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Original Article

Synergistic Effects of Dietary β-glucan plus *Lactobacillus pentosus* and *Lactobacillus plantarum* as a Synbiotic on Growth Performance and Digestive Enzyme Activity of Juvenile Rainbow trout (*Oncorhynchus mykiss*)

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Abstract
Synbiotics, which are a combination of prebiotic and probiotic supplements, are one of the most commonly used feed additives in aquaculture. Present study was carried out to evaluate the effect of dietary supplement of two strains of intestinal bacteria *Lactobacillus plantarum* and *Lactobacillus pentosus* from the intestinal tract of the Shabot (*Tor grypus*) with β-glucan on growth performance and digestive enzyme activity of rainbow trout (*Oncorhynchus mykiss*) fingerlings. The fish were divided randomly into 8 treatment groups (for 60 days) containing control (group 1), 1% β-glucan (group 2), *Lactobacillus plantarum* (group 3), *Lactobacillus pentosus* (group 4), *Lactobacillus plantarum* + *Lactobacillus pentosus* (group 5), *Lactobacillus plantarum* with 1% β-glucan (group 6), *Lactobacillus pentosus* with 1% β-glucan (group 7), *Lactobacillus plantarum* + *Lactobacillus pentosus* with 1% β-glucan (group 8). After 60 days, the fish fed combination of two probiotics at equal proportion with 1% β-1,3-glucan (group 8) had higher growth performances than the other treatment groups. Digestive enzyme activities such as ALP, α-amylase, trypsin, lipase and protease in groups including probiotics and prebiotic, particularly in group 8 in parallel with growth performances, had higher than other groups. However, the enzyme activity of chemotrypsin had no significant difference between treatments. These results indicate that a combination of host-derived probiotics (*L. plantarum* and *L. pentosus)* with β-1,3-glucan has a significant potential as an important synbiotics to enhance the nutrients utilization and activity of digestive enzymes in rainbow trout juveniles; However, further research is needed to determine the proper supplement for this commercially valuable product.

Key words: Probiotic bacteria, Synbiotic, *Oncorhynchus mykiss*, Digestive enzymes, Growth performances

Introduction
Aquaculture has evolved as the fastest-growing food-producing sector and developed as an important component in food security. The use of antibiotics and

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chemotherapeutics in aquaculture has been associated with several negative effects such as the emergence of drug-resistant bacteria, environmental pollution, and the accumulation of toxic residues in fish tissues, which is harmful to human health. Therefore, it is crucial to explore alternative approaches that promote the growth and health of farmed fish while reducing the risks associated with the use of these chemicals (Panigrahi and Azad, 2007). Alternative treatments are developed such as vaccines; however, remain inconclusive in some types of farmed fish (Chinabut and Puttinaowarat, 2005). Feed additives that include vitamins, minerals, probiotics, and prebiotics have shown promising results in improving the health and performance of aquatic animals. Probiotics and prebiotics, for example, promote gut health and enhance immunity, thereby reducing the risk of disease outbreaks in farmed fish. Moreover, they can improve the digestibility of feed and nutrient absorption, leading to better growth rates and feed conversion ratios (Nagappan et al, 2021).

Over the last years, more attention has been oriented towards host-derived probiotics, in particular the gastrointestinal (GI) microbiome, as an important component of fish health. The probiotics are cultures of special microorganisms, which have been used as feed additives that improve the health of terrestrial and aquatic. Most probiotics are supplied as live supplements in food, which must have the ability to survive passage through the intestinal tract. The benefit to the host may arise as a nutritional effect, whereby the bacteria are able to break down toxic or otherwise non-nutritious components of the diet, which can be then digested by the host (Terpou et al, 2019). Probiotics have been shown to improve the energy expenditure derived from other sources such as carbohydrates and increase the incorporations of protein for growth, increase the immunity and disease resistance of host organisms. Although scientists have demonstrated the beneficial effects of using probiotics as fish feed additives, information on the interaction among probiotic species, digestive enzymes and probiotics in fish diets is very scarce. Some information on the effect of probiotics on Indian major carp and rainbow trout and other indigenous and exotic fishes of major economic importance is available (Ramírez-Torrez et al, 2019; Ramos et al, 2017; Merrifield et al, 2010). In addition less characterized than in higher vertebrates, the fish GI microbiome is increasingly recognized for its pervasive benefits on the health, nutrition, development and well-being of its host (Ghanbari et al, 2015; Llewellyn et al, 2015). Consequently, natural feed additives targeting beneficial host effects via the promotion of indigenous microbial population (prebiotic), the administration of exogenous live microorganisms (probiotics) or their combination (synbiotic) are rapidly emerging as valuable tools within integrated programs to maintain good health and achieve the prospective performances in aquaculture (Burgos-Aceves et al, 2016). Although a number of exogenous and commercial probiotics have been shown to be effective in cold water species culture (Ramos et al, 2017; Merrifield et al, 2010), only few reports have been published yet on the effectiveness of endogenous probiotics in trout culture.

Prebiotics are types of dietary fiber that are not digested by the organism body but instead serve as food for the beneficial bacteria in our gut microbiome (Gibson et al, 2004; Qiang et al, 2009; Rurangwa et al, 2009). By promoting the growth and activity of these beneficial bacteria, prebiotics can help improve various aspects of our health, including digestion, immunity, and nutrient absorption (Sakai 1999; Szilagyi, 2002; Li and Gatlin, 2004; Torrecillas et al, 2007; Dalmo and Bogwald, 2008; Andrews et al, 2009;

Yousefian and Amiri, 2009; Geraylou et al, 2013; Selim et al, 2014).

β-1,3-Glucan is a glucose homopolymer composed of (1,6)-glycosidic branches with either β(1,3) or β(1,4) backbone structures and it has been extensively used as a prebiotic in different fish species in the aquaculture industry. Its natural origin also makes it an ideal feed additive without causing any food safety problems. β-1,3-Glucan one of prebiotics has been used extensively in different fish species such as Atlantic salmon (*Salmo salar* L.) (Paulsen et al, 2001), rainbow trout (*Oncorhynchus mykiss*) (Walbaum,1792) (Lauridsen and Buchmann, 2010), rohu (*Labeo rohita*) (Misra et al, 2006), koi (*Cyprinus carpio* koi) (Lin et al, 2011), and mirror carp (*C. carpio* L.) (Kühlwein et al, 2013)., Nile tilapia (Pilarski et al, 2017), white shrimp (*Litopenaeus vannamei*) (Wu et al, 2016), Persian sturgeon (*Acipenser persicus*) (Aramli et al, 2015). β-1,3-Glucan is considered an ideal feed additive in the aquaculture industry because of its natural origin and thus does not cause any food safety problems (Meena et al, 2013).

Prebiotics such as β-glucans have been shown to have direct effects on the immune system of aquatic animals, and can also provide substrates for the growth and colonization of probiotic bacteria. The combined use of pre- and probiotics, known as synbiotics, has shown promise in improving growth performance, health conditions, and disease resistance in fish through their synergistic effects. However, while some studies have shown positive effects of synbiotics in aquaculture, there is still a need for further research to fully understand the mechanisms underlying their beneficial effects (Nadal et al, 2020).

Thus, the present study was performed to evaluate the potential effect of individual or combined administration of dietary isolated probiotics from the native microflora associated with fish and β-glucan on growth performance, and the digestive enzymes activity of rainbow trout juveniles.

Materials and Methods

Source of Probiotics

Food supplementation was done using *Lactobacillus plantarum* subsp. *plantarum* and *Lactobacillus pentosus*. These strains were obtained from a previous study by Mohammadian et al (2016) using biochemical parameters and 16S rRNA gene sequencing. These isolates were cultivated in MRS broth (Pronadisa, Madrid, Spain) and incubated at 30 ℃. Bacterial strains were kept at -80 °C until they were needed. β-glucan was ground into a fine powder before being added with the above-mentioned ingredients, as stated by Merrifield et al, (2010).

Experimental Design

The experiment was carried out in the aquatic health laboratory (Chamran University, Ahwaz, Iran). Six hundred juvenile rainbow trout (15.22±0.24 gr) were randomly allocated into eight experimental groups, in triplicates. Each experimental diet was as follows: basal diet (G1), basal diet supplemented with 1% β-1,3-glucan (G2), *Lactobacillus plantarum* (G3), *Lactobacillus pentosus* (G4), *Lactobacillus plantarum + Lactobacillus pentosus* (G5), *Lactobasillus plantarum* with 1% β-1,3-glucan (G6), *Lactobacillus pentoseus* with 1% β-1,3-glucan (G7) and *Lactobacilus plantarum+Lactobasilus pentoseus* with 1% β-1,3-glucan (G8).

Diet Preparation

The experimental feed is being prepared in a shaking incubator at 25 ºC and two *Lactobacillus* bacterial strains were cultured overnight in MRS broth. The bacteria were rinsed twice with phosphate-buffered saline (PBS, 0.1 M, pH = 7.2) and resuspended in the same bacterial solution after 10 minutes of centrifugation (2000 g). A spectrophotometer was used to adjust the bacteria concentration to 3×10^9 CFU ml^{-1}. According to the AOAC technique, the basal diet had 40.5% crude protein, 6.2% crude fat, 5% ash, and 395 Kcal per 100 g^{-1} gross energy. The test product was an aqueous suspension with a 10% concentration of β-1,3-glucan (ImmuneGluTM, made from *Saccharomyces cerevisiae* cell walls; Green Cross Veterinary Products Co., Gyeonggi-do, Korea). The probiotic-enriched diets were made by gently spraying the needed amount of bacterial suspension on the control food (16 ml bacterial suspension per kg diet) and mixing it in a drum mixer, bit by bit, to achieve a final probiotic concentration of ~10^8 CFU gr^{-1}. They were packaged in sterile conditions.

Sample Collection

At the end of the experiment (60 days), three starved fish were randomly removed from each tank (total= 9/treatments) and after being euthanized, fresh tissue (internal gut) samples were collected under sterile conditions to assess the effect of synbiotics and probiotics on digestive enzyme activity. The samples were homogenized (Heidolph instruments, Germany) for intestinal enzyme using a cold homogenizing solution comprising 100 mM Tris–HCl, 0.1 mM EDTA, and 0.1% Triton X-100 pH=7.8 (1:9 v/w), centrifugation (13,500 g, 30 min, 4°C) and then, the supernatant was collected and preserved at 80 °C for subsequent measurements (Mohammadian et al, 2017; Rungruangsak-Torrissen et al, 2002).

Growth and Dietary Performances

Juvenile of rainbow trout (mean body weight: 15.22±0.24 gr) was randomly divided among the tanks after a 14-day acclimatization period, with 20 fish per tank. Three replicates of each diet treatment were studied. All of the fish were fed twice a day, between 8:00 a.m. and 14:00 p.m. For the whole 60-day raising period, the feeding rate was fixed at 3% body weight on day^{-1}. During each ration, the fish were exposed to their respective diet for 4 hours; the uneaten feed was then siphoned away, kept, and dried separately in order to calculate the feed conversion ratio (FCR). Prior to stocking (control-0d), during the experiment (i.e., 30d), and at the end of the feeding trial, all fish body weights were recorded (i.e., 60d). To do this, all fish were starved for 24 hours prior to sampling or biometry, and each fish was then weighed individually. All growth performance and feed utilization metrics were computed as previously indicated, including body weight gain (BWG%), condition factor (CF, gr cm^{-3}), specific growth rate (SGR%), feed conversion ratio (FCR), the protein efficiency ratio (PER), and relative weight gain (RGR) (Mohammadian *et al.*, 2017). The following formulas were used to do the calculations: FER percent = 100 (FBW–IBW)/feed consumed, DWG = (final weight/initial weight)/time, SGR percent = 100 (lnFBW–lnIBW)/days, FCR= feed consumed/ (FBW–IBW), PER= IBW/protein intake, and RGR= (final weight – initial weight) / initial weight. The survival rate was also assessed over the course of the trial.

Intestinal enzyme activity

As previously stated, the homogenized intestinal sample was centrifuged. Bradford (1976) was used to assess the activity of total protein content in the gut using the diluted supernatant and bovine serum albumin as a reference. The α-amylase activity of the intestine was also measured using a soluble starch solution (Sigma–Aldrich) as the substrate, as described by Areekijsereeet et al. (2004). Amylase activity was measured in mol maltose generated per milligram of protein per minute. At room temperature, trypsin activity was determined using N-Benzoyl-L-arginine ethyl ester (BAEE) as a substrate in the presence of 0.1 mM HCl (Erlanger et al, 1961; Hummel, 1959). The release of fatty acids as a result of enzymatic hydrolysis of triglycerides to glycerol in the stabilized emulsion of olive oil, Fluka TM (Borlongan, 1990), was used to assess lipase activity. According to a modified approach (Otto *et al.,* 1946), total ALP activity in homogenized tissue was measured at 410 nm and 37 °C using P-nitrophenyl phosphate as substrate and 2-amino-2-methyl-1-propanol buffer (0.84 mM, pH= 10.3). Casein (Sigma–Aldrich) was used as a substrate for measuring protease activity, and the result was subsequently reacted with Folin's reagent (Anson, 1938, with modifications). The absorbencies of each individual sample were determined using a spectrophotometer (UV-2802S; Unico, Shanghai, China), and the enzyme activities that were recorded as absorbance were modified and then reported as specific activity (U mg^{-1}protein min^{-1}) (Sun et al, 2012).

SPSS version 22 was used to analyze the data. ANOVA and 95% confidence intervals were used to assess the findings. The Duncan test, with a significance level of 0.05%, was also utilized to assess mean differences.

Results

Growth Performance

Table 1 shows the growth performance and feed utilization of rainbow trout fed with two different probiotics and β-glucan in combination and separately for 60 days. Group 8 had significantly greater final body weights, weight gains, relative growth rate, specific growth rate, protein efficiency ratio and feed conversion ratio than the other groups after 60 days (p<0.05).

Table 1: Growth parameters of rainbow trout on different treatments on day 60 of the experiment

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Initial W (gr)	9.7±0.3^{a}	9.7±0.2^{a}	9.7±0.4^{a}	9.7±0.2^{a}	10.1±0.2^{a}	9.6±0.4^{a}	9.5±0.4^{a}	9.6±0.3^{a}
Final W (gr)	77.3±0.88^{e}	82.39±1.09^{d}	84.71±0.83^{d}	84.10±0.16^{d}	87.68±0.78^{c}	90.66±0.55^{b}	90.01±0.69^{b}	94.31±0.65^{a}
DWG	1.13±0.01^{f}	1.21±0.01^{e}	1.25±0.01^{d}	1.24±0.003^{d}	1.29±0.01^{c}	1.36±0.01^{b}	1.34±0.01^{b}	1.41±0.01^{a}
RGR	87.45±0.16^{d}	88.23±0.12^{c}	88.55±0.06^{c}	88.47±0.12^{c}	88.48±0.07^{c}	89.96±0.17^{a}	89.45±0.05^{a}	89.93±0.1^{a}
SGR (%)	3.46±0.02^{e}	3.57±0.01^{d}	3.61±0.008^{c}	3.60±0.01^{c}	3.60±0.01^{c}	3.83±0.02^{a}	3.75±0.008^{b}	3.83±0.02^{a}
FCR	0.90±0.03^{b}	0.83±0.03^{c}	0.96±0.04^{a}	0.79±0.03^{d}	0.84±0.03^{c}	0.82±0.04^{c}	0.71±0.005^{e}	0.67±0.005^{f}
PER	2.77±0.12^{d}	3.03±0.14^{c}	2.62±0.13^{d}	3.16±0.14^{c}	2.98±0.12^{c}	3.05±0.1^{c}	3.50±0.02^{b}	3.76±0.03^{a}
FER	119.99±4.88^{c}	121.15±5.80^{c}	104.73±5.45^{d}	126.28±5.93^{c}	119.06±4.87^{c}	122.01±6.84^{c}	140.18±1.05^{b}	150.35±1.23^{a}

Each value represents as a mean ± standard deviation. Different lower superscripts denote a significant difference between values in each row (P<0.05).

Digestive Enzyme Activity

On the 60th day of the experiment, the G8 had the highest specific activity of α-amylase, alkaline phosphatase, lipase, trypsin and protease compared with other groups (Figure 1). In this study, the investigation focused on assessing the activity of various enzymes across distinct experimental groups. The findings can be summarized as follows: α-amylase: Among the groups, the G3 group exhibited the highest α-amylase activity, demonstrating a statistically significant difference compared to the control group (G1). Enzyme trypsin: Notably, the G5, and G7 displayed significant differences in trypsin activity compared to the other experimental groups. Chymotrypsin: In the case of chymotrypsin activity, it was observed that the G2 treatment displayed a significant difference compared to the control group. Additionally, the two groups G6 and G8 exhibited significant differences in chymotrypsin activity compared to the control group. Alkaline phosphatase: The highest level of alkaline phosphatase activity was recorded in the treatment involving G8 and G4. Lipase: All experimental treatments demonstrated a significant difference in lipase activity compared to the control group, with the G5 treatment displaying the highest level of lipase activity. These results underscore the diverse effects that different combinations of Plantarum, Pentose, and beta-glucan can exert on biochemical enzyme activity.

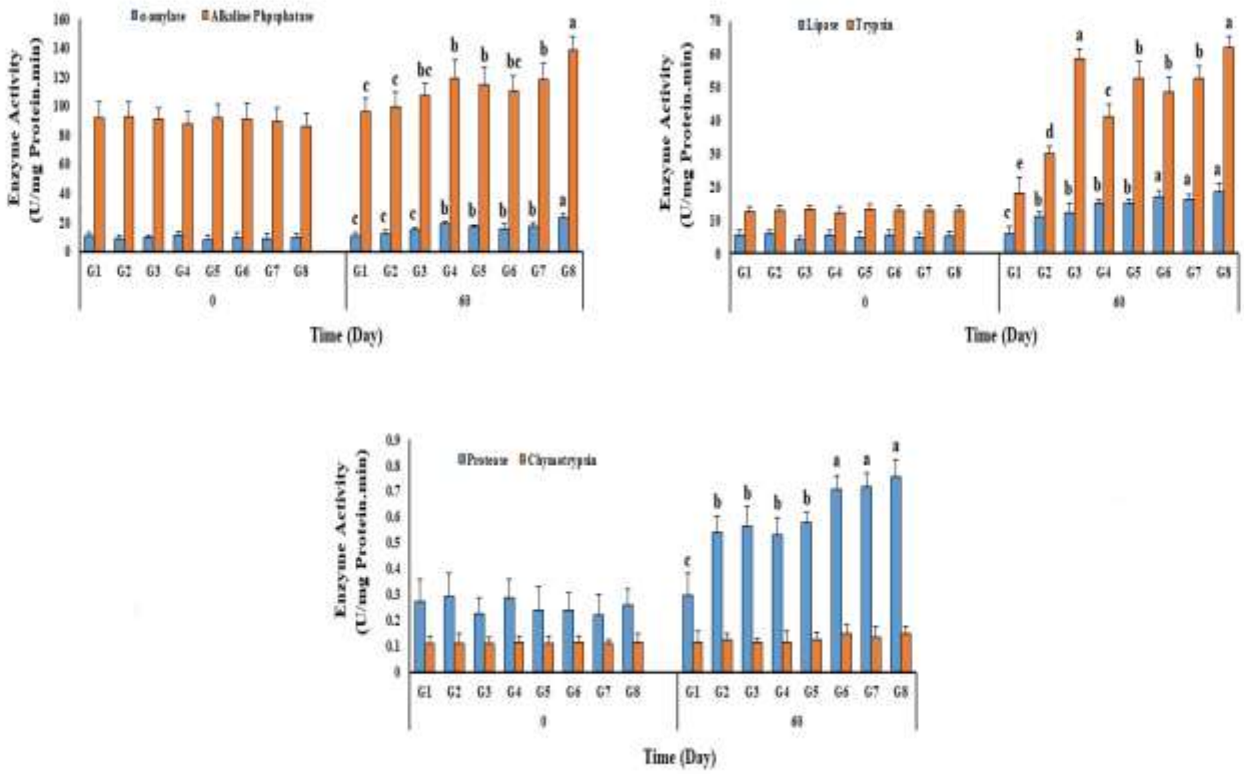

Figure 1: Specific activities of α-amylase, alkaline phosphatase, lipase, trypsin, protease and chymotrypsin of rainbow trout fed different levels of dietary synbiotic. Data represent the mean ± SD.

Discussion

Food additives are now used as one of the diet formula components in aquaculture all over the world (Allam et al, 2020; Fayed et al, 2019). These food additives are employed in the aquaculture industry to promote growth performance, feed consumption, disease resistance, stress relief, and environmental impact (de Araújo et al, 2018; Mansour et al, 2021; García-Beltrán et al, 2020; Mansour et al, 2017; Mansour et al, 2021). Synbiotics, which are a combination of prebiotic and probiotic supplements, are one of the most commonly used feed additives. Synbiotics help the host by selectively encouraging the growth of beneficial microorganisms in the intestines and activating the metabolism of health-promoting bacteria, thereby improving animal survival and welfare (Ringø and Song, 2016; Opiyo et al, 2019; Wang et al, 2017).

The results showed that feeding pre- and probiotics to rainbow trout for 60 days resulted in increased growth and digestive enzyme activity. Other fish species have been studied for the impact of β-1,3-glucan on general growth performance (Mohammadian et al, 2019). While some research found benefits, others did not (Meena et al, 2013). These disparities in results may be due to a variety of factors, including differences in species, experimental setup, supplementation protocol (dosage, duration), and sampling approach (Hoseinifar et al, 2010; 2013). β-1,3-glucan is a type of polysaccharide that is found in the cell walls of various fungi and some other organisms. While it is not entirely clear how β-1,3-glucan promotes animal growth, there is evidence to suggest that it can improve digestive function by activating various enzymes in the gastrointestinal tract. One possibility is that β-1,3-glucan may act as a prebiotic, which means that it can promote the growth and activity of beneficial bacteria in the gut. This, in turn, could help to improve overall digestive health and nutrient absorption in animals, leading to better net energy usage. Another possible mechanism by which β-1,3-glucan may promote animal growth is through its effect on the immune system. Some studies have suggested that β-1,3-glucan can stimulate the immune system and enhance the production of certain cytokines, which are signaling molecules that help to regulate immune function. Improvements in immune function could help animals to resist disease and other stressors, leading to improved growth and overall health. Overall, while the exact mechanism by which β-1,3-glucan promotes animal growth is not fully understood, there is evidence to suggest that it can improve digestive function and immune function, both of which may contribute to better overall health and growth in animals (Miest et al, 2016). This finding is consistent with earlier studies showing that dietary probiotics, prebiotics, and synbiotics improve growth performance and feed consumption in a variety of species (Enferadi et al, 2018; Rahimnejad et al, 2018; Taheri Mirghaed et al, 2018). Compared to separate pre- and probiotic diets, the beneficial effects of combining pre- and probiotic administration have been attributed to an improved health status, greater prebiotic digestibility, or improved probiotic survival and colonization.

In the present study, digestive enzymes activity was evaluated and significant changes were seen in treatment groups especially in the G8 group. These results could be due to synergistic effect of probiotics in this group which might be amplified by β-1,3-glucan. Digestive enzymes such as protease, amylase, trypsin, chymotrypsin, alkaline phosphatase, and lipase are enhanced by the use of probiotics and prebiotics. To increase the activeness of the probiotic bacteria, either the gut microbe is modified or the probiotic bacterium secretes the enzyme (Adel et al, 2017). These additions change the bacterial populations in the intestine and promote the colonization of beneficial bacteria (Hassaan et al, 2014). Because digestive enzymes are at the heart of the metabolic process, any disturbance in their activity could result in a loss of nutrients (Pauchet et al, 2008). The introduction of synbiotics to rainbow trout affected enzyme activity, according to the findings of this study. In the same studies, dietary supplementation with prebiotics and probiotics improved enzyme activity levels, and different levels of synbiotics have the ability to enhance probiotic substitution and digestive enzyme activities, which improve digestive system efficiency and, ultimately, growth (Kumar et al, 2018; Essa et al, 2010; Dehaghani et al, 2015). Another study looked at the activities of digestive enzymes in Japanese flounder (*Paralichthys olivaceus*) and found that the activities of protease and amylase were significantly higher in fish fed prebiotic-supplemented diets than in fish fed a control diet (Ye et al, 2011). As a result, microorganisms and their enzymes play an important role in the digestion process by increasing total enzyme activity in the gut (Ding et al, 2004; Ziaei-Nejad et al, 2006; Munilla-Moran et al, 1990) and stimulating the production of endogenous enzymes (Wang et al, 2017;

Ochoa-Solano and Olmos-Soto, 2006), which can increase feed digestibility, which could explain the improved growth and feed utilization. Increased digestive enzyme activity would allow the host to degrade more nutrients, resulting in improved digestion and possibly increased weight gain and/or feed efficiency. The results showed that the use of prebiotics and probiotics increases the growth indices and activity of digestive enzymes in the treated groups compared to the control group. This increasing trend in groups containing a combination of probiotics and prebiotics, especially in group 8 compared to other groups was more.

In conclusion, the present study revealed that the dietary supplementation of synbiotics which contains *L. plantarum*, *L. pentosus* and β-1,3-glucan improved significantly growth performance and digestive enzyme activities compared to other groups which can be due to the synergistic effect of probiotics and prebiotics in it.

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Conflict of Interest

The authors declared that there is no conflict of interest.

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اثرات هم افزایی بتا گلوکان جیره به همراه لاکتوباسیلوس پنتوزوس و لاکتوباسیلوس پلانتاروم به عنوان یک سین بیوتیک بر عملکرد رشد و فعالیت آنزیم‌های گوارشی ماهی قزل آلای رنگین کمان جوان

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چکیده

سین‌بیوتیک‌ها ترکیبی از مکمل‌های پری‌بیوتیک و پروبیوتیک هستند و یکی از متداول‌ترین افزودنی‌های خوراکی در آبزی‌پروری محسوب می‌شوند. دو سویه باکتری درون زاد جدا شده از ماهی شیربت به نام‌های لاکتوباسیلوس پلنتاروم و لاکتوباسیلوس پنتوسئوس در این مطالعه مورد ارزیابی قرار گرفتند و اثرات این باکتری‌ها را بر روی عملکرد رشد و فعالیت آنزیم‌های گوارشی ستگاه گوارش ماهی قزل‌آلای رنگین کمان مورد بررسی قرار گرفت. این آزمایش به صورت کاملا تصادفی در ۸ تیمار طراحی شد. ۱- غذای بدون مکمل یا غذای پایه، ۲- غذای حاوی CFU/gr۱۰۸ لاکتوباسیلوس پلنتاروم، ۳- لاکتوباسیلوس پنتوسئوس ۱۰۸ CFU/gr، ۴- لاکتوباسیلوس پلنتاروم و لاکتوباسیلوس پنتوسئوس به نسبت مساوی، ۵- لاکتوباسیلوس پلنتاروم و لاکتوباسیلوس پنتوسئوس به نسبت مساوی و یک درصد بتاگلوکان در هر گرم خوراک، ۶- لاکتوباسیلوس پلنتاروم و یک درصد بتاگلوکان در هر گرم خوراک، ۷- لاکتوباسیلوس پنتوسئوس و یک درصد بتاگلوکان در هر گرم خوراک، ۸- حاوی یک درصد بتاگلوکان در هر گرم خوراک. برای هر تیمار ۶۰ قطعه بچه ماهی قزل‌آلا به وزن ۲±۱۵ در مخازن ۳۰۰ لیتری تقسیم‌بندی شد و به مدت ۶۰ روز مورد پرورش قرار گرفتند. اختلاف میانگین وزنی در ابتدا و انتهای آزمایش بررسی شد. بعد از ۶۰ روز نتایج نشان داد ماهیانی که با ترکیب دو پروبیوتیک به نسبت مساوی به همراه بتاگلوکان و همچنین پلنتاروم به تنهایی تغذیه شده بودند، بهترین عملکرد رشد را دارا بودند. اما در پایان آزمایش فعالیت آنزیم گوارشی مانند آلکالین فسفاتاز، کیموتریپسین و آلفاآمیلاز همسو با عملکرد رشد در تیمارهای تغذیه شده با پلنتاروم به تنهایی و ترکیب دو پروبیوتیک به نسبت مساوی به همراه بتاگلوکان بود اما میزان فعالیت تریپسین، لیپاز و پروتئاز در گروه پلنتاروم به همراه پنتوسئوس بیش‌ترین بود در حالی که این گروه کم‌ترین عملکرد رشد را به خود اختصاص داده بود. این نتایج نشان داد که ترکیب باکتری‌های درون زاد مانند پلنتاروم و پنتوسئوس و به همراه پری بیوتیک بتاگلوکان دارای پتانسیل معنی‌داری از جهت افزایش کاربرد غذایی، و فعالیت آنزیم‌های گوارشی در بچه ماهیان قزل‌آلای رنگین کمان بودند هرچند برای تعیین مکمل مناسب برای این گونه تجاری ارزشمند، نیاز به تحقیق بیش‌تری است.

کلمات کلیدی: باکتری‌های پروبیوتیک، سینبوتیک، قزل‌آلای رنگین کمان، آنزیم‌های گوارشی، عملکرد رشد

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