Dietary mannan oligosaccharide and Bacillus subtilis in diets for Nile tilapia (Oreochromis niloticus)

Rafael Vieira de Azevedo1*, João Carlos Fosse Filho2, Samuel Louzada Pereira2, Leonardo Demier Cardoso2, Dalcio Ricardo de Andrade2 and Manuel Vazquez Vidal Júnior2

1Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural, Av. Conde D’Eu, 344, 29670-000, Ibiraçu, Espírito Santo, Brazil.
2Universidade Estadual do Norte Fluminense Darcy Ribeiro, Centro de Ciências e Tecnologias Agropecuárias, Campos dos Goytacazes, Rio de Janeiro, Brazil. *Author for correspondence. E-mail: azevedorv84@gmail.com

ABSTRACT. A six week study was conducted to investigate the supplementation of prebiotic (Mannan oligosaccharide – MOS, from yeast Saccharomyces cerevisiae), probiotic (Bacillus subtilis – BS, C-3102 strain) and their combination in diets for Nile tilapia. 192 fishes (4.03 ± 0.28 g) were distributed into 16 tanks (40-L), in a completely randomized design (n=4). The following treatments were evaluated: control; prebiotic - 2 g MOS kg⁻¹; probiotic - 2 g BS kg⁻¹ and synbiotic - 1 g MOS kg⁻¹ plus 1 g BS kg⁻¹. Fishes fed diets pre-, pro- and synbiotic supplemented performed better in average daily gain, feed conversion rate, specific growth rate, protein efficiency ratio, carcass yield, total and standard length and body height than those maintained on control diets. The probiotic supplementation resulted in higher villus height and intestinal perimeter ratio than the control diet while the pre- and synbiotic supplementation in diets resulted in higher intestinal perimeter ratio. Carcass protein and ether extract were, respectively, higher and lower in fish fed synbiotic diets than other fish. The results of this study indicated that the mannan oligosaccharide and Bacillus subtilis supplementation, isolated or combined (synbiotic), could improve growth, body index, intestine morphometry and carcass composition in Nile tilapia.

Keywords: Aquaculture, prebiotic, probiotic, synbiotic, tilapia farming.

Mananoligossacarídeo e Bacillus subtilis em dietas para tilápia do Nilo (Oreochromis niloticus)

RESUMO. Um estudo de seis semanas foi conduzido para investigar a suplementação de prebiótico (mananoligossacarídeo – MOS, oriundo da levedura Saccharomyces cerevisiae), probiótico (Bacillus subtilis – BS, cepa C-3102) e sua combinação em dietas para tilápia do Nilo. Foram distribuídos 192 peixes (4,03 ± 0.28 g) em 16 tanques (40-L) em delineamento inteiramente casualizado (n=4). Avaliaram-se os tratamentos: controle, 2 g MOS kg⁻¹, 2 g BS kg⁻¹ e 1 g MOS kg⁻¹ mais 1 g BS kg⁻¹ (simbiótico). As rações prebiótico, probiótico e simbiótico resultaram em melhores média de ganho diário, conversão alimentar, taxa de crescimento específico, eficiência protéica, rendimento de carcaça, comprimentos total, padrão e altura comparando-se a ração controle. A ração probiótico resultou em maiores altura de vilosidades e relação entre perímetros intestinais que peixes alimentados com ração controle, enquanto rações prebiótico e simbiótico resultaram em peixes com maior relação entre perímetros intestinais que peixes alimentados com ração controle. A ração simbiótica resultou em peixes com, respectivamente, maiores e menores porcentagens de proteína e extrato etéreo na carcaça. Os resultados sugerem que a suplementação de mananoligossacarídeo e Bacillus subtilis, isolado ou combinado (simbiótico), melhorou o crescimento, os índices corporais, a morfometria intestinal e a composição da carcaça em tilápia do Nilo.

Palavras-chave: Aquicultura, cultivo de tilápias, prebiótico, probiótico, simbiótico.

Introduction

Tilapias are the second most farmed freshwater fish in the world after carps, mainly due to features such as ability to reproduce in captivity, rusticity, fast growth rate, feed on a low trophic and good flesh quality. The Nile tilapia (Oreochromis niloticus) occupies a prominent position in the Brazilian fish farming, representing around 43% of production in (Instituto Brasileiro de Geografia e Estatística [IBGE], 2014).

The rapid expansion and intensification of fish farming, combined with the increase in intensive production strategies at higher densities, have resulted in the emergence of diseases that cause considerable economic losses and hinder the sustainable development of the industry (Rico et al., 2014).

Antibiotics have been used to prevent and treat diseases in aquatic animals and sub-therapeutic dosages have often been used for promoting growth. However, the antibiotics use may result into the
development of resistant bacteria, presence of antibiotic residues in the flesh and destruction of the microbial population in the aquatic environment (Marques et al., 2005). As a result, various alternative strategies for the antibiotic use have been proposed, among them the use of pre- and probiotics.

Prebiotics are non-digestible food ingredients that beneficially affect the host by stimulating the growth and/or activity of one or a limited number of bacteria in the colon selectively (Gibson & Roberfroid, 1995).

Probiotics are live microorganisms which when administered in suitable amounts; confer benefits to the health of the host by improving the balance of the intestine microbiota (Verschuere, Rombaut, Sorgeloos, & Verstraete, 2000). Synbiotic are the combination of prebiotics and probiotics that beneficially affects the host by improving the survival rate and modulation of microbial community in the gastrointestinal tract, by selectively stimulating the growth or by activating the metabolism of one or a limited number of beneficial bacteria (Gibson & Roberfroid, 1995).

One of the most common prebiotics used in animal nutrition is the mannan oligosaccharide (MOS). In aquaculture, this prebiotic demonstrates improvement of growth performance, survival, feed utilization, non-specific immunity and disease resistance (Burr, Hume, Ricke, Nisbet, & Gatlin III, 2008; Liu et al., 2013; Safari, Shahsavani, Paolucci, & Atash, 2014). Among the probiotics commonly used, the genus Bacillus is one of the most extensively evaluated as aquaculture feed supplements and has been demonstrated to improve a number of attributes when supplemented in diets of aquatic organisms (Azevedo, Fosse Filho, Pereira, Andrade, & Júnior, 2016; Geng et al., 2012; Ghosh, Sinha, & Sahu, 2008; Giri, Sukumaran, Sen, & Jena, 2014; Gupta, Gupta, & Dhawan, 2014).

Despite much information on the use of single pre- and probiotics, less information is found on their combined effects. However, the results showed that might yield better results than the individual application of pre- and probiotics (Azevedo et al., 2015; Rodriguez-Estrada, Satoh, Haga, Fushimi, & Sweetman, 2009; Zhang et al., 2013).

This study was carried out to evaluate the effect of single or combined supplementation of MOS and B. subtilis on the growth, body indices, intestine morphometry and carcass composition in Nile tilapia (Oreochromis niloticus).

Material and methods

As prebiotic, a MOS derived from the cell wall of the yeast Saccharomyces cerevisiae was evaluated. As the probiotic microorganism, spores of BS C-3102 strain in powder were used (1 x 10¹⁰ CFU per gram of product). The synbiotic was formed from a mixture (1:1) of MOS and BS.

The study was conducted at the Sector of Aquaculture of the Laboratório de Zootecnia e Nutrição Animal at the Universidade Estadual do Norte Fluminense Darcy Ribeiro (Campos dos Goytacazes, Rio de Janeiro, Brazil). A total of 192 Nile tilapia juvenile GIFT strain (4.03 ± 0.28 g) were adapted to a commercial diet and experimental facilities before the beginning of feeding trial for one week. Fishes were randomly distributed into 16 plastic tanks (40-L), kept indoors in a recirculation water system, in a completely randomized design and four replications. The following treatments were evaluated: control; prebiotic - 2 g MOS kg⁻¹; probiotic - 2 g BS kg⁻¹ and synbiotic - 1 g MOS kg⁻¹ plus 1 g BS kg⁻¹.

Water quality parameters such as temperature, pH and dissolved oxygen were measured daily and weekly ammonia-N. During the experimental period, temperature ranged over 28.2 ± 1.3°C, pH was 6.8 ± 0.8, dissolved oxygen 4.2 ± 0.5 mg L⁻¹ and ammonia-N remained below 0.1 mg L⁻¹. The tanks were daily cleaned through siphoning out the material residues (fish feces and uneaten food).

Four diets were formulated and supplemented or not with pre-, pro- and synbiotic (Table 1).

MOS and BS were added to the basal diet at the expense of wheat flour. Dietary ingredients were ground into powder (0.5 mm), thoroughly mixed and blended oil and water to form dough. The dough was passed through a pelletizer-making device to obtain 3-mm diameter pellets. Pellets were dried in an oven at 50°C and stored in freezer at -20°C until use.

The feeding trial was conducted for six weeks and fish were fed to apparent satiety four times daily (08.00, 11.00, 14.00 and 17.00 hours).

At the end of the experiment, fish were starved for 24 hours. All surviving fish were anesthetized with Benzocaine (10 mg L⁻¹), weighed (0.01 g) and measured (0.01 cm) as for the body total and standard lengths and height (Pires et al., 2011). Eight fish from each treatment were randomly selected and killed by Benzocaine overdose for the analysis of body indexes, intestine morphometric analysis and carcass composition.

The liver and viscera were removed, separated and weighed. Fish carcasses were weighed for calculation of the carcass yield and stored in freezer at -20°C until carcass composition analysis. Also, gut samples were fixed in 10% neutral-buffered formalin for 24 hours and then transferred into 70% ethanol until histological examination.
Table 1. Composition of experimental diets of natural basis

| Ingredient (g kg⁻¹) | Control | Prebiotic | Probiotic | Synbiotic |
|---------------------|---------|-----------|-----------|-----------|
| Soybean meal        | 410.0   | 410.0     | 410.0     | 410.0     |
| Wheat flour         | 250.0   | 248.0     | 248.0     | 248.0     |
| Corn meal           | 200.0   | 200.0     | 200.0     | 200.0     |
| Fish meal           | 79.7    | 79.7      | 79.7      | 79.7      |
| Corn flour          | 34.0    | 34.0      | 34.0      | 34.0      |
| Soybean oil         | 16.1    | 16.1      | 16.1      | 16.1      |
| Supplement mineral and vitamin¹ | 10.0  | 10.0      | 10.0      | 10.0      |
| Mannan oligosaccharide | -      | 2.0       | 0.0       | 1.0       |
| Bacillus subtilis    | -       | -         | 2.0       | 1.0       |
| Antioxidant BHT      | 0.2     | 0.2       | 0.2       | 0.2       |

Proximate composition

| Dry matter (g kg⁻³) | 864.66 | 867.52 | 867.52 | 865.71 |
| Crude protein (g kg⁻³) | 276.64 | 276.61 | 272.32 | 275.58 |
| Crude energy (kcal kg⁻¹) | 4114 | 4106 | 4111 | 4098 |
| Crude fiber (g kg⁻³) | 49.79 | 49.60 | 49.31 | 49.40 |
| Crude lipid (g kg⁻³) | 44.69 | 44.62 | 44.33 | 44.55 |
| Mineral matter (g kg⁻³) | 127.72 | 138.28 | 143.43 | 152.38 |

¹Composition kg⁻¹: Mg – 2,600 mg; Zn – 14,000 mg; Fe – 10,000 mg; Cu – 1,400 mg; Co – 20 mg; Se – 60 mg; Vit. A – 1,000,000 UI; Vit. D₃ – 400.00 UI; Vit. E – 10,000 mg; Vit. K₃ – 500 mg; Vit. B₁ – 2,500 mg; Vit. B₂ – 2,500 mg; Vit. B₆ – 2,500 mg; Vit. B₁₂ – 3,000 mcg; Vit. C – 50,000 mg; Folic acid – 500 mg; Pantothenic acid – 500 mg; Niacin – 10,000 mg; Biotin – 80,000 mcg; Choline – 200,000 mg; Inositol – 35,000 mg; Etoxiquin – 15,000 mg. ²Analyzed according AOAC (2005). ³Value analyzed by calorimetric bomb (1341 Parr Instrument Company, IL, USA).

Growth, feed utilization parameters and survival rate were determined as follows: daily feed intake (DFI) = 100 x (total feed intake / experimental period); average daily gain (ADG) = 100 x (final body weight – initial body weight) / experimental period; feed conversion rate (FCR) = feed consumed / weight gain; specific growth rate (SGR) = 100 x (ln final weight – ln initial weight) / experimental period; protein efficiency ratio (PER) = weight gain / protein intake and survival rate (SUR) = 100 x (number of fish remaining / initial number of fish).

Besides the total length (TL), standard length (SL) and height (H), body indexes were determined as follows: carcass yield (CY) = 100 x (fish weight without viscera / total fish weight); hepatosomatic index (HSI) = 100 x (liver weight / total weight) and viscerosomatic index (VSI) = 100 x (viscera weight / total weight).

Results and Discussion

There was no effect of supplements on DFI and SUR (p > 0.05) (Table 2). Fishes fed diets pre-, pro- and synbiotic supplemented performed better in terms of ADG, FCR, SGR and PER than those maintained on control diets (p < 0.05).

In the case of body indexes, the supplements did not affect HSI and VSI values (p > 0.05) (Table 3). The pre-, pro- and synbiotic supplementation in diets resulted in better CY, TL, SL and H than control diet (p < 0.05).

Similar results have been reported for aquatic species fed MOS (Gültepe, Salnur, Hoşsu, & Hisar, 2011; Refstie, Baeverfjord, Seim, & Elvebø, 2010; Staykov, Spring, Denev, & Sweetman, 2007), BS (Essa et al., 2010; Giri et al., 2014) and MOS plus BS as synbiotic (Azevedo et al., 2016; Daniels, Merrifield, Ringø, & Davies, 2013) on growth, feed utilization and survival.
Table 2. Growth, feed utilization and survival of Nile tilapia

| Parameter | Control | Prebiotic | Probiotic | Synbiotic | p-value |
|-----------|---------|-----------|-----------|-----------|---------|
| DFI (g day\(^{-1}\)) | 0.48±0.02\(^a\) | 0.48±0.02\(^a\) | 0.48±0.02\(^b\) | 0.49±0.01\(^b\) | 0.4955 |
| ADG (g day\(^{-1}\)) | 0.26±0.02\(^a\) | 0.33±0.01\(^a\) | 0.32±0.03\(^a\) | 0.33±0.01\(^a\) | 0.1914 |
| FCR | 1.87±0.15\(^a\) | 1.49±0.05\(^b\) | 1.52±0.08\(^a\) | 1.44±0.11\(^a\) | 0.0114 |
| SGR (% day\(^{-1}\)) | 3.55±0.15\(^a\) | 3.98±0.11\(^b\) | 3.93±0.21\(^b\) | 4.09±0.15\(^b\) | 0.0142 |
| PER (%) | 1.68±0.14\(^a\) | 2.10±0.07\(^b\) | 1.93±0.11\(^b\) | 2.03±0.06\(^b\) | 0.0069 |
| SUR (%) | 93.75±4.17\(^a\) | 95.83±4.81\(^a\) | 97.92±4.17\(^b\) | 95.83±4.81\(^a\) | 0.6636 |

\(^a\)DFI, daily feed intake; ADG, average daily gain; FCR, feed conversion rate; SGR, specific growth rate; PER, protein efficiency ratio; SUR, survival rate. Values followed by a different letter within the same line were different (p < 0.05).

Table 3. Body indices (%) in Nile tilapia

| Parameter | Control | Prebiotic | Probiotic | Synbiotic | p-value |
|-----------|---------|-----------|-----------|-----------|---------|
| TL (cm) | 9.07±0.19\(^a\) | 9.86±0.19\(^a\) | 9.67±0.10\(^b\) | 9.82±0.17\(^a\) | 0.0234 |
| SL (cm) | 7.19±0.17\(^a\) | 7.92±0.08\(^b\) | 7.76±0.14\(^a\) | 7.76±0.22\(^a\) | 0.0221 |
| H (cm) | 2.70±0.13\(^a\) | 3.05±0.04\(^b\) | 3.21±0.33\(^a\) | 3.10±0.11\(^b\) | 0.0248 |
| CY (%) | 55.93±5.13\(^a\) | 64.28±1.79\(^b\) | 66.13±0.95\(^b\) | 63.31±4.19\(^a\) | 0.0011 |
| HSI (%) | 1.77±0.49\(^a\) | 1.43±0.44\(^b\) | 1.42±0.69\(^a\) | 1.56±0.50\(^a\) | 0.5134 |
| VSI (%) | 2.51±0.86\(^a\) | 2.52±0.68\(^b\) | 2.37±0.25\(^a\) | 2.62±0.65\(^b\) | 0.4466 |
| SI (%) | 2.51±0.56\(^a\) | 2.52±0.68\(^a\) | 2.37±0.25\(^a\) | 2.62±0.65\(^b\) | 0.4466 |

\(^a\)TL, total length; SL, standard length; H, body height; CY, carcass yield; HSI, hepatosomatic index; VSI, viscerosomatic index. Values followed by a different letter within the same line were different (p < 0.05).

The mechanisms by which prebiotics and probiotics can improve the performance are still unclear. However, Bacillus sp. can synthesize various vitamins and extracellular enzymes (Azokpota, Hounhouigan, Nago, & Jakobsen, 2006), while MOS can selectively modulate the gut microbiota and improve the integrity of the intestinal villi (Safari et al., 2014). The greatest growth observed by the fish who received supplemented diets, may be due to better feed utilization, as observed in this research through improved FCR and PER.

In this study, there was no influence of pre-, pro- and synbiotic supplementation on the DFI. A common difficulty observed when new supplements or alternative food sources are used in fish feed is the acceptability, which is related to palatability (Carvalho, Azevedo, Ramos, & Braga, 2012). The similarity in feed intake values in this study suggests that the supplementation of the evaluated supplements did not alter the palatability of feed.

The results showed that FCR and PER can be improved by supplementation of pre-, pro- and synbiotic. Feed formulations accounts for more than 50% of the total production costs in intensive aquaculture. Increasing FCR by improving dietary nutrients assimilation would have a direct positive effect on profitability of aquaculture (Azevedo et al., 2015). Some factors may be responsible for improved feed utilization due to the inclusion of prebiotic and probiotic in diets for fish, including the enzymatic contribution by beneficial bacteria (Aly, Ahmed, Ghareeb, & Mohamed, 2008; Anguiano, Pohlenz, Buentello, & Gatlin, 2013; Bairagi, Ghosh, Sen, & Ray, 2002), increased maturation of the gastrointestinal tract (Anguiano et al., 2013; Mello et al., 2013; Salze, McLean, Schwarz, & Craig, 2008) and improved feed apparent digestibility coefficients of nutrients and energy (Burr et al., 2008; Grisdale-Helland, Helland, & Gatlin-III, 2008; Mohapatra et al., 2012).

The structural knowledge of the intestinal mucosa may provide important information for studies on fish nutrition. Similarly to results obtained in this study, some authors observed structural improvement of intestine morphometry in fish fed diets MOS or BS supplemented (Mello et al., 2013; Schwarz, Furuya, Natali, Gaudio, & Lima, 2011). Intestinal absorption capacity is related to the surface area available for absorption, which depends on the villi size and number. To maintain digestive and absorptive intestinal capacity there must be a balance in cell turnover (renewal and cell loss). However, when in response to any agent (anti-nutritional factor, microorganisms) may occur imbalance in the turnover and the consequent change in villus height.

MOS is a non digestible glucomannan derived from the cell wall of Saccharomyces cerevisiae, being rich source of mannose which is available for bacterial adhesion, which adsorbing pathogens prevents its binding to the intestinal wall (Newman, 1994). When the bacterial adhesion to the enterocytes is inhibited, there is no formation of colonies that can turn nutrients to the animal unavailable or infect their intestinal cells, thus there is an improvement in intestinal health, increase the integrity of the intestinal villi and, consequently, better utilization of nutrients (Pelican et al., 2005).

According to Pelican et al. (2005), the presence of undesirable microorganisms in contact with the
intestinal mucosa can lead to imbalance and interference in the cell renewal modifying the villus height, length and width. Thus, it can be inferred that the opposite (presence of beneficial microorganisms) can positively affect the rate of cell renewal, resulting in improvement in the structure of the villi intestinales. The highest value in PR presented by fish fed supplemented diets suggests a better integrity of the intestinal mucosa, allowing its better development and therefore greater efficiency in the absorptive process, which may explain the improved FCR and PER.

Results of fish carcass composition show that MO, CE and MM values were unaffected by supplement in diets (p > 0.05), while CP and EE content were, respectively, higher and lower in fish fed symbiotic supplemented diets than other fish (Table 5).

Table 5. Proximate carcass composition of Nile tilapia

| Parameter | Control | Prebiotic | Probiotic | Synbiotic | p-value |
|-----------|---------|-----------|-----------|-----------|---------|
| MO (%)    | 75.09±2.26 | 74.49±2.56 | 74.65±2.76 | 74.50±2.92 | 0.6137  |
| CP (%)    | 51.3±0.87  | 51.31±0.52 | 52.00±0.44  | 53.71±1.17 | 0.0132  |
| EE (%)    | 16.86±0.26  | 16.82±0.14 | 16.28±0.09  | 15.02±0.85 | 0.0012  |
| CE (kcal kg⁻¹) | 5025±51.12 | 4942±102.32 | 4908±65.15 | 4797±69.05 | 0.6788  |
| MM (%)    | 17.26±0.33 | 18.05±0.39 | 17.70±0.27 | 17.71±0.80 | 0.8121  |

The carcass composition of fish can be changed both by nutrient concentration in diets as the feed rate (Shearer, 1994). In this study, symbiotic supplementation resulted in an increase in CP and reduced EE content in carcass, agreeing with Ayce, Yilmaz, Genc and Aktas (2007) fed hybrid tilapia reduced EE content in carcass, agreeing with Ayce, supplementation resulted in an increase in CP and rate (Shearer, 1994). In this study, synbiotic refer to supplement combining prebiotics and probiotics in a form of synergism, increasing their isolated beneficial effects, which was observed and probiotics in a study by Cerezuela, Meseguer and Esteban (2011), synbiotic refer to supplement combining prebiotics and probiotics in a form of synergism, increasing their isolated beneficial effects, which was observed.

Conclusion

The results of this study indicated that the mannan oligosaccharide and Bacillus subtilis supplementation, isolated or combined (symbiotic), could improve growth, feed utilization, body indexes, intestine morphometry and carcass composition in Nile tilapia.

Acknowledgements

The authors are grateful for the financial support provided by Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro – FAPERJ and Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENF.

References

Aly, S. M., Ahmed, Y. A.-G., Ghareeb, A. A.-A., & Mohamed, M. F. (2008). Studies on Bacillus subtilis and Lactobacillus acidophilus, as potential probiotics, on the immune response and resistance of Tilapia nilotica (Oreochromis niloticus) to challenge infections. Fish & Shellfish Immunology, 25(1), 128-136.

Anguiano, M., Pohlenz, C., Buentello, A., & Gatlin, D. M. (2013). The effects of prebiotics on the digestive enzymes and gut histomorphology of red drum (Sciaenops ocellatus) and hybrid striped bass (Morone chrysops× M. saxatilis). British Journal of Nutrition, 109(4), 623-629.

AOAC. (2005). - Association Official Analytical Chemist (2005) (Official Methods of Analysis (18th ed.) ed.). Gaithersburg, Maryland, USA: AOAC.

Ayce, G. M., Yilmaz, E., Genc, E., & Aktas, M. (2007). Effects of dietary mannan oligosaccharides (MOS) on growth, body composition, and intestine and liver histology of the hybrid tilapia (Oreochromis niloticus x O. aureus). The Israel Journal of Aquaculture, 55(1), 10-16.

Azevedo, R. V., Fosse Filho, J. C., Cardoso, L. D., Mattos, D. C., Júnior, V., Vazquez, M., Andrade, D. R. (2015). Economic evaluation of prebiotics, probiotics and symbiotics in juvenile Nile tilapia. Revista Ciência Agronômica, 46(1), 72-79.

Azevedo, R. V., Fosse Filho, J. C., Pereira, S. L., Andrade, D. R., & Júnior, V. (2016). Prebiotic, probiotic and symbiotic for Trichogaster leeri larvae (Bleeker, 1852, Perciformes, Osphronemidae). Arquivo Brasileiro de Medicina Veterinaria e Zootecnia, 68(3), 795-804.

Azokpota, P., Hounhouigan, D. J., Nago, M. C., & Jakobsen, M. (2006). Esterase and protease activities of Bacillus spp. from aflatin, iru and sonru; three African locust bean (Parkia biglobosa) condiments from Benin. African Journal of Biotechnology, 5(3), 265.

Bagheri, T., Hedayati, S. A., Yavari, V., Alizade, M., & Farzanfar, A. (2008). Growth, survival and gut microbial load of rainbow trout (Oncorhynchus mykiss) fry given diet supplemented with probiotic during the two months of first feeding. Turkish Journal of Fisheries and Aquatic Sciences, 8(1), 43-48.

Bairagi, A., Ghosh, K. S., Sen, S. K., & Ray, A. K. (2002). Enzyme producing bacterial flora isolated from fish digestive tracts. Aquaculture International, 10(2), 109-121.

Burr, G., Hume, M., Ricke, S., Nisbet, D., & Gatlin III, D. (2008). A preliminary in vitro assessment of
GroBiotic®-A, brewer's yeast and fructooligosaccharide as prebiotics for the red drum Sciaenops ocellatus. *Journal of Environmental Science and Health Part B, 43*(3), 253-260.

Carvalho, J. S. O., Azevedo, R. V., Ramos, A. P. S., & Braga, L. G. T. (2012). Agroindustrial byproducts in diets for Nile tilapia juveniles. *Revista Brasileira de Zootecnia, 41*(3), 479-484.

Cerezuela, R., Meseguer, J., & Esteban, M. A. (2011). Current knowledge in symbiotic use for fish aquaculture: a review. *Journal of Aquaculture Research & Development, 2011*(51), 1-7.

Daniels, C. L., Merrifield, D. L., Ringo, E., & Davies, S. J. (2013). Probiotic, prebiotic and symbiotic applications for the improvement of larval European lobster (*Homarus gammarus*) culture. *Aquaculture, 416*, 396-406.

Essa, M. A., El-Serafy, S., El-Ezabi, M. M., Daboor, S. M., El-Serafy, S., & El-Ezabi, M. M. (2010). Effect of different dietary probiotics on growth, feed utilization and digestive enzymes activities of Nile tilapia, *Oreochromis niloticus*. *Journal of the Arabian Aquaculture Society, 5*(2), 143-162.

Geng, X., Dong, X. H., Tan, B. P., Yang, Q. H., Chi, S. Y., Liu, H. Y. Liu, X.-Q. (2012). Effects of dietary probiotic on the growth performance, non-specific immunity and disease resistance of cobra, *Rachycentron canadum*. *Aquaculture Nutrition, 18*(1), 46-55.

Ghosh, S., Sinha, A., & Sahu, C. (2008). Dietary probiotic supplementation in growth and health of live-bearing ornamental fishes. *Aquaculture Nutrition, 14*(4), 289-299.

Gibson, G. R., & Roberfroid, M. B. (1995). Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. *Journal of Nutrition, 125*(6), 1401-1412.

Giri, S. S., Sukumaran, V., Sen, S. S., & Jena, P. K. (2014). Effects of dietary supplementation of potential probiotic *Bacillus subtilis* VSG1 singularly or in combination with *Lactobacillus plantarum* VSG3 or/and *Pseudomonas aeruginosa* VSG2 on the growth, immunity and disease resistance of *Labeo rohita*. *Aquaculture Nutrition, 20*(2), 163-171.

Grisdale-Helland, B., Helland, S. J., & Gatlin-III, D. M. (2008). The effects of dietary supplementation with mannanoligosaccharide, fructooligosaccharide or galactooligosaccharide on the growth and feed utilization of Atlantic salmon (*Salmo salar*). *Aquaculture, 283*(1), 163-167.

Gültepe, N., Salnur, S., Hoşçu, B., & Hisar, O. (2011). Dietary supplementation with Mannanoligosaccharides (MOS) from Bio-Mos enhances growth parameters and digestive capacity of gilthead sea bream (*Sparus aurata*). *Aquaculture Nutrition, 17*(5), 482-487.

Gupta, A., Gupta, P., & Dhawan, A. (2014). Dietary supplementation of probiotics affects growth, immune response and disease resistance of *Cyprinus carpio* fry. *Fish & Shellfish Immunology, 41*(2), 113-119.

Instituto Brasileiro de Geografia e Estatística [IBGE] (2014). *Produção da pecuária municipal, 2013*. Brasília, DF: IBGE.

Liu, B., Xu, L., Ge, X., Xie, J., Xu, P., Zhou, Q., ... Zhang, Y. (2013). Effects of mannan oligosaccharide on the physiological responses, HSP70 gene expression and disease resistance of *Allophagnenicetus crucian* carp (*Carassius auratus gibelio*) under *Aeromonas hydrophila* infection. *Fish & Shellfish Immunology, 34*(6), 1395-1403.

Marques, A., Dinh, T., Ioakeimidis, C., Huys, G., Swings, J., Verstraete, W., ... Bossier, P. (2005). Effects of bacteria on *Artemia franciscana* cultured in different gnotobiotic environments. *Applied and Environmental Microbiology, 71*(8), 4307-4317.

Mello, H., Moraes, J. R. E., Niza, I. G., Moraes, F. R., Ozzório, R. O. A., Shimada, M. T., ... Gustavo S. (2013). Beneficial effects of probiotics on the intestine of juvenile Nile tilapia. *Pesquisa Veterinaria Brasileira, 33*(6), 724-730.

Mohapatra, S., Chakraborty, T., Prusty, A. K., Das, P., Paniprasad, K., & Mohanta, K. N. (2012). Use of different microbial probiotics in the diet of rohu, *Labeo rohita* fingerlings: effects on growth, nutrient digestibility and retention, digestive enzyme activities and intestinal microflora. *Aquaculture Nutrition, 18*(1), 1-11.

Newman, K. (1994). Mannan-oligosaccharides: Natural polymers with significant impact on the gastrointestinal microflora and the immune system. *Biotechnology in the Feed Industry, 10*, 167-174.

Pelicano, E. R. L., Souza, P. A., Souza, H. B. A., Oba, A., Borago, M. M., Zeola, N. M. B. L., ... Lima, T. M. A. (2005). Carcass and cut yields and meat qualitative traits of broilers fed diets containing probiotics and prebiotics. *Revista Brasileira de Ciência Agrícola, 7*(3), 169-175.

Pires, A. V., Pedreira, M. M., Pereira, I. G., Fonseca Júnior, A., Araújo, C. V., & Silva, L. H. (2011). Predição do rendimento e do peso do filé da tilápia-do-Nilo. *Acta Scientiarum. Animal Sciences, 33*(3), 315-319.

Refstie, S., Baeverfjord, G., Seim, R. R., & Elvebo, O. (2010). Effects of dietary yeast cell wall β-glucans and MOS on performance, gut health, and salmon lice resistance in Atlantic salmon (*Salmo salar*) fed sunflower and soybean meal. *Aquaculture, 305*(1), 109-116.

Rico, A., Oliveira, R., McDonough, S., Matser, A., Khatikarn, J., Satapornvanit, K., ... Brink, P. J. (2014). Use, fate and ecological risks of antibiotics applied in tilapia cage farming in Thailand. *Environmental Pollution, 191*, 8-16.

Rodriguez-Estrada, U., Satoh, S., Haga, Y., Fushimi, H., & Sweetman, J. (2009). Effects of single and combined supplementation of *Enterococcus faecalis*, mannan oligosaccharide and polyhydroxybutyrate acid on growth performance and immune response of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Science, 57*(3), 609-617.

Safari, O., Shahsavani, D., Paolucci, M., & Atash, M. M. S. (2014). Single or combined effects of fructo-and...
mannot oligosaccharide supplements on the growth performance, nutrient digestibility, immune responses and stress resistance of juvenile narrow clawed crayfish, *Astacus leptodactylus* leptodactylus Eschscholtz, 1823. *Aquaculture*, 432, 192-203.

Salze, G., McLean, E., Schwarz, M. H., & Craig, S. R. (2008). Dietary mannan oligosaccharide enhances salinity tolerance and gut development of larval cobia. *Aquaculture*, 274(1), 148-152.

Schwarz, K. K., Furuya, W. M., Natali, M. R. M., Gaudezi, M. C., & Lima, P. A. G. (2011). Mannanoligosaccharides in diets for tilapia larvae. *Revista Brasileira de Zootecnia*, 40(12), 2634-2640.

Shearer, K. D. (1994). Factors affecting the proximate composition of cultured fishes with emphasis on salmonids. *Aquaculture*, 119(1), 63-88.

Staykov, Y., Spring, P., Denev, S., & Sweetman, J. (2007). Effect of a mannan oligosaccharide on the growth performance and immune status of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture International*, 15(2), 153-161.

Sweetman, J., Tort L, Torrecillas, S., Makol, A., Caballero, M. J., Montero, D., Robaina, L., Real, F., ... Izquierdo, M. S. (2007). Immune stimulation and improved infection resistance in European sea bass (*Dicentrarchus labrax*) fed mannan oligosaccharides. *Fish & Shellfish Immunology*, 23(5), 969-981.

Verschuere, L., Rombaut, G., Sorgeloos, P., & Verstraete, W. (2000). Probiotic bacteria as biological control agents in aquaculture. *Microbiology and Molecular Biology Reviews*, 64(4), 655-671.

Zhang, C.-N., Li, X.-F., Xu, W.-N., Jiang, G.-Z., Lu, K.-L., Wang, L.-N., ... Liu, W. B. (2013). Combined effects of dietary fructooligosaccharide and *Bacillus licheniformis* on innate immunity, antioxidant capability and disease resistance of triangular bream (*Megalobrama terminalis*). *Fish & Shellfish Immunology*, 35(5), 1380-1386.

Received on March, 18, 2016.
Accepted on July 26, 2016.

License information: This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.