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The effects of coriander (*Coriandrum sativum*) seeds on the growth performance, growth hormone, antibacterial capacity, and immune response of European sea bass (*Dicentrarchus labrax*)

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THE EFFECTS OF CORIANDER (*CORIANDRUM SATIVUM*) SEEDS ON THE GROWTH PERFORMANCE, GROWTH HORMONE, ANTIBACTERIAL CAPACITY, AND IMMUNE RESPONSE OF EUROPEAN SEA BASS (*DICENTRARCHUS LABRAX*)

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Abstract

Coriander seeds are among the functional herbal supplements, but their effects on aquatic animals are still lacking. Herein we evaluated the effects of coriander seeds on the growth performance, growth hormone, antibacterial capacity, and immune response of European sea bass (*Dicentrarchus labrax*). Fish with initial mean weights of 5.08 ± 0.12 g/fish were allocated in four groups (in triplicate) and fed dietary coriander at 0, 5, 10, and 20 g/kg for 150 days. The growth performance, feed utilization, and survival rate of fish fed dietary coriander meaningfully increased (P<0.05). The protein efficiency ratio gradually increased (P<0.05) in fish fed coriander seeds compared with the control. On the other hand, the feed conversion ratio was gradually decreased (P<0.05) in fish fed coriander seeds comparing with the control. The survival rate was markedly increased (P<0.05) in European sea bass fed dietary coriander regardless of the inclusion level. Further, no differences were seen among fish fed varying levels of coriander (P<0.05). The level of blood growth hormone was markedly higher (P<0.05) in European sea bass fed dietary coriander at 20 g/kg than fish fed 0 and 5 g/kg. The abundance of intestinal *Vibrio* spp. and fecal coliform were obviously lower (P<0.05) in fish fed 10 and 20 g/kg than in fish fed the coriander-free diet. Further, fish fed 20 g/kg had lower (P<0.05) *Vibrio* spp. and fecal coliform counts than fish fed 10 g/kg. Fish fed dietary coriander had significantly higher (P<0.05) hematocrit, hemoglobin, red blood cells (RBCs), and white blood cells (WBCs) than fish fed the control. The lysozyme and phagocytic activities were meaningfully increased (P<0.05) in fish fed 10 and 20 g/kg compared with fish fed 0 and 5 g/kg of dietary coriander. In conclusion, dietary coriander could be included in the diets at 10–20 g/kg to improve the growth performance, growth hormone, feed utilization, and immune response of European sea bass.

Key words: aquaculture, coriander, sea bass, growth hormone, blood health

Aquaculture is the production of aquatic animals under controlled conditions to produce food and guarantees an income for humanity (Cottrell et al., 2020; Galappaththi et al., 2020). The expansion of aquaculture activity requires sustainable solutions involved in enhancing the well-being and productivity of aquatic animals (Hazreen-Nita et al., 2022; Paray et al., 2021). Nowadays, great concern was given to the term "functional nutrition" which means that aquafeed should consider both the essential requirement and supplemental additives to achieve the basic metabolic and physiological functions and enhance the welfare and productivity of aquatic animals (Abdul Kari et al., 2021; Dawood, 2022; Encarnação, 2016). In this regard, many functional additives were applied in aquafeed, such as immunostimulants, growth promoters, probiotics, prebiotics, medicinal herbs, and exogenous enzymes (Bae et al., 2020; Can et al., 2012 b; Zheng et al., 2020).

Medicinal herbs or phytogenics are safe and active supplements involved in several roles in aquaculture (Alagawany et al., 2021; Pu et al., 2017). Many studies illustrated that medicinal herbs could replace antibiotics representing an alternative environmental approach for organic aquaculture (Elumalai et al., 2021; Valenzuela-Gutiérrez et al., 2021). The functionality of medicinal herbs is associated with the high content of active components such as phenolics, tannins, alkaloids, saponins, glycosides, steroids, terpenoids, and flavonoids (Caipang et al., 2021). Indeed, the rich value of medicinal herbs attracted the attention of academia and farmers to use them as antibacterial, growth promoters, immunostimulants, and antioxidative additives (Adel et al., 2021). Several species and forms of medicinal plants were investigated and recommended in aquaculture. Coriander (*Coriandrum sativum*) is a herbal plant that belongs to the Apiaceae (or carrot) family and can grow in several areas around the globe (Laribi et al., 2015; Lasram et al., 2019). Coriander seeds have high valued components, including linalool, terpenoids, linoleic acid, vitamin C, and minerals (Ca, Zn, Mg, Fe, and K) (Begnami et al., 2018; Talapatra et al., 2010). Coriander seeds could be used in food preparation as appetizers and attractive flavors attributed to their excellent taste. Functionally, coriander seeds showed high growth-promoting, antibacterial, immune, and antioxidative responses (Bahrekazemi et al., 2020; Msaada et al., 2017). The application of coriander resulted in high growth performance, immune and antioxidative responses in *Catla catla* (Innocent et al., 2011), beluga (*Huso huso)* (Bahrekazemi et al., 2020), Nile tilapia (*Oreochromis niloticus* L.) (Ahmed et al., 2020), and rainbow trout (*Oncorhynchus mykiss)* (Naderi Farsani et al., 2019). However, due to the species-specific roles of herbal additives, coriander seeds need to be evaluated based on a species-specific manner.

European sea bass (*Dicentrarchus labrax)* is a vital marine fish in the aquaculture industry with significant economic value (Abdel-Tawwab et al., 2020; Can et al., 2012 a). However, its production is challenged with the spread of infection involved in increasing fish mortality (Dawood et al., 2020). Exclusively, this study aimed at testing the effects of coriander on the growth performance, blood health, antibacterial capacity, and immunity of European sea bass.

Material and methods

Diets and experimental procedure

Four nutritionally balanced diets (crude protein, 45.01% and total lipid, 15.50%) were formulated using the ingredients presented in Table 1. The ingredients were well mixed then divided into four. The basal formulations were then mixed with coriander seeds powder at 0, 5, 10, and 20 g/kg. The prepared formulations were mixed with fish oil and water then pelleted with a lab meat mincer fixed with a pelletizer (El-Adl Co.TM, Tanta, Egypt) to produce dough pellets (2–3 mm). Powdered coriander seeds were obtained from a local market (Alexandria, Egypt). Coriander powder is derived from the seeds of the coriander plant. The identification and composition of coriander powder were defined by following Ahmed et al. (2020) and Naderi Farsani et al. (2019). The formulated diets were dried at room temperature; then, after cooling, the diets were kept in plastic bags till used.

Juveniles of European sea bass were obtained from the National Institute of Oceanography and Fisheries (NIOF), Alexandria, Egypt. Fish were kept in concrete tanks of 1 × 8 × 3 m (L × W × D) for adaptation. Randomly, twenty-five fish were collected and kept frozen (−20°C) for initial proximate analysis. Then fish of equal initial weight (5.08 ± 0.10 g/fish) were distributed in twelve hapas (1 × 1 × 1 m; L × W × D) (15 fish in each) representing four groups (triplicates). The hapas were fixed in four concrete tanks (each tank with three hapas). All tanks were provided with an inlet water source and outlets. Fish were fed the test diets twice daily (08:00 and 15:00) up to the satiation level for 150 days. Fish were weighed biweekly to check the growth performance and health condition. The water quality was tested regularly during the trial and recorded: salinity (33.05 ± 0.32 ppt), dissolved oxygen (6.11 ± 0.11 mg/L), water temperature (26.33 ± 0.52°C), ammonia (0.03 ± 0.01 mg/L), and pH (7.12 ± 0.04).

Table 1. Formulation and chemical composition of the basal diet

Ingredients	g/kg	Chemical analysis	
Fish meal (65%)	440	Dry matter (%)	91.62
Shrimp meal	100	Crude protein (%)	45.01
Soybean (48%)	100	Lipid (%)	15.50
Gluten (corn 60%)	50	Ash (%)	10.67
Wheat (14% CP)	80	Crude fiber (%)	2.43
Wheat bran	100	Nitrogen free extract (NFE) (%)	26.40
Fish oil	100	Gross energy (MJ/kg)	21.28
Dicalcium phosphate	10		
Vitamin and mineral mixture	20		
Total	1000		

[1]Vitamin and mineral mixture is previously detailed by Ashry et al. (2021).

[2]Gross energy based on protein (23.6 KJ/g), lipids (39.5 KJ/g), and carbohydrate (17.2 KJ/g).

Final sampling

At the end of the trial, all fish were fasted for 24 h then weighed and counted to calculate the growth performance, feed efficiency, and survival rate.

Five fish from each tank were collected and washed with fresh water and used for carcass composition. Fish were kept at −20°C till analysis.

The fish were anesthetized by tricaine methanesulfonate (MS-222) while their blood was taken to minimize the stress. Then, another three fish per hapa were collected for blood collection and bled from the caudal vein. Heparinized syringes (2.5 mL) were used for hematological analysis, while non-heparinized syringes were used to collect serum. For serum collection, blood was kept for 4 h at 4°C, then centrifuged at 3000 × g for 15 min at 4°C. Serum was kept at −20°C until analysis.

Intestinal antibacterial count

The distal intestines were dissected from 3 fish per hapa and homogenized in 10 mL of 3% sterile sodium chloride solution. The homogenized samples were diluted from 10^{-1} to 10^{-5}. Selective agar media were used to grow bacteria using 1 mL from diluted samples. The count of *Vibrio* spp. was determined by using thiosulfate-citrate-bile salt-sucrose (TCBS) agar (Kousoulaki et al., 2015). For *Escherichia coli*, modified fecal coliform (mFC) agar was used (ISO (International Organization for Standardization) No. 9308/1, 1990). Incubation of the plates was carried out at 30°C for 24–48 h for enumeration, except for the mFC medium, which was incubated at 44°C for 24 h.

Biochemical analysis, hematology, and immunity analysis

The diets and the whole fish body were analyzed for moisture, crude protein, crude lipids, and ash using standard methods (AOAC, 1998).

The white blood cell (WBC) and red blood cell (RBC) counts were undertaken following standard procedures (Houston, 1990). Hematocrit was determined by the micro hematocrit method, while the hemoglobin concentration was determined with a spectrophotometer (Model RA 1000, Technicon Corporation, Pittsburgh, Pennsylvania, USA) at 540 nm, using the Blaxhall and Daisley (1973) method. The monocyte, lymphocyte, and neutrophil differential counts were determined using the Wright Giemsa staining method. The mean corpuscular hemoglobin (MCH), mean corpuscular volume (MCV), and mean corpuscular hemoglobin concentration (MCHC) were calculated by following Dacie and Lewis (1999).

Serum total proteins and albumins were determined according to Doumas et al. (1981) and Dumas and Biggs (1972). Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities were detected by following the method of Reitman and Frankel (1957). The growth hormone was estimated in the serum samples according to Lugo et al. (2008) using a non-competitive ELISA with 96-well MaxiSorp plates (Nalge Nunc International, Roskilde, Denmark). The absorbance was measured at 492 nm in a spectrophotometer (Titertek Multiskan Plus).

The leukocyte phagocytic function was determined following the method of Cai et al. (2004). The number of leukocytes that engulfed bacteria was counted as a percentage in relation to the total leukocyte number in the smear from the phagocytosis assay. By following Kawahara et al. (1991), the phagocytic activity and phagocytic index were determined. The lysozyme activity of serum was assayed according to the method described by Demers and Bayne (1997).

Statistical analysis and growth performance calculation

Weight gain (WG, g) = final body weight (FBW) – initial body weight (IBW); Specific growth rate (SGR, % day) = ((ln (FBW) – ln (IBW)) ÷ duration (120 days)) × 100; Survival (%) = 100 × (final number of fish ÷ initial number of fish); Feed conversion ratio (FCR) = weight of feed (g) ÷ live weight gain (g); Protein efficiency ratio (PER) = live weight gain (g) ÷ dry protein intake (g).

The obtained data were subjected to a normal distribution and homogeneity of variance by Shapiro–Wilk and Levene tests. When homogeneity was approved the data were analyzed with one-way ANOVA. Differences between means were tested at the P<0.05 level using the Duncan test as a post-doc test. Analyses were carried out via SPSS version 22 (SPSS Inc., Armonk, NY, USA). The analyzed data are represented as the mean ± standard error (SE) (n = 3).

Results

Growth performance and carcass composition

The growth performance, feed utilization, and survival rate of European sea bass fed dietary coriander are presented in Table 2. The final weight (FBW), weight gain (WG), and specific growth rate (SGR) were meaningfully increased (P<0.05) in European sea bass fed coriander at 5, 10, and 20 g/kg. The FBW and WG were higher in fish fed 20 g/kg than fish fed 5 g/kg without significant differences with fish fed 10 g/kg. Further, the SGR was higher (P<0.05) in fish fed 10, and 20 g/kg than fish fed 5 g/kg. The protein efficiency ratio was gradually increased (P<0.05) in fish fed coriander seeds compared with the control. On the other hand, the feed conversion ratio was gradually decreased (P<0.05) in fish fed coriander seeds compared with the control. The survival rate was markedly increased (P<0.05) in European sea bass fed dietary coriander regardless of the inclusion level.

Table 2. Growth performance of European seabass fed dietary coriander

Item	Coriander (g/kg)			
	0	5	10	20
IBW (g)	5.09±0.12	5.08±0.10	5.05±0.19	5.15±0.17
FBW (g)	46.36±0.42 c	50.74±0.24 b	56.12±0.68 ab	60.66±0.95 a
WG (g)	41.27±0.45 c	45.66±0.33 b	51.07±0.66 ab	55.51±0.89 a
SGR (%/day)	1.47±0.02 c	1.54±0.02 b	1.61±0.02 a	1.64±0.02 a
FI (g/fish)	81.33±1.20	81.33±0.58	82.67±0.88	80.00±0.58
FCR	1.97±0.01 a	1.77±0.01 b	1.62±0.01 c	1.44±0.01 d
PER	1.13±0.01 d	1.25±0.01 c	1.37±0.01 b	1.54±0.01 a
Survival (%)	88.33±4.41 b	95.00±2.89 a	95.00±2.89 a	98.33±1.67 a

*Values in the same row with different letters are significantly different (P<0.05). IBW: initial body weight (g), FBW: final body weight (g), WG: weight gain (g), SGR: specific growth rate, FCR: feed conversion ratio, PER: protein efficiency ratio.

Table 3. Carcass composition of European seabass fed dietary coriander

Item	Initial	Coriander (g/kg)			
		0	5	10	20
Dry matter (%)	33.09±0.36	33.09±0.24	33.21±0.44	33.70±0.18	33.88±0.13
Crude protein (%)	54.92±0.25	54.92±0.29	53.54±0.35	53.68±0.28	54.33±0.18
Lipids (%)	25.81±0.59	25.81±0.78	27.67±0.33	28.00±0.38	27.51±0.25
Ash (%)	16.88±0.18	16.88±0.62	16.84±0.34	16.79±0.32	16.85±0.57

No marked differences were seen between the initial and final body chemical composition (P<0.05). Further, no differences were found among fish fed varying levels of coriander (P<0.05) (Table 3).

Growth hormone level

The level of blood growth hormone was markedly higher (P<0.05) in European sea bass fed dietary coriander at 20 g/kg than fish fed 0 and 5 g/kg (Figure 1). Further, no significant differences were observed between fish fed 10 and 20 g/kg (P<0.05).

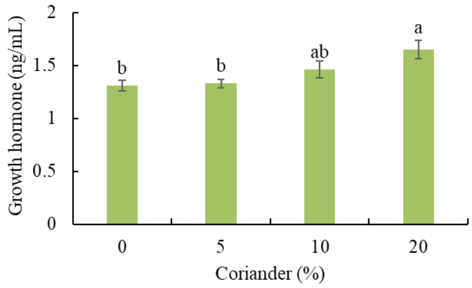

Figure 1. Growth hormone levels in the blood of European sea bass fed coriander supplementation. Bars with different letters are significantly different (P<0.05)

Intestinal antibacterial count

The abundance of intestinal *Vibrio* spp. (Figure 2 A) and fecal coliform (Figure 2 B) were obviously lower (P<0.05) in fish fed 10 and 20 g/kg than fish fed the coriander-free diet. Further, fish fed 20 g/kg had lower (P<0.05) *Vibrio* spp. and fecal coliform counts than fish fed 10 g/kg.

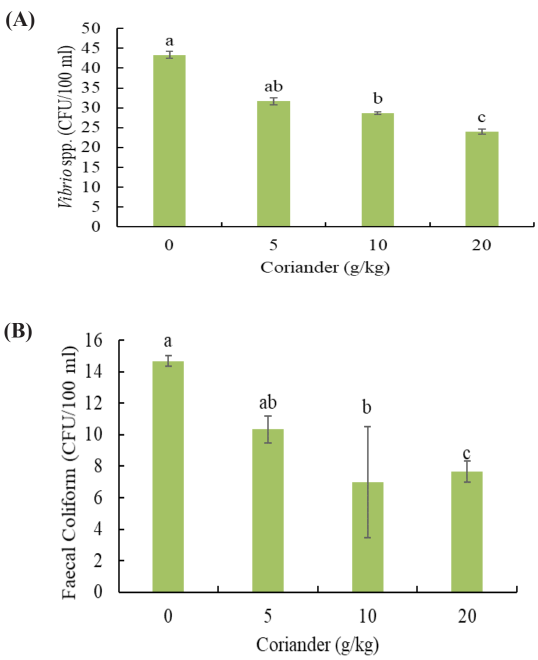

Figure 2. Intestinal harmful bacterial count: (A) *Vibrio* spp. and (B) fecal coliform of European seabass fed dietary coriander. Bars with different letters are significantly different (P<0.05)

Hematological and blood biochemical indices

Fish fed dietary coriander had significantly higher (P<0.05) hematocrit, hemoglobin, red blood cells (RBCs), and white blood cells (WBCs) than fish fed the control (Table 4). Markedly fish fed 20 g/kg had higher (P<0.05) hematocrit, hemoglobin, RBCs, and WBCs than fish fed 10 g/kg. No significant alterations were seen on the MCV, MCH, MCHC, lymphocytes, monocytes, and eosinophils (P<0.05).

Table 4. Hematological indices of European seabass fed dietary coriander

Item	Coriander (g/kg)			
	0	5	10	20
Hematocrit (%)	7.88±0.36 c	8.80±0.71 b	9.75±0.40 ab	10.13±0.34 a
Hemoglobin (g/100ml)	29.73±0.65 c	34.35±1.06 b	36.31±0.69 a	37.48±0.18 a
RBCs ($\times10^6$/mm^3)	3.15±0.05 c	3.71±0.28 b	3.97±0.08 a	4.14±0.08 a
MCV (µm^3/cell)	99.67±1.71	101.40±0.37	102.00±0.34	102.25±0.23
MCH (pg/cell)	29.85±0.09	30.50±0.30	30.70±0.45	31.34±0.44
MCHC (mg/dl)	28.93±0.19	29.69±0.38	29.82±0.40	30.11±0.20
WBCs ($\times10^3$/mm^3)	25.56±1.32 c	26.69±1.38 b	26.84±3.92 b	27.48±1.71 a
Lymphocytes (%)	39.62±0.48	39.96±0.55	40.46±0.34	40.77±0.20
Monocytes (%)	4.15±0.32	4.54±0.10	4.77±0.24	5.01±0.00
Eosinophils (%)	0.62±0.07	0.71±0.08	1.49±0.06	1.59±0.08

*Values in the same row with different letters are significantly different (P<0.05). RBCs: red blood cells, MCV: mean corpuscular volume, MCH: mean corpuscular hemoglobin, MCHC: mean corpuscular hemoglobin concentration, WBCs: white blood cells.

The blood biochemical traits also were not impacted by dietary coriander showing normal values for healthy fish (P<0.05; Table 5).

Immune response

The lysozyme activity was meaningfully increased (P<0.05) in fish fed 10 and 20 g/kg compared with fish fed 0 and 5 g/kg of dietary coriander (Figure 3 A). Further, fish fed coriander at 20 g/kg had higher (P<0.05) phagocytic activity than fish fed 0 and 5 g/kg without significant differences (P<0.05) with fish fed 10 g/kg (Figure 3 B).

Table 5. Blood biochemical indices of European seabass fed dietary coriander

Item	Coriander (g/kg)			
	0	5	10	20
ALT (U/l)	82.08±0.09	81.81±0.17	82.16±0.07	82.83±0.23
AST (U/l)	78.86±0.58	78.67±0.67	79.00±0.58	79.33±0.88
Total proteins (g/dL)	4.98±0.13 b	5.12±0.12 ab	5.29±0.09 a	5.30±0.02 a
Albumin (g/dL)	2.54±0.10 b	2.72±0.17 ab	2.96±0.08 a	3.06±0.13 a
Globulin (g/dL)	2.44±0.06	2.4±0.11	2.33±0.13	2.24±0.16
Urea (mg/dL)	4.22±0.18	4.17±0.14	4.19±0.18	4.29±0.17
Creatinine	0.55±0.04	0.56±0.05	0.58±0.05	0.58±0.02
Total cholesterol (mg/dL)	294.67±7.86	278.33±0.88	263.33±1.45	251.00±1.00

AST: aspartate aminotransferase and ALT: alanine aminotransferase.

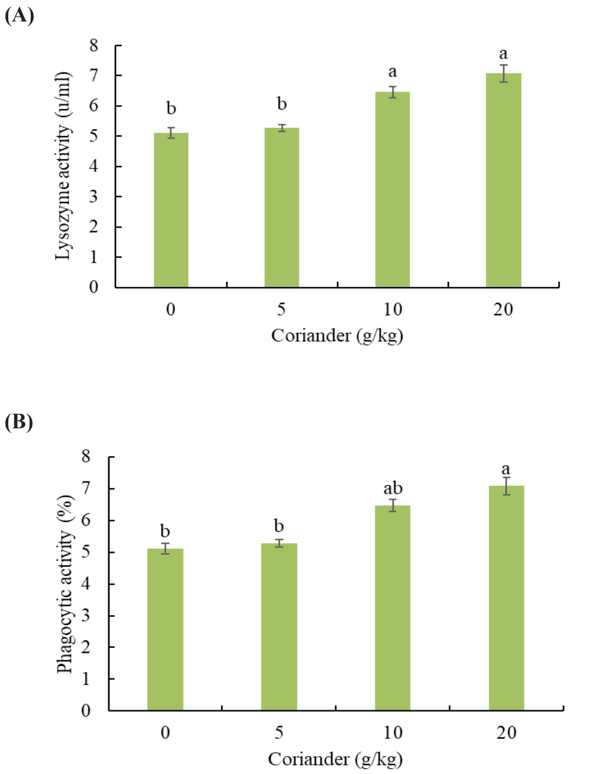

Figure 3. Blood lysozyme (A) and phagocytic (B) activities of European seabass fed dietary coriander. Bars with different letters are significantly different (P<0.05)

Discussion

Aquatic animals are suffering from various farming implications involved in the reduction of health status and survivability (Dawood et al., 2021 c; Kari et al., 2022). The inclusion of medicinal herbs in aquafeed is widely applied to enhance the productivity and wellbeing of aquatic animals (Elumalai et al., 2021). In the literature, many studies illuminated the functionality of medicinal herbs as potential supplements that could enhance the performance and reduce the infection with pathogenic invaders (Dawood et al., 2021 b). Coriander is among these herbal supplements recommended for aquatic animals (Abdou Said et al., 2021); however, no previous reports evaluated the effects of coriander in the diets of European sea bass. The results showed marked improvements in the growth performance and final weight of European sea bass fed dietary coriander for 150 days. In the same line, Naderi Farsani et al. (2019) reported that rainbow trout fed dietary coriander had enhanced growth performance and weight gain. The enhanced growth performance can be related to reduced feed conversion ratio (FCR) and increased protein efficiency ratio (PER) under the present study conditions. The FCR and PER parameters refer to the quality of feed and protein utilization in fish intestines. Indeed, high digestion of feeds and absorption of nutrients through fish intestines result in efficient metabolic and physiological function in the entire body and thereby enhanced health status and growth performance (Gatlin, 2003; Pohlenz and Gatlin, 2014). Coriander is rich in vitamin C and minerals, which are required to complete specific physiological functions in fish bodies (Begnami et al., 2018; Talapatra et al., 2010). Further, the antibacterial potential of coriander inhibits the growth of pathogenic bacteria in fish intestines (Mandal and Mandal, 2015). Concurrently the digestibility of aquafeed could increase, and the activity of digestive enzymes increase (Dawood, 2021). Also, coriander is expected to protect the mucosal intestinal tissue leading to efficient nutrient absorption. In this regard, the results also showed reduced counts of pathogenic intestinal bacteria (*Vibrio* spp. and fecal coliform), indicating the antibacterial capacity of coriander (Dawood et al., 2021 a). Reduced pathogenic bacteria are related to the possible antibacterial capacity of coriander that can break down the cell walls of pathogenic bacteria and weaken its harmful effects on the local intestinal mucosal and immunological status (Silva and Domingues, 2017). In line with the current study, dietary curcumin (Ashry et al., 2021) and cinnamon (Habiba et al., 2021) medicinal herbs in aquafeed resulted in a reduced abundance of pathogenic bacteria in fish intestines. The increased antibacterial capacity in fish intestines could explain the high digestion ability of European sea bass and thereby increased growth performance (Dawood, 2021). Interestingly, the survival rate of fish fed coriander is higher than fish fed the control diet.

One of the main outputs of this study is the enhancement of the growth hormone level in the blood of European sea bass fed dietary coriander. In this context, Habiba et al. (2021) also reported high levels of growth hormone in the blood of European sea bass treated with dietary cinnamon. The activation of insulin-like growth factor (IGF-1) by medicinal herbs is thought to enhance growth hormone production from the pituitary gland (Takasao et al., 2012), leading to the improved synthesis of proteins needed to build the entire body tissues (Hlebowicz et al., 2009). The enhanced secretion of growth hormone could also explain the increased growth performance of European sea bass in this study. The increased survival rate is the direct result of healthy fish and the absence of stressful conditions. Further, good management and feeding practices could explain the high survival rate in fish fed coriander. Coriander seems to be an appropriate strategy that can enhance the general health status and wellbeing of European sea bass.

The detected hematological variables could reveal the influence of coriander on the general health status of fish, especially when treated with different feed additives (Morante et al., 2021; Sangari et al., 2021). The results showed that the hematocrit, hemoglobin, red blood cells (RBCs), and white blood cells (WBCs) were markedly increased in European sea bass upon coriander feeding. Similarly, Naderi Farsani et al. (2019) indicated that coriander feeding resulted in improved hematocrit, hemoglobin, RBCs, and WBCs in rainbow trout. The enhancement of hematological values could indicate the regulated metabolic and immunological status of fish (Fazio et al., 2020; Magouz et al., 2021). Indeed, coriander is believed to enhance feed utilization and local intestinal immunity, thereby good metabolism and physiological status (Abdou Said et al., 2021). In correlation with the hematological profile, biochemical blood indices are reliable tools, referring to the levels of proteins and lipids, liver-related enzymes, kidney metabolites, hormones, and antibodies in fish bodies (Roohi et al., 2017; Yılmaz and Ergün, 2018). The inclusion of medicinal herbs is known for its influence on metabolism regulation leading to well-balanced blood metabolites levels (Ahmadifar et al., 2021; Guardiola et al., 2018). The results showed no influence of coriander feeding on the liver-related enzymes (ALT and AST) and kidney-related metabolites (urea and creatinine), indicating that European sea bass has healthy livers and kidney tissues. The results can be attributed to the non-toxic effects of coriander besides its metabolic regulation roles (Begnami et al., 2018; Talapatra et al., 2010). The study also indicated high total protein, albumin, and globulin levels in the blood of European sea bass fed dietary coriander. Concurrently, Naderi Farsani et al. (2019) illustrated that rainbow trout treated with coriander had increased blood proteins levels. The increased protein levels in the blood are also correlated with increased hematocrit, hemoglobin, RBCs, and WBCs under this study conditions referring to the positive influence on fish metabolic, physiological, and immunological status (Fazio, 2019).

One of the critical factors of the activation of innate and humoral immunity of aquatic animals is the application of supplements to improve local intestinal immunity (Alagawany et al., 2021). In this context, medicinal herbs, including coriander, are known for their local immunity activation resulting from the high antibacterial effects of herbal components (Bahrekazemi et al., 2020; Msaada et al., 2017). The study showed activated lysozyme and phagocytic activities in European sea bass fed dietary coriander. Similarly, Ahmed et al. (2020) and Naderi Farsani et al. (2019) stated that Nile tilapia and rainbow trout fed dietary coriander had enhanced immune responses. Increased lysozyme and phagocytic activity indicate that European sea bass can tolerate the infection with pathogenic bacteria due to the role of lysozyme activity in breaking down the cell wall of pathogenic bacteria (Saurabh and Sahoo, 2008; Siwicki and Studnicka, 1987). Further, activated phagocytic activity can also be related to increased WBCs, which show the ability of leucocytes to damage the pathogenic bacteria (Dowding and Scholes, 1993). Coriander has a high content of vitamin C, which acts as a natural immunostimulatory agent (Begnami et al., 2018; Talapatra et al., 2010). Further, the high content of polyphenols in coriander can reduce the number of harmful bacteria in the fish intestines and reduce the secretion of toxic substances involved in the damage of epithelial cells and intestinal barriers (Ahmadifar et al., 2020). Concurrently, coriander can protect the local intestinal immunity leading to high immune response (Dawood, 2021).

Conclusions

In conclusion, dietary coriander could be included in the diets of European sea bass at 10–20 g/kg. The inclusion of coriander resulted in improved growth performance, growth hormone, feed utilization, and intestinal antibacterial capacity. Further, coriander supplementation regulated the blood hematological and biochemical variables leading to activated immune response. However, further studies are required to reveal the antioxidative capacity of coriander using molecular-based techniques.

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