

Effect of Increasing Dietary Prebiotic GroBiotic[®]-A Concentration on Growth Performance, Body Indices and Haematological Parameters in Rainbow Trout (*Oncorhynchus mykiss*) Fingerling

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ABSTRACT An 84-day feeding trial was carried out on fingerling (4.44 ± 0.06 g) rainbow trout (*Oncorhynchus mykiss*, Walbaum, 1792) to evaluate the effect of dietary supplementation with a commercial prebiotic GroBiotic[®]-A (G-A) on the growth, feed efficiency, haematology and immunological parameters. Treatments containing various inclusions of G-A (0 %, 0.5 %, 1.0 %, 1.5 %, 2.0 %, 2.5 %, and 3.0 %) were added to a commercial fish diet and were fed twice daily at 2-6 % of body weight. The highest weight gain (WG), specific growth rate (SGR) and average daily gain (ADG) were obtained in fish fed the diet containing 2.5 % G-A followed by 3.0 % inclusion ($P < 0.05$). The highest feed efficiency (FE), protein efficiency ratio (PER) and net protein utilization (NPU) were also recorded in the 2.5 % G-A inclusion ($P < 0.05$). Survival was significantly higher ($P < 0.05$) in fish fed with 2 % and 2.5 % G-A supplement ($P < 0.05$). Although higher Hb, haematocrit, RBC, WBC, MCH, MCHC, MCV, lymphocytes, and neutrophils were observed at all G-A supplemented diets, the differences among them were not significant ($P > 0.05$). On the other hand, significantly higher difference ($P < 0.05$) in lysozyme and immunoglobulin (IgM) concentrations were observed in 2.5% G-A inclusion. The results of this study indicated that 2.5 % G-A inclusion had a better performance on growth and haematoimmunological parameters in rainbow trout fingerling.

Key words: Feed efficiency, Fish, Growth performance, *Oncorhynchus mykiss*, Prebiotic GroBiotic[®]-A

1 INTRODUCTION

Rainbow trout (*Oncorhynchus mykiss*) is one of the most commonly farmed freshwater trout (FAO, 2011) and is popular in Europe, South and North American countries as well as Iran.

Recently, Chile produced the largest amount of rainbow trout while Iran ranked 8th in global production (IFRO, 2011). However, production figures in Iran in recent years have been declining due to the outbreak of bacterial

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infections, particularly by *Aeromonas hydrophila*, *Pseudomonas fluorescens* and *Streptococcus* spp. Bacterial diseases are considered to be a significant constraint to the development of the aquaculture sector over the years (Bondad-Reantaso *et al.*, 2005; Leung and Bates, 2013). During the last two decades, traditional use of antibiotics in aquaculture has been criticized because of the potential development of antibiotic-resistant bacteria, the presence of antibiotic residues in seafood, the destruction of microbial populations in the aquacultural environment and the suppression of the aquatic animal's immune system (Smith *et al.*, 2003; Cabello 2004; Sørum 2006; Sapkota *et al.*, 2008, Noga *et al.*, 2011). Furthermore, vaccines cannot be used alone as a universal disease control measure in aquaculture (Amábile-Cuevas *et al.*, 1995). Concerted research efforts have concentrated on optimising production with eco-friendly alternatives to the therapeutic use of antimicrobials. A new approach, that is gaining acceptance within the industry, is the use of prebiotic to control potential pathogens (Gomez-Gil *et al.*, 2000, Sapkota *et al.*, 2008, Noga *et al.*, 2011). They expressed the effects of various inclusion levels of prebiotic, GroBiotic®-A (G-A) on the growth performance, body indices, haematology parameters, and non-specific immune responses of rainbow trout juveniles. GroBiotic®-A is now regarded as a viable alternative to manage fish health. Similarly, xylooligosaccharides (XOS), fructooligosaccharides (FOS), inulin, lactulose and lactosucrose and other carbohydrate sources have received increasing interest for fish health benefits (Sealey *et al.*, (2007); Mussatto and Mancilha 2007). The presence of prebiotics is responsible for the enhancement of cell growth and also restricts the growth of harmful bacteria in the colon (Foolad *et al.*, 2012). The purpose of this study was to explore growth performance, haematology and non-specific immune reactions of fingerlings rainbow trout fed varying levels of

functional nutrient in the form of dietary prebiotic, GroBiotic®-A in order to determine an optimum inclusion level.

2 MATERIALS AND METHODS

2.1 Rearing conditions and experimental fish

Trout fingerlings (4.44 ± 0.06 g average weight) from a hatchery in north of Iran were transported in oxygenated containers at $15.0 \pm 1.1^\circ\text{C}$. Fish were acclimatised in laboratory conditions for 1 week prior to the commencement of the study. Thereafter, fish with similar body weight were randomly distributed into eighteen tanks ($1.5 \times 1.5 \times 0.45$ m, $\approx 1\text{m}^3$) at a density of 25 fish/ tank to evaluate the effect of prebiotic supplementation in the diet. The total water exchange in the tank was set at 0.2 lit/sec. The feeding trial was conducted for 84 days.

2.2 Test Diets

Commercial rainbow trout feeds (FFT and GFT1 (Table 1) from Chineh Feed Manufacturing Co., Tehran, Iran) supplemented with varying levels of G-A (International Ingredient Corporation, Fenton (St. Louis, Missouri, USA) were used in the study. Six concentrations of prebiotic (G-A), including 0.5 %, 1 %, 1.5 %, 2 %, 2.5 %, and 3 % were added to both the FFT and GFT1 feeds (Table 1), plus a control treatment without adding prebiotic. The G-A was prepared according to the manufacturer's instructions and the designated doses were sprayed on the diets. The FFT diet was used when the fish weighed between 5–20g while the GFT1 was used for the fish that were above 20g approximately 6 weeks after the commencement of feeding. The treatments were carried out in triplicates. Proximal composition of the feeds and carcass sample analyses were based on the AOAC (1997) standard reference methods. Dietary variations in protein for the

prebiotic and control diets ranged between 43.18 % and 43.30 % and between 40.35 % to 40.58 %, while lipid content averaged 13.70 % and 15.15 % in the FFT and GFT1 based diets, respectively (Table 1).

Experimental diets were manually supplied at 2-5 % of fish size and at three daily intervals.

2.3 Determination of nutritional effects and survival

The average weight of the fish from each treatment group was measured at 2-week intervals, while the weight of individual fish in each treatment was measured for somatic growth and survival at the end of the feeding trial. At the end of 12 weeks, feed efficiency (FE), specific growth rate (SGR), survival rate (SR), net protein utilization (NPU), protein efficiency ratio (PER), protein intake (PI), total feed intake per fish (FI), condition factor (CF), were measured as follows:

2.4 Growth parameters

FE = [weight of produced trout (g)/weight of consumed food (g)] (De Silva, 1995).

PER (%) = [(wet weight of produced trout (g) × 100)/weight of consumed food (g)] (Helland et al., 1996).

SGR (%) = [(Ln Wf – Ln Wi) × (100/t)] (Heveroy et al., 2005).

ADG Average Daily Gain (%) = [(Wf – Wi)/total days) × 100] (De Silva, 1995).

Where t is the time of rearing in days, lnWi is the natural logarithm of the weight of the fish individual at the start of the experiment, and lnWt is the natural logarithm of the weight of the juvenile at the end of the experiment (84 days). Wi and Wf are fish weight (g), and TL is total length (cm).

Survival rate (%) = [(final number of fish × 100)/initial number of fish] (Heveroy et al., 2005)
Total feed intake per fish (FI) = [total feed intake/number of fish] (Helland et al., 1996)

Protein intake (PI) = [feed intake (g) × percent protein in the diet] (Helland et al., 1996)

NPU = [(protein in muscle after experiment – protein in muscle before experiment)/PI]

CF = [(Wf × 100)/TL³] (Austreng, 1978).

Table 1 Proximate composition of rainbow trout (*Oncorhynchus mykiss*) fed diets varying concentrations of GroBioTic[®]-A and control for 84 days¹

Treatments	Experiment Diets	Proximate composition						
		Moisture (%)	Protein (%)	Lipid (%)	Fiber (%)	Ash (%)	NFE ¹⁰ (%)	GE ¹¹ (kJ.g ⁻¹)
Control	FFT ²	5.83 ± 0.14	43.30 ± 0.07	13.57 ± 0.15	6.57 ± 0.09	9.12 ± 0.03	27.44 ± 0.13	20.31 ± 0.03
	GFT1 ³	6.74 ± 0.01	40.36 ± 0.17	15.16 ± 0.05	7.24 ± 0.08	8.52 ± 0.09	28.73 ± 0.22	20.48 ± 0.03
G-A1 ⁴	FFT+G1	5.79 ± 0.12	43.19 ± 0.11	13.70 ± 0.15	6.52 ± 0.11	9.12 ± 0.17	27.47 ± 0.44	20.34 ± 0.06
	GFT1+G1	6.91 ± 0.07	40.42 ± 0.10	15.15 ± 0.06	7.18 ± 0.06	8.58 ± 0.12	28.67 ± 0.13	20.44 ± 0.01
G-A2 ⁵	FFT+G2	5.89 ± 0.05	43.29 ± 0.21	13.60 ± 0.21	6.48 ± 0.15	9.14 ± 0.04	27.43 ± 0.22	20.38 ± 0.07
	GFT1+G2	6.91 ± 0.03	40.35 ± 0.06	15.15 ± 0.03	7.22 ± 0.09	8.57 ± 0.18	28.70 ± 0.25	20.41 ± 0.02
G-A3 ⁶	FFT+G3	5.85 ± 0.11	43.18 ± 0.04	13.65 ± 0.30	6.49 ± 0.20	9.15 ± 0.06	27.53 ± 0.42	20.43 ± 0.06
	GFT1+G3	6.92 ± 0.06	40.58 ± 0.28	15.17 ± 0.11	7.31 ± 0.05	8.50 ± 0.17	28.44 ± 0.30	20.40 ± 0.01
G-A4 ⁷	FFT+G4	5.76 ± 0.11	43.19 ± 0.11	13.69 ± 0.12	6.51 ± 0.07	9.13 ± 0.03	27.47 ± 0.19	20.49 ± 0.10
	GFT1+G4	6.83 ± 0.05	40.38 ± 0.06	15.18 ± 0.15	7.33 ± 0.10	8.51 ± 0.04	28.59 ± 0.09	20.76 ± 0.04
G-A5 ⁸	FFT+G5	5.92 ± 0.10	43.21 ± 0.20	13.68 ± 0.06	6.47 ± 0.17	9.20 ± 0.10	27.43 ± 0.10	20.67 ± 0.03
	GFT1+G5	6.80 ± 0.10	40.37 ± 0.05	15.19 ± 0.15	7.20 ± 0.11	8.51 ± 0.08	28.72 ± 0.26	20.49 ± 0.05
G-A6 ⁹	FFT+G6	5.73 ± 0.16	43.30 ± 0.13	13.68 ± 0.03	6.56 ± 0.06	9.14 ± 0.09	27.31 ± 0.27	20.53 ± 0.03
	GFT1+G6	6.85 ± 0.15	40.56 ± 0.06	15.19 ± 0.04	6.59 ± 0.07	9.22 ± 0.02	28.44 ± 0.07	20.61 ± 0.04

1 Values are mean ± SD (n=3)

2 Fingerling Rainbow Trout Feed (commercial Rainbow Trout food, Chine Co.)

3 Grow out Rainbow Trout Feed (commercial Rainbow Trout food, Chine Co.)

4 GroBioTic[®]-A (A commercial prebiotic) 0.5% of diet

5 GroBioTic[®]-A (A commercial prebiotic) 1% of diet

6 GroBioTic[®]-A (A commercial prebiotic) 2% of diet

7 GroBioTic[®]-A (A commercial prebiotic) 2.5% of diet

8 GroBioTic[®]-A (A commercial prebiotic) 3% of diet

9 GroBioTic[®]-A (A commercial prebiotic) 3% of diet

10 Nitrogen free extract = [100 – (protein + lipid + ash + fiber)]

11 Gross energy content (Brafield 1985)

2.5 Body indices

Body indices, hepatosomatic index (HSI), viscerosomatic weight (VSI), and intraperitoneal fat (IPF) were determined (AOAC 1997). Muscle and liver samples were also collected for proximate analysis:

Hepatosomatic index (HSI %) = $[100 - (\text{liver weight (g)}/\text{body weight (g)})]$ (AOAC 1997).

Intraperitoneal fat (IPF %) = $[100 - (\text{intraperitoneal fat weight (g)}/\text{body weight (g)})]$ (AOAC 1997).

Viscerosomatic weight (VSI %) = $[100 - (\text{viscera weight}/\text{body weight})]$ (AOAC 1997).

2.6 Blood parameters

Upon completion of the experiment, (17 h after the last feeding) (Shimeno *et al.*, 1990), 3 fish from each tank (9 fish per treatment) were sampled and placed directly into a bucket filled with 10 L of freshwater mixed with 200 ppm of tricainemethanesulfonate (MS-222; Sigma-Aldrich Corporation, St. Louis, MO, USA). Then, blood was drawn from the caudal vein of the sampled fish for the determination of haematological parameters immediately after anesthetization.

2.7 Haematocrit

Haematocrit was determined according to the methods described by Schäperclaus *et al.* (1993). Blood samples were placed into standard heparinised microhematocrite capillary tubes and centrifuged immediately for 4 min at $10,000\times g$ by using a Hawksley centrifuge (Lancing, Sussex, England). The haematocrit value was calculated according to the following formula:

$PCV = [\text{height of packed red cells (mm)}/\text{height of packed red cells and plasma (mm)}] \times 100$ Where, PCV is the packed cell volume (mm).

2.8 Haemoglobin concentration

The cyano-haemoglobin method was used to determine the haemoglobin concentration at

wavelength of 540 nm in experimental fish with a CECIL 1020, England spectrophotometer at 540 nm. The haemoglobin concentration of the blood sample was estimated using a standard curve. A cover slip was placed over a Neubauer haemocytometer, a specially designed slide that acts as a blood cell counting chamber (Blaxhall and Daisley 1973). Then were computed mean cell volume (MCV), mean cell hemoglobin concentration (MCHC) and the amount of hemoglobin per erythrocyte (MCH) by the following formula (AOAC 1997):

Haemoglobin concentration (g dL^{-1}) = $[\text{absorbance of sample}/\text{absorbance of standard} \times \text{concentration of standard}]$

Mean corpuscular haemoglobin concentration (MCHC) g dL^{-1} = $[\text{haemoglobin g\%/hematocrit volume \%} \times 100]$

Mean corpuscular haemoglobin (MCH) pg cell^{-1} = $[\text{haemoglobin g\%/erythrocyte } (10^6 \text{mm}^{-3}) \times 10]$

Mean corpuscular volume (MCV) μm^3 = $[\text{haematocrit volume}/\text{erythrocyte } (10^6 \text{mm}^{-3}) \times 10]$

2.9 Total red blood cell count (erythrocyte/RBC 10^6mm^{-3})

Total red blood cell count (RBC) and white blood cells (WBC or LC) was performed according to the methods of the EWOS Technology Centre (2000) and Johnson *et al.*, (2002). The blood samples in the heparin tubes were diluted 200 times with phosphate-buffered saline (PBS), and red blood cell concentrations were calculated in a haemocytometer chamber using a microscope.

White blood cells were measured using Natt–Herrick solution as the diluent and were stained in a Neubauer haemocytometer.

2.10 Lysozyme assay

Lysozyme level in blood sera samples was estimated by turbidimetric evaluation according to the protocol by Ellis (1990), with slight

modifications. The blood samples were maintained at room temperature for 1 h, centrifuged at $10,000\times g$ for 10 min, and the separated sera were frozen at -20°C until used for the lysozyme assay within 7 d of sampling. Aliquots ($175\mu\text{L}$) of *Micrococcus lysodeikticus* suspension (Sigma) (0.375 mg mL^{-1} , 0.05 M PBS, pH 6.2) were mixed with $25\mu\text{L}$ of each sample, and optical density was measured after 15 and 180 s by spectrophotometer (BioPhotometer; Eppendorf, Germany) at 600 nm. PBS was used as the blank, and results were expressed in amounts of lysozyme (μg) per 1 mg of sample calibrated to a standard curve using hen egg white lysozyme (Sigma) in PBS.

2.11 IgM

IgM level in blood sera was determined by immunoturbidimetric assay with a Parsazmun kit (www.parsazmun.com) and Eurolyser with slight modifications. At the end of the 4, 8, and 12 weeks feeding trials and after 4 weeks post injection, 3 healthy fish (with no obvious signs of skin injury or visceral granuloma) from each tank (9 fish per treatment) were anesthetized with tricaine methanesulfonate (MS-222). Blood samples (1 mL) were obtained from the caudal vein of each specimen using a 2-mL syringe. After clotting, the sample was centrifuged ($5000\times g$) for 5 min, and the serum was removed and frozen at -20°C until used. In this test, each sample was diluted with physiological serum at a ratio of 1:10. Then, standard polyclonal antibody was added to the sample. The complex of IgM with polyclonal antibodies caused the solution to become turbid, and the degree of opacity was directly related to serum IgM concentration.

The solution was prepared in a special cuvette, and IgM was determined using an autoanalyser (Eurolyser, Austria).

2.12 Statistical analysis

Data were analyzed by SPSS ver. 15.1 (Statistical Package for Social Sciences) and analyzed using analysis of variance (ANOVA). Comparison among treatment means was carried out using Duncan's Multiple Range Test to evaluate any significant differences at the level of 0.05. Standard deviation ($\pm\text{SD}$) was calculated to determine the range of means. Treatment mean differences were tested between whole feeding regimes, at each GroBiotic[®]-A levels.

3 RESULTS

3.1 Growth performance

The growth performance of the fish fed diets supplemented with different levels of G-A after 84-days feeding trial is displayed in Table 2. SGR and ADG were significantly higher ($P<0.05$) in fish fed diets supplemented with G-A level above 1.5%. A significant difference ($P<0.05$) in increased FE was found among the treatments. PER and NPU also were significantly higher ($P<0.05$) in fish fed diets supplemented with G-A level above 1%. No significant difference ($P>0.05$) was found in protein indices among the treatments. As for the feed intake, the diets supplemented with G-A showed higher values than the basal diet (0% G-A).

Survival of rainbow trout was significantly improved ($P<0.05$) in all the G-A supplemented diets, the highest of which was observed in 2.5% G-A.

Table 2 Initial weight, final weight, percentage weight gain, specific growth rate, average daily growth, survival, Feed intake, feed efficiency, protein efficiency ratio, Net protein utilization and productive protein value of rainbow trout (*Oncorhynchus mykiss*) fed diets containing varying Concentrations of GroBiotic®-A and control for 84 days¹

Parameters	Treatments									
	G-A 1	G-A 2	G-A 3	G-A 4	G-A 5	G-A 6	Control			
WI (g) ²	4.46 ± 0.07	4.48 ± 0.04	4.40 ± 0.06	4.43 ± 0.03	4.40 ± 0.11	4.45 ± 0.05	4.46 ± 0.05			
WF (g) ³	38.98 ± 0.74 ^e	38.92 ± 1.84 ^e	38.24 ± 1.17 ^e	41.93 ± 1.12 ^b	45.21 ± 1.46 ^b	43.24 ± 1.13 ^{ab}	36.76 ± 2.14 ^e			
WG (%) ⁴	774.09 ± 18.14 ^e	768.86 ± 39.36 ^e	770.08 ± 33.11 ^e	847.08 ± 18.41 ^b	933.09 ± 14.86 ^b	871.51 ± 29.04 ^b	724.04 ± 41.60 ^e			
SGR (%) ⁵	2.58 ± 0.02 ^e	2.57 ± 0.05 ^e	2.57 ± 0.05 ^e	2.68 ± 0.02 ^b	2.78 ± 0.02 ^b	2.71 ± 0.04 ^b	2.51 ± 0.06 ^e			
ADG (%) ⁶	41.10 ± 0.86 ^e	41.00 ± 2.17 ^e	40.29 ± 1.47 ^e	44.64 ± 1.29 ^b	48.60 ± 1.62 ^b	46.18 ± 1.36 ^{ab}	38.45 ± 2.50 ^e			
Survival (%) ⁷	97.33 ± 2.31 ^{ab}	94.67 ± 2.31 ^{ab}	97.33 ± 2.31 ^{ab}	98.67 ± 2.31 ^a	98.67 ± 2.31 ^a	97.33 ± 2.31 ^{ab}	93.33 ± 2.31 ^b			
Feed intake	40.24 ± 1.78 ^{bc}	41.20 ± 0.23 ^{ab}	41.77 ± 1.07 ^{ab}	41.55 ± 0.85 ^{ab}	42.99 ± 0.65 ^a	41.36 ± 1.16 ^{ab}	39.00 ± 0.86 ^e			
FE ⁸	0.86 ± 0.03 ^{cd}	0.84 ± 0.04 ^{bc}	0.81 ± 0.01 ^e	0.90 ± 0.01 ^b	0.95 ± 0.02 ^a	0.94 ± 0.00 ^{ab}	0.83 ± 0.04 ^{bc}			
PER ⁹	1.99 ± 0.06 ^{cd}	1.97 ± 0.09 ^{cd}	1.89 ± 0.03 ^d	2.08 ± 0.02 ^{bc}	2.19 ± 0.04 ^a	2.16 ± 0.01 ^{ab}	1.89 ± 0.08 ^d			
NPU (%) ¹⁰	4.77 ± 2.61 ^{cd}	2.40 ± 0.01 ^d	7.46 ± 0.92 ^{bc}	8.27 ± 1.28 ^b	13.84 ± 1.29 ^a	9.97 ± 2.79 ^b	2.24 ± 0.61 ^d			

¹ Values are mean ± SD (n=3). Mean values within columns with different superscript letters are significantly different (P < 0.05)

² WI = Initial weight.

³ WF = Final weight

⁴ WG = [(WF - WI)/WI] × 100

⁵ SGR% = [(LnWF - LnWI) / Total days (D)] × 100

⁶ ADG (%) = [(WF - WI) / Total days (D)] × 100

⁷ Survival rate (%) = [(Final fish number / Initial fish number) × 100]

⁸ Feed efficiency = weight gain (g) / food intake (g)

⁹ Protein efficiency ratio = weight gain (g) / protein intake (g)

¹⁰ Net Protein Utilization (NPU) = [(WF × Protein Muscle Final) - (WI × Protein Muscle Initial/Protein Consumed)]

Table 3 Carcass proximate compositions of rainbow trout (*Oncorhynchus mykiss*) fed control and varying Concentrations of GroBiotic®-A and control diet for 84 days¹

	At the end							
	At the start	G-A 1	G-A 2	G-A 3	G-A 4	G-A 5	G-A 6	Control
Protein (%)	14.68 ± 0.13	15.50 ± 0.43 ^d	15.10 ± 0.00 ^e	15.85 ± 0.16 ^e	16.17 ± 0.21 ^{bc}	17.06 ± 0.06 ^a	16.23 ± 0.06 ^b	15.06 ± 0.11 ^f
Lipid (%)	9.40 ± 0.05	7.59 ± 0.45 ^b	8.23 ± 0.06 ^c	7.44 ± 0.12 ^b	7.44 ± 0.03 ^b	7.05 ± 0.04 ^e	7.09 ± 0.05 ^e	8.02 ± 0.07 ^a
Ash (%)	1.87 ± 0.03	1.22 ± 0.02 ^b	1.21 ± 0.06 ^b	1.23 ± 0.23 ^b	1.38 ± 0.11 ^{ab}	1.46 ± 0.05 ^d	1.44 ± 0.05 ^d	1.21 ± 0.02 ^b
Moisture (%)	75.10 ± 0.36	75.16 ± 0.13 ^a	74.93 ± 0.05 ^{ab}	74.89 ± 0.63 ^{ab}	74.49 ± 0.10 ^{bc}	74.24 ± 0.09 ^e	74.51 ± 0.18 ^{bc}	75.01 ± 0.02 ^a

¹ Values are mean ± SD (n=3). Mean values within columns with different superscript letters are significantly different (P < 0.05)

3.2 Proximate composition of carcasses

A significant difference ($P < 0.05$) in the protein, lipid, and moisture content of carcass were found among the treatments. The concentrations of protein and ash were higher in the diet supplemented with 2.5 % G-A (17.06 ± 0.06 % and 1.46 ± 0.05 %, respectively), whereas those of lipid and moisture were lower (Table 3).

3.3 Body indices

The results of the body indices (HSI, IPF, and VSI) are summarized in Table 4. Although some differences in HSI, IPF and VSI were found among the treatments, they were not significant ($P > 0.05$).

3.4 Haematological/immunological parameters

Haematological parameters of the trout fed with various levels of G-A for 12-weeks are given in Table 5. Although no significant differences ($P > 0.05$) in haematological parameters were found among different treatments, higher values for haematocrit (PCV), haemoglobin (Hb), RBC, WBC, and neutrophils were recorded in fish fed diets supplemented with G-A levels above 1.5%. The immunoglobulin (IgM) and lysozyme values were significantly higher ($P < 0.05$) in fish fed with G-A levels above 1.5 % (Table 5).

Table 4 Hepatosomatic index (HSI), intraperitoneal fat (IPF), viscerosomatic index (VSI), and condition factor of rainbow trout (*Oncorhynchus mykiss*) fed control and varying concentrations of GroBiotic®-A and control diet for 84 days¹

Parameters	Treatments						
	G-A 1	G-A 2	G-A 3	G-A 4	G-A 5	G-A 6	Control
CF (%) ²	1.20 ± 0.04	1.20 ± 0.03	1.19 ± 0.01	1.21 ± 0.04	1.18 ± 0.06	1.20 ± 0.02	1.24 ± 0.02
HSI (%) ³	1.15 ± 0.17	1.12 ± 0.13	1.03 ± 0.18	1.05 ± 0.25	1.04 ± 0.14	0.97 ± 0.06	1.13 ± 0.10
VSI (%) ⁴	13.02 ±	12.67 ±	14.00 ±	12.07 ±	12.64 ±	11.86 ±	14.04 ±
IPF (%) ⁵	1.27 ± 0.12	1.33 ± 0.55	1.38 ± 0.15	1.39 ± 0.51	1.41 ± 0.25	1.51 ± 0.22	1.33 ± 0.69

1 Values are mean ± SD (n=3).

2 Condition factor (CF %) = [(weight / L3) × 100]

3 Hepatosomatic index (HSI%) = [100 - (liver weight / body weight)]

4 Intra-peritoneal fat (IPF %) = [100 - (intra-peritoneal fat weight / body weight)]

5 Viscerosomatic weight (VSI %) = [100 - (viscera weight / body weight)]

Table 5 Haematology/immune parameters of rainbow trout (*Oncorhynchus mykiss*) fed diets containing varying levels of GroBiotic®-A and control diet for 12 weeks¹

Haematology parameters	Treatments						Control
	G-A 1	G-A 2	G-A 3	G-A 4	G-A 5	G-A 6	
RBC(cells × 10 ⁶ /mm ³) ²	0.99 ± 0.04 ^e	0.99 ± 0.04 ^e	1.00 ± 0.04 ^e	1.12 ± 0.03 ^b	1.18 ± 0.05 ^a	1.14 ± 0.04 ^{ab}	0.97 ± 0.08 ^c
WBC(cells × 10 ³ /mm ³) ³	9.25 ± 0.82 ^c	9.33 ± 0.68 ^c	9.50 ± 0.77 ^c	10.75 ± 0.42 ^b	12.50 ± 1.05 ^a	11.42 ± 0.66 ^{ab}	8.92 ± 0.38 ^c
Hematocrit (%)	40.17 ± 2.48 ^{cd}	41.83 ± 1.47 ^{bcd}	42.50 ± 2.07 ^{bc}	44.50 ± 1.87 ^b	47.83 ± 3.54 ^a	44.33 ± 2.66 ^b	39.33 ± 0.82 ^d
Hemoglobin(g/dL)	6.57 ± 0.43 ^b	7.08 ± 1.41 ^b	7.13 ± 0.44 ^b	7.88 ± 0.22 ^{ab}	8.52 ± 0.72 ^a	8.30 ± 1.40 ^{ab}	6.58 ± 0.57 ^b
Lymphocytes (%)	98.83 ± 1.17 ^a	98.67 ± 1.47 ^a	97.83 ± 0.98 ^{ab}	97.33 ± 1.21 ^b	96.83 ± 0.52 ^b	97.17 ± 0.98 ^b	99.00 ± 0.63 ^a
Neutrophils (%)	1.17 ± 1.17 ^b	1.33 ± 0.52 ^b	2.17 ± 0.98 ^c	2.67 ± 1.21 ^a	3.17 ± 1.47 ^a	2.83 ± 0.98 ^a	1.00 ± 0.63 ^b
MCV(μm^3) ⁴	408.70 ± 35.15 ^{ab}	424.19 ± 12.52 ^a	426.20 ± 25.00 ^{ab}	397.36 ± 14.03 ^{ab}	404.95 ± 35.47 ^{ab}	387.69 ± 17.52 ^b	409.51 ± 37.39 ^{ab}
MCH(pg/cell) ⁵	66.84 ± 6.31	72.05 ± 15.64	71.66 ± 6.92	70.42 ± 2.38	72.15 ± 7.38	72.68 ± 12.42	68.47 ± 7.70
MCHC(g/dL) ⁶	16.37 ± 1.06	16.97 ± 3.56	16.81 ± 1.23	17.73 ± 0.67	17.82 ± 1.09	18.73 ± 2.90	16.74 ± 1.44
<i>Immune parameters</i>							
IgM(mg/ml) ⁷	37.78 ± 1.01 ^d	40.02 ± 3.08 ^d	44.75 ± 3.61 ^c	49.38 ± 3.44 ^b	55.20 ± 2.73 ^a	50.60 ± 3.18 ^b	37.65 ± 1.82 ^d
Igsozyme(mg/ml)	9.49 ± 0.60 ^d	9.49 ± 0.68 ^d	10.80 ± 0.48 ^c	12.16 ± 0.85 ^b	12.99 ± 0.40 ^a	12.66 ± 0.61 ^{ab}	9.54 ± 0.17 ^d

1 Values are mean ± SD (n=3). Mean values within columns with different superscript letters are significantly different (P < 0.05)

2 Erythrocyte or total red blood cell counts

3 Leukocyte or total white blood cell counts

4 Mean corpuscular volume = [(Haematocrit × 10) / RBC]

5 Mean corpuscular volume = [(Haemoglobin × 10) / RBC]

6 Mean corpuscular hemoglobin concentration = [(Haemoglobin × 100) / Haematocrit]

7 Immunoglobulin (IgM)

4 DISCUSSION

In this study, growth performance of *O. mykiss* showed an increasing trend with increasing G-A levels and was significantly higher (23 %) in fish fed with the diet supplemented with 2.5 % G-A. Positive effects of various prebiotics on growth of hybrid red tilapia (Hanley *et al.*, 1995) and the European catfish (Bogut *et al.*, 2006) have also been reported. The growth improvement and enhanced protein utilization upon adding prebiotics have been attributed to the improvement in digestive enzymes activities and absorption of food (Xu *et al.*, 2009; Burr *et al.*, 2010). Feed utilization indices in *O. mykiss* showed improved protein efficiency ratio (PER), protein utilization (NPU) and feed efficiency (FE) by adding prebiotic, which is in correspondence with several earlier works dealing with the application of prebiotics in rainbow trout (Staykov *et al.*, 2007; Rodrigues-Estrada *et al.*, 2009; Řehulka *et al.*, 2011) and several other species (Li and Gatlin, 2004, 2005; Buentello *et al.*, 2010; Grisdale-Helland *et al.*, 2008; Lochmann, 2011); Zheng *et al.*, 2011). Besides, the reason of enhanced growth could be related to improved stability of intestinal microbial flora (Fuller, 1989).

Beside improving the FE, SGR, and FI, prebiotic also significantly enhanced feed efficiency and resistance of *O. mykiss*; significantly higher ($P < 0.05$) PER and survival rates were also recorded in fish fed G-A prebiotic above 1.5 %. (Table 2). The higher survival rates in the prebiotic-treated groups may also indicate improved response potential and improved ability to tolerate the damaging conditions likely encountered in the rearing tanks (Olsen *et al.*, 2001). Supplementation with G-A modified body composition by decreasing the fat and increase in protein contents (Table 3), which was in correspondence with an earlier study in rainbow trout (Yilmaz *et al.*, 2007). Values for visceral somatic indices (VSI), intraperitoneal fat (IPF) and hepatosomatic

index (HSI) did not significantly differ among the treatments (Table 4), which were similar to an earlier result in rainbow trout (Yilmaz *et al.*, 2007). However, Refstie *et al.*, (2006) revealed a higher relative gut weight (relative to total body weight) in Atlantic salmon fed inulin, but the relative liver and stomach weights were unaffected. Furthermore, McKelley *et al.* (2007) showed that in the Atlantic salmon with the exception of the distal intestinal somatic index, inulin administration in the diet did not affect other gastric organosomatic indices. The insignificant difference for HSI value in the fish fed various levels of G-A in this study (Table 4) is in agreement with the previous studies in Atlantic salmon (Rosenlund, *et al.*, 2001; Menoyo *et al.*, 2003, 2005), Murray cod (Francis *et al.*, 2007) and turbot (Regost *et al.*, 2001).

Haematological characteristics have been studied in numerous fish species to determine their normal ranges, and any variation from normal is indicative of problems in fish physiological processes (Rainza-Paiva *et al.*, 2000). In this study, higher concentrations of haemoglobin, haematocrit, RBC, WBC, MCH, MCHC, MCV, lymphocytes, and neutrophils were observed in the fish fed with various levels of G-A compared to the control diet, but the difference among the treatments was not significant ($P > 0.05$). In contrast, lysozyme and IgM concentrations significantly differed ($P < 0.05$) among different G-A treatments, peaking at 2.5% (Table 5). This observation indicates that fish fed with supplementary G-A are healthier, possibly due to the increased enzymatic levels in the blood plasma. Similar results have also been reported (Carnevali *et al.*, 2006; Rollo *et al.*, 2006). In the present experiment, haematocrit value agreed with the findings of Li and Gatlin (2004) who reported that haematocrit value in the hybrid striped bass did not increase. Our results for HB, HC, WBC, RBC, MCH, MCHC, and MCV in rainbow

trout were not significantly different ($P>0.05$) among treatments and were similar to values reported by Sheikholeslami (2008). A higher immune response was stimulated when diets supplemented with G-A level above 1.5% were used (Table 5). Serum lysozyme increased in fish fed various levels of G-A (Table 5), which was in agreement with an earlier finding by Sheikholeslami (2008).

The results indicated that an inclusion level of 2.5% of GroBiotic®-A yielded an optimal growth performance, feed efficiency, body indices, and haematological parameters in rainbow trout (*O. mykiss*) fry.

Further studies are needed to recognize the optimum duration of prebiotic supplementation to the fish, particularly rainbow trout. In addition, it would be suggested to evaluate the long term effect of GroBiotic-A in rainbow trout and other fish species.

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Zheng, Z.L., Wang, K.Y. and Gatlin, D.M. Evaluation of the Ability of GroBiotic®-

بررسی اثر افزایش میزان پری بیوتیک گروبیوتیک A بر روی رشد، فاکتورهای بدن و پارامترهای خونی در بچه ماهیان قزل‌آلای رنگین کمان (*Oncorhynchus mykiss*)

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چکیده اثر مصرف مکمل غذائی (گروبیوتیک A) بر روی رشد، ضریب تبدیل غذا، فاکتورهای خونی و ایمنی در ماهی قزل‌آلای انگشت قد (۴۴/۴ ± ۰/۰۶ گرم) طی مدت ۸۴ روز و در ۷ تیمار و هر تیمار در ۳ تکرار بررسی شد. تیمارهای آزمایشی شامل درصدهای صفر، ۰/۵، ۱/۰، ۱/۵، ۲، ۲/۵ و ۳ درصد از گروبیوتیک A به جیره غذای ماهی بوده است. غذادهی روزانه ۲ نوبت و به میزان ۲-۶ درصد از وزن بدن ماهی انجام شد. نتایج نشان داد ماهی تغذیه شده با جیره ۲/۵٪ گروبیوتیک A به‌طور قابل ملاحظه‌ای بالاترین افزایش وزن (WG)، نرخ رشد ویژه (SGR) و میانگین افزایش وزن روزانه (ADG) برخوردار شد (P < ۰/۰۵). همچنین، پارامترهایی همچون بازده خوراک (FE)، نسبت بازده پروتئین (PER) و استفاده از پروتئین خالص (NPU) در ماهی به‌طور قابل توجهی از بالاترین میزان در جیره غذایی گروبیوتیک A (۲/۵٪) برخوردار شد (P < ۰/۰۵). بالاترین بازماندگی در جیره محتوی ۲/۵٪ گروبیوتیک A بود (P < ۰/۰۵). مقادیر هموگلوبین، هماتوکریت، WBC، RBC، MCV، MCHC، MCH، لنفوسیت و نوتروفیل‌ها در ماهی‌های تغذیه شده از مکمل گروبیوتیک A مشاهده شد، اما تفاوت معنی‌داری در میان تیمارها مشاهده نشد (P < ۰/۰۵). از سوی دیگر، لیزوزیم و ایمونوگلوبولین (IgM) در غلظت مختلف تفاوت معنی‌داری (P) نشان داد و بالاترین در رژیم غذایی ۲/۵٪ همراه بود (P < ۰/۰۵). نتایج حاصل از این مطالعه نشان داد که مکمل رژیم غذایی با گروبیوتیک A ۲/۵٪ دارای اثر مثبت در قزل‌آلای رنگین کمان انگشت قد بود.

کلمات کلیدی: *Oncorhynchus mykiss*, Prebiotic GroBiotic®-A، رشد، ضریب غذا، ماهی