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Evaluation of brewers yeast (*Saccharomyces cerevisiae*) as a feed supplement for hybrid striped bass (*Morone chrysops*×*M. saxatilis*)

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Abstract

Two separate feeding trials were conducted to evaluate graded levels of dried brewers yeast in the diet of hybrid striped bass. A basal diet was formulated to contain 40% protein, 10% lipid and an estimated digestible energy level of 3.5 kcal/g. In Trial 1, three incremental levels of dried brewers yeast (1%, 2% and 4% of diet) were added to the basal diet in place of cellulose. In Trial 2, the same levels of brewers yeast were added to the basal diet, but menhaden fish meal and menhaden oil were adjusted to provide isonitrogenous and isolipidic diets. Each diet was fed to three (Trial 1) or four (Trial 2) replicate groups of juvenile hybrid striped bass twice daily at rates approximating apparent satiation for 6 or 8 weeks. After the second feeding trial, a *Streptococcus iniae* bath challenge was executed to test the effects of diet on disease resistance.

Enhanced weight gain and feed efficiency were generally observed in fish fed the diets supplemented with yeast compared to the basal diet in both trials. In the second trial, body composition of whole fish, hemocrit and serum lysozyme levels were observed to be within normal ranges and not influenced by the various dietary treatments. After 9 weeks of feeding in the second trial, exposure to *S. iniae* resulted in no mortality and reduced signs of disease in fish fed diets supplemented with 2% and 4% brewers yeast, while 20% mortality was observed in fish fed the control diet ($P=0.1$).

In the second trial, blood neutrophil oxidative radical production, extracellular and intracellular superoxide anion production of head kidney macrophages and serum lysozyme were measured after 16 weeks of feeding each diet. Fish fed the diet with 2% brewers yeast were found to have significantly ($P<0.01$) higher blood neutrophil oxidative radical and extracellular superoxide anion production of head kidney macrophages than control fish. However, no significant differences in intracellular superoxide anion and serum lysozyme were observed among the treatments.

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Based on the result of this study, it is concluded that brewers yeast positively influenced growth performance and feed efficiency of hybrid striped bass as well as resistance to *S. iniae* infection. In addition, results of immune response assays demonstrate that brewers yeast can be administered for relatively long periods without causing immunosuppression.

Keywords: Hybrid striped bass; Brewers yeast; *Saccharomyces cerevisiae*; Immune response; Bacterial resistance; *Streptococcus iniae*

1. Introduction

Hybrid striped bass production is considered to be the fastest growing segment of the U.S. aquaculture industry over the past decade and is poised to become a global seafood delicacy in the 21st century (Harrell and Webster, 1997; Kohler 2000). However, one major constraint to hybrid striped bass aquaculture is suboptimal production efficiency stemming from intrinsically high sensitivity to various stressors and susceptibility to infectious agents during normal aquacultural production. Although viral diseases are not a primary threat to fish culture activity thus far, heavy economic loss may be caused by other pathogenic organisms, including bacteria, fungus and protozoan ectoparasites (Kohler, 2000).

In recent years, there have been growing concerns about the adverse effects of the bacterium *Streptococcus iniae* in the aquaculture of many economically important marine and freshwater fish species including rainbow trout (Eldar and Ghittino, 1999), Nile tilapia (Bowser et al., 1998), hybrid tilapia (Perera et al., 1997), yellowtail (Kaige et al., 1984), Japanese flounder (Nguyen et al., 2001a,b), hybrid striped bass (Sealey and Gatlin, 2002a), red drum (Eldar et al., 1999; Colorni et al., 2002), rabbitfish *Siganus* (Yuasa et al., 1999) and even wild fishes (Colorni et al., 2002). This bacterium may cause heavy losses from mortality, reduced growth and unmarketable appearance in various fish species. Unfortunately, hybrid striped bass is one of the most susceptible fish to *S. iniae* infection. *S. iniae* is also associated with acute cellulitis in humans. Although some reports suggest that the fish and human *S. iniae* might be genetically different (Dodson et al., 1999), all reported occurrences of the human disease were associated with puncture wounds or abrasions and handling of infected fish or contaminated water (Greenlees et al., 1998). Therefore, an effective preventive strategy is not only needed to limit economical loss in aquaculture, but also to protect the health of aquaculturists and fish processing workers.

In aquaculture, traditional methods for treating infective pathogens include a limited number of government-approved antibiotics and chemotherapeutics. However, the disadvantages such as marginal effectiveness and high cost are obvious (Sealey and Gatlin, 2001). These treatments also may cause the accumulation of chemicals in the environment and/or fish, thus posing potential threats to consumers and the environment. An alternative strategy, besides vaccine development, is nutritional modulation of immune responses and disease resistance of aquaculture species. Research on the subject of nutritional modulation, especially evaluation of natural extracts or synthetic compounds, which may enhance the immune responses and disease resistance of hybrid striped bass, is still in

its infancy. In the United States, because there is no therapeutic approved by the U.S. Food and Drug Administration specifically for hybrid striped bass, research on this topic is of special urgency.

Yeast by-products from the brewing industry are natural diet additives that have been shown to positively influence non-specific immune responses (Siwicki et al., 1994; Anderson et al., 1995) as well as growth (Rumsey et al., 1991; Oliva-Teles and Goncalves, 2001) of some fish species. However, yeast products have not been investigated with hybrid striped bass. In addition, doses and time of administration have been recognized to have important effects on immunostimulant function, and efficacy of oral administration of immunostimulants has been reported to decrease over time (Sakai, 1999). The present study was conducted to determine the effects of graded levels of brewers yeast *Saccharomyces cerevisiae* on growth performance, body composition and resistance to *S. iniae* infection in hybrid striped bass. In addition, the efficacy of long-term oral administration of brewers yeast was explored by comparing various immune responses.

2. Materials and methods

2.1. Experiment 1

An initial feeding trial was conducted to evaluate growth performance of hybrid striped bass fed graded levels of brewers yeast. The basal diet of Keembiyehetty and Gatlin (1997), which utilized menhaden meal as the protein source, was modified to contain 40% protein, 10% lipid and an estimated digestible energy level of 3.5 kcal/kg (Table 1). This diet satisfied and/or exceeded all known nutrient requirements of hybrid striped bass (Gatlin, 1997) or other warmwater fishes (National Research Council, 1993). Dried brewers yeast (Brewtech®) was supplied by International Ingredient Corporation (St. Louis, MO, USA). Three incremental levels (1%, 2% and 4% of diet) were added to the control diet in place of cellulose. Procedures for diet preparation and storage were as previous described (Rawles and Gatlin, 1998).

Juvenile hybrid striped bass (*Morone saxatilis* × *M. chrysops*) were obtained from a commercial supplier (Keo Fish Farm, Keo, AR) and maintained indoors at the Texas A&M University Aquacultural Research and Teaching Facility prior to the feeding trial. Fish were then graded by size and groups of 10 fish with a total weight of 253 ± 5 g/group were stocked into 110-l aquaria. The basal diet was fed to all fish in 110-l aquaria during a 1-week conditioning period. Water flow rate were maintained at approximately 650 ml/min via a recirculating system, which maintained water quality through mechanical and biological filtration (Sealey and Gatlin, 2002a). Salinity was maintained at 2.5–3.5 ‰ using well water and synthetic sea salt (Fritz Industries, Dallas, TX, USA). Low-pressure electrical blowers provided aeration via air stones and maintained dissolved oxygen (DO) levels at or near saturation. Water temperature was at 26 ± 1 °C throughout the trial and a 12-h light:12-h dark photoperiod was maintained with fluorescent lights controlled by timers.

Each diet was fed to fish in triplicate groups at 3% of body weight daily, except during the last week of the trial, in which feeding rate reduced to 2.5% of body weight. The

Table 1
Composition of experimental diets in Experiment 1

Constituent	Basal diet	Yeast supplementation (%)		
		1	2	4
Ingredient (% dry weight)				
Menhanden fish meal[a]	59.0	59.0	59.0	59.0
Dextrin[b]	22.5	22.5	22.5	22.5
Menhaden oil[a]	3.7	3.7	3.7	3.7
Mineral premix[c]	3.0	3.0	3.0	3.0
Vitamin premix[c]	4.0	4.0	4.0	4.0
Carboxymethyl cellulose[b]	2.0	2.0	2.0	2.0
Cellulose[b]	5.8	4.8	3.8	1.8
Brewers yeast[d]	0	1	2	4
Proximate analysis (% dry matter)				
Dry matter	88.5	92.6	92.4	92.5
Crude protein ($N \times 6.25$)	39.8	40.8	40.7	42.1
Crude lipid	11.2	10.4	10.8	10.4
Ash	14.2	14.0	14.5	14.4

[a] Omega Protein, Reedville, VA. Menhaden fish meal contained 67.8% protein and 10.7% lipid at a dry-weight basis.
[b] US Biochemical, Cleveland, OH.
[c] Same as Gaylord and Gatlin (2000).
[d] International Ingredient Corporation, St. Louis, MO. Brewers yeast contained 50.7% crude protein and 2% crude lipid (dry-weight basis).

feeding trial was conducted for 6 weeks. Group weights of fish in each aquarium were obtained weekly and feed amounts adjusted accordingly. At the end of both feeding trials, three representative fish from each aquarium were anesthetized with tricaine methane sulfonate (MS-222), and approximately 0.5 ml of blood was collected from the caudal vasculature using a 1-ml syringe and 27-gauge needle for hematocrit determination.

2.2. Experiment 2

The second feeding trial was conducted to further evaluate growth responses of hybrid striped bass fed graded levels of brewers yeast as well as some of their immune responses. The basal diet formulation was the same as one in Experiment 1. Three incremental levels of dried brewers yeast (1%, 2% and 4% of diet) were added to the basal diet and cellulose, menhaden meal and menhaden oil were adjusted to provide isonitrogenous and isolipidic diets (Table 2).

Prior to initiation of this feeding trial, juvenile hybrid striped bass obtained from Keo Fish Farm were subjected to a 2-week conditioning period to adjust to standardized regimes in a recirculating culture system consisting of 38-l aquaria (Gaylord and Gatlin, 2000). Water was maintained in the system at 25 ± 1 °C and was provided to each aquarium at a rate of 500 ml/min. Salinity was maintained to 1.5–2‰. Optimal water quality (DO ≥ 6 mg/l, total ammonia nitrogen ≤ 0.3 mg/l) was maintained by biofiltration and aeration as in Experiment 1. Groups of 15 juvenile hybrid striped bass weighing

Table 2
Composition of experimental diets in Experiment 2

Constituent	Basal diet	Yeast supplementation (%)		
		1	2	4
Ingredient (% dry weight)				
Menhanden fish meal[a]	57.9	57.2	56.4	55.0
Dextrin[b]	24.9	25.1	25.0	24.9
Menhaden oil[a]	2.4	2.4	2.5	2.7
Mineral premix[c]	3.0	3.0	3.0	3.0
Vitamin premix[c]	4.0	4.0	4.0	4.0
Carboxymethyl cellulose[b]	2.0	2.0	2.0	2.0
Cellulose[b]	5.8	5.3	5.1	4.4
Brewers yeast[d]	0	1.0	2.0	4.0
Proximate analysis (% dry matter)				
Dry matter	89.6	88.5	88.6	88.8
Crude protein ($N \times 6.25$)	40.4	40.5	40.7	40.7
Crude lipids	9.6	9.0	9.5	9.2
Ash	14.2	14.4	14.4	14.2

[a] Omega Protein, Reedville, VA. Menhaden fish meal contained 69% protein and 13.2% lipid at a dry-weight basis.

[b] US Biochemical, Cleveland, OH.

[c] Same as Gaylord and Gatlin (2000).

[d] International Ingredient Corporation, St. Louis, MO. Brewers yeast contained 50.7% crude protein and 2% crude lipid (dry-weight basis).

approximately 9.7 g/fish were stocked into individual aquaria such that initial weight averaged 142 ± 5 g/group. Each experimental diet was fed to four replicate groups of fish for 8 weeks. All groups were fed their respective diets at the same fixed rate (initially 5% of body weight per day and gradually reduced to 3%). This rate was adjusted each week to maintain a level approaching apparent satiation. Fish were fed in the morning and evening, 7 days each week. Growth and feed efficiency were monitored weekly by collectively weighing each group of fish.

At the end of this feeding trial, three representative fish from each aquarium were anesthetized with MS-222, and blood collected as previously described for Experiment 1. After a sample of whole blood was taken for hematocrit determination, serum was isolated by centrifugation ($3000 \times g$ for 5 min) and kept at -80 °C for lysozyme assay (Engstad et al., 1992). After bleeding, the fish were frozen for whole body composition analysis (Rawles and Gatlin, 1998).

An additional 30 fish previously fed each of the experimental diets for a total of 9 weeks were exposed to an estimated LD_{50} dose of *S. iniae*. A virulent isolate of *S. iniae* originally obtained from the brain of an infected tilapia (*Oreochromis* sp.) was biochemically identified and provided by the Texas Veterinary Medicine Diagnostic Laboratory. The bacterial suspension was prepared according to the method described by Sealey and Gatlin (2002b) and diluted to a concentration of 2.6×10^5 CFU/ml in fresh well water. Thirty fish from each dietary treatment, pooled separately in mesh baskets, were immersed in the bacterial suspension for 2 h. After bacterial exposure, the 30 fish from each dietary

treatment were divided into three groups of 10 and placed into 38-l aquaria in an isolated culture system that received a constant supply of well water at 25 ± 1 °C. Fish continued to be fed their respective diets to apparent satiation twice daily and mortality was monitored for 2 weeks. The brains of dead fish were streaked on modified selective agar (Nguyen and Kanai, 1999) to confirm death from *S. iniae*.

After the second feeding trial and diseases challenge, additional fish continued to be fed each experimental diet to apparent satiation for a total of 16 weeks. After this extended feeding trial period, four fish from each treatment were bled from the caudal vasculature. Neutrophil oxidative radical production was determined following the procedure described by Siwicki et al. (1994). Absorbance was converted to Nitro Blue Tetrazolium (NBT) units based on a standard curve of NBT diformazan per milliliter of blood. Serum samples were separated as described above for lysozyme assay (Engstad et al., 1992). Also, after 16 weeks, eight fish per treatment were euthenized and head kidney samples were taken for macrophage isolation and assay of extracellular and intracellular superoxide anion. This assay followed the procedure of Sealey and Gatlin (2002a). The amount of extracellular superoxide anion was calculated from the formula: nmol superoxide anion/well=(Δabsorbance after 60 min × 100)/6.3 (Pick and Mizel, 1981).

Data from both feeding trials and the bacterial challenge were subjected to analysis of variance and Duncan's multiple range test using the Statistical Analysis System (SAS, 1985). Differences in treatment means were considered significant at $P < 0.05$.

3. Results

3.1. Experiment 1

In Experiment 1, hybrid striped bass fed the diets supplemented with 1% and 2% Brewtech dried brewers yeast had up to 20% more weight gain compared to fish fed the basal diet during the course of the feeding trial (Table 3). However, fish fed the diet supplemented with 4% brewers yeast had weight gain similar to fish fed the basal diet and

Table 3
Performance of hybrid striped bass fed diets containing various amounts of dried brewers yeast for 6 weeks in Experiment 1[a]

Dietary brewers yeast (%)	Weight gain (% of initial weight)[b]	Feed efficiency (g gain/g feed)	Survival (%)	Hematocrit (%)
0	86	0.41	85	37.7
1	104	0.54	96.7	44.4
2	98	0.51	93.3	39.3
4	85	0.48	100	37.6
$Pr>F$[c]	0.26	0.15	0.24	0.28
Pooled se	8.51	0.038	3.97	5.23

[a] Values represent means of three replicate groups except the basal diet that had two replicate groups.
[b] Fish initially averaged 25.3 g.
[c] Significance probability associated with the *F* statistic.

Table 4
Performance of hybrid striped bass fed diets containing various amounts of dried brewers yeast for 8 weeks in Experiment 2[a]

Dietary brewers yeast (%)	Weight gain (% of initial weight)[b]	Feed efficiency (g gain/g feed)	Survival (%)	Hematocrit (%)	Lysozyme (10^3 units/l)
0	396	0.91	98.3	44.6	939
1	418	0.96	98.3	49.4	811
2	388	0.93	98.3	44.1	811
4	413	0.93	93.3	45.8	712
$Pr>F$[c]	0.10	0.19	0.24	0.36	0.50
Pooled se	8.14	0.013	3.97	2.08	165

[a] Values represent means of four replicate groups.
[b] Fish initially averaged 9.7 g.
[c] Significance probability associated with the F statistic.

responses of fish fed the various diets were not significantly different. One replicate group of fish fed the control diet also was excluded from analysis because of mortality experienced during weighing due to toxicity from net disinfectant. Survival and hematocrits of fish in all other replicates were high and not affected by diet (Table 3).

3.2. Experiment 2

In Experiment 2, weight gain, feed efficiency and survival of fish fed all experimental diets were excellent (Table 4). In this experiment, however, dietary effects on weight gain tended to be significant at $P<0.1$, and fish fed the diets with 1% and 4% brewers yeast had the highest gain. Hematocrits of fish fed the various diets were not significantly affected by diet (Table 4). Serum lysozyme was highly variable in hybrid striped bass in Experiment 2 (Table 4), with no significant effects of dietary yeast supplementation observed. Whole body composition of hybrid striped bass was not significantly affected by the dietary supplementation of brewers yeast in Experiment 2 (Table 5).

Table 5
Body composition of hybrid striped bass fed diets containing various amounts of dried brewers yeast for 8 weeks in Experiment 2[a]

Dietary brewers yeast (%)	Moisture (%)	% Fresh weight		
		Protein	Lipid	Ash
0	68.9	17.1	8.4	4.1
1	69.2	17.2	7.8	4.3
2	68.1	17.6	7.8	4.5
4	69.4	17.1	8.3	4.2
$Pr>F$[b]	0.512	0.057	0.516	0.250
Pooled se	0.14	0.37	0.16	0.064

[a] Values represent means of composite samples of three fish from each of four replicate groups except the basal diet and 2% brewers yeast supplementation group that had three replicate groups.
[b] Significance probability associated with the F statistic.

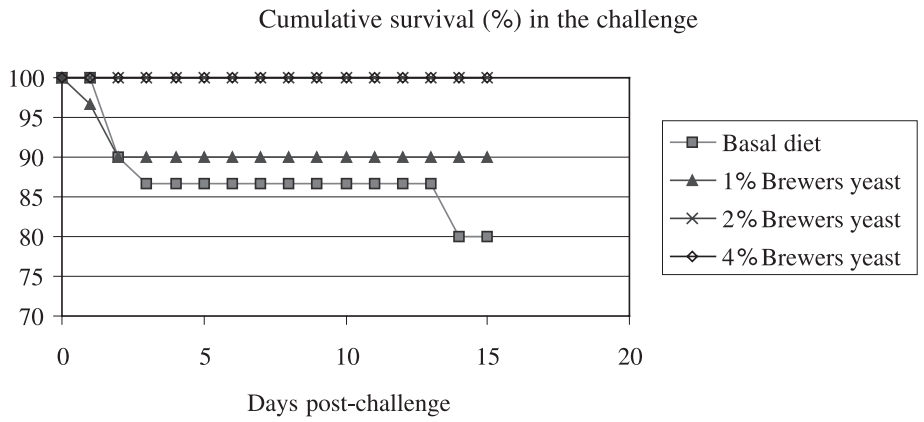

Fig. 1. Percent cumulative survival of hybrid striped bass fed incremental levels of brewers yeast (1%, 2% and 4%) for 9 weeks and subsequently exposed to *S. iniae* bath ($P = 0.1$). Symbols represent means of three replicate tanks per treatment. Pooled S.E. was 5.77.

3.3. S. iniae challenge

The controlled exposure of hybrid striped bass to a virulent strain of *S. iniae* at the end of the feeding trial in Experiment 2 resulted in limited mortality after the challenge (Fig. 1). Fish fed diets with 2% and 4% Brewtech brewers yeast did not experience mortality, while 20% and 10% mortality was observed in fish fed the control diet and 1% brewers yeast supplemented diet, respectively, although differences in survival were not statistically significant.

3.4. Immune responses after long-term administration

After 16 weeks of feeding the diet in Experiment 2, neutrophil oxidative radical production, serum lysozyme, intracellular and extracellular superoxide anion of head

Table 6
Blood neutrophil oxidative radical production (NBT test), serum lysozyme, intracellular superoxide anion production of head kidney macrophages and extracellular superoxide anion production of hybrid striped bass after long-term (16-week) oral administration of graded levels of brewers yeast in Experiment 2[a]

Dietary brewers yeast (%)	NBT test (mg ml^{-1})	Lysozyme (unit ml^{-1})	Intracellular superoxide anion (O.D. at 620 nm)	Extracellular superoxide anion (nmol O_2^-)
0	1.99[c]	1246.7	0.897	2.679[c]
1	2.59[ab]	1073.3	1.039	3.694[b]
2	3.09[a]	965	1.293	4.511[ab]
4	2.31[bc]	1155	1.091	4.86[a]
Pr>F[b]	0.004	0.19	0.466	0.006
Pooled se	0.083	0.013	0.062	0.123

[a] Values in a column that do not have the same superscript are significantly different at $P \leq 0.05$ based on Duncan's multiple range test.

[b] Significance probability associated with the *F* statistic.

kidney phagocytic cells were tested (Table 6). Significant differences ($P<0.01$) in neutrophil oxidative and extracellular superoxide anion of head kidney phagocytic cells were observed among fish fed control diet and yeast-supplemented diets.

4. Discussion

Single cell proteins, including yeast and bacteria, have been viewed as promising substitutes for fishmeal in fish diets. Researchers have evaluated the nutritional value of brewers yeast *S. cerevisiae* in lake trout (Rumsey et al., 1990), rainbow trout (Rumsey et al., 1991) and sea bass (Oliva-Teles and Goncalves, 2001) by comparing growth performance, feed efficiency, liver uricase and nitrogen retention. Based on these studies, brewers yeast could replace up to 25–50% of fish meal protein without adversely affecting growth of these species. In the present study, brewers yeast was evaluated for its potential as an immunostimulant at relatively low inclusion levels.

In Experiment 1, the fish were not in optimal condition as reflected in chronic, low-level mortality (as high as 15%). Dietary supplementation of brewers yeast, especially at 1%, tended to improve the growth and health of fish in that experiment. In Experiment 2, weight gain, feed efficiency and survival of fish fed all diets were excellent. The fishes' high state of health and optimal environmental conditions may have limited potential expression of dietary effects on fish performance.

Hemocrits of fish fed the various diets in Experiments 1 and 2 were variable, but within normal ranges (Hrubec et al., 2001; Sealey and Gatlin, 2002c) and highest for fish fed 1% brewers yeast. Differences in fish size may have accounted for some of the differences in hematocrit values observed between experiments. Serum lysozyme, which is one measure of non-specific immunity, was highly variable in hybrid striped bass in both experiments. The average lysozyme levels in the present study were within the range reported by Sealey and Gatlin (2002c).

Although Streptococcicosis is attracting more attention, information on effect of nutrition on resistance to this disease is limited. Matsuyama et al. (1992) observed intraperitoneal injection of β-1,3-glucan derived from *Schizophyllum commune* and *Sclerotium glucanicum* could significantly enhance the percent survival of yellowtail after *Streptococcus* sp. challenge. However, for the present, few strategies other than vaccination have been proven to enhance resistance to *S. iniae* infection of any fish species. There is some evidence that antibiotic treatment has been ineffective (Klesius et al., 2000). After exposure to *S. iniae* in Experiment 2, hybrid striped bass fed diets with 2% and 4% brewers yeast did not experience mortality, while 20% mortality was observed in fish fed the control diet. Constant disease signs were observed including dermal hemorrhages around the mouth, base of fins and anus, erratic swimming, dark skin pigmentation and slow acceptance or refusal of feed, which are similar to those of tilapia described by Perera et al. (1994, 1997) and Evans et al. (2000). However, noticeable better feeding and less dark skin pigmentation were generally observed in fish fed diets with 2% and 4% yeast supplementation.

Some reports (Matsuo and Miyazano, 1993; Sakai, 1999) have indicated that long-term oral administration of immunostimulants to fish may induce immunosuppression. To

determine this phenomenon in hybrid striped bass, after 16 weeks of feeding, non-specific immune responses including blood neutrophil oxidative radical production, serum lysozyme, extracelluar and intracellular superoxide anion of head kidney macrophages were tested. Significant differences ($P < 0.01$) in blood neutrophil oxidative radical production and extracellular superoxide anion of head kidney phagocytic cells were observed among fish fed the basal diet and yeast-supplemented diets. These results confirm early reports (Siwicki et al., 1994; Anderson et al., 1995) on effects of dietary brewers yeast on immune responses including neutrophil oxidative radical production and serum immunoglobulin level in rainbow trout. No significant differences of serum lysozyme and intracellular superoxide anion of phagocytic cells were observed among fish. The intracellular superoxide anion and extracellular superoxide anion of head kidney phagocytic cells of fish fed the basal diet were observed to be similar to that of Sealey and Gatlin (2002b,c).

Brewers yeast is a source of nucleic acids and polysaccharides including glucans. β-1,3-glucans have been recognized to effectively enhance immune functions of many aquaculture species including African catfish (Yoshida et al., 1995), Atlantic salmon (Engstad et al., 1992), rainbow trout (Jorgensen et al., 1993; Siwicki et al., 1994) and shrimp *Penaeus monodon* (Thanardkit et al., 2002). β-1,3-Glucan is generally viewed as the factor in brewers yeast with a known immunological mechanism (Gannam and Schrock, 2001). Sakai et al. (2001) reported that the nucleotides from brewers yeast RNA were capable of enhancing the phagocytic and oxidative activities of kidney phagocytic cells, serum lysozyme in common carp as well as resistance to *Aeromonas hydrophila*. Burrells et al. (2001) also reported that dietary nucleotides, extracted from brewers yeast, could enhance resistance to various pathogenic infections in Atlantic salmon. However, the extent to which RNA in brewers yeast contributes to the beneficial influences of dietary brewers yeast on immune responses and resistance to *S. iniae* infection of hybrid striped bass is not clear.

It was concluded that brewers yeast positively influenced growth performance and feed efficiency of hybrid striped bass as well as resistance to *S. iniae* infection. In addition, results of immune response assays demonstrate that brewers yeast can be administered for relatively long periods without causing immunosuppression.

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