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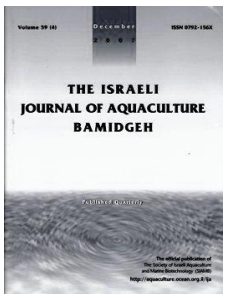

Use of Organically Certified Yeast in the Diet of Juvenile Rainbow Trout (*Oncorhynchus mykiss*): Growth Performance, Nutrient Utilization, and Fatty Acid Composition

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Key words: juvenile rainbow trout, *Oncorhynchus mykiss*, organically certified yeast, growth performance, feed utilization, fatty acid composition

Abstract

This study evaluated the effects of the dietary organically-certified yeast, NuPro™, used as a replacement for fishmeal, on growth performance, nutrient utilization, and fatty acid composition in juvenile rainbow trout, *Oncorhynchus mykiss*. Two reference diets (conventional and organic) and three experimental diets (including 10%, 20%, or 30% NuPro™) were formulated. Diets were assigned to triplicate groups of 20 fish (4.0 g) for 12 weeks. There were no differences in growth performance or feed conversion ratio (FCR) between the two reference groups and growth responses were similar among experimental groups ($p>0.05$). Fish fed the 20% diet grew significantly better than the conventional group ($p<0.05$). Similarly, there were no significant differences in nutrient utilization between reference groups or between experimental groups, and none in body composition between any group ($p>0.05$). The highest n-3/n-6 ratio was obtained in fish fed the organic diet and the lowest in fish fed the 30% diet. Results show that organically certified yeast can contribute be an effective alternative to plant proteins in organic trout feed.

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Introduction

Organic fish farming emphasizes human health without using pesticides, chemicals, or genetically modified products and ensures animal welfare by decreasing stocking densities. However, there are problems with organic aquaculture production such as the absence of internationally-recognized universally-accepted regulations and standards for producing and handling organic aquaculture products (Franz, 2005). One of the most important limitations is obtaining cost-effective organic feed ingredients, a problem that could obstruct the advance toward organic fish production (Lunger et al., 2006, 2007).

Fishmeal, an organic protein source in organic fish production, is expensive and adds too much pressure on wild fish stocks to be used as the sole protein source in organic feeds. On the other hand, plant proteins have limitations due to genetic modifications, deficient essential amino acid and fatty acid profiles, high crude fiber, poor palatability, anti-nutritional factors, high complex carbohydrate contents, and mycotoxin contamination (Francis et al., 2001).

Single cell proteins including micro algae, bacteria, and yeast are alternative protein sources in fish feeds (Davies and Wareham, 1988). They have balanced amino acid profiles, B-complex vitamins, pigments, nucleotides, and complex carbohydrates such as glucans (Oliva-Teles and Gonçalves, 2001; Li et al., 2005; Oliva-Teles et al., 2006). An organically certifiable commercial yeast source (NuPro™) successfully replaced 10% of the fishmeal in a diet for rainbow trout with no detrimental effect on growth or feed utilization (Staykov et al., 2009). In this study,we tested NuPro™ as a protein supplement to fishmeal in diets for rainbow trout (*Oncorhynchus mykiss*) without including other plant proteins (i.e., soybean meal) under organic production conditions.

Materials and Methods

Production system, fish, experimental design. The feeding trial was conducted in fifteen 150-l cylindrical fiberglass tanks in a semi-recirculating freshwater system, aerated at 900 l/h using sand and biological filtrations. Temperature was 17±1°C, dissolved oxygen 7.8±0.01 mg/l, pH 7.5±0.02, and ammonia 0.0±0.01 mg/l. The water flow rate was approximately 12.0 l/min for each tank. A natural photoperiod existed throughout the experimental period and all tanks had similar light conditions.

Juvenile rainbow trout (1 g) were obtained from a private trout farm (Keskinler Trout Farm, Bayramic, Canakkale, Turkey) and acclimated to laboratory conditions at the Fish Nutrition and Aquarium Unit of the Faculty of Fisheries at Canakkale Onsekiz Mart University for two weeks during which they were fed a commercial diet (Bagci Feed Company, crude protein 50%, crude lipid 18%). After acclimation, the fish (4 g) were transported in accordance with Naturland Standards guidelines (Naturland, 2006) and randomly distributed into experimental tanks at 20 fish per tank, with three tanks arbitrarily allocated to each of the five dietary treatments. Groups were weighed every two weeks to calculate growth and feed utilization. Fish were fed by hand three times a day to visual satiation and feed intake was recorded daily for 84 days.

Experimental diets. Five isoenergetic experimental diets were formulated to contain approximately 46.0% crude protein and 18% lipid (Table 1). Two diets (conventional and organic) did not contain NuPro™ and served as reference groups. The conventional diet contained wheat meal, and the organic diet included organic wheat meal as the main carbohydrate source. NuPro™ (Alltech Inc. Nicholasville, KY, USA), an organically certifiable yeast source, contains crude protein 50%, crude fat 0.45%, nitrogen free extract 29.94%, fiber (acid detergent fiber) 1.18%, ash 8.84%, phosphorus 1.63%, calcium 0.96%, and total nucleic acids 7.0%. It is a new source of balanced protein, nucleotide, and peptide. The product was used to replace fishmeal in the experimental diets at inclusion levels of 10%, 20%, or 30%, without incorporating any other plant protein such as soybean or corn gluten meals.

Sampling and chemical analysis. Three individuals were randomly sampled from the original batch in each tank at the beginning of the experiment and three more from each tank at the end of the trial. Samples were stored at -25°C to determine whole body proximate analysis. Analyses of crude protein, moisture, and ash in diets and the whole

Table 1. Formulation, chemical composition, and essential amino acid composition of reference and experimental diets.

	Reference diets		*NuPro™ (%)*		
	Conventional	*Organic*	*10*	*20*	*30*
Fishmeal[1]	68	65	59.5	53.9	48.4
NuPro™[2]	0	0	10	20	30
Wheat [3]	15.5	0	0	0	0
Organic wheat[4]	0	18.9	14.1	9.5	4.5
Fish oil[5]	14.7	14.3	14.6	14.8	15.3
Vitamin[6]	0.5	0.5	0.5	0.5	0.5
Mineral[7]	0.3	0.3	0.3	0.3	0.3
Binder (guar gum)[8]	1.0	1.0	1.0	1.0	1.0
Chemical analyses					
Crude protein (%)	46.3	45.7	46.0	45.5	46.4
Crude lipid (%)	18.0	18.1	18.0	17.9	18.0
Crude ash (%)	12.0	11.8	10.7	9.6	8.5
Crude fiber (%)	0.7	1.1	0.9	0.7	0.5
NFE (%)	23.0	23.3	24.4	26.3	26.6
Gross energy (MJ/kg)	22.03	22.68	21.99	22.21	22.38
Essential amino acids (g/16 g N)					
Methionine	1.21	1.17	1.16	1.15	1.14
Cysteine	0.42	0.41	0.42	0.43	0.43
Lysine	3.56	3.42	3.39	3.37	3.34
Threonine	1.74	1.67	1.73	1.79	1.85
Isoleucine	2.54	2.45	2.40	2.35	2.31
Histidine	1.07	1.03	1.04	1.04	1.05
Valine	2.29	2.21	2.22	2.22	2.23
Leucine	3.28	3.16	3.20	3.23	3.27
Arginine	2.60	2.50	2.45	2.40	2.35
Phenylalanine	1.90	1.83	1.86	1.89	1.92

[1] Anchovy fishmeal, Can Kardesler Fish Meal Corp., Samsun, Turkey
[2] Alltech Incorporated, Nicholasville, KY, USA
[3] Kepez Un, Çanakkale, Turkey
[4] Tiryaki Agro Foods Corporation, Gaziantep, Turkey
[5] Anchovy fish oil, Can Kardesler Fish Meal Corp., Samsun, Turkey
[6] Per g mixture: 342 IU vitamin A, 329 IU vitamin D3, 0.0274 IU vitamin E, 5.48 mg vitamin K3, 2.05 mg vitamin B1, 3.42 mg vitamin B2, 20.5 mg vitamin B3, 5.48 mg vitamin B5, 2.05 mg vitamin B6, 2.74 mg vitamin B12, 24.0 mg vitamin C; Kartal Chemical Inc., Kocaeli, Turkey
[7] Per g mixture: 0.411 mg biotin, 0.685 mg folic acid, 12.3 mg Zn, 4.80 mg Mn, 1.64 mg Cu, 0.274 mg I, 0.0274 mg Se, 125 mg Ca, 189 mg K; Kartal Chemical Inc., Kocaeli, Turkey
[8] Kartal Chemical Inc., Kocaeli, Turkey

fish body were performed according to standard procedures (AOAC, 2000). Dry matter was determined by drying at 105°C until a constant weight was obtained. Ash was measured by incineration in a muffle furnace at 525°C for 12 h. Crude protein (N × 6.25) was analyzed by the Kjeldahl method after acid digestion using the Gerhardt system. Crude fiber was determined by acid/alkali hydrolysis recovering filtered residue, and ignition of the dried sample for 3 h. Nitrogen-free extract (NFE) was computed by adding the values of crude protein, lipid, ash, and fiber and subtracting the sum from 100. Gross energy was calculated using the conversion factors of 23.7 kJ/g for protein, 39.5 kJ/g for lipid, and 17.2 kJ/g for carbohydrate (Brett and Groves, 1979).

Amino acid analysis. Diet samples of approximately 60 mg were hydrolyzed in 10 ml of 6 M HCl in screw-capped tubes (AOAC, 2000). The tubes were flushed with N2 and then heated at 110°C for 24 h. The hydrolysates were rotary-evaporated to dryness under vacuum at 40°C, then re-dissolved in a sodium citrate buffer at pH 2.2. The amino acids were separated by ion-exchange chromatography on a Shimadzu RF-10AXL sodium column and detected following postcolumn derivatization with ninhydrin by measuring absorbance at 350-450 nm. The detected amino acids were identified and quantified using external standards after adjustments by linear regression. Standard amino acids were purchased from Sigma-Aldrich Co., USA, as a synthetic amino acid mixture.

Lipid extraction and fatty acid analysis. Dietary and whole body lipids were extracted with chloroform/methanol (2:1 v/v) according to the procedure of Folch et al. (1957). Fatty acids in the total lipid were esterified into methyl esters by saponification with 0.5 N methanolic NaOH and transesterified with 14% boron trifluoride-methanol (AOAC, 2000). Fatty acid methyl esters (FAME) were analyzed using a flame ionization gas chromatograph (Shimadzu GC-2014) equipped with a Omegawax 250 capillary column (30 ml X 0.25 mm internal diameter), a flame ionization detector (FID), and a split injection system with nitrogen carrier gas. The injector port and detector temperatures were maintained at 250°C and 260°C, respectively. The column temperature program was held at 140°C for 5 min, then elevated at a rate of 3°C/min to 200°C. Total run time was 60 min per sample. Fatty acids were identified by comparing their retention times to authentic standard fatty acid standards (Sigma-Aldrich Co., USA).

Growth performance and somatic indices. Growth performance was evaluated by determining specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), thermal-unit growth coefficient (TGC), net protein utilization (NPU), and net energy utilization (NEU). Condition factor (K), dress-out (DO), hepatosomatic index (HSI), and viscerosomatic index (VSI) were calculated on 10 fish per tank.

Statistical analysis. All data were subjected to analysis of variance (ANOVA) and multiple range test ($p<0.05$) of least square difference (LSD) using the statistical software package Statgraphics 7.0 of Manugistics Inc., Rockville, MD, USA (Zar, 2001). Results were considered statistically significant at the 5% level. Data were analyzed by linear regression with the amount of NuPro™ and the amount of fatty acid in the feed as variables.

Results

All diets were well accepted by the trout. Percent survival did not differ among treatments (Table 2). Polyunsaturated fatty acids n-6 (PUFA n-6) were significantly higher in trout fed the 30% diet, while the n-3/n-6 ratio was significantly higher in trout fed with the organic diet; in most cases, the fatty acid profile was linearly related to the proportion of individual fatty acids in the feed (Table 3).

Table 2. Growth performance, nutrient utilization, biological indices, and body composition of rainbow trout fed diets containing different amounts of NuPro™ as partial replacement of fishmeal for 12 weeks (n = 3).

	Reference diets		*NuPro™ diets (%)*		
	Conventional	*Organic*	*10*	*20*	*30*
Survival (%)	96.67±0.45	91.67±0.68	96.67±0.37	91.67±0.85	93.33±0.71
Mean initial wt (g)	4.0±0.07	4.1±0.02	4.1±0.02	4.1±0.01	4.3±0.13
Mean final wt (g)	62.71±0.89^{a}	67.67±3.98^{ab}	67.27±1.84^{ab}	73.21±1.35^{b}	70.40±3.41^{ab}
SGR (%/day)[1]	3.24±0.04^{a}	3.33±0.07^{ab}	3.29±0.03^{ab}	3.42±0.02^{b}	3.39±0.09^{ab}
TGC[2]	0.162±0.00	0.169±0.01	0.168±0.00	0.171±0.00	0.170±0.00
Feed intake (g/fish/day)	1.74±0.03^{a}	1.81±0.03^{ab}	1.87±0.01^{b}	1.84±0.03^{b}	1.83±0.01^{b}
FCR[3]	0.83±0.02^{a}	0.84±0.01^{a}	0.89±0.01^{b}	0.87±0.01^{ab}	0.87±0.01^{ab}
PER[4]	2.64±0.06^{ab}	2.67±0.04^{b}	2.53±0.02^{a}	2.60±0.03^{ab}	2.52±0.04^{a}
NPU (%)[5]	45.99±1.11^{c}	47.07±0.76^{c}	43.51±0.40^{ab}	45.75±0.53^{bc}	41.38±0.60^{a}
NEU (%)[6]	50.83±1.23	52.26±0.85	51.01±0.47	50.12±0.58	50.12±0.72
Biological indices					
K[7]	1.5±0.03	1.5±0.04	1.7±0.02	1.7±0.05	1.6±0.04
DO[8]	83.0±0.62	81.5±1.03	81.4±2.04	82.5±0.71	83.0±1.81
HSI[9]	1.9±0.11	2.0±0.11	1.9±0.10	1.9±0.08	1.9±0.07
VSI[10]	16.1±0.84	19.1±2.08	19.1±1.02	18.7±0.34	16.4±1.50
Body composition					
Moisture	65.71±1.06	65.37±0.38	64.23±0.52	64.71±0.78	65.45±0.30
Protein	17.76±0.41	17.47±0.71	17.30±0.53	18.11±0.15	16.75±.74
Lipid	13.10±.71	13.92±0.71	14.17±1.09	13.72±1.09	14.66±0.60
Ash	2.07±0.10	2.18±0.18	1.93±0.27	2.10±0.09	2.30±0.10

[1] Specific growth rate = 100(ln final fish wt) - (ln initial fish wt)/experimental days
[2] Thermal-unit growth coefficient = 100(final body wt 1/3 - initial body wt 1/3)/(temperature × experimental days)
[3] Feed conversion ratio = feed intake/wt gain
[4] Protein efficiency ratio = 100(wt gain/dietary protein intake)
[5] Net protein utilization = 100(protein gain)/(dietary protein intake
[6] Net energy utilization = 100(energy gain)/(dietary energy intake)
[7] Condition factor = 100(fish wt/fish length^{3})
[8] Dress-out = 100(fish weight - gut wt)/fish wt
[9] Hepatosomatic index = 100(liver wt/fish wt)
[10] Viscerosomatic index = 100(viscera wt/fish wt)

Table 3. Effects of experimental diets on flesh fatty acid profiles (% of fatty acids) and relationship between levels of fatty acids in feeds and fish.

	Fatty acids in feeds					*Fatty acids in fish*					
	Reference diets		*NuPro™ (%)*			*Reference diets*		*NuPro™ (%)*			
	Conventional	*Organic*	*10*	*20*	*30*	*Conventional*	*Organic*	*10*	*20*	*30*	r^2
Saturated fatty acids (SFA)											
14:0	6.5	7.1	6.1	6.3	7.2	5.7	5.7	5.3	5.4	6.2	0.8488
15:0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.6938
16:0	14.0	14.1	14.6	15.3	13.1	17.6	16.5	16.7	16.8	17.9	0.4760
17:0	0.6	0.5	0.6	0.7	0.5	0.3	0.3	0.3	0.3	0.3	0.7451
18:0	2.3	2.3	2.3	2.2	2.2	3.4	3.2	3.4	3.5	3.4	0.0987
20:0	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.9877
Total SFA	23.9	24.3	24.0	24.9	23.3	27.3	26.0	25.9	26.2	28.2	0.5953
Monoenes											
16:1n-7	8.9	8.6	8.1	8.3	8.6	10.4	9.0	8.4	8.5	9.2	0.9040
16:2n-4	0.9	0.9	0.9	0.9	1.0	0.6	0.6	0.6	0.6	0.7	0.8739
16:3n-4	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.6021
18:1n-9	10.0	11.1	11.2	12.0	9.0	18.4	17.2	17.6	18.4	16.5	0.3672
18:1n-7	2.8	2.8	2.7	2.9	2.2	3.0	2.9	2.7	3.0	3.3	0.5137
20:5n-4	0.4	0.3	0.4	0.3	0.4	0.4	0.5	0.4	0.5	0.5	0.5751
20:1n-9	13.6	13.1	12.5	11.8	11.6	10.5	12.2	12.3	11.9	11.7	0.1989
22:1n-11	6.4	6.6	6.3	6.5	6.1	6.7	7.5	6.6	7.0	6.3	0.9490
Total monoenes	43.6	43.9	42.4	43.2	39.3	50.4	50.4	48.9	50.2	48.4	0.8141
Polyunsaturated fatty acids (PUFA)											
18:2n-6	2.0	1.5	1.8	1.6	1.9	3.2	1.8	2.8	2.6	3.1	0.8643
18:3n-6	0.2	0.2	0.2	0.3	0.8	0.2	0.2	0.2	0.2	0.9	0.9946
18:3n-3	0.5	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.9461
18:4n-3	0.9	1.1	0.9	0.9	1.1	0.8	0.9	0.8	0.8	0.9	0.8580
20:2n-6	0.3	0.2	0.3	0.2	0.4	0.3	0.2	0.3	0.2	0.4	0.9794
20:4n-6	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	1.0000
20:5n-3	5.3	4.4	5.2	4.4	4.4	3.0	3.0	3.0	2.9	2.9	0.6244
22:5n-3	0.8	0.7	0.9	0.9	0.7	0.7	0.8	1.0	1.0	0.6	0.7875
22:6n-3	16.9	15.9	15.6	15.6	16.5	10.2	12.0	11.8	11.8	12.6	0.1966
Total n-6 PUFA	2.9	2.4	2.7	2.5	3.5	4.2	2.6	3.8	3.4	4.8	0.8860
Total n-3 PUFA	24.3	22.6	23.0	22.1	23.1	15.2	17.1	17.0	16.9	17.4	0.6159
N-3/n-6	8.3	9.6	8.4	9.0	6.6	3.6	6.6	4.5	5.0	3.7	0.6575

Discussion

Dietary inclusion of the organically certifiable yeast NuPro™ up to 30% did not have any adverse effects on survival, feed intake, feed utilization, or growth performance of the juvenile rainbow trout. Trivial mortalities were recorded in all treatments during the first two weeks due to initial handling of the fish. Test diets were quite palatable so that all feeds were readily accepted by the trout throughout the feeding period. This is because the high levels of fishmeal in all diets, even the 30% diet, maintained the taste. Indeed, except for the conventional diet, there were no differences in feed intake among groups.

The fish fed the NuPro™ experimental diets had significantly higher feed intakes than those fed the conventional diet. In this context, possible palatability-enhancing properties of NuPro™ should be investigated. Similarly, dietary inclusion of yeast products caused no palatability problems in gilthead sea bream (Oliva-Teles et al., 2006) or sea bass (Oliva-Teles and Gonçalves, 2001). On the other hand, feed intake was lower in tilapia fed diets containing a bacterial single cell protein than in those fed a fishmeal-based diet (Davies and Wareham, 1988) and there were palatability problems in a 100% organically certified yeast-based diet fed to cobia (Lunger et al., 2006).

The growth rate and feed utilization in trout fed the experimental diets corresponded well with rainbow trout of similar size grown in similar water conditions (Figueiredo-Silva et al., 2005). Growth performance was significantly affected in the 20% diet, although the level of fishmeal was 8.5% lower than in the conventional feed. Partial

supplementation with this yeast source seems to have had beneficial effects on the trout performance. Likewise, growth and feed utilization significantly improved in rainbow trout fed a diet supplemented with 25% brewers yeast, although the chemical specifications of the tested products were different (Rumsey et al., 1991).

Yeast and derived products are suitable alternative protein sources in other fish species. Growth performance of the rainbow trout in our study was similar to that of *Labeo rohita* (Pal et al., 2007), and feed utilization was similar to the fishmeal-based control in juvenile carnivorous cobia fed a diet containing 25% incorporation of yeast (Lunger et al., 2006). In European sea bass juveniles, 50% dietary brewers yeast supplementation produced equivalent growth rates as the control diet (Oliva-Teles and Gonçalves, 2001). When 30% fishmeal with replaced by torula yeast in diets for tilapia fry, growth performance and feed conversion ratio significantly improved (Olivera-Novoa et al., 2002). In contrast, growth performance and feed conversion ratio were lower in lake trout fed a diet including 50% yeast protein than in those fed the casein/gelatin-based control diet (Rumsey et al., 1990).

Our FCR values were in accordance with previous findings (Figueiredo-Silva et al., 2005; Morris et al., 2005). There was a slight but insignificant increase in FCR as the level of NuPro™ increased, showing that all test diets were well utilized and that NuPro™ does not negatively affect nutrient digestibility. However, in cobia, higher substitution levels of NuPro™ resulted in a higher FCR (Lunger et al., 2006).

PER was similar in some previous studies in rainbow trout (Fournier et al., 2002), but superior in others (Steffens, 1994). The decreasing trend in PER and significant depression in NPU can be attributed to the high concentrations of nucleic acids in NuPro™ that result in elevated plasma-N, uric acid, and urea-N excretion (Fournier et al., 2002). This was not the case in sea bream because they can tolerate relatively high levels of RNA extract from yeast (Oliva-Teles et al., 2006).

Condition factor (K), HSI, and VSI were measured to assess the energy intake, nutritional, and physiological status of the trout. The K of rainbow trout fed the yeast-based diets were slightly higher but not significantly different than in fish fed the controls. HSI did not significantly differ among groups, in agreement with previous studies on rainbow trout (Thiessen et al., 2003). The dress-out percentage values in our study were similar to previous studies on rainbow trout (Tekinay and Davies, 2001).

Incorporation of organically certified yeast did not alter moisture, protein, or lipid body contents. However, body protein and lipid levels of cobia was influenced by dietary inclusion of NuPro™ (Lunger et al., 2007). Also, yeast products altered body fat content in gilthead sea bream (Oliva-Teles et al., 2006) although body fat level was not affected in European sea bass (Oliva-Teles and Gonçalves, 2001). The body ash content of our rainbow trout was not influenced by the yeast product, as found in other fish species (Li et al., 2005).

Fatty acid composition of fish reflects the fatty acid composition in the diet (De Francesco et al., 2004). The fatty acid profile in the fish in the present study was impacted by that of the feed, as in other studies on rainbow trout (Morris et al., 2005). The experimental diets of the present study contained both n-3 and n-6 highly unsaturated fatty acids such as linoleic (18:2n-6), linolenic (18:3n-3), eicosapentaenoic (20:5n-3; EPA), and docosahexaenoic (22:6n-3; DHA) acids and may have satisfied the essential fatty acid requirements of juvenile rainbow trout (Sargent et al., 2002). The n-3/n-6 ratio of fish fed vegetable oil and meal diets is lower than that of fish fed fishmeal-based diets in carnivorous fish species (Bell et al., 2003; De Francesco et al., 2004). However, our study shows that up to 30% inclusion of organically certified yeast-based protein as partial replacement of fishmeal has no negative effect on fatty acid profiles.

In conclusion, the results of the present trial indicate that organically certified yeast can be safely used at an inclusion level up to 30% in organic rainbow trout diets without incorporation of any other plant protein such as soybean or corn gluten meals. As long as the production cost of organically certified yeast is reduced, it can be used as a protein source with a lower level of fishmeal, especially in organic fish feeds. Further, it can be an effective biological support to fishmeal instead of plant proteins such as soybean meal

in diets for juvenile rainbow trout. More research is needed to evaluate the use of different levels of this product with lower levels of fishmeal (>46%) in diets for rainbow trout. It is also important to examine the health benefits of NuPro™ with respect to stress physiology and immunocompetence in intensive fish production systems.

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