components of the basal diet were mixed with *A. sativum* in an appropriate concentration, to get four different experimental diets: 0g (control group), 50, 100 and 200mg/kg of *A. sativum*. The diets were made into pellets, allowed to dry and stored at  $4^\circ\text{C}$  until use. During this study, fish were

fed (7% of body weight) ten times a day (6:00, 7:30, 9:00, 10:30, 12:00, 13:30, 15:00, 16:30, 18:00, 19:30) for 56 days (Table 1). Daily supplied feed was recorded, and uneaten feed was collected 3h after feeding by syphoning procedure, followed by drying, weighing and finally subtracted from the total amount of supplied diets to calculate the actual feed intake.

All fish were deprived of food 24h before weighing and sampling, and the following parameters were measured at the end of 8 weeks feeding trial (Wahli *et al.*, 2003),

Feed conversion ratio (FCR) = feed intake (g) /weight gain (g).

Protein efficiency ratio (PER) = wet weight gain (g)/ protein intake

Daily Growth Rate (DGR) =  $\frac{[(WG \times 100)/(Wi + Wf)/2]}{t}$ .

Where Wi is initial weight, Wf is final weight, WG is weight gain and T is number of days in the feeding period.

### Sample collection

At the end of the experimental trial, fish were deprived of food for 24h before sample collection. For blood sample collection, ten *M. cephalus* larvae from each individual tank (30 fish per group) were anaesthetized with clove oil (30mg L<sup>-1</sup>). Blood samples were obtained from the caudal vein of individual fish (15 fish per treatment, 5 fish per tank). Blood samples were immediately divided into two half parts. One half was transferred to a tube containing anti-coagulant (heparin) for studying the respiratory burst assay and make hematological

analysis, while the other half was transferred to non-heparinized tubes for biochemical and immunological studies. Sera samples were isolated by blood

centrifugation Hettich model DV200 (3000 rpm, 10 min) and stored at -20°C until use.

**Table 1: Dietary formulation and proximate composition of the basal diet.**

<b>Ingredient</b>	<b>Composition (%)</b>
Fish meal	48.0
Wheat flour	18.7
Soy bean meal	21.0
Soy bean oil	3.0
Fish oil	3.0
Mineral premix <sup>a</sup>	1.5
Vitamin premix <sup>a</sup>	2.0
Binder <sup>b</sup>	2.0
Antifungi <sup>c</sup>	0.4
Antioxidant <sup>d</sup>	0.4
Total	100
<b>Proximate composition (% dry weight)</b>	
Crude protein	50.6
Crude lipid	12.9
Ash	14.8
Fiber	1.5
Moisture	6.3
NFE <sup>e</sup>	15.6

<sup>a</sup>Premix detailed by Fereidouni *et al.* (2015).

<sup>b</sup>Ametbinder™, MehrTaban-e-Yazd, Iran.

<sup>c</sup>ToxiBan antifungal (Vet-A-Mix, Shenan- doah, IA).

<sup>d</sup>Butylated hydroxytoluene (BHT, Merck, Germany).

<sup>e</sup>Nitrogen-free extracts (NFE) = dry matter - (crude protein + crude lipid + ash + fiber).

### *Hematological assays*

To measure blood parameters, conventional methods of mammalian blood parameters were used with little change (Rehulka, 2000). Total red blood cells (RBC:  $10^6 \text{ mm}^{-3}$ ) and white blood cells (WBC:  $10^3 \text{ mm}^{-3}$ ) were enumerated in an improved Neubauer hemocytometer using Hayem and Turck diluting fluids (Rehulka, 2000). Hematocrit (HCT, %) was determined by standard microhematocrit method and expressed as percentage (Rehulka, 2000). Hemoglobin (Hb,  $\text{g dl}^{-1}$ ) level

was determined according to cyanomethemoglobin procedure according to Trenzado *et al.* (2009).

### *Biochemical analysis*

Globulin, total protein and albumin were estimated at 35°C in fish sera using commercial kits (Pars Azmoon Company, Tehran, Iran) and a biochemical auto analyzer (Eurolyser, Belgium).

### *Immune parameters*

Serum lysozyme activity was measured according to the method described by Ellis (1999) with some modifications. Briefly, 25  $\mu$ L of sera was added to 1 mL of a suspension of *Micrococcus lysodeikticus* (0.2 mg mL<sup>-1</sup>) in a 0.05M sodium phosphate buffer (pH 6.2) and the absorbance was measured at 670nm after 30s and 180s by spectrophotometer (Biophotometer, Eppendorf).

Phagocytic activity of blood leukocytes was measured using May–Grunwald–Giemsa-stained yeast cells (Baba *et al.*, 2015) that had been phagocytized by the cells. One hundred microliters of the leukocyte solution were mixed with 2000  $\mu$ L of boiled yeast solution (preparing a yeast cell-to-leukocyte ratio of 20:1). The combination was then incubated at laboratory temperature for 60 min by gentle shaking. Following incubation, this mixture was smeared on the glass slides and allowed slides to be air-dried, fixed in 95% ethanol, re-dried and stained with May–Grunwald–Giemsa. The phagocytic cells and phagocytosed yeast were counted, and PA was determined by evaluating 100 phagocytes using a light microscope (Baba *et al.*, 2015).

PA = (number of phagocytic cells with engulfed yeast/number of phagocytic cells)  $\times$  100:

Serum total immunoglobulin (Ig) content was measured according to the method described by Adel *et al.* (2015) using a microprotein determination method (C-690; Sigma), prior and after precipitating down the immunoglobulin

molecules by means of a 12% solution of polyethene glycol (Sigma). The difference in protein content was considered as the IgM content.

Finally, respiratory burst activity in leucocytes was measured by chemiluminescent assay (CL) by a method described by Secombes and Chung (1988) using CL analysis (LUMI scan Ascent T392, Finland). Light emission results are expressed in the form of relative light units per second (RLU s<sup>-1</sup>) recorded by luminometer.

### *Challenge test*

*P. damsela* (SK7 strain) which had been originally isolated from suspected fish were obtained from Iran Veterinary Organization (IVO, Chabahar, Iran) and cultured in tryptic soy broth (TSB, Merck, Darmstadt, Germany) at 25°C for 48h. After 56 days week-feeding with different doses of garlic extract and control groups (10 $\times$ 3=30 fish per group) were challenged by immersion (Im) of *P. damsela* in 0.9% (w/v) saline containing 7.2 $\times$ 10<sup>4</sup> cells mL<sup>-1</sup> (Akbari and Kakoolaki, 2019). All fish were fed with the basal diet thereafter and kept under observation for 10 days to record any abnormal behavior, clinical signs and mortality. At the end of the challenge test, cumulative survival rate (%) was calculated.

### *Statistical analysis*

All the tests were performed in triplicate. The data were subjected to statistical analysis using the SPSS software version no. 21 (SPSS Inc., Chicago, IL, USA). The statistical analysis was done

by using one-way analysis of variance (ANOVA) followed by Duncan's multiple range tests. *P*-value of <0.05 was considered significant.

## Results

### Growth indices

The results of growth and nutrition indices are shown in Table 2. Based on these results, significant difference was observed in final weight, specific growth rate (SGR), daily growth rate (DGR), protein efficiency ratio (PER) and feed

conversion ratio (FCR) in 100 and 200mg garlic extract/Kg of food treatments compared to other treatments ( $p<0.05$ ). Highest rates of mentioned parameters were observed in 100mg/kg garlic extract treatment ( $p<0.05$ ). Also final weight, daily growth rate, protein efficiency ratio and feed conversion ratio of 50mg of garlic extract per kg of food did not show significant difference with control treatment ( $p>0.05$ ).

**Table 2: Growth performance of *M. cephalus* larvae fed diets enriched with different levels of garlic extract (0, 50, 100 and 200mg/kg) for 8 weeks.**

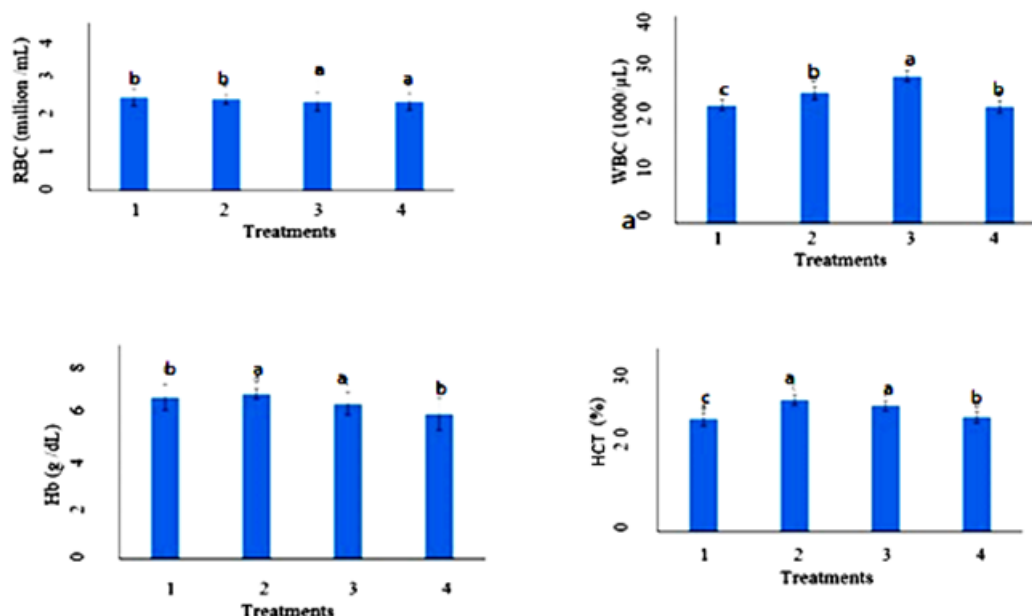
Parameter	Treatments (mg/kg of garlic extract)			
	0	50	100	200
Initial weight (g)	0.75±0.06 <sup>a</sup>	0.75±0.03 <sup>a</sup>	0.74±0.03 <sup>a</sup>	0.68±0.02 <sup>a</sup>
Final weight (g)	4.59± 0.17 <sup>b</sup>	4.68± 0.28 <sup>b</sup>	5.02± 0.16 <sup>a</sup>	5.20± 0.29 <sup>a</sup>
DGC	0.88± 0.02 <sup>b</sup>	0.89± 0.01 <sup>b</sup>	1.05± 0.01 <sup>a</sup>	1.07± 0.04 <sup>a</sup>
FCR	1.14±0.12 <sup>a</sup>	1.10±0.10 <sup>a</sup>	0.92±0.20 <sup>b</sup>	0.93±0.31 <sup>b</sup>
PER	1.50± 0.10 <sup>c</sup>	1.85± 0.13 <sup>b</sup>	1.98± 0.21 <sup>a</sup>	2.01± 0.13 <sup>a</sup>

Data are presented as mean ± S.D. Values in each row with different superscripts show significant difference ( $p<0.05$ ).

### Hematological indices

The range of RBC, WBC, Hemoglobin (Hb), Hematocrit (HCT) changes in different treatments are shown in Figure 1. The number of WBC and RBC counts from control to 100mg/kg garlic extract treatment increased gradually and decreased in 200mg/kg level. Hemoglobin levels were significantly different in studied treatments ( $p<0.05$ ).

Lowest and highest amounts of hemoglobin were observed in the treatment containing 200mg/kg garlic extract and in the treatment containing 100mg/kg garlic extract, respectively. Changes in hematocrit levels in different treatments did not show any particular trend. Lowest and highest levels of hematocrit were observed in control and 50mg/kg garlic extract treatments.



**Figure 1:** Hematological profile of *M. cephalus* larvae fed for 8 weeks with diets enriched with different levels of garlic extract (Treatments 1 to 4 contain 0, 50, 100 and 200mg/kg garlic extract, respectively). Data are presented as mean $\pm$ S.D. Values with different superscripts show significant difference ( $p < 0.05$ ).

#### Biochemical parameters

Effects of garlic extract on total proteins, albumin, and globulin levels of grey mullet serum are shown in Figure 2. The levels of globulin, total proteins and albumin in the serum of fish fed with diets enriched with different levels of garlic extract were significantly increased compared to those of the control ( $p < 0.05$ ). Also the highest levels of globulin, total protein and albumin were observed in the treatment containing 100mg garlic extract/kg of food ( $p < 0.05$ ).

#### Immune parameters

Mean changes in lysozyme activity, serum total immunoglobulin (Ig) content, phagocytic activity and respiratory burst activity are shown in Figure 3. The immune indices (lysozyme activity, serum total immunoglobulin (Ig) content,

phagocytic activity and respiratory burst activity) increased significantly in 100mg garlic extract/kg of food treatment compared to other treatments, especially the control ( $p < 0.05$ ). Although, no significant difference was observed between the treatment containing 50mg of garlic extract per kg of food with 200mg garlic extract/kg of food ( $p < 0.05$ ).

#### Cumulative mortality rate after challenge with *Photobacterium damsela* bacteria

The percentage of cumulative mortality after challenge with *P. damsela* for 10 days in various experimental treatments is shown in Figure 4. Results revealed that treatment containing 100mg garlic extract/Kg food had the highest survival after challenging with *P. damsela* compared to other treatments ( $p < 0.05$ ).

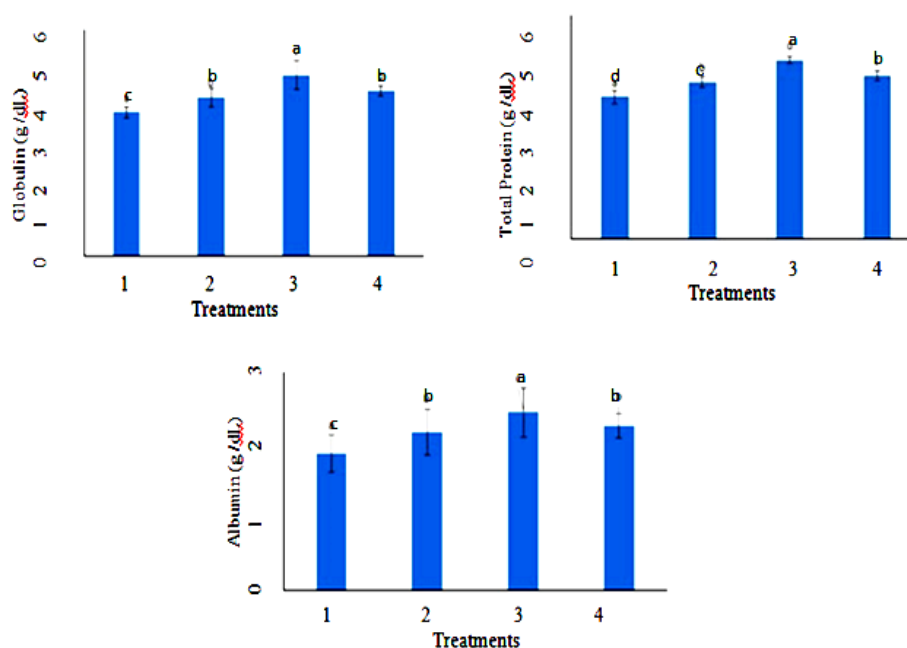


Figure 2: Biochemical profile of *M. cephalus* larvae fed for 8 weeks with diets enriched with different levels of garlic extract (Treatments 1 to 4 contain 0, 50, 100 and 200mg/kg garlic extract, respectively). Data are presented as mean $\pm$ S.D. Values with different superscripts show significant difference ( $p < 0.05$ ).

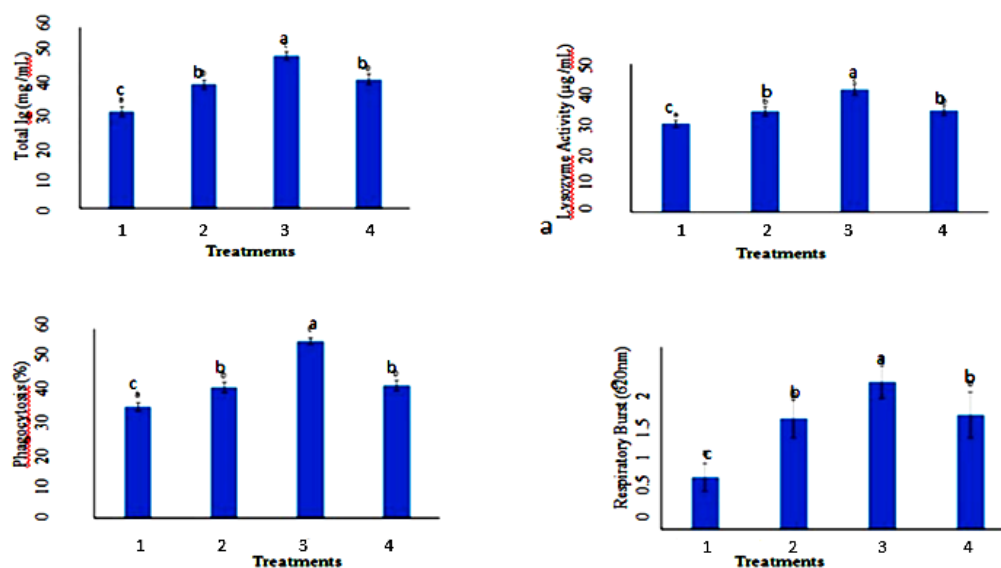


Figure 3: lysozyme activity, serum total immunoglobulin (Ig) content, phagocytic activity and respiratory burst activity of *M. cephalus* larvae fed for 8 weeks with diets enriched with different levels of garlic extract (Treatments 1 to 4 contains 0, 50, 100 and 200mg/kg garlic extract, respectively). Data are presented as mean $\pm$ S.D. Values with different superscripts show significant difference ( $p < 0.05$ ).



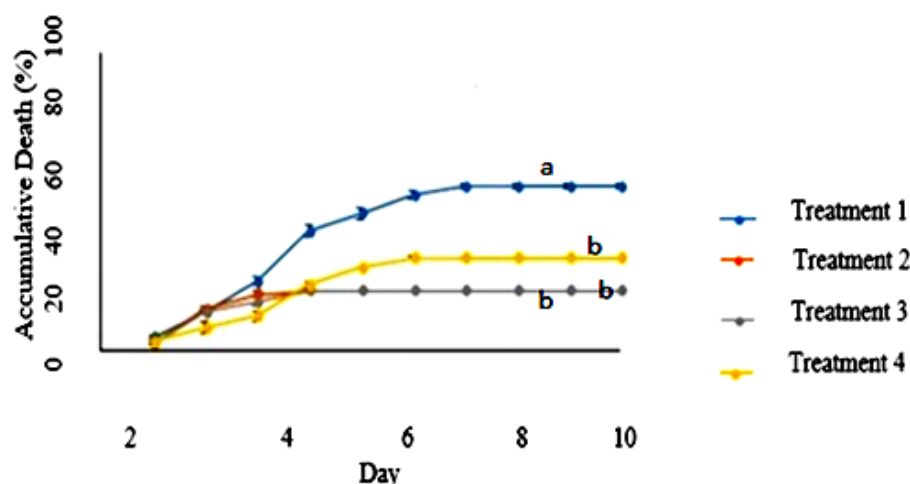


Figure 4: The percentage of cumulative mortality in *M. cephalus* larvae fed with diets supplemented with garlic extract against *Photobacterium damsela* (Treatments 1 to 4 contains 0, 50, 100 and 200mg/kg garlic extract, respectively). Data are presented as mean±S.D. Values with different superscripts show significant difference ( $p < 0.05$ ).

## Discussion

Based on the results, significant difference was observed in final weight, specific growth rate (SGR), daily growth rate (DGR), protein efficiency ratio (PER) and feed conversion ratio (FCR) in 100 and 200mg garlic extract/Kg treatments compared to other treatments ( $p < 0.05$ ). In a similar study, highest weight gain, the best percentage of protein efficacy ratio, the highest protein production rate and the lowest food intake were observed in 150mg/kg garlic essential oils compared to control (Khalil *et al.*, 2001). Khalil *et al.* (2001) confirmed that allicin in garlic plant enhance the intestinal function, improved nutrition and better utilizes energy and finally improved the growth performance. Lee *et al.* (2012) showed that a diet containing 0.5% of garlic extract improve the growth performance of *Acipenser ruthenus*. Garlic extract (30 g/kg) in Nile tilapia (*O. niloticus*) led to

better weight gain, protein efficiency ratio and decreased feed conversion ratio (Shalaby *et al.*, 2006). Contrary to these results, there was no significant difference in growth performance of African catfish (*Clarias gariepinus*) that received garlic extracts (Nwabueze, 2012). These differences may be related to age or size of fish, fish species, culture conditions, diet composition, level of garlic extract and different kinds of garlic plant (powders, oils or extracts) used in the feed (Akrami *et al.*, 2015).

The number of WBC and RBC counts increased gradually from control to 100mg/kg garlic extract treatment and then decreased in 200mg/kg level. In a similar study, Shalaby *et al.* (2006) showed that increased levels of garlic in tilapia fish diet increased the RBC count. The haemoglobin (Hb) in the blood has an important role and acts as carrier for oxygen in tissues. Hemoglobin levels were significantly different in the

studied treatments ( $p < 0.05$ ). Lowest and highest amount of hemoglobin were observed in the treatment containing 200mg/kg garlic extract and in the treatment containing 100mg/kg garlic extract, respectively. In a similar study, Chitsaz *et al.* (2018) showed that, haemoglobin content was significantly higher in 1% garlic peel than other studied diets (0. 0.5%, 1.5% and 2%). Changes in hematocrit levels in different treatments did not show any particular trend. Lowest and highest levels of hematocrit were observed in the control and 50mg/kg garlic extract treatments. Nwabueze (2012) reported that addition garlic extract to *Clarias garepinus* diet, significantly increased Hct, RBC and Hb indices in 0.5% garlic group compared to other treatments. Also, in Saleh *et al.* (2015) study, significant increase in hemoglobin content and hematocrit value were observed in sea bass (*Dicentrarchus labrax*) fry feed with garlic powder compared to the control group.

Albumin and globulin levels in serum are dependent on the amount of total protein in the blood serum (Akrami *et al.*, 2015). Albumin is synthesized in the liver, and it is important to maintain osmotic pressure and also act as a carrier of various substances, including lipids, hormones, minerals and vitamins, and plays an important role in the transport of compounds such as medications in the blood and can transport the compounds such as drug in the blood (Adel *et al.*, 2015). The levels of globulin, total proteins and albumin in serum of fish fed

with diets enriched with different levels of garlic extract increased significantly compared to control ( $p < 0.05$ ). Also the highest levels of globulin, total protein and albumin were observed in the treatment containing 100mg garlic extract/kg of food ( $p < 0.05$ ). Shalaby *et al.* (2006) reported that factors such as sex, spawning, food, osmotic pressure, temperature, light, age, and oxygen can affected serum total protein. They also showed that the use of 20 and 30g of garlic per kg of diet resulted in a significant increase in the plasma protein content of Nile tilapia (*O. niloticus*) compared to the control. Chitsaz *et al.* (2018) also showed that the use of garlic's essential oil resulted in a significant increase in plasma protein concentrations in beluga juvenile (*H. huso*) compared to control treatment. Sahu *et al.* (2006) reported that addition of 0.1, 0.5 and 1% of garlic to the diet resulted in a significant increase in plasma protein and globulin level compared to control treatment in *L. rohita*.

The results of this study showed that the immune indices including lysozyme activity, serum total immunoglobulin (Ig) content, phagocytic activity and respiratory burst activity significantly increased in the 100mg garlic extract/kg of food treatment compared to other treatments, especially control ( $p < 0.05$ ). *Allium* species play an important role in improving the immune system by increasing immune responses such as increasing lymphocyte synthesis, increasing cytokine release, and

increasing phagocytic activity. Sahu *et al.* (2006) reported that the use of garlic extract with doses of 1, 5 and 10g per kg of food resulted in a significant increase in anion superoxide, lysozyme activity, total protein, albumin, and bactericidal activity of *Labeo rohita* compared with the control. Also, Ndong and Fall (2011) showed that addition of 0.5 grams per kilogram of garlic in hybrid tilapia (*O. niloticus* × *O. aureus*) feed significantly increased the number of leukocytes, respiratory burst activity, phagocytic and lysozyme activities.

Total immunoglobulins (Ig) play an important role on the immunity of fish (Sun *et al.*, 2012). Several studies have shown that total immunoglobulin levels are associated with factors such as age, environmental conditions, fish health status, the use of different immune stimulants, and concentration and time of exposure (Picchitti *et al.*, 2001). The results of this study showed that the addition of 100mg garlic extract/kg of diet showed the highest plasma Ig level compared to the other treatments. In Karimi Pashaki *et al.* (2018) study, highest levels of lysozyme and IgM were reported in common carp fingerlings fed with a diet containing 5g kg<sup>-1</sup> of garlic extract. Talpur and Ikhwanuddin (2012) reported that using 10g kg<sup>-1</sup> garlic in the *Lates calcarifer* diet had significant increase in lysozyme activity and IgM level. The effects of immune stimulation and increase of fish resistance following consumption of garlic have been related to the presence of allicin, vitamin A and vitamin C in garlic plant (Khodadadi and Nosrati, 2012).

Photobacteriosis caused by bacterial strain of *P. damsela* is a major problem in aquaculture industry, which leads to high mortality rates in marine fish. This negative gram bacterium was often observed in Japanese sea bass and Japanese yellow tail (Bakopoulos *et al.*, 1997). The present study showed that the fish fed with 100mg garlic extract/kg of food had the lowest cumulative mortality compared to the other garlic extract treatments and control group after challenge with *P. damsela* ( $p<0.05$ ). The highest cumulative mortality (55%) was observed in control treatment ( $p<0.05$ ). Our results are in agreement with those obtained on *M. cephalus* fed with *Echinacea purpurea*-supplemented diet against *P. damsela* infections. Also, mortalities of Nile tilapia (*Oreochromis niloticus*) following challenge with *Pseudomonas fluorescens* were lower in groups that received garlic compared to the control treatment (Diab *et al.*, 2008). In a similar study, Adel *et al.* (2016) showed that resistance of rainbow trout fed with diets containing 2% and 3% *Mentha piperita* plant extract were higher than those of the control group after challenging with *Y. ruckeri*.

In conclusion, the results suggested that dietary administration of garlic extract especially in the 100mg garlic extract/Kg concentration is recommended for enhancing growth performance, nutritional function, immunity and resistance of *M. cephalus* larvae against *P. damsela*.

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## References

- Adel M., Safari R., Pourgholam R., Zorriehzahra J. and Esteban M.A., 2015.** Dietary peppermint (*Mentha piperita*) extracts promote growth performance and increase the main humoral immune parameters (both at mucosal and systemic level) of Caspian brown trout (*Salmo trutta caspius* Kessler, 1877). *Fish and Shellfish Immunology*, 47, 623-629. DOI: 10.1016/j.fsi.2015.10.005.
- Adel M., Pourgholam R., Zorriehzahra S.J. and Ghiasi M., 2016.** Hemato-immunological and biochemical parameters, skin antibacterial activity, and survival in rainbow trout (*Oncorhynchus mykiss*) following the diet supplemented with *Mentha piperita* against *Yersinia ruckeri*. *Fish & Shellfish Immunology*, 55, 267-273. DOI: 10.1016/j.fsi.2016.05.040.
- Akbari P., Negahdari Jafarbeigi Y. and Sondakzahi A., 2016.** Effects of garlic (*Allium sativum* L) extract on growth, feed utilization and carcass composition in *Mugil cephalus* (Linnaeus, 1758) larvae. *Iranian Journal of Fisheries Sciences*, 15(1), 552- 557.
- Akbary, P., and Kakoolaki, S., 2019.** Growth, hematological, innate immune responses of *Mugil cephalus* fed with *Echinacea purpurea*-supplemented diet against *Photobacterium damsela* infections. *International Journal of Environmental Science and Technology*, 16(1), 325-334. DOI: 10.1007/s13762-017-1578-6.
- Akrami R., Gharaei A., Razeghi Mansour M. and Galeshi A., 2015.** Effects of dietary onion (*Allium cepa*) powder on growth, innate immune response and hemato-biochemical parameters of beluga (*Huso huso* Linnaeus, 1754) juvenile. *Fish and Shellfish Immunology*, 45, 828-834. DOI: 10.1016/j.fsi.2015.06.005.
- Baba E., Uluköy G. and Öntaş C., 2015.** Effects of feed supplemented with *Lentinula edodes* mushroom extract on the immune response of rainbow trout, *Oncorhynchus mykiss*, and disease resistance against *Lactococcus garvieae*. *Aquaculture*, 448, 476-482. DOI: 10.1016/j.aquaculture.2015.04.031.
- Bakopoulos V., Peric Z., Rodger H., Adams A. and Richards R.H., 1997.** First report of fish Pasteurellosis from Malta. *Journal of Aquatic Animal Health*, 9, 26-33. DOI:10.1577/15488667(1997)009<0026:FROFPF
- Chitsaz H., Orazi H., Keramat Amirkolaie A. and Akrami R., 2018.** Effect of garlic peel on haematological, biochemical and digestive enzyme activity in beluga

- juvenile (*Huso huso*). *Iranian Journal of Aquatic Animal Health*, 4(1), 13-28.
- Corzo-Martinez M., Corzo N. and Villamiel M., 2007.** Biological properties of onions and garlic. *Trends in Food Science and Technology*, 18, 609-625. DOI: 10.1016/j.tifs.2007.07.011.
- Dadgar Sh., Seidgar M., Nekuiefard A., Valipour A.R., Sharifian M. and Hafezieh M., 2019.** Oral administration of garlic powder (*Allium sativum*) on growth performance and survival rate of *Carassius auratus* fingerlings. *Iranian Journal of Fisheries Sciences*, 18(1), 71-82. DOI: 20.1001.1.15622916.2019.18.1.6.1
- Dalmo R.A. and Seljelid R., 1995.** The immunomodulatory effect of LPS, laminarin and sulphated laminaran [(1, 3)-d-glukan] on Atlantic Salmon, *S. salar*, macrophages in vitro. *Journal of Fish Diseases*, 18, 175-185. DOI: 10.1111/j.1365-2761.1995.tb00275.x
- Diab A.S., Mesalhy S., John G., Abde-Hadi Y. and Mohammed M.F., 2008.** Effect of garlic, black seed and Biogen as immunostimulants on the growth and survival of Nile tilapia, *Oreochromis niloticus* (Teleostei: Cichlidae), and their response to artificial infection with *Pseudomonas fluorescens*. *African Journal of Aquatic Science*, 33(1), 63-68. DOI: 10.2989/AJAS.2007.33.1.7.391
- Dugenci S.K., Arda N. and Candan A., 2003.** Come medicinal plants as immunostimulants for fish. *Journal of Ethnopharmacology*, 88(1), 99-106. DOI: 10.1016/s0378-8741(03)00182-x
- Ellis A., 1999.** Immunity to bacteria in fish. *Fish and Shellfish Immunology*, 9, 291-308. DOI: 10.1006/fsim.1998.0192
- Fazlolahzadeh F., Keramati K., Nazifi S., Shirian S. and Seifi S., 2011.** Effect of garlic (*Allium ativum*) on haematological parameters and plasma activities of ALT and AST of Rainbow trout in temperature stress. *Australian Journal of Basic and Applied Sciences*, 5, 84-90. DOI: 10.1590/S1678-91992006000200003
- Fereidouni M.S., Akbary P. and Soltanian S., 2015.** Survival rate and biochemical parameters in *Mugil cephalus* (Linnaeus, 1758) larvae fed garlic (*Allium sativum* L.) extract. *American Journal of Molecular Biology*, 5, 7-15. DOI: 10.4236/ajmb.2015.51002
- Fromtling R.A. and Bulmer G.S., 1978.** In vitro effect of aqueous extract of garlic (*Allium sativum*) on the growth and viability of *Cryptococcus neoformans*. *Mycologia*, 70(2), 397-405. DOI: 10.1080/00275514.1978.12020240
- Galina J., Yin G., Ardo L. and Jeney Z., 2009.** The use of immunostimulating herbs in fish. An overview. *Journal of Fish Physiology and Biochemistry*, 35(4), 669-676. DOI: 10.1007/s10695-009-9304-z
- Harikrishnan R., Nisha M.R. and Balasundaram C., 2003.** Hematological and biochemical parameters in common carp,

- Cyprinus carpio*, following herbal treatment for *Aeromonas hydrophila* infection. *Aquaculture*, 221, 41-50. DOI: 10.1016/S0044-8486(03)00023-1
- Harris J.C., Cottrell S.L., Plummer S. and Lloyd D., 2001.** Antimicrobial properties of *Allium sativum* (garlic). *Applied Microbiology and Biotechnology*, 57: 282-286. DOI: 10.1007/s002530100722
- Irkin R. and Korukluoglu M., 2006.** Control of *Aspergillus niger* with garlic, onion and leek extracts. *African Journal of Biotechnology*, 6(4), 384-287. DOI: 10.5897/AJB2007.000-2018
- Ispir U. and Dörücü M., 2005.** A study of the effects of levamisole on the immune system of rainbow trout (*Oncorhynchus mykiss*, Walbaum). *Turkish Journal of Veterinary and Animal Sciences*, 29(5), 1169-1176.
- Karimi Pashaki A., Zorriehzahra S.M.J., Ghasemi M, Sharif Rohani M. and Hosseini S.M., 2018.** Effects of dietary garlic extract on some blood, immunity and growth parameters of common carp fingerlings (*Cyprinus carpio*). *Iranian Journal of Aquatic Animal Health*, 4(2), 28-39. DOI: 10.29252/ijaah.4.2.28
- Khalil R.H., Nadia B.M. and Suleiman M.K., 2001.** Effect of Diojen and Levamisol Hicl on the Iminio response of cultured *Oreochromis niloticus* to *Aeromonas hydrophila* vaccine. *Bemisuef Journal of Egypt Veterinarian Medicine*, 11(2), 381-392. DOI: 10.29252/ijaah.4.2.28
- Khodadadi M. and Nosrati A.E., 2012.** Effect of sowing date and planting density on yield and yield Components of white garlic of Hamadan. *Seed and Plant Production Journal*, 27-2(4), 491-500, (in Persian). <https://www.cabdirect.org/cabdirect/abstract/20113394559>
- Kyo E., Uda N., Suzuki A., Kakimoto M., Ushijima M., Kasuga S. and Itakura Y., 1998.** Immunomodulation and antitumor activities of aged garlic extract. *Phytomedicine*, 5, 259-267. DOI: 10.1016/S0944-7113(98)80064-0
- Lee D.H., Ra C.S., Song Y.H., Sung K.I. and Kim J.D., 2012.** Effects of dietary garlic extract on growth, feed utilization and whole body composition of juvenile sterlet sturgeon (*Acipenser ruthenus*). *Asian-Australasian Journal of Animal Sciences*, 25, 577-583. DOI: 10.5713/ajas.2012.12012.
- Lee J.Y. and Gao Y.G., 2012.** Review of the application of garlic, *Allium sativum*, in aquaculture. *Journal of the World Aquaculture Society*, 43(4), 447-458. DOI: 10.1111/j.1749-7345.2012.00581.x
- Maniat M., Ghotbeddin N. and Rajabzadeh Ghatrami E., 2014.** Effect of garlic on growth performance and body composition of benni fish (*Mesopotamichthys sharpeyi*). *International Journal of*

- Biosciences*, 5(4), 269-277. DOI: 10.12692/ijb/5.4.269-277
- Ndong D. and Fall J., 2011.** The effect of garlic (*Allium sativum*) on growth and immune responses of hybrid tilapia (*Oreochromis niloticus* x *Oreochromis aureus*). *Journal of Clinical Immunology and Immunopathology Research*, 3(1), 1-9.
- Nobahar Z., Gholipour-Kanani H., Kakoolaki SH. and Jafaryan H., 2014.** Effect of garlic (*Allium sativum*) and nettle performance and hematological parameter of beluga (Huso huso). *Iranian Journal of Aquatic Animal Health*, 1(1), 63-69. <https://ijaah.ir/article-1-68-en.pdf>
- Nwabueze A.A., 2012.** The effect of garlic (*Allium sativum*) on growth and haematological parameters of *Clarias gariepinus* (Burchell, 1822). *Sustainable Agriculture Research*, 1(2), 222-228. DOI: 10.22004/ag.econ.231382
- Picchitti S., Scapigliati G., Fanelli M., Barbato F., Canese S. and Mastrolla L., 2001.** Sex-related variations of serum immunoglobulins during reproduction in gilthead sea bream and evidence for a transfer from the female to the eggs. *Journal of Fish Biology*, 59, 1503-1511 .DOI: 10.1111/j.1095-8649.2001.tb00215.x
- Rehulka J., 2000.** Influence of astaxanthin on growth rate, condition, and some blood indices of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 190, 27-47. DOI: 10.1016/S0044-8486(00)00383-5
- Sahu S., Das B.K., Mishra B.K., Pradhan J. and Sarangi N., 2006.** Effect of *Allium sativum* on the immunity and survival of *Labeo rohita* infected with *Aeromonas hydrophila*. *Journal of Applied Ichthyology*, 23(1), 80-86. DOI: 10.1111/j.1439-0426.2006.00785.x
- Saleh N.E., Michael F.R. and Toutou M.M., 2015.** Evaluation of garlic and onion powder as phyto-additives in the diet of sea bass (*Dicentrarchus labrax*). *Egyptian Journal of Aquatic Research*, 41, 211-217. DOI: 10.1016/j.ejar.2015.03.008
- Secombes C.J. and Chung S., 1988.** Analysis of events occurring within teleost macrophages during the respiratory burst. *Comparative Biochemistry and Physiology*, 89, 539-544. DOI: 10.1016/0305-0491(88)90171-X
- Shalaby A.M., Khattab Y.A. and Abdel Rahman A., 2016.** Effects of garlic (*Allium sativum*) and chloramphenicol on growth performance, physiological parameters and survival of Nile tilapia (*Oreochromis niloticus*). *Journal of Venomous Animals and Toxins including Tropical Diseases*, 12, 172-201. DOI: 10.1590/S1678-91992006000200003
- Siwicki A.K., Anderson D.P. and Rumsey G.L., 1994.** Dietary intake of immunostimulants by rainbow trout affects non-specific immunity and protection against furunculosis. *Veterinary Immunology and Immunopathology*, 14, 139-159.

DOI: 10.1016/0165-2427(94)90062-0.

**Sun Y.Z., Liu C., Qiu R. and Sun L., 2012.** A divalent DNA vaccine based on Sia10 and OmpU induces cross-protection against *Streptococcus iniae* and *Vibrio anguillarum* in Japanese flounder. *Fish and Shellfish Immunology*, 32, 1216-1222. DOI: 10.1016/j.fsi.2012.03.024

**Talpur A.D. and Ikhwanuddin M., 2012.** Dietary effects of garlic (*Allium sativum*) on haematoimmunological parameters, survival, growth, and disease resistance against *Vibrio harveyi* infection in Asian sea bass, *Lates calcarifer* (Bloch). *Journal of Aquaculture*, 364, 6–12. DOI: 10.1016/j.aquaculture.2012.07.035

**Trenzado C.E., Morales A.E., Palma J.M. and Higuera M.D.L., 2009.** Blood antioxidant defenses and hematological adjustments in crowded/uncrowded rainbow trout (*Oncorhynchus mykiss*) fed on diets with different levels of antioxidant vitamins and HUFA. *Comparative Biochemistry and Physiology Part C*, 149, 440-447. DOI: 10.1016/j.cbpc.2008.10.105

**Wahli T., Verlhac V., Griling P., Gabaudan J. and Aebischer C., 2003.** Influence of dietary vitamin C on the wound healing process in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 225, 371-386. DOI: 10.1016/S0044-8486(03)00302-8