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RESEARCH PAPER

Evaluating Two Different Additive Levels of Fully Autolyzed Yeast, *Saccharomyces cerevisiae*, on Rainbow Trout (*Oncorhynchus mykiss*) Growth Performance, Liver Histology and Fatty Acid Composition

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Abstract

This study examined the effects of fully autolyzed *Saccharomyces cerevisiae* (ASC) on rainbow trout (*Oncorhynchus mykiss*) growth performance, liver histology and fatty acid composition. 2700 rainbow trout (4.9 ±0.1 g mean weight) were acclimated to rearing conditions and then randomly divided into three groups of triplicate cages. Rainbow trout were feed with three different doses of ASC (0 (control), 1 ‰ and 2 ‰) for 70 days. At the end of the study, growth performance, liver histology, fatty acid composition and survival rate were determined. Feed conversion ratio was significantly decreased and specific growth rate was increased ($P<0.01$) on 2‰ ASC added group compared to other groups. No differences were observed among group's liver histology. Whole-body proximate composition showed no differences among groups ($P>0.05$) except in fat content, which was enhanced in both ASC groups compared to control ($P<0.05$). The fatty acid composition of fish fillets differed only marginally among the experimental groups. The muscles of fish fed the diets with ASC had a significantly decreased in 18:0 ($P<0.05$) and an increased in 15:1 ($P<0.01$) content compared to control groups. The content of n-3 fatty acids and DHA/EPA ratio were not affected by ASC addition. In conclusion, the results of the study indicate that 2‰ supplementation level of the ASC showed beneficial effects on the growth performance without affecting moisture, protein and ash content of rainbow trout.

Keywords: Autolyzed *Saccharomyces cerevisiae*, Rainbow Trout, Growth Performance, Fatty Acid Composition, Liver Histology.

Introduction

Trout is major cultured finfish species in Turkey and it has reached its maximum production in 2015 with 108090 tons. Moreover, trout production in Turkey is continually increasing in conjunction with developing technologies and their application onto fish farms. However, the higher disease susceptibility of the cultured organism due to deterioration of water quality and elevation of the other stressful conditions emerged even though the more intensification of fish production is achieved. (Bondand-Reantaso *et al*., 2005).

There are some limiting factors in aquaculture such as fish diseases, which is one of the main problem in aquaculture, and antibiotic practices are a common approach to resolve these problems (Austin and Austin, 1989). However the antibiotic usage have been limited in many countries due to increasing bacteria resistance against antibiotic and residues on the carcass (Smith *et al*., 1994). Likewise the existence of residues in aquaculture products menaces human health. Nowadays, the use of probiotics and prebiotics are being industrialized to control diseases and a wholesome microbial environment in aquaculture systems could sustain (Verschuere *et al*., 2000; Bachère 2003; Defoirdt *et al*., 2005, Apún-Molina *et al*., 2009).

Probiotic is defined as any microbial adjunct that has beneficial consequences on the host through an enhancement in the use of feed or by enhancing the host reaction to disease (Irianto and Austin, 2002; Kesarcodi-Watson *et al*., 2008; Abdel-Tawwab *et al*., 2008). There are some different probiotic species such as *Bifidobacterium* sp., *Lactobacillus* sp., *Enterococcus* sp., *Vibrio* sp., *Saccharomyces* sp.., and *Bacillus* sp, which are currently used in aquaculture (Kumar, Mukherjee *et al*., 20016).

Saccharomyces cerevisiae (Baker's yeast), contain numerous immunostimulant complexes such as chitin, β-glucan, mannan oligosaccharides and nucleic acids. All those natural products have the capability to improve growth performance of various fish species (Gopalakannan and Arul 2010).

Effects of nucleic acids or β-glucan in finfish were studied previously (Li and Gatlin, 2003; Wache *et al*., 2006; Chiu *et al*., 2010; Gopalakannan and Arul, 2010). In these investigations, some factors such as growth performance, disease resistance and blood immune response were reported. However, there is no published information regarding the effects of completely autolyzed *Saccharomyces cerevisiae* (ASC) on histological changes and fatty acid composition in rainbow trout tissues. Therefore, this study was performed to investigate the effect of dietary ASC on rainbow trout growth performance, fillet fatty acid composition and liver histology.

Materials and Methods

Diet Preparation

ASC was added to the commercial fish feed (Skretting) at two doses 1‰ and 2‰ served as treatments (Ustaoğlu Güven, 2010) (Table 1). The diet containing no supplementation was control and all these prepared feed was stored at 4^{o}C until they were used. The ASC was diluted into 1% sunflower oil, thoroughly homogenized and added to feed. The same volume of oil (without the ASC) was added to the control diet.

Fish and Feeding Trial

Juveniles rainbow trout (average individual weight of 4.9 ± 0.1 g) were provided from Experimental Animal Center of Kastamonu University, Turkey. The experiment was performed in Germeçtepe Dam Lake, in three replicates for each treatment, and two thousand and seven hundred fish were allocated into 2 m^3 fish cages (600 fish/cage) equally. The fish were fed with the experimental diets *ad- libitum* three times a day for 70 days. Throughout the experiment, water quality parameters were measured daily and as average dissolved oxygen was 7.41 ± 0.2 mg/L, temperature was 17.4 ± 0.1 °C, pH was 7.3 ± 0.2.

Histopathological Examination

Changes on liver histology of rainbow trout were examined on the 70th day of the experiment. 9 fish from each cage were euthanatized by overdose of MS-222 for organs collection at the end of the feeding trial. Organs were carefully removed, immediately fixed in a 10% buffered solution of formalin, dehydrated in a graded ethanol series, and embedded in paraffin. Sections were cut at 5 µm and stained with hematoxylin and eosin for light microscopic investigation. Inflammation, damage or regeneration of tissue, and nuclear position of organs sections were tested for general abnormalities (Hisar *et al*., 2002).

Proximate and Fatty Acid Composition

Crude protein, lipid, moisture and ash of the experimental feed and fish muscles were determined by methods as defined in A.O.A.C. (2000) methods. Determination of fatty acid composition of lipids from the fillet of rainbow trout tissues were maintained with a mixture of chloroform and methanol (2:1, v/v; (Folch *et al*., 1957) containing 0.01% BHT. Lipid extracts were stored at −20 °C prior to analysis. Fatty acid compositions of the fishes were determined according to Miller *et al*. (2007).

Growth Performance

At the end of the study, all fish in each tank were individually weighted, and 9 fish from each replicates were used to investigate production performance. Growth parameters were computed as follows: Feed Conversion Ratio (FCR) = feed intake (g) / weight gain (g) x 100. Specific Growth Rate (SGR) (% day-1) = 100 x [(ln final fish weight) – (ln initial fish weight)] / days fed. Feed Intake (FI) (%) = daily feed intake (g) x 100 / biomass (g) Protein Efficiency Ratio (PER) = wet body mass gain/crude protein intake (Wojno, 1977; Laird and Needham 1987; Fowler 1991) .

Statistics

Statistical analyses were performed using one-way ANOVA. For multiples comparisons of the means Tukey-Kramer HSD was used. All the results were treated significant at the 5% and 1% level. All statistical analysis was performed using the SPSS software version 17.

Results

The growth parameters, feed conversion rate and survival rate of the fish were presented in Table 2. No significant differences were observed on survival rate of different experimental groups.. The final

Table 1. Proximate composition of experimental feed. Values are provided as mean ± standard error

	Commercial Feed
Moisture (g kg^{-1})	9±0.24
Protein (g kg^{-1})	45±0.11
Fat (g kg^{-1})	20±0.23
Ash (g kg^{-1})	4.1±0.49
Cellulose	3.9±0.78

weights, specific growth rates and feed conversation ratio of fish fed feed with ‰ 2 ASC were significantly improved.

Histological analysis did not show any pathological changes on livers of the fish (Figure 1). Muscle proximate composition analysis (Table 3) also uncovered that, crude protein, moisture and ash were unaffected ($P<0.05$) in the trial. However the total

Table 2. Growth performance of fish fed experimental diets

	Diets		
	Basal Diet (Control)	Diet 1 (added ‰1 *S. cerevisae*)	Diet 2 (added ‰2 *S. cerevisae*)
Initial weight (gr)	4.96±0.10	4.88±0.10	4.88±0.10
Final weight (gr)	14.90±0.40^{a}	14.52±0.70^{a}	18.46±0.30^{b}
Feed conversion ratio (FCR)	1.20±0.10^{a}	1.22±0.10^{a}	0.86±0.09^{b}
Specific growth rate (% day^{-1})	1.90±0.10^{a}	1.88±0.10^{a}	2.22±0.09^{b}
Survival	87.50±8.80	70.00±6.60	86.67±10.60
Growth (%)	311.93±15.90^{a}	309.37±10.60^{a}	378.82±8.42^{b}

Values are provided as mean ± standart error (n=10). Values with different superscripts in horizontal row are significantly different ($P<0.05$).

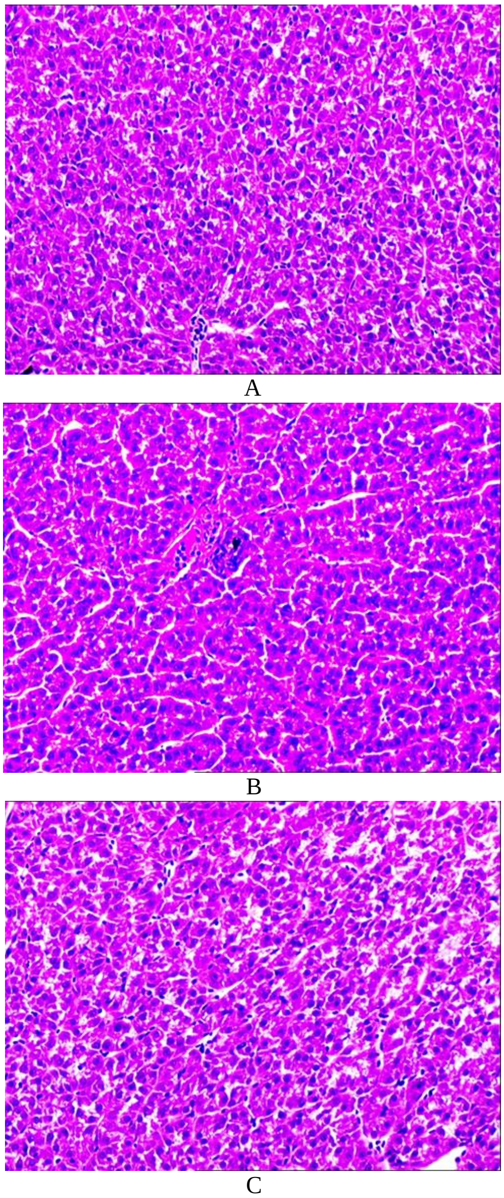

Figure 1. Histological findings in fish treated with different doses of ASC and control(A: Control B: ‰ 1 C: ‰ 2).

lipid level in fish fed with 1‰ and 2‰ ASC were significantly increased.

Fatty acids composition of fish muscles were (Table 4) slightly influenced by dietary treatments. Fatty acid 18:0 ($P<0.05$) was significantly decreased in all experimental groups compared to control and 15:1 ($P<0.01$) was significantly elevated in ‰2 ASC group. The totals of n-3 fatty acids did not differ among the three experimental groups and neither were any differences seen in total of n-6 fatty acids or in any other totals of fatty acids including saturated [SFA], monounsaturated [MUFA] and polyunsaturated [PUFA] fatty acids. Furthermore, rations of docosahexaenoic acid (22:6 n-3; DHA) to eicosapentaenoic acid (20:5 n-3; EPA) were also very similar and non-significant among the fish muscles.

Discussion

In the current study, ASC was tested as feed additive for growth and liver histology in rainbow trout. It was indicated that ASC added at 2‰ to fish feed was effective for positive growth promotion. However, any positive or negative effects of ASC have not been observed on liver histology. At this point, growth promotion may enable and render a better growth in the rainbow trout.

In recent years, in aquaculture, there has been great attention in the use of brewer's yeast as a probiotic owing to brewer’s yeast have been indicated to modulate intestinal microbiota and affect growth promotion positively in different fish species (Abdel-Tawwab *et al*., 2008; Hoseinifar *et al*., 2011; Goda *et al*., 2012). In the present study, fish fed diet with 2‰ level of ASC showed a significant decreasing on FCR and increasing SGR level even though dietary ASC supplementations did not significantly affect survival rate. The improved growth and feed utilization observed in the present study are in agreement with those reported by Diab *et al*. (2006), who fed Nile

Table 3. Proximate composition of whole-body rainbow trout fed with experimental diets for 70 days. Values are provided as mean ± standard error (n=10 per treatment). Values with different superscripts in row are significantly different ($P<0.05$)

	Diets		
	Basal Diet (Control)	Diet 1 (added ‰1 *S. cerevisae*)	Diet 2 (added ‰2 *S. cerevisae*)
Moisture (g kg^{-1})	73.02±0.10	71.67±0.09	72.19±0.51
Protein (g kg^{-1})	19.87±0.10	19.98±0.10	19.78±0.03
Fat (g kg^{-1})	4.78±0.10^{a}	6.79±0.07^{b}	6.16±0.41^{b}
Ash (g kg^{-1})	2.33±0.10	2.29±0.06	2.27±0.04

Table 4. Percentage of fatty acids of fillets of fish fed diets with the different doses of *S. cerevisae*. 10 fillets were analyzed in each of the three group’s replicates. Standard deviations are indicated following average values. Statistical differences among the groups are indicated at level of $P<0.05$ (*) or $P<0.01$(**)

	Diets		
	Basal Diet (Control)	Diet 1 (added ‰1 *S. cerevisae*)	Diet 2 (added ‰2 *S. cerevisae*)
C14:0	1.30±0.12	1.24±0.15	1.23±0.17
C14:1	1.25±0.02	0.23±0.01	0.21±0.01
C15:1	0.11±0.03	1.61±0.02	2.01±0.03**
C16:0	19.33±0.28	19.27±0.30	19.13±0.27
C16:1	1.17±0.12	1.06±0.11	1.12±0.11
C17:0	0.34±0.03	0.29±0.02	0,31±0.02
C17:1	0.01±0.00	0.25±0.02	0.33±0.03
C18:0	5.50±0.15*	4.50±0.12	4.81±0.14
C18:1n9c+t	9.83± 0.73	8.50±0.61	8.48±0.62
C18:2n6c	6.27±0.40	5.10±0.22	4.76±0.32
C18:3n3	1.50±0.10	1.53±0.15	1.31±0.13
C20:1n9	0.94±0.20	0.69±0.15	0.74±0.18
C20:3n3+ 3n6	1.33±0.21	1.31±0.19	1.39±0.21
C20:4n6	0.72±0.22	0.54±0.21	0.49±0.21
C20:5n3	6.86±0.35	6.93±0.36	7.09±0.38
C22:1n9	0.00±0.00	0.28±0.05	0.42±0.20
C22:6n3	42.24±1.94	46.08±2.03	45.43±1.82
Σ SFA	26.47±0.32	25.29±0.33	25.48±0.32
Σ MUFA	14.62±0.72	13.21±0.61	14.04±0.62
Σ PUFA	58.91±0.38	61.50±0.20	60.48±0.32
DHA/EPA	6.15±0.05	6.65±0.07	6.40±0.05

tilapia diets supplemented with *Echinacea purpurea*, *Origanum dictamnus* and *Saccharomyces cerevisiae* ; Peng and Gatlin III (2003) fed hybrid striped bass diet with *Saccharomyces cerevisiae*; Noh *et al*. (1994) fed Israeli carp diets supplemented with antibiotics, enzymes, yeast culture and probiotics; Pooramini *et al*. (2009) fed rainbow trout diet with *Saccharomyces cerevisiae* and Goda *et al*. (2012) fed Nile tilapia with *Saccharomyces cerevisiae* found that increased growth performance and feed utilization efficiency. In contrast, Günter and Jimenez-Montealegre (2004) found that *Bacillus subtilis* added in the feed does not improve growth of tilapia, in fact an adverse effect was reported.

The increased fish growth in the experimental group may possibly be due to many different factors. According to some authors, the beneficial effect of the probiotics were related with improved gut morphology and/or or stimulated production of some enzymes on the intestinal tract (Heidarieh *et al*. 2012; De Schrijver and Ollevier, 2000; Lara-Flores *et al*. 2003; Günter and Jimenez-Montealegre, 2004). On the other hand, Barnes *et al*. (2006) reported that some essential and non-essential amino acids in yeast, *Saccharomyces cerevisiae*, were frequently accountable for increasing the palatability of fish food items. Another important factor is that the proteolytic activity of the probiotic bacterium that stimulate and/or produce some enzymes on the intestinal tract (Heidarieh *et al*. 2012). Turbot (*Scophthalmus maximus*), fed with *Vibrio proteolyticus*-based diet, showed enhanced protein digestibility and improved growth. Our study is in line with those results.

No significant differences were observed in crude protein, moisture and ash of muscle in fish fed with different doses of ASC are in line with the outcomes of Kobeisy and Hussein (1995), Oliva-Teles and Goncalves, (2001) and Fournier *et al*. (2002), who reported that muscle composition was not affected by dietary yeast. However the yeast supplementation significantly affected the fat deposition in the fish body. These results suggest that ASC supplementations act in increasing feed intake with a subsequent enhancement of fat deposition on fish body composition.

Henderson (1996), suggested that monounsaturated fatty acids are preferred for energy production in fish.. The significantly lower fraction of 18:0 in the muscle of fish fed diets with ASC compare to control could possibly be related to higher energy needs for enhanced growth, development of cells and tissues, and concomitant increases in combustion of this fatty acid. Further, it was also determined that the relative content of the important n-3 fatty acids tended to decline as lipid deposition increased in the muscle of fish fed diets with ASC. However, although only minor changes in the fatty acid composition of the trout muscles were identified, the present study did not present any differences in total of SFA, MUFA or PUFA.

In conclusion, the present study designates that ASC positively enhanced growth performance and feed utilization without affecting moisture, protein and ash content, and fatty acid composition, and liver histology of rainbow trout when applied at the dose of 2‰. The ASC could be used as a new probiotic in rainbow trout industry of Turkey.

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References

Abdel-Tawwab, M., Abdel-Rahman, M.A., Nahla-Ismael, E.M. 2008. Evaluation of commercial live bakers' yeast, *Saccharomyces cerevisiae* as a growth and immunity promoter for Fry Nile tilapia, *Oreochromis niloticus* (L.) challenged in situ with Aeromonas hydrophila. Aquaculture., 280: 185–189. doi:10.1016/j.aquaculture.2008.03.055

AOAC International, 2000. Association of Official Analytical Chemists. Official Methods of Analysis (17th ed.).Washington DC. 2200 pp.

Apun-Molina J.P., Miranda A.S., Gonzalez A.L., Martinez-Diaz S.F., Rojas-Contreras, M. 2009. Effect of potential probiotic bacteria on growth and survival of tilapia *Oreochromis niloticus* L., cultured in the laboratory under high density and sub-optimum temperature. Aquaculture Research, 40:887–894. DOI: 10.1111/j.1365-2109.2009.02172.x

Austin, B and Austin, D.A. 1989. Methods for the microbiological examination of fish and shellfish. Chichester: Ellis Horwood.

Bache`re, E. 2003. Anti-infectious immune effectors in marine invertebrates: potential tools for disease control in larviculture. Aquaculture, 227:427–438. doi.org/10.1016/S0044-8486(03)00521-0

Barnes, M.E., Durben, D.J., Reeves, S.G., Sanders, R. 2006. Dietary yeast culture supplementation improves initial rearing of McConaughy strain rainbow trout. Aquacult. Nutr., 12: 388–394. DOI: 10.1111/j.1365-2095.2006.00439.x

Bondad-Reantaso, M., Subasinghe, R.P., Arthur, J.R., Ogawa, K., Chinabut, S., Adlard, R.,

Tan, Z., Shariff, M. 2005. Disease and health management in Asian aquaculture. Vet.

Parasitology, 132: 249–272. doi.org/10.1016/j.vetpar.2005.07.005

Chiu, CH., Cheng, C.H. Gua, WR., Guu, Y.K., Cheng, W. 2010. Dietary administration of the probiotic. *Saccharomyces cerevisiae* P13. enhanced the growth innate immune responses and disease resistance of the grouper. *Epinephelus coioides*. Fish and Shellfish Immunology, 29(6):1053-9. doi:10.1016/j.fsi.2010.08.019

Defoirdt, T., Bossier, P., Sorgeloos, P., Verstraete, W., 2005. The impact of mutations in the quorum sensing systems of *Aeromonas hydrophila*, *Vibrio* *anguillarum*, and *Vibrio harveyi* on their virulence towards gnotobiotically cultured Artemia franciscana. Environ. Microbiol, 7:1239–1247. DOI: 10.1111/j.1462-2920.2005.00807.x

De Schrijver, R. and Ollevier, F. 2000. Protein digestion in juvenile turbot (*Scophthalmus maximus*) and effects of dietary administration of *Vibrio proteolyticus*. Aquaculture, 186:107–116. doi:10.1016/S0044-8486(99)00372-5

Diab, A.S., Abdel-Hadi, Y.M., Ahmed, M.H., Saber, S.F., Aboel-Atta, M.E. 2006. Out-doorstudy on the use of Echinacea (*Echinacea purpurea*), Marjoram (*Origanum dictamnus*) and yeast (*Saccharomyces cerevisiae*) as feed additives for *Oreochromis niloticus*. Egypt. J. Agric. Res. 84 (18): 537–551.

Fowler, L.G., 1991. Poultry by-product meal as a ditary protein Sources in fall chinook salmon diets. Aquaculture, 99:309-321. doi:10.1016/0044-8486(91)90251-2

Fournier, V., Gouillou-Coustans, M. F.; Metailler, R., Vachot, C., Moriceau, J., Le Delliou, H., Huelvan, C., Desbruyeres, E., Kaushik, S. J. 2002. Nitrogen utilization and ureogenesis as affected by dietary nucleic acid in rainbow trout (*Oncorhynchus mykiss*) and turbot (*Psetta maxima*). Fish Physiol. Biochem. 26:177–188. DOI: 10.1023/A:1025465603604.

Goda, A.M.A., Mabrouk, H.A.H., Wafa, M.A.E., Afifi, T.M. 2012. Effect of Using Baker's Yeast and Exogenous Digestive Enzymes as Growth Promoters on Growth, Feed Utilization and Hematological Indices of Nile tilapia, *Oreochromis niloticus* Fingerlings. Journal of Agricultural Science and Technology. B12: 15-28.

Gopalakannan A. and Arul V. 2010. Enhancement of the innate immune system and disease-resistant activity in *Cyprinus carpio* by oral administration of β-glucan and whole cell yeast. Aquaculture Research. 41:884e92. DOI: 10.1111/j.1365-2109.2009.02368.x

Günther, J. and Jimenez-Montealegre, R. 2004. Effect of the probiotic Bacillus subtilis on the growth and food utilization of tilapia (*Oreochromis niloticus*) and prawn (*Macrobrachium rosenbergii*) under laboratory conditions. Revista de biologia tropical, 52(4):937-943.

Heidarieh, M., Mirvaghefi, A. R., Akbari, M., Farahmand, H., Sheikhzadeh, N., Shahbazfar, A. A., Behgar, M. 2012. Effect of dietary Ergosan on growth performance, digestive enzymes, intestinal histology, hematological parameters and body composition of rainbow trout (*Oncorhynchus mykiss*). Fish physiology and biochemistry, 38(4): 1169-1174. DOI: 10.1007/s10695-012-9602-8

Henderson, R. J. 1996. Fatty acid metabolism in freshwater fish with particular reference to polyunsaturated fatty acids. Arch. Anim. Nutr. 49: 5–22. DOI: 10.1080/17450399609381859

Hisar, O., Yanik, T., Hisar, S. A., 2002. Clinical and pathological investigation of Psychrobacter immobilis infection in rainbow trout (Oncorhynchus mykiss, Walbaum). The Israeli Journal of Aquaculture – Bamidgeh, 54(4): 189-196. http://hdl.handle.net/10524/19062

Hoseinifar, S.H., Mirvaghefi, A., Merrifield, D.L. 2011. The effects of dietary inactive brewer's yeast *Saccharomyces cerevisiae* var. ellipsoideus on the growth, physiological responses and gut microbiota of juvenile beluga (*Huso huso*). Aquaculture, 318:90–94. doi:10.1016/j.aquaculture.2011.04.043

Irianto. A.. Austin. B. 2002. Use of probiotics to control furunculosis in rainbow trout. *Oncorhynchus mykiss* (Walbaum). J. Fish Dis. 25:333–342. DOI: 10.1046/j.1365-2761.2002.00375.x

Kesarcodi-Watson. A.. Kaspar. H.. Josie Lategan. M.. Gibson. L. 2008. Probiotics in aquaculture: the need. principles and mechanisms of action and screening processes. Aquaculture, 274:1–8. doi:10.1016/j.aquaculture.2007.11.019

Kobeisy, M. A. and Hussein, S. Y. 1995. Influence of dietary live yeast on growth performance and some blood constituents in Oreochromis nileoticus. Proc. 5th Scientific Conference of Animal Nutrition, Ismailia, Egypt, 1 Dec. 1995, pp. 417–425.

Kumar R, Mukherjee SC, Ranjan R, Nayak SK. 2008. Enhanced innate immune parameters in Labeo rohita (Ham.) following oral administration of *Bacillus subtilis*. Fish Shellfish Immunol, 24:168e72. http://dx.doi.org/10.1016/j.fsi.2007.10.008

Laird, L.M. and Needham, T. 1987. Salmon and Trout Farming. Ellis Horword Limited, Haslet Pres: a division of John Wiley & Sons, New York-Chichester- Brisbane-Toronto, 15 pp.

Lara-Flores, M., Olvera-Novoa, M.A., Guzman-Méndez, B.E., López- Madrid, W. 2003. Use of the bacteria Streptococcus faecium and Lactobacillus acidophilus, and the yeast *Saccharomyces cerevisiae* as growth promoters in Nile tilapia (*Oreochromis niloticus*). Aquaculture, 216: 193–201. doi:10.1016/S0044-8486(02)00277-6

Li P. Gatlin DM. 2003. Evaluation of brewers yeast (*Saccharomyces cerevisiae*) as a feed supplement for hybrid striped bass (*Morone chrysops M. saxatilis*). Aquaculture. 219:681e92. doi:10.1016/S0044-8486(02)00653-1

Miller, M.R., Nichols, P.D., Carter, C.G. 2007. Replacement of dietary fish oil for Atlantic salmon parr (*Salmo salar* L.) with a stearidonic acid containing oil has no effect on omega-3 long-chain polyunsaturated fatty acid concentrations. Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology, 146(2): 197–206. doi:10.1016/j.cbpb.2006.10.099

Noh, H., Han, K.I., Won ,T.H., Choi Y.J. 1994. Effect of antibiotics, enzymes, yeast culture and probiotics on the growth performance of Israeli carp. Korean Journal of Animal Science, 36: 480-486.

Oduleye, S. O. 1982. Growth and growth regulation in the cichlids. Aquaculture, 27(3):301-306. doi:10.1016/0044-8486(82)90065-5

Oliva-Teles, A. and Goncalves, P., 2001. Partial replacement of fishmeal by brewer's yeast (*Saccaromyces cerevisae*) in diets for sea bass (*Dicentrarchus labrax*) juveniles. Aquacult. 202: 269–278. doi:10.1016/S0044-8486(01)00777-3

Peng, Li, DelbertM. Gatlin III, 2003. Evaluation of brewer's yeast (*Saccharomyces cerevisiae*) as a feed supplement for hybrid striped bass (*Morone chrysops*×*M. saxatilis*). Aquaculture, 219: 681–692. doi:10.1016/S0044-8486(02)00653-1

Pooramini, M., Kamali, A., Hajimoradloo, A., Alizadeh, M., Ghorbani, R. 2009. Effect of using yeast (*Saccharomyces cerevisiae*) as probiotic on growth parameters, survival and carcass quality in rainbow trout Oncorhynchus mykiss fry. International Aquatic Research, 1(1): 39-44.

Smith, J.L., Zaluzec, E.Z., Wery, J.P., Niu, L., Switzer, R.L., Zalkin, H., Satow, Y. 1994. Structure of the allosteric regulatory enzyme of purine biosynthesis. Science, 264(5164):1427-33

Ustaoğlu Güven, A. 2010. Gökkuşağı alabalığı rasyonlarına maya otolizatı ilavesinin performans, bazı kan parametreleri ve lizozim aktivitesi üzerine etkisi. Ankara Üniversitesi, Doktora Tezi, Ankara.

Verschuere, L., Rombaut, G., Sorgeloos, P., Verstraete, W., 2000. Probiotic bacteria as biological control agents in aquaculture. Microbiol. Mol. Biol. Rev. 64:655–671. doi: 10.1128/MMBR.64.4.655-671.2000

Wache Y. Auffray F. Gatesoupe FJ. Zambonino J. Gayet V. Labbe L. 2006. Cross effect of the strain of dietary *Saccharomyces cerevisiae* and rearing condition on the onset of intestinal microbiota and digestive enzymes in rainbow trout. *Oncorhynchus mykiss*. fry. Aquaculture, 258:470e8. doi:10.1016/j.aquaculture.

Wojno, T., 1977. Evaluation of the Feeding Value of Palish Feeds and Ewas Feed For Fry of Rainbow Trout (*Oncorhynchus mykiss*). Roczniki Nauk Rolniezych, Seria 11:(98)-2.