

## Research Article

# Evaluation of feed efficiency, growth and biochemical parameters of rainbow trout (*Oncorhynchus mykiss*) juveniles fed with different levels of Alphamune prebiotic

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## Abstract

This research was conducted to evaluate the effect of different levels of Alphamune prebiotic on growth performance and blood chemistry of rainbow trout (*Oncorhynchus mykiss*) juvenile. Rainbow trout with an initial weight of  $16.46 \pm 0.09$  g were randomly assigned to four dietary treatments for eight weeks. The dietary treatment was: 0 (ALP0), 1 (ALP1), 1.5 (ALP1.5), and 2 (ALP2) g of Alphamune prebiotic/kg of basal diet. The results showed that there was no significant difference in survival rate and SGR at the end of the trial. A significant difference was observed in the final weight and weight gain, and the highest one was obtained in ALP1.5 treatment ( $p < 0.05$ ). Food conversion rate (FCR) was affected by Alphamune levels and the lowest FCR was observed in ALP1.5 treatment. Blood biochemistry assay revealed that glucose, triglyceride, and cholesterol were not influenced by Alphamune's different levels.

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There were significant differences in IgM and total protein and the highest value was obtained in ALP2. These results showed that 1.5% Alphamune prebiotic (ALP1.5) had a positive effect on growth performance and biochemical parameters of rainbow trout juveniles.

**Keyword:** Alphamune, Prebiotic, Growth, *Oncorhynchus mykiss*

## Introduction

In recent years, aquaculture has been one of the fastest-growing sectors of food production and has rapidly become a dynamic and growing industry (Piazzon *et al.*, 2017). The use of functional feed additives has increased due to public awareness of the antibiotic disadvantages for human health and the banning of antibiotics used in aquaculture. (Zhongzhen *et al.*, 2019). Prebiotics are the indigestible ingredient that has beneficial effects on the host by improving the health, by

stimulating the growth or activity of several bacterial species residents in the gut (Hoseinifar *et al.*, 2014a; Gibson *et al.*, 2017). Prebiotics improve the balance of the intestinal microbiota and increase the defense mechanism of the body (Li and Gatlin, 2004). Nutrients that are classified as prebiotics should have properties such as being indigestible in the upper gastrointestinal tract, selective fermentation by one or more beneficial intestinal bacteria, and stimulating intestinal microbiota to produce healthier compounds (Fooks and Gibson, 2002). Besides, the most important products of prebiotic metabolism are short-chain fatty acids (SCFAs) which are absorbed through the intestinal epithelium and strengthen enterocytes and improve nutrition (Mahious and Ollevier, 2006b). The most important compounds used as prebiotics are inulin, fructooligosaccharides, glucooligosaccharides, Galactooligosaccharide, mannan oligosaccharides, isomaltooligosaccharides, and xylooligosaccharides (Ringo *et al.*, 2010). Alphamune is a mixture of  $\beta$  glucans (24%) and mannan oligosaccharide (15%) and it is produced as a by-product of *Saccharomyces cerevisiae* (Huff *et al.*, 2006). Numerous studies indicate dietary supplementations of mannan oligosaccharides improve growth performance and immune parameters of rainbow trout (Staykov *et al.*, 2007; Aimrkolaie *et al.*, 2016). Also, several studies showed that immune activity in the different fish species improves by supplementation of  $\beta$ -glucan (Ganguly *et al.*, 2013; Hoseinifar *et al.*, 2014, 2015). Previous studies on prebiotic

mostly focused on different types of oligosaccharides alone as a source of prebiotic, but little is known about the efficiency of a mixture of carbohydrate sources. Therefore, this study aimed to investigate the effect of different levels of Alphamune on the hematological parameters of rainbow trout.

## Material and methods

### Fish and experimental condition

A total of 300 rainbow trout juveniles ( $16.46 \pm 0.09$  g) were obtained from a commercial fishery center and were randomly assigned to 12 tanks at a density of 25 fish per tank (300 L). The fish were acclimated to the experimental condition and fed with the commercial diet for 2 weeks. After acclimation, fish were fed with experimental diets at the rate of 2% body weight, three times a day for 56 days. Water quality parameters were regularly checked periodically and the flow rate was found 200 L/h, dissolved oxygen was  $7.31 \pm 0.60$  mg/L, pH was  $7.65 \pm 0.2$ , water temperature ranged from  $12.2 \pm 1.98$  °C. The water volume was renewed one-third of the total before the first feeding time in the morning. Any mortality was removed daily and recorded survival rate.

### Experimental diet

Diet components were purchased from the Mazandaran Animal & Aquatic Feed (Sari, Mazandaran, Iran). A basal diet with different levels of Alphamune ALP0 (0 g/kg Alphamune diet prebiotic), ALP1 (1 g/kg Alphamune diet prebiotic), ALP1.5 (1.5 g/kg Alphamune diet prebiotic) and ALP2 (2 g/kg

Alphamune diet prebiotic), (Provided by Alpharma Co, Sao Paulo, Brazil) were formulated based on rainbow trout nutritional needs (Table 1). The mixed dough was

extruded through an electric meat grinder (Electrokar EC-1, Tehran, Iran) to form pellets with a 3 mm diameter. Then, the pellet was air-dried at 50 °C.

**Table 1.** The ingredient used in the experimental diet

Alphamune level Ingredient (g/kg diet)	0	1	1.5	2
Fish meal	430	430	430	430
Soybean meal	200	200	200	200
Wheat gluten	50	50	50	50
corn	40	40	40	40
Fish oil	65	65	65	65
Sunflower oil	65	65	65	65
Mineral and Vitamin premix	15	15	15	15
Alphamune binder	0	1	1.5	2
	15	15	15	15
<b>Proximate composition (g/kg dry matter)</b>				
Crude protein	360	360	360	360
Crude lipid	220	220	220	220
Ash	140	142	140	140
Carbohydrate	192	192	192	192

**1 kg Mineral Supplementation contained:** co, 100; I, 400; se, 20; Zn, 10,000; Fe, 6,000; Cu, 600; Mn, 5,000

**5 kg Vitamin Supplementation 0.5% contained:** vitamin A 80,000 IU/ kg; vitamin D3 2,000 IU/kg; vitamin k 20 mg/kg; thiamin 60 mg/kg; riboflavin 60 mg/ kg; pyridoxine 100 mg/kg; pantothenic acid 150 mg/kg; niacin 300 mg/kg; biotin 2 mg/kg; folic acid 20 mg/kg; vitamin B12 0.1 mg/kg; inositol 300 mg/kg; ascorbic acid 600 mg/kg; choline chloride 3000 mg/kg. Carbohydrate = 100 - (crude protein + crude lipid + ash + moisture).

### Growth performance

At the end of the experiment, feeding was stopped for 24 hours, after that the fish in each tank were separately weighed and the growth performance was calculated as below (Mohammadzadeh *et al.*, 2017):

Weight gain: final weight (g) – initial weight (g)

Body weight increase (BWI, %) =  $100 \times [\text{final weight (g)} - \text{initial weight (g)}] / \text{initial weight (g)}$

Feed conversion ratio (FCR) = dry weight of feed given (g) / WG (g)

Specific growth rate (SGR) =  $\text{Ln final weight} - \text{Ln initial weight} \times 100 / \text{days}$

Condition factor (CF) = body weight/body length<sup>3</sup> × 100

### Sample collection

At the end of the feeding trial, seven fish from each tank were sampled for hematological and blood biochemistry test. For preventive stress, fish feeding was stopped for 24 hours then were anesthetized by a stock solution of clove oil (Kralicin) solution (50-70 ppm) (Esmaeili *et al.*, 2017b). Blood samples were collected by venipuncture of the caudal vein using a sterile 2-ml syringe and introduced to both heparinized and nonheparinized tubes. Non-heparinized blood was centrifuged (1,600 × g for 10 min) to obtain the serum. Supernatant was separated and stored at -20°C for later analysis.

### Blood biochemistry

Levels of glucose, triglyceride (TG), total cholesterol, total protein, and IgM were measured by a colorimetric method using Pars Azmoon kit with an autoanalyzer (Hitachi 902, Boehringer Mannheim Germany).

### Statistical analysis

SPSS software (version 16, Chicago, IL, USA) was used to analyze data. Shapiro-Wilk and Levene's tests were applied to check the data normality and homogeneity of variances, respectively. The effect of the treatments on growth performance and blood biochemistry was examined by one-way analysis of variance (ANOVA). Duncan's multiple range tests were used to assess differences among four treatments in growth performance factors and blood biochemistry.

### Results

The growth indices of rainbow trout juveniles fed by different levels of Alphamune are shown in Table 2. There was no significant survival rate and SGR at the end of the trial ( $p > 0.05$ ). After 8 weeks, a significant difference was observed in the final weight and WG, and the highest one was obtained in ALP1.5 treatment ( $p < 0.05$ ). FCR was affected by various dietary Alphamune levels and the lowest FCR was observed in ALP1.5 treatment ( $p < 0.05$ ).

Effect of Alphamune different levels on blood biochemistry indices of rainbow trout juveniles was presented in Table 3. Blood biochemistry assay revealed that glucose, triglyceride and cholesterol were not influenced by Alphamune different levels ( $p > 0.05$ ). There were significant differences in IgM and total protein and the highest value was obtained in ALP2.

**Table 2.** Growth performance of rainbow trout fed experimental diets containing different levels of Alphamune for eight weeks

Growth indices	Diet			
	ALP0	ALP1	ALP1.5	ALP2
Initial weight (g)	16.12 ± 0.1	16.75 ± 0.36	16.5 ± 0.8	16.49 ± 0.1
Final weight (g)	73.47 ± 2.39 <sup>b</sup>	74.61 ± 1.23 <sup>b</sup>	77.44 ± 1.36 <sup>a</sup>	75.23 ± 1.66 <sup>ab</sup>
WG (g)	57.35 ± 1.96 <sup>b</sup>	57.86 ± 1.15 <sup>b</sup>	60.94 ± 1.62 <sup>a</sup>	58.74 ± 1.71 <sup>ab</sup>
SGR	2.70 ± 0.48	2.66 ± 0.14	2.76 ± 0.05	2.71 ± 0.32
FCR	1.08 ± 0.11 <sup>a</sup>	1.08 ± 0.10 <sup>a</sup>	1.03 ± 0.12 <sup>b</sup>	1.07 ± 0.06 <sup>ab</sup>
Survival rate (%)	100	100	100	100

Values are represented by means ± SDM of triplicate tanks; means without letter labels are not significantly different. The letters a, and b indicate significant differences in the treatments according to Duncan's multiple range tests ( $p < 0.05$ ).

**Table 3.** Blood biochemistry indices of rainbow trout fed experimental diets containing different levels of Alphamune for eight weeks

Blood biochemistry indices	Diet			
	ALP0	ALP1	ALP1.5	ALP2
Glucose (mg/dL)	22.02 ± 1.75	25.3 ± 1.32	27.75 ± 1.16	27.19 ± 1.7
Triglyceride (mg/dL)	76.17 ± 4.39	82.14 ± 4.16	79.61 ± 3.23	84.83 ± 19.26
Cholesterol (mg/dL)	58.65 ± 4.26	58.24 ± 4.32	62.46 ± 4.15	64.94 ± 4.71
IgM (mg/ml)	2.70 ± 0.48	2.76 ± 0.05	2.66 ± 0.14	2.71 ± 0.32
Total protein (g/dL)	3.05 ± 0.206 <sup>b</sup>	4.10 ± 0.584 <sup>ab</sup>	4.56 ± 0.441 <sup>ab</sup>	5.01 ± 0.24 <sup>a</sup>

Values are represented by means ± SDM of triplicate tanks; means without letter labels are not significantly different. The letters a, and b indicate significant differences in the treatments according to Duncan's multiple range tests ( $p < 0.05$ ).

## Discussion

Many studies have been performed in association with adding dietary supplements (prebiotics and probiotics) to improve fish growth performance and immunity. In the present study, the result showed that the addition of 1, 1.5 and 2 g/kg Alphamune in rainbow trout diet has led to a significant difference in final weight and weight gain, and the highest final weight and weight gain were observed in fish fed with 1.5 g/kg Alphamune. The results of the present study are consistent with the results of Li and Gatlin (2005) and Torrecillas *et al.* (2007) who reported higher final weight in hybrid striped bass (*Morone chrysops* × *M. saxatilis*), rainbow trout (*Oncorhynchus mykiss*) and European sea bass (*Dicentrarchus labrax*) fed with different prebiotic. Miandare *et al.* (2016) reported the significant effect of galactooligosaccharide on the growth performance of goldfish (*Carassius auratus gibelio*). Besides, Hoseinifar *et al.* (2013) reported the effect of dietary galactooligosaccharide on increasing some growth parameters in Caspian roach (*Rutilus rutilus*). Positive effects of Alphamune on fish growth found in this study may be due to the composition of this prebiotic. The mannan oligosaccharide in the Alphamune is a good source of nutrients for the growth and activity of gastrointestinal flora bacteria such as lactic acid bacteria, lactobacilli and bifidobacteria (Ringo *et al.*, 1998). Mannan oligosaccharides are nondigestible compounds that provide the location of mannose (the main compound of mannan oligosaccharide) on the intestine and

prevent the binding of pathogenic bacteria to the intestinal epithelial cells and also prevent the formation of colonies (Pryor *et al.*, 2003; Newman, 2007). These properties improve intestinal function and absorb more nutrients, thereby improving nutritional efficiency and enhancing growth (Bolu *et al.*, 2009).  $\beta$  glucan, another component of Alphamune, also has positive effects on growth performance (Misra *et al.*, 2006; Zhou *et al.*, 2009) as well as it has beneficial effects on fish immune systems and their resistance to bacterial and viral infections (Sang and Fotedar, 2010). Therefore, the positive effect of Alphamune on growth performance may be due to the improvement of intestinal morphological features, alteration of the gastrointestinal microbial population by mannan oligosaccharides and improvement of the immune system by  $\beta$ -glucan.

In the current study, the best FCR was observed in fish fed with 1.5 g/kg Alphamune and had a significant difference with the control group. This result is similar to the result of Staykov *et al.* (2007) on rainbow trout who reported that mannan oligosaccharide improves FCR. MOS can produce glucose, which provides energy for the metabolism of body tissues and promotes growth and improves FCR (Torrecillas *et al.*, 2011).

The results of the present study showed that a lower level of Alphamune (1.5 gr/kg) can improve growth indices better than a higher level (2 gr/kg). Therefore, it seems that

Alphamune at lower levels has better effects on the population of beneficial microorganisms in the gastrointestinal tract or gastrointestinal morphology, while in high levels probably due to lack of fermentation and decomposition leads to the accumulation of these carbohydrates and have adverse effects on intestinal enterocytes (Olsen *et al.*, 2001).

In this study, glucose, triglyceride and cholesterol were not influenced by Alphamune different levels. A similar result was reported by Akrami *et al.* (2010) in rainbow trout fed with mannan oligosaccharides and  $\beta$ -glucan. IgM and total protein levels in fish fed with different Alphamune levels were higher than in the control group. Yousefian *et al.* (2012) reported that levels of 0.5 and 2% galactooligosaccharide increased total Ig and total protein levels compared to the control group in zebrafish (*Danio rerio*). A similar result was reported by Hoseinifar *et al.* (2013) in Caspian roach fed with galactooligosaccharide. Miandare *et al.* (2016) reported that supplemented diet with 2% of galactooligosaccharides increased total mucus protein in goldfish. Total protein and immunoglobulin increased in the treated groups, indicating that enhancement of nonspecific immunity. However, a definite statement in this regard requires careful consideration of other immunity indicators.

The results of this study showed that the addition of different levels of Alphamune prebiotics per kg of diet caused a significant change in growth parameters and some blood biochemical factors. Therefore, it seems that the 1.5% Alphamune prebiotics has better

effects on the population of beneficial microorganisms in the gastrointestinal tract or gastrointestinal morphology, while in high amounts probably due to lack of fermentation and decomposition leads to accumulation of these carbohydrates and adverse effects on fish growth performance.

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## Conflict of interest

Authors have no conflict of interest on this work.

## References

- Aimrkolaie, A.K., Yansari A.T. and Khalesi, M.K., 2016. Calculation of protein and energy requirements in beluga sturgeon (*Huso huso*) using a factorial approach. *Journal of Animal Physiology and Animal Nutrition*, 97, 485-494. <https://doi.org/10.1111/j.1439-0396.2012.01289.x>
- Akrami, R., Ghelichi, A. and Gharaei, A., 2010. The use of prebiotics in aquaculture. Azadshahr. *Journal of Fisheries*, 4, 77-84.
- Bolu, S.A., Ojo, V., Oyeleke, B.A., Ajiboye, A.O., Baa Sambo, A. and Oluyemi, O., 2009. Response of broiler chicks to graded levels of alphamune G supplementation. *International Journal of Poultry Science*, 8, 32-34. <https://doi.org/10.3923/ijps.2009.32.34>

- Esmaili, M., Abedian Kenari, A. and Rombenso, A., 2017. Effects of fish meal replacement with meat and bone meal using garlic (*Allium sativum*) powder on growth, feeding, digestive enzymes and apparent digestibility of nutrients and fatty acids in juvenile rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792). *Aquaculture Nutrition*, 23, 1225-1234. <https://doi.org/10.1111/anu.12491>
- Fooks, L.J. and Gibson, G.R., 2002. Probiotics as modulators of the gut flora. *British Journal of Nutrition*, 88(S1), 39-49. <https://doi.org/10.1079/BJN2002628>
- Ganguly, S., Dora, K.C., Sarkar, S. and Chowdhury, S., 2013. Supplementation of prebiotics in fish feed: a review. *Reviews in Fish Biology and Fisheries*, 23, 195-199. <https://doi.org/10.1007/s11160-012-9291-5>
- Gibson, G.R., Hutkins, R., Sanders, M.E., Prescott, S.L., Reimer, A., Salminen, J., Scott, k., Stanton, C., Swanson, K., Cani, P., Verbeke, K. and Reid, G., 2017. The international scientific association for probiotics and prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. *Nature reviews gastroenterology and hepatology*, 14, 491-502. <https://doi.org/10.1038/nrgastro.2017.75>
- Hoseinifar, S.H., Esteban, M.A., Cuesta, A. and Sun, Y.Z., 2015a., Prebiotics and fish immune response: a review of current knowledge and future perspectives. *Journal of Reviews in Fisheries Science & Aquaculture*, 23(4), 315-328. <https://doi.org/10.1080/23308249.2015.1052365>
- Hoseinifar, S.H., Khalili, M., Rostami, H.K. and Esteban, M.A., 2013. Dietary galactooligosaccharide affects intestinal microbiota, stress resistance, and performance of Caspian roach (*Rutilus rutilus*) fry. *Fish & Shellfish Immunology*, 35(5), 1416-1420. <https://doi.org/10.1016/j.fsi.2013.08.007>
- Hoseinifar, S.H., Ringo, E., Shenavar Masouleh, A. and Esteban, M.A., 2014a. Probiotic, prebiotic and synbiotic supplements in sturgeon aquaculture: a review. *Journal of Reviews in Aquaculture*, 8(1), 89-102. <https://doi.org/10.1111/raq.12082>
- Huff, G.R., Huff, W.E., Rath, N.C., Tellez, G., 2006. Limited treatment with B-1, 3/16 improves production values of broiler chickens challenged with *Escherichia coli*. *International Journal of Poultry Science*, 85, 613-618. <https://doi.org/10.1093/ps/85.4.613>
- Li, P. and Gatlin, D.M. III., 2004. Dietary brewer's yeast and the prebiotic GroBiotic AE influence growth performance, immune responses and resistance of hybrid striped bass (*Morone chrysops* × *M. saxatilis*) to *Streptococcus iniae* infection. *Aquaculture*, 231, 445-456. <https://doi.org/10.1016/j.aquaculture.2003.08.021>
- Li, P. and Gatlin, D.M. III., 2005. Evaluation of the prebiotic GroBiotic-A and brewer's yeast as dietary supplements for sub-adult

hybrid striped bass (*Morone chrysops* × *M. saxatilis*) challenged *in situ* with *Mycobacterium marinum*. *Aquaculture*, 248, 197-205.

<https://doi.org/10.1016/j.aquaculture.2005.03.005>

Mahious, A.S., Gatesoupe, F.-J., Hervi, M., Metailler, R. and Ollevier, F., 2006b. Effect of dietary inulin and oligosaccharides as prebiotics for weaning turbot, *Psetta maxima* (Linnaeus, C. 1758). *Aquaculture International*, 14, 219-229. <https://doi.org/10.1007/s10499-005-9003-4>

Miandare, H.K., Farvardin, S., Shabani, A., Hoseinifar, S.H. and Ramezani, S.S., 2016. The effects of galactooligosaccharide on systemic and mucosal immune response, growth performance and appetite related gene transcript in goldfish (*Carassius auratus gibelio*). *Fish & Shellfish Immunology*, 55, 479-483.

<https://doi.org/10.1016/j.fsi.2016.06.020>

Misra, C. K., Das, B. K., Mukherjee, S. C. and Pattnaik, P., 2006. Effect of multiple development of larval cobia. *Aquaculture*, 274(1), 148-152.

Mohammadzadeh, S., Noverian, A.H., Ouraji, H. and Falahatkar, B., 2017. Growth, body composition and digestive enzyme responses of Caspian Kutum, *Rutilus frisii* (Kamenskii, 1901), juveniles fed different levels of carbohydrates. *Applied Ichthyology*, 2017, 1-8. <https://doi.org/10.1111/jai.13411>

Newman, K., 2007. Form follows function in picking MOS product. *Feedstuffs*, 79, 1-2.

Olsen, R.E., Myklebust, R., Kryvi, H., Mayhew, T.M. and Ringo, E., 2001. Damaging effect of dietary inulin to intestinal enterocytes in Arctic charr (*Salvelinus alpinus* L.). *Aquaculture Research*, 32, 931-934. <https://doi.org/10.1046/j.1365-2109.2001.00626.x>

Piazzon, M.C., Caldach-Giner, J.A., Fouz, B., Estensoro, I., Simó-Mirabet, P., Puyalto, M., Karalazos, V., Palenzuela, O., Sitjà-Bobadilla, A. and Pérez-Sánchez, J., 2017. Under control: how a dietary additive can restore the gut microbiome and proteomic profile, and improve disease resilience in a marine teleostean fish fed vegetable diets. *Microbiome*, 5(1), p.164. <https://doi.org/10.1186/s40168-017-0390-3>

Pryor, G.S., Royes, J.B., Chapman, F.A. and Miles, R.D., 2003. Mannan oligosaccharides in fish nutrition: effects of dietary supplementation on growth and gastrointestinal villi structure in gulf of Mexico sturgeon. *North American Journal of Aquaculture*, 65, 106-111. [https://doi.org/10.1577/1548-8454\(2003\)65<106:MIFNEO>2.0.CO;2](https://doi.org/10.1577/1548-8454(2003)65<106:MIFNEO>2.0.CO;2)

Ringo, E., 1998. Arctic charr, *Salvelinus alpinus* (L.), reared in fresh and sea water. An experimental study of lipid digestion and intestinal microflora. PhD thesis, Norwegian College of Fishery Science, University of Tromsø.

- Ringo, E., Olsen, R.E., Gifstad, T., Dalmo, R.A., Amlund, H., Hemre, G.I. and Bakke, A.M., 2010. Prebiotics in aquaculture: a review. *Aquaculture Nutrition*, 16, 117-136. <https://doi.org/10.1111/j.1365-2095.2009.00731.x>
- Sang, H.M. and Fotedar, R., 2010. Effects of dietary  $\beta$ -1,3-glucan on the growth, survival, physiological and immune response of marron, *Cherax tenuimanus*(smith, 1912). *Fish & Shellfish Immunology*, 28, 957-960. <https://doi.org/10.1016/j.fsi.2010.01.020>
- Staykov, Y., Spring, P., Denev, S. and Sweetman, J., 2007. Effect of a mannan oligosaccharide on the growth performance and immune status of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture International*, 15, 153-161. <https://doi.org/10.1007/s10499-007-9096-z>
- Torrecillas, S., Makol, A., Caballero, M.J., Montero, D., Gines, R., Sweetman, J. and Izquierdo, M.S., 2011a. Improved feed utilization, intestinal mucus production and immune parameters in sea bass (*Dicentrarchus labrax*) fed mannan oligosaccharides (MOS). *Aquaculture Nutrition*, 17, 223-233. <https://doi.org/10.1111/j.1365-2095.2009.00730.x>
- Torrecillas, S., Makol, A., Caballero, M.J., Montero, D., Robaina, L., Real, F., Sweetman, J., Tort, L. and Izquierdo, M.S., 2007. Immune stimulation and improved infection resistance in European sea bass (*Dicentrarchus labrax*) fed mannan oligosaccharides. *Fish and Shellfish Immunology*, 23, 969-981. <https://doi.org/10.1016/j.fsi.2007.03.007>
- Yousefian, M., Hedayatifard, M., Fahimi, S., Shikholeslami, M., Irani, M., Amirina, C. and Mousavi, S.E., 2012. Effect of prebiotic supplementation on growth performance and serum biochemical parameters of kutum (*Rutilus frisii kutum*) fries. *Asian Journal of Animal and Veterinary Advances*, 7, 684-692. <https://doi.org/10.3923/ajava.2012.684.692>
- Zhongzhen, L., Ngoc T.T., Peina, J., Zaiqiao, s., Xiaobo, W. and Shengkang, B. 2019. Effects of prebiotic mixtures on growth performance, intestinal microbiota and immune response in juvenile chu's croaker, *Nibea coibor*, *Fish and shellfish immunology*, 89, 564-573. <https://doi.org/10.1016/j.fsi.2019.04.025>
- Zhou, C., Liu, B., Wang, G., Xie, J., Ge, X. and Su, Y., 2009a. Effects of the compound of oligosaccharide and Chine medicines and flavomycin on growth disease resistance of allogynogenetic crucian carp (*Carassius auratus gibelio* var. E'erqisi, Bloch). *Freshwater Fisheries*, 39, 44-51.