The Open Access Israeli Journal of Aquaculture – Bamidgeh

Published by the
The Society of Israeli Aquaculture and Marine Biotechnology (SIAMB)
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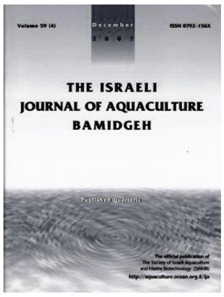
ISSN 0792 - 156X

PUBLISHER:

The Society of Israeli Aquaculture and Marine Biotechnology (SIAMB)

The Israeli Journal of Aquaculture - Bamidgeh, IJA_70.2018.1518, 13 pages



Efficiency of Dietary β-glucan Supplementation on Growth, Body Composition, Feed, and Nutrient Utilization in Juveniles of Pompano Fish (*Trachinotus ovatus,* Linnaeus, 1758)

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Keywords: pompano fish; β-glucan; Trachinotus ovatus; growth; feed utilization

Abstract

An 8-week experiment was conducted to examine the effect of increasing levels of dietary β-glucan on the growth performance, feed utilization, and body composition of juvenile pompano (*Trachinotus ovatus*). Pompano (mean initial weight, 6.45 g) were fed five diets containing five levels of β-glucan (D1 (control): 0%; D2: 0.05%; D3: 0.10%; D4: 0.20%; and D5: 0.40%. Results showed that growth performance, body composition, efficacy of feed and nutrient utilization were significantly affected by dietary β-glucan levels. After 8-weeks of feeding, weight gain, daily weight gain, specific growth rate, final body weight, coefficient of variation were highest in pompano fed 0.05% and 0.10% β-glucan in the diet ($P \leq 0.034$), while growth of fish fed 0.2% and 0.4% β-glucan did not significantly differ compared to fish fed the control diet ($P \geq 0.170$). Survival rate of juvenile pompano was not influenced by β-glucan supplement in the diet ($P \geq 0.383$). In addition, feed utilization daily feed intake, feed conversion ratio, and feed conversion efficiency were significantly lower in fish fed diets supplemented with 0.01–0.10% β-glucan ($P \leq 0.027$). In contrast, feeds supplemented with 0.2 to 0.4% β-glucan did not influence the feed utilization of pompano after 56 days of diet feeding ($P \geq 0.051$). Protein was significantly higher in the flesh of pompano fed 0.05% to 0.10% β-glucan ($P \leq 0.001$), while lipid content in fish decreased significantly with graded levels of β-glucan in the diet ($P \leq 0.044$). After 56 days, protein efficiency ratio (PER), protein productive value (PPV), and fractional rates of protein growth (K_g), were significantly higher in fish fed diets supplemented with 0.05 -0.10% β-glucan ($P \leq 0.025$).

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Introduction

Pompano *Trachinotus ovatus* (Carangidae family) is a carnivorous fish found in China, Japan, Australia, Vietnam, and other countries (Liu and Chen, 2009). Pompano is a highly valued aquaculture species with a rapid growth rate, high quality flesh, and tasty flesh. In recent years culture of this species has developed rapidly in Asia and it has become one of the most common marine species in Vietnam, and is in high demand (Wang et al., 2013; Zhang et al., 2014). Study of various nutrient requirements for golden pompano is necessary to save feed costs and improve farming efficiency. The recorded optimum protein requirements of golden pompano range from 43%-49% (Liu et al., 2011b), lipid between 6%-6.5% (Wang et al., 2014), and carbohydrate from 11.2%-16.8% (Zhou et al., 2015). The optimal requirements of methionine (Lin et al., 2015) and lysine (Niu et al., 2013) for golden pompano have also been determined.

In aquaculture, antibiotics have been used as growth promoters for many years (Hernández, 2005), however these are harmful to aquatic species, the environment, and human health. Use of antibiotics was banned in aquaculture (FAO, 2002; Hernández, 2005), therefore more research is needed to find antibiotic replacement (Song et al., 2014).

Research revealed that glucan-specific receptors are present on phagocytic cell membranes of several species (Brown and Gordon, 2001). β-glucan administration was reported to improve immunological responses, disease resistance, intestinal microbiota in invertebrates (Klaenhammer et al., 2012; Kokoshis et al., 1978). Also, in aquaculture, β-glucan application was reported to boost growth performance in many species including large yellow croaker (*Pseudosciaena crocea*) (Ai et al., 2007), Atlantic salmon (*Salmo salar*) (Refstie et al., 2010), koi carp (*Cyprinus carpio koi*) (Lin et al., 2011) and rohu (*Labeo rohita*) (Misra et al., 2006). However, other studies did not show positive effects on growth performance, e.g. European sea bass (*Dicentrarchus labrax*) (Bagni et al., 2005). One previous publication demonstrated the efficacy of dietary β-glucan on growth performance of pompano (Do-Huu et al., 2016).

To the best of our knowledge, the role of dietary β-glucan supplementation on feed utilization and nutrient utilization of pompano is still not fully understood. Therefore, the aim of the present study is to examine the efficacy of dietary β-glucan supplementation on growth performance, changes in body composition, and nutrition efficiency of pompano *T. ovatus*.

Material and methods

Diet ingredients and preparation

The same diet formulation was also used in a previous study on the effects of β-glucan supplementation on pompano (Do-Huu et al., 2016). The control diet (D1) and its composition is given in Table 1. The control diet was supplemented with 0.05%, 0.10%, 0.20% and 0.40% of Macrogard® (Biorigin, Brazil) to make four supplemental diets, D2, D3, D4 and D5, respectively. Corn starch was used to replace Macrogard® in the control diet (D1). Only the proportion of corn starch was changed in proportion to the Macrogard® supplement. Diets were cold extruded into 2 mm pellets, air-dried, and then stored in plastic bags at -4°C until use.

Table 1. Composition of the basal diet with crude protein 47.5%, crude lipid 6.4%.

Ingredients	*Percentage*
Fish meal (62% - Vietnam)	43.60
Gluten (wheat)	22.10
Soybean	10.40
Fish oil	4.10
Binder	1.10
Mineral premix	1.50
Vitamin premix	1.50
Corn starch	17.70
TOTAL	*100*

Experimental fish

Pompano juveniles, *Trachinotus ovatus* (6.45 g ± 0.25, mean weight ± SD) were obtained from a local hatchery. Fish were kept in 2 m^3 tank and acclimated for 3 weeks prior to the experiment during which they were fed a commercial diet. The trial was conducted in the indoor facilities of the Institute of Oceanography, Nha Trang. A total of 30 culture tanks (300 L, sized 50 × 80 × 80 cm) were equipped with an independent recirculation system with a flow rate of ~500 L per hour. Water quality (NH_4/NH_3, NO_2, salinity and pH) were measured every 3 days. Temperature was measured daily. Fish were kept under a natural photoperiod condition throughout the experiment.

Experimental layout

Following acclimation, twenty-four fish were randomly stocked in each of the experimental tanks with six replicates for each treatment. To minimize stress, twelve fish were stocked in each tank fort the first round and then the rest were added to fill the tanks up to 24 fish per tank. The experiment lasting 56 days was designed to compare growth performance, feed, and nutrition utilization, of pompano fed on the experimental diets supplemented with four concentrations of β-glucan. The various diets were randomly allocated to the tanks.

Each tank served as one experimental unit to calculate growth, and feed utilization. During the experimental period, feeds were weighed and recorded daily for each tank. The fish were hand-fed a daily ration 3% body weight, which was then visually adjusted to apparent satiation three times a day (7:30, 12:00, and 17:30 h).

Twenty minutes after feeding, the uneaten feed was siphoned out, dried, and weighed to determine net feed consumption. Fish were weighed at 2-week intervals. Body composition was sampled and analyzed at days 0 and 56 (end). Nutrient content of each diet was also analyzed.

Sampling and data collection

During the feeding trial, all fish were individually weighed on day 0, and again every 14 days thereafter. Fish were starved for 24 h prior to weighing and sampling. The numbers of dead fish were recorded and removed daily. At day 56 (end of feeding trial), one fish from each replicate tank (6 fish per treatment) was sacrificed and a sample of the muscle was taken and stored at -20°C for later proximate composition analysis.

Proximate analysis of experimental diet and cultured fish

Samples of each feeding diet (n = 6) were collected for analysis protein and lipid content. In addition, the composition of a pooled sample of 15 fish prior to the feeding trial was randomly collected for initial proximate analysis of protein and lipid content. At the end of the experiment (day 56), twelve fish from each treatment were randomly collected and sacrificed for carcass composition analysis. Crude protein and crude lipid were measured following standard methods (Bligh and Dyer, 1959; Bradford, 1976).

Data calculation

Calculation of Growth performance

Weight gain WG (g), specific growth rate (SGR, % d^{-1}) were calculated as the following formulae:

$$WG = (Wt - Wo)$$

$$SGR = 100 \times [\text{Ln}(Wt) - \text{Ln}(Wo)]/\text{days}$$

Where Wo and Wt were initial body weight and body weights of fish at time t (g).

Survival rate was calculated as follows:

$$\text{Survival rate} = 100 \times (Nt) / No.$$

Where No was the initial number of fish and Nt was the number of fish at time (t) respectively (Do-Huu et al., 2013).

Variation in body weight was estimated by the coefficient of variation (CV, %) with the following formula: CV (%) = 100 × SD / $\bar{X}$.

Where SD was standard deviation and $\bar{X}$ was the mean weight of fish (Van Ham et al., 2003).

Calculation of feed utilization of pompano fed different levels of β-glucan

Feed consumption (FC) was estimated by subtracting uneaten feed from feed provided on a dry-matter basis. Daily feed intake (DFI, % BW/d), feed conversion ratio (FCR) and feed conversion efficiency (FCE) were calculated as follows: DFI (% BW/d) = 100 × FC / [(Wt + Wo)/2]/days; FCR = FC / WG; FCE = WG / FC (Helland et al., 1996; Miliou et al., 2005). Final biomass (g) total weight fish in each replicate tank at day 56, biomass gain (g/d): [total final weight of fish (g) - total initial weight (g)]/ days.

Calculations of nutrition utilization of pompano fed different levels of β-glucan

Protein efficiency ratio (PER), protein productive value (PPV) and fractional rates of protein growth (K_g) were calculated as follows: PER = WG / $P_{con.}$, PPV = 100 × [(Wt × Pt – Wo × Po] / P_{con} (De Silva and Anderson, 1995; Mundheim et al., 2004). K_g (%/d) = 100 × [Ln(P_t) – Ln(P_o)]/days (Wootton, 1990). Where Wo and Wt are initial and final body weight, Po and Pt are initial and final fish body protein in fish (%), $P_{con.}$: protein consumption (g), WG: weight gain (g), Pt and Po are protein content in fish at final and initial trial.

Statistical analysis

Data are presented as treatment means ± standard error of the mean (SEM). The tank served as the experimental unit for each variable measured on growth and feed utilization. Data were analyzed by one-way Analysis of Variance (ANOVA) to test the effects of the experimental diets. Before analysis, data were checked for variance homogeneity by using the Kolmogorov–Smirnov and Levene tests, and data were transformed if necessary. When significant differences were found ($P < 0.05$), the least significant difference (LSD) post hoc test was applied. The relationships between β-glucan concentrations in the diets, growth performance, feed and nutrition utilizations were tested by Pearson correlation (*r*). All statistical analyses were performed in SPSS 18 (IBM, Chicago, IL).

Results

Water quality in different treatments

Water quality in all experimental tanks during the experiment is summarized in Table 2. There were no significant differences between all these parameters measured during the experiment period ($P \geq 0.142$).

Table 2. Water quality parameters in different treatments. Data are presented as mean ± SEM.

	Diets				
	D1	*D2*	*D3*	*D4*	*D5*
Temperature (°C)	28.5 ± 0.50	28.6 ± 0.40	28.7 ± 0.41	28.7 ± 0.31	28.6 ± 0.32
NH_4/NH_3 (mg/L)	0.03 ± 0.01	0.04 ± 0.01	0.03 ± 0.02	0.04 ± 0.01	0.04 ± 0.01
NO_2 (mg/L)	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
Salinity (‰)	34.22 ± 0.21	34.51 ± 0.16	34.50 ± 0.21	34.32 ± 0.20	34.41 ± 0.18
pH	8.10 ± 0.02	8.11 ± 0.02	8.21 ± 0.02	8.10 ± 0.02	8.31 ± 0.01

Growth performance of pompano fed different levels of β-glucan

Growth performance average final weight, weight gain, daily weight gain, survival and coefficient of variation are presented in Table 3. In general, dietary β-glucan supplementation significantly affected growth performance of pompano (Table 3).

Mean final weight, weight gain (WG) and daily weight gains (DWG) were significantly higher in pompano fed diets supplemented with 0.05% and 0.10% β-glucan compared to WG and DWG of fish fed the control diet ($P \leq 0.034$). However, WG and DWG of fish fed the diet supplemented with 0.20% and 0.40% β-glucan did not differ significantly compared to those values in fish fed the control diet ($P \geq 0.326$).

Table 3. Growth performance of pompano fed different levels of β-glucan in the diet (n = 6). Data are presented as mean ± SEM. Different letters indicate significant differences between treatments.

	Diets				
	D1	*D2*	*D3*	*D4*	*D5*
Initial weight (g)	6.29 ± 0.05	6.35 ± 0.07	6.51 ± 1.90	6.30 ± 0.21	6.35 ± 0.56
Final weight (g)	41.22 ± 2.25^{a}	43.97 ± 5.23^{bc}	49.14 ± 3.18^{c}	42.55 ± 3.65^{a}	39.93 ± 6.44^{ab}
WG (g)	31.70 ± 1.97^{a}	41.49 ± 2.20^{bc}	43.71 ± 2.60^{c}	36.07 ± 5.07^{a}	33.56 ± 2.48^{ab}
DWG (g/d)	0.57 ± 0.04^{a}	0.74 ± 0.04^{bc}	0.78 ± 0.05^{c}	0.64 ± 0.09^{a}	0.60 ± 0.04^{ab}
SGR (%/d)	3.15 ± 0.09^{a}	3.61 ± 0.09^{bc}	3.62 ± 0.08^{c}	3.30 ± 0.21 ^{a}	3.26 ± 0.09^{ab}
Survival rate (%)	92.22 ± 1.76	95.84 ± 1.86	93.06 ± 3.98	93.06 ± 5.45	97.22 ± 1.76
CV_w (%)	31.19 ± 2.41^{a}	16.36 ± 2.15^{b}	12.75 ± 2.32^{b}	25.25 ± 4.53^{a}	30.73 ± 2.79^{a}

WG (g): Weight gain, DWG (g/d): Daily weight gain, SGR (%/d): Specific growth rate, CV_w (%): Coefficient of variation.

In the four groups of fish fed β-glucan supplemented diets with, (D2, D3, D4 and D5), WG and DWG of fish fed diet D4 did not significantly differ from those values in fish fed D2, D3 and D5 (P ≥ 0.089), while WG and DWG in fish fed the diet with 0.40% β-glucan (D5) was significantly lower compared to fish fed the diet D3 (P = 0.028); however, no significant differences were observed between WG and DWG in fish fed D5, D4, and D2 (P ≥ 0.079).

Survival rate of pompano among diet treatments ranged from 92.22-97.22%. However, there was no significant difference in the survival rate of pompano fed different diets (P ≥ 0.383).

Coefficient of variation (CV,%) was highest in the control diet fish (31.19%) and lowest in fish fed diets D3 and D2, with CV values of 12.75% and 16.36%, respectively. CV values in D2 and D3 fish were significantly lower than CV in D1 fish (P ≤ 0.002), also CV in fish fed D2 and D3 significantly differed from CV in fish fed D4 and D5 (P ≤ 0.045). However, no significant differences (P ≥ 0.170) were observed between CV of fish fed diets D1, D4 and D5 (see Table 3).

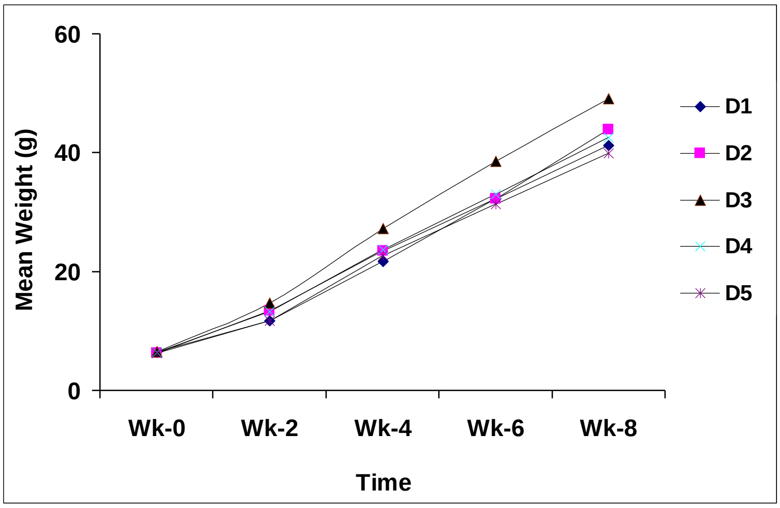


Fig.1. Growth of pompano fed diets with different levels of β-glucan supplementation.

Fortnightly mean weight of experimental pompano is presented in Figure 1. There was no significant difference (P ≥ 0.452) in mean weight of fish between diet treatments at the beginning of the trial. However, weight variation between diet treatment groups increased from day 14 and was highest at the end (day 52) of the trial (Figure 1).

At day 14, mean weight of fish fed D2 (0.05% BG), D3 (0.10% BG) and D4 (0.20% BG) were significantly higher than weight of fish fed the basal D1 or diet D5 (0.4% BG)

(P ≤ 0.046). However, there were no significant differences between mean weight of fish fed diets D2, D3 and D4 (P ≥ 0.096).

At the end of the experiment (Day 56), weight of fish fed diets D2 and D3 was significantly higher compared to weight of fish fed control diets, (P ≤ 0.041), but weight of fish fed diets D4 and D5 did not significantly differ (P ≥ 0.337) from that of fish fed the basal diet (Fig. 1).

Table 4: Feed utilization of pompano fed different levels of β-glucan supplemented in the diets (n=6). Data are presented as mean ± SEM. Different letters indicate significant differences between treatments.

	Diets				
	D1	*D2*	*D3*	*D4*	*D5*
FC (g/tank)	479.08 ± 18.82	529.79 ± 42.36	552.99 ± 14.43	472.37 ± 50.64	499.46 ± 26.87
DFI (%BW/d)	9.60 ± 0.29^{a}	8.6 ± 0.42^{b}	8.7 ± 0.37^{b}	8.64 ± 0.45^{ab}	9.68 ± 0.34^{a}
FCR	1.47 ± 0.07^{a}	1.24 ± 0.04^{b}	1.30 ± 0.05^{bc}	1.38 ± 0.04^{abc}	1.45 ± 0.05^{ac}
FCE	0.69 ± 0.03^{a}	0.81 ± 0.03^{b}	0.77 ± 0.03^{bc}	0.73 ± 0.02^{abc}	0.70 ± 0.02^{a}
DBG (g/d)	5.87 ± 0.34^{a}	7.64 ± 0.58^{b}	7.65 ± 0.44^{b}	6.13 ± 0.70^{a}	6.24 ± 0.47^{ab}

FC: feed consumption (g/tank), DFI: daily feed intake (% BW/d), FCR: feed conversion ratio, FCE: feed conversion efficiency, DBG: daily biomass gain (g/d).

Feed utilization of pompano fed different levels of β-glucan supplementation

Feed utilization, biomass at day 56, and protein and lipid content in diets, are shown in Table 4. At the end of the experiment (day 56), total feed consumption ranged from 479.08-552.99 g per tank, with no significant differences among diet treatments (P ≥ 0.132). In addition, significant differences (P ≤ 0.026) in feed intake (FI) and daily feed intake (DFI) were observed when supplemented 0.05-0.10% β-glucan in the diet of pompano, while FI and DFI in groups of fish fed diets with 0.20% and 0.40% β-glucan did not significantly differ from those values in fed fish control diet (P ≥ 0.053). Also, there was no significant difference in FI and DFI between three groups of fish fed D2, D3 and D4 (P ≥ 0.055).

Feed conversion ratio (FCR) and feed conversion efficiency (FCE) were significantly lower for fish fed diets D2 and D3, and highest in fish fed the control diet (D1), diet D4 and D5. There were significant differences in FCR and FCE between fish fed diet D2 and D3 (P ≤ 0.027), but no significant difference in FCR and FCE in fish diet D4 and D5 (P ≥ 0.051) in comparison to those values in fish fed the control diet (D1).

Furthermore, final biomass, and daily biomass gain were significantly higher (P ≤ 0.031) in pompano fed diets D2 and D3 compared to fish fed the control diet. However, those parameters in fish fed diets D4 and D5 did not significantly differ (P ≥ 0.623) from fish fed the control (Table 4).

The average protein and lipid content in the diets ranged between 47.28-47.33% and 7.06-7.08%, respectively. Protein and lipid contents of the diets were not significantly different (P ≥ 0.861) between the experimental diets (Data not shown).

Body composition of pompano fed different levels of β-glucan at day 56

At day 0, the average protein (CP) and lipid (CL) content of the fish ranged from 15.91%-16.14% CP and 5.32%-5.48% LP, respectively. At the end of feeding trial (day 56), protein content in the flesh of pompano among the treatments ranged from 16.48-17.99%, while lipid content ranged from 6.10%-6.55%. In general, dietary β-glucan supplementation significantly affected fish body composition.

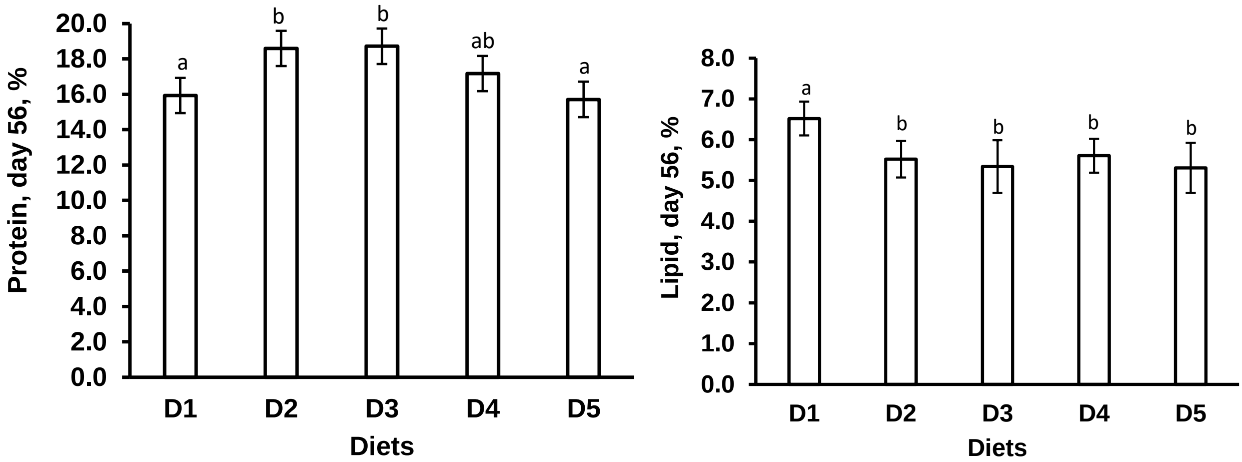
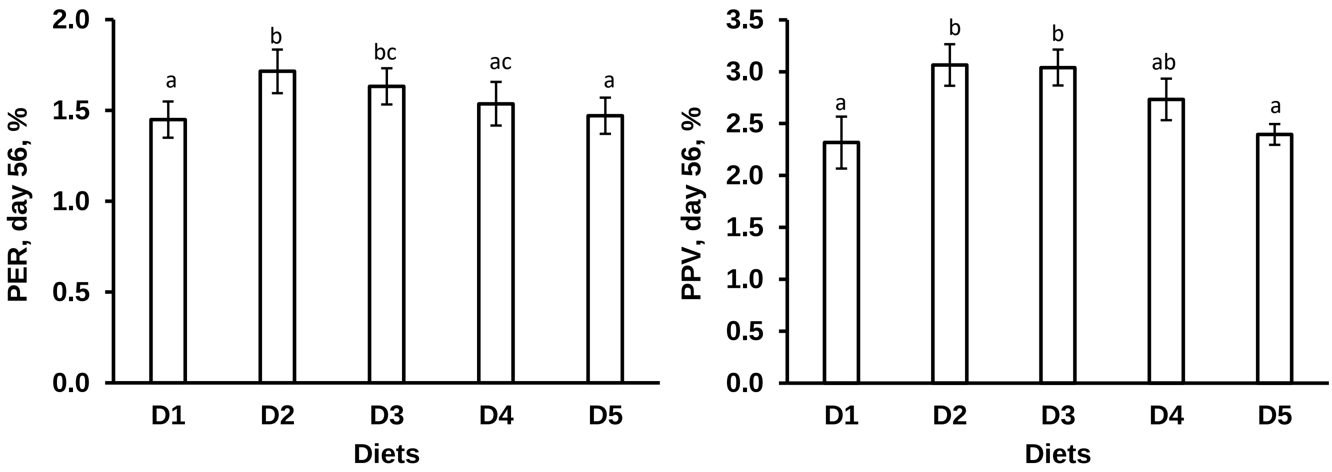


Fig. 3. Body composition (crude protein and crude lipid) of pompano fed different concentrations of β-glucan in the diets at day 56 (n = 12). Data are presented as mean ± SEM. Different letters indicated significant differences between treatments.

Crude protein content increased significantly with increasing levels of β-glucan supplementation, and highest protein content was in fish fed D2 and D3, which was significantly higher compared to protein content in fish fed D1 ($P \leq 0.001$). There was a decrease in protein content with higher levels of β-glucan (D4: 0.2% β-glucan and D5: 0.40% β-glucan) in the diet. Results showed that no significant difference in protein content of fish body was observed from D4 or D5 compared to D1 ($P \geq 0.056$), but protein content in fish fed D4 and D5 was significantly lower than in fish fed D2 and D3 ($P \leq 0.001$). Dietary β-glucan significantly reduced lipid content in the muscle of pompano in comparison to those fed D1 ($P \leq 0.044$), however, lipid content in fish fed any levels of β-glucan supplementation did not differ significantly ($P \geq 0.659$) from each other. (Fig. 3).

Protein efficient ratio (PER) and fractional rates of protein growth (K_g) in pompano fed levels of β-glucan at day 56

The results of protein efficient ratio (PER), protein productive value (PPV), and fraction rate of protein growth (Ks) are presented in Figure 4. In general, protein efficient ratio (PER), protein productive value (PPV), and fractional rates of protein growth (K_g) of pompano was significantly influenced by the dietary β-glucan supplementation.



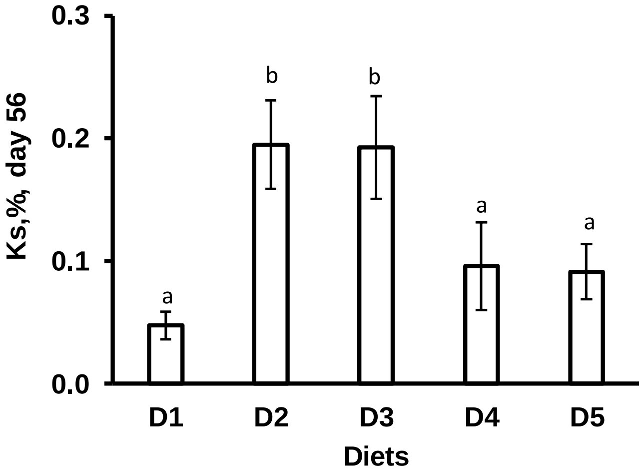


Fig. 4. Protein efficient ratio (PER), protein productive value (PPV) and fractional rates of protein growth (K_g) of pompano fed different levels of β-glucan (day 56). (n = 6). Data are presented as mean ± SEM. Different letters indicated significant differences between treatments.

Protein efficient ratio (PER) values were significantly higher in fish fed diets supplemented β-glucan at concentrations of 0.05% (D2) and 0.10% (D3) compared to PER in fish fed control (D1) (P ≤ 0.025). In contrast, there were no significant differences in PER values either between fish fed diets D4, D5 and D1 (P ≥ 0.266) or between fish fed diets D3 and D4 (P = 0.224). Moreover, at day 56, protein productive value (PPV) was significantly higher in fish fed D2 and D3 compared to fish fed control (D1) and fish fed D5 (P ≤ 0.004), but no significant differences in PPV values between either D4, D5 and D1 (P ≥ 0.057) or between D2, D3 and D4 (P ≥ 0.122). In addition, fractional rates of protein growth (K_g) were significantly higher in fish fed D2 and D3 compared to K_g in fish fed the control diet (D1) (P ≤ 0.003). Conversely, K_g did not significantly differ between fish fed D1 (control), D4 and D5 (P ≥ 0.289). (Fig. 4).

Relationships between levels of dietary β-glucan supplementation and growth rate (SGR), feed conversion ratio (FCR) and protein productive value (PPV)

At day 56, β-glucan concentrations in the diet were significantly and positively correlated (*r* ≥ 0.708, P ≤ 0.0001) with mean weight, weight gain, daily weight gain, specific growth rate, daily weight increase, final biomass, and daily biomass gain of pompano (Table 5). CV showed a significant and negative correlation with the concentration of β-glucan in the diet (*r* = - 0.441, P = 0.015). FB and DBG was significantly and positively correlated with β-glucan concentrations (*r* ≥ 0.401, P < 0.027). In growth performance, SGR had highest correlation with dietary β-glucan concentrations (*r* = 0.708 P = 0.0001).

Table 5. Pearson correlation (*r*) matrix amongst dietary β-glucan inclusion levels (%) and growth rate, feed and nutrient utilization of pompano at day 56.

	Weight	*WG*	*DWG*	*SGR*	*Survival*	*CV*	*DBG*
r	0.683**	0.688**	0.689**	0.708**	0.342	-0.441*	0.404*
Sig.	0.000	0.000	0.000	0.000	0.065	0.015	0.027
	FC	*DFI*	*FCR*	*FCE*	*PER*	*PPV*	*K_g*
r	-0.070	-0.433*	-0.451*	-0.369*	0.623**	0.627**	0.374*
Sig.	0.714	0.017	0.012	0.045	0.000	0.000	0.042

** Correlation is significant at the 0.05 level (2-tailed).*

*** Correlation is significant at the 0.01 level (2-tailed).*

In the feed utilization group, FI, DFI, FCR, FCE, were significantly and negatively correlated with concentrations of β-glucan in the diet (*r* ≥ - 0.433, P ≤ 0.017), with the highest significant correlation in the FCR value (*r* = 0.623, P = 0.012). Similarly, in the nutrient utilization the PER, PPV, and K_g were significantly and positively correlated with levels of β-glucan supplementation in the diet (*r* ≥ 0.374, P ≤ 0.042), the highest correlation being in PPV values (*r* = 0.627, P = 0.0001).

Discussion

This study highlighted the importance of dietary β-glucan requirements to growth, feed utilization, and nutrient utilization, of pompano *T. ovatus.* In accordance with previous research (Do-Huu et al., 2016), the present study confirmed that growth of pompano significantly improved when diet was supplemented with 0.05% and 0.10% dietary β-glucan. This is in accordance with other studies showing that dietary β-glucan could boost growth performance in a number of aquaculture species including snakehead fish, *Channa striata* (Munir et al., 2016), Atlantic salmon, *Salmo salar* (Refstie et al., 2010), snapper, koi carp, *Cyprinus carpio koi* (Lin et al., 2011), large yellow croaker, *Pseudosciaena crocea* (Ai et al., 2007) and rohu, *Labeo rohita* (Misra et al., 2006). In contrast, in other studies β-glucan administration did not show positive effects on growth performance, e.g. European sea bass, *Dicentrarchus labrax* (Bagni et al., 2005). Possible factors are the concentration of β-glucan administration in the diet, species specific response, and experimental conditions (Dalmo and Bogwald, 2008; Do-Huu et al., 2016) as well as administration time (Do-Huu et al., 2016; Misra et al., 2006).

In our study, pompano (6.45 g), fed β-glucan diets, had maximal growth rate of 3.62%/d, which is higher than that of pompano reported by Liu et al. (2011a), but lower than results by Wang et al. (2013). Although all the above experiments cited, including our experiment were conducted for 8 weeks, it is difficult to compare as there were differences in fish size, experimental conditions, and diets, between the experiments.

In this study, pompano grew very rapidly and the differences between the diets were detected after 14 days. Fast improvement in growth rate may be due to the energy benefits obtained through β-glucan administration (Ai et al., 2007), manipulation of intestinal microbiota (Do-Huu et al., 2016; Ringø et al., 2010), and production of digestive enzymes by these beneficial bacteria (Wu et al., 2014). However, in this study, energy benefit, gut microbiota, and digestive enzymes were not examined. To understand more about the correlation between those factors and the growth of pompano, further studies should be conducted.

β-glucan administration significantly boosted the growth of pompano and their survival rates did not differ significantly between the diet treatments after 56 days of feeding. Similar findings were reported in another study on snakehead fish (*Channa striata*) showing that β-glucan supplementation did not affect survival of this species (Munir et al., 2016).

Biochemical composition such as protein and lipids is often used as an indicator of fish nutritional condition and health status (Jobling, 1983). Body composition of fish plays an important role in aquaculture as it impacts on fish growth, survival, and the efficiency of food utilization (Breck, 2014). In the present study, dietary β-glucan supplementation significantly affected pompano body composition. Our results revealed that protein content of pompano was correlated positively with dietary β-glucan, while the lipid content of the fish had an inverse relationship with β-glucan concentrations. Similar results on effects of dietary β-glucan supplementation on body composition of other fish species have been reported. Increased protein content but reduced lipid content was reported in snakehead fish *Channa striata,* fed β-glucan inclusion in the diet (Munir et al., 2016).

It was also reported that dietary β-glucan improved protein levels in white fish, *Rutilus frisii kutum*, while it did not influence the lipid, ash, and moisture, of this species (Rufchaie and Hoseinifar, 2014). Moreover, significant differences in carcass protein levels were observed in Nile tilapia fed commercial live bakers' yeast *Saccharomyces cerevisiae* (Abdel-Tawwab et al., 2008). Both protein and lipid content increased in red sea bream *Pagrus major,* fed β-glucan inclusion in the diet (Mohebbi et al., 2012). In contrary to the above findings, other studies revealed that β-glucan administration did not influence protein and lipid content in rainbow trout, *Oncorhynchus mykiss* (Sealey et al., 2008), in turbot, *Scophthalmus maximus* (Fuchs et al., 2015) and Nile tilapia (Selim and Reda, 2015).

Coinciding with those results, it was reported that administration of other prebiotics failed to show changes in body composition of lobster, *Panulirus homarus* (Do-Huu and Jones, 2014). Body composition may be influenced by prebiotic supplementation however response depends on the species (Grisdale-Helland et al., 2008). It was reported that the excessive dietary energy supplementation can result in high lipid deposition of fish body (Page and Andrews, 1973). Lipid content significantly increased in species such as red drum, *Sciaenops ocellatus* (Serrano et al., 1992), flounder, *Paralichthys olivaceus* (Lee and Kim, 2005), largemouth bass, *Micropterus salmoides* (Anne et al., 2005), cuneate drum, *Nibea miichthioides* (Wang et al., 2006) and blackspot seabream, *Pagellus bogaraveo* (Figueiredo-Silva et al., 2010) when fed high dietary lipid levels. In the current study, lipid content in pompano reduced with the increasing levels of dietary β-glucan. In contrary to our findings, no significant difference was found in body lipid content between pompano fish fed different dietary protein or lipid levels (Wang et al., 2013). Body composition of aquaculture fish depends on endogenous and exogenous factors (Shearer 1994). Protein content is related to fish size, while lipid content depends on the diet of cultured fish (Shearer, 1994).

In addition, optimal feed utilization plays a vital role in aquaculture as it can help to save feed costs or improve benefits for the culturists. In the present study, high feed utilization was significant throughout the trial for pompano fed diets with β-glucan supplementation after 56 days of diet feeding. Our study revealed that feed conversion ratio (FCR) was lowest in fish fed 0.05% β-glucan (FCR = 1.24), while FCR was highest in fish fed the control diet (FCR = 1.47). In accordance with other studies, the present study concurred that supplementation of β-glucan in the diet could improve feed conversion ratio (FCR), feed conversion efficiency (FCE), protein efficient ratio (PER), protein productive value (PPV), and fractional rates of protein growth (K_g) of pompano. This is in line with findings that feed efficiency including feed intake (FI) and feed efficient ratio (FER) of Atlantic salmon, *Salmo salar* significantly improved with increasing levels of β-glucan in the diet (Refstie et al. 2010). Similarly, lower FCR were observed in snakehead fish, *Channa striata* fed β-glucan diet (Munir et al., 2016). Another study also indicated that FCR was significantly lower in Nile tilapia fed dietary β-glucan supplementation (Selim and Reda, 2015).

Moreover, our study found that protein efficient ratio (PER), protein productive value (PPV), and fractional rates of protein growth (K_g) significantly increased with the increasing levels of β-glucan in the diet of pompano. These results are in agreement with previous studies reported in other species. Increase in PER was observed in snakehead fish (*Channa striata*) fed β-glucan diet (Munir et al. 2016). In contrast with the above studies, dietary β-glucan did not influence protein efficiency ratio (PER) of Nile tilapia (Selim and Reda, 2015).

The present study revealed that administration of dietary β-glucan improved growth performance, feed efficiency and protein efficiency together with higher biomass of pompano at the end of the feeding trial. Higher growth rate together with lower FCR and more protein efficiency in pompano fed the diets supplemented with β-glucan were found. This indicates that higher benefits could be attained with supplementation of β-glucan in the diet of pompano. However, to understand this completely, experiments in outdoor and commercial culture conditions should be conducted.

From the present findings, it could be suggested that optimum growth and nutrient utilization can be achieved by supplementing low concentrations of β-glucan in the diet of pompano. Higher growth rates observed, together with lower feed utilization, could suggest lowering feeding cost and environmental benefits with less waste per unit of production when supplying appropriate levels of β-glucan in the diet of pompano. However, this should be measured experimentally.

In conclusion, the results of the present study confirmed that supplementation of β-glucan in the diet could improve the growth, protein content in flesh, feed conversion ratio, feed conversion efficiency, protein efficient ratio, and protein productive value in pompano, *T. ovatus*. It is recommended that supplementation of 0.5-1.0 g/kg β-glucan in the diet to obtain maximal growth, feed utilization and protein utilization of juvenile pompano. However, other potential positive benefits of dietary β-glucan supplementation including increased resilience to pathogens should be further investigated. Also, the effects of dietary β-glucan at different life stages beyond those in this study such as larvae, fry, and broodstock rearing under commercial conditions should be examined experimentally.

Acknowledgments

This research was funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number: 106-NN.05-2014.06. We particularly thanks Dr. Fernando and Biorigin for providing Macrogard®. The authors would like to express special thanks to Dr. Huynh Minh Sang, Nguyen Thi Thanh Thuy, Nguyen Thi Nguyet Hue, Nguyen Thi Kim Bich for their help.

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