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Utilization of *Shochu* Distillery By-products for Culturing the Common Carp *Cyprinus carpio* L.

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Abstract: *Shochu* distillery by-product (SDBP) was applied for culturing the common carp *Cyprinus carpio* L. Four experimental diets were formulated by mixing commercial fish feed and wheat flour with SDBP (I) and supplementing it either with vitamins (II), fish oil (III), or both (IV). A control diet contained only commercial fish feed and wheat flour. These diets were fed to the fish twice daily for 40 days to estimate weight gain (WG), feed intake (FI), food conversion ratio (FCR) and specific growth rate (SGR). All fish gained weight increments after the feeding experiment, but with no significant difference in FI among the diets except for diet III. Fish fed with diet III had low FCR and SGR, *i.e.*, their growth retardation. However, SDBP might be used as a supplement for fish feed to foster the growth of fish.

Key words: *Shochu* distillery by-products, nutrition, growth, *Cyprinus carpio*

Introduction

Culture of the common carp *Cyprinus carpio* L. has been a successful and widespread means of producing protein for human consumption. Cyprinids qualitatively form one of the most important group of cultured fish worldwide, with a total production of 13 million metric ton in 1997 (FAO, 1999).

The success of commercial aquaculture operations depends on a variety of factors within the fields of biology, engineering and economics. One key biological component is the availability of suitable diets that are efficiently digested and provide the required nutrients for good growth. Among the major carps, *C. carpio* is the fastest growing species and, hence, has become a preferred fish of the farming community.

The fish is predominantly a zooplankton and bottom fauna feeder, but the shortage of natural food in rearing ponds under high stocking densities has necessitated resorting to a supplementary feeding (Bardach *et al.*, 1972; Kaushik, 1995; Seenappa and Devaraj, 1995).

The dietary protein content and biological value of expensive fish meal appears to be one of the most important factors to increase common carp production. In order to improve the yield, less expensive protein sources, including *shochu* distillery by-products (SDBP) have been used to partially or totally replace fish meal. SDBP is an underutilized by-product of a highly

extensive liquor production from sweet potato, locally called ***shochu***, in Japan. This liquid distillery by-product is a tremendous waste output, but its utilization as an animal feedstuff has drawn some interests. So far, the favorable effects of SDBP-based diets on the growth of chicken, pigs and cows have been studied (Mahfudz ***et al.***, 1996; Mahfudz ***et al.***, 1997) but are little known on fish.

Apart from replacing with cheaper alternative feed sources, such as SDBP-based diets, there are other developments that could be expected in the aquaculture feed industry. High-value aquafeeds for intensively cultured species are usually formulated with emphasis on minimizing environmental degradation while improving larval survival and growth (Ohtsuka ***et al.***, 1998). Related to the cost and environmental concerns in aquaculture is the motivation to utilize biogenic waste materials as a possible feed source for profitable fish production. This study thus aims to determine the feed consumption levels and growth performance of common carp, when fed with different nutritional formulations of SDBP-based diets preliminarily in a short time scale.

Materials and Methods

Feeding condition

Juvenile common carp ***Cyprinus carpio*** L. were obtained from Kaneko Hatchery in Yamaguchi Prefecture, Japan and kept in indoor tanks (30x36x60 cm) filled with 50 L of aerated declorinated freshwater at 27±0.1°C. One-third of the water in tanks was replaced every morning throughout the study period.

Prior to the feeding experiment, all fish underwent a week conditioning period, when they adjusted to the pelleted diet and standardized environmental condition. Five common carps were placed in each of 15 rectangular tanks filled with aerated dechlorinated freshwater. Each tank, equipped with a supplemental aerator, was considered as an experimental unit. The fish in each tank were randomly provided with a test diet. The initial size (mean±SD) was 10.8±0.6 g for control group, 10.8±0.8 g for diet I, 10.9±0.7g for diet II, 10.7±1.0 g for diet III and 10.9±1.0 g for diet IV.

Thereafter, fish were fed daily with the control and test diets ***ad libitum*** for one hour at 0700 and 1700 for 40 d. The amounts of feeds consumed were regularly recorded by noting the number of pellets (1.0 g wet weight/piece) ingested by the fish, which was then converted to dry weight basis.

Experimental diets

Shochu distillery by-products (SDBP) were obtained from a ***shochu*** production company in Kagoshima Prefecture, Japan. SDBP samples, the pH of which was adjusted from 4.0 to 7.0 with 4 ***N*** sodium hydroxide, were stored in a freezer at -30°C prior to use.

The control diet used was a commercial fish feed (Nippon Formula Food Co., Tokyo, Japan). A commercial wheat flour (Nisshin Seifun Co., Tokyo, Japan) was added to make sticky diets. The test diets were formulated as in Table 1. Diet I contained commercial fish feed, commercial wheat flour and SDBP; Diet II added with vitamin mixture; Diet III added with fish oil (pollack oil) (Riken Vitamin Co., Tokyo, Japan) and Diet IV added with vitamin mixture and fish oil. These diets

were prepared by thoroughly mixing the dry ingredients until dough was produced. The dough was then passed through a hand-made pelletizer. Each diet on wet basis was assigned randomly to three tanks, each containing five fish and two feedings daily. The amount of feeding was calculated as the dry weight of feed consumed to apparent satiation for 40 d.

Proximate compositions (Table 2) of the test diets were determined as: ash by use of a muffle furnace at 550°C for 12 h; moisture by drying at 105 °C for 12 h; crude lipids by a Soxhlet extraction method (AOAC, 1990) and crude proteins (N × 6.25) by a semi-micro Kjeldahl method (Bligh and Dyer, 1959).

Water quality

Water temperature, pH and dissolved oxygen were recorded daily in the morning before water was changed. Unionized ammonia in the tanks were determined once a week according to the method of Strickland and Parsons (1972).

Table 1: Formulation of SDBP and control diets used for feeding experiment

	Diet (g 100 g^{-1})				
Ingredient	Control	I	II	III	IV
Commercial fish feed[1]	50.00	47.90	47.65	44.40	44.15
Commercial wheat flour[2]	50.00	47.90	47.65	44.40	44.15
SDBP[3]	-	4.20	4.20	4.20	4.20
Vitamin mixture[4]	-	-	0.50	-	0.50
Fish oil[5]	-	-	-	7.00	7.00

[1] Crude protein 39.0%, Crude oil 3.0%, Crude fiber 5.0%, Ash 15.0%, Calcium 1.5%, Phosphorus 1.3%, Moisture 35.2%; Energy 268.8 kcal g^{-1}, [2] In 100g: Protein 12.0 g, Lipid 1.8 g, Carbohydrate 69.0 g, Ash 1.4g, Moisture 15.8 g; Energy 368.3 kcal g^{-1}, [3] Protein 37.8%, Lipid 15.2%, Ash 3.6%, Fiber 22.6%, Nitrogen-Free Extract (NFE) 19.7%, Moisture 1.1%; Energy 442.6kcal g^{-1}, [4] In 1000g: Vitamin A, 400,000 IU; B_1, 10,000 mg; B_2, 1,500 mg; B_6, 1,200 mg; B_{12}, 850 μg; C, 14,000 mg; D_3, 80,000 IU; E, 8,000 mg; K, 50 mg; Nicotonic acid amide, 1,000 mg; Calcium pantothenate, 5,000 mg; Folic acid, 300 mg; Biotin, 2,000 μg; Choline chloride, 20,000 mg; Inositol, 3,000 mg. [5] Fish oil

Table 2: Proximate compositions of the test diets in dry basis

	Diet (g 100g^{-1})				
	Control	I	II	III	IV
Ash	6.56	6.58	6.92	6.40	6.35
Crude Protein	30.64	30.77	30.74	30.70	30.15
Crude Lipid	4.40	4.37	4.17	4.46	4.55
Carbohydrate	51.84	54.26	52.92	53.92	54.84
Energy (kcal g^{-1})	425.96	436.36	428.86	435.39	436.89

Table 3: Growth performance of common carp fed with SDBP and control diets

	Body weight (g)					
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Diet	Initial	Final	WG	(g)	FCR	(% d^{-1})
Control	10.8 ± 0.6a	36.0 ± 1.8c	25.3 ± 2.4bc	53.2 ± 1.8b	2.1 ± 0.2ab	3.0 ± 0.3cd
I	10.8 ± 0.7a	41.0 ± 1.6d	30.2 ± 1.6c	57.1 ± 3.2b	1.8 ± 0.2a	3.3 ± 0.1d
II	10.9 ± 0.7a	32.2 ± 1.7bc	22.9 ± 1.8b	55.5 ± 2.1b	2.4 ± 0.2abc	2.7 ± 0.2bc
III	10.7 ± 1.0a	24.5 ± 2.2a	13.8 ± 2.8a	41.0 ± 2.8a	3.0 ± 0.8c	2.1 ± 0.2a
IV	10.9 ± 1.0a	28.3 ± 1.7ab	17.4 ± 1.9a	51.3 ± 2.4b	2.9 ± 0.4bc	2.4 ± 0.3ab

WG : Weight gain = final weight- initial weight (g)

FI : Feed intake = cumulative feed consumption (g $fish^{-1}d^{-1}$)

FCR : Feed conversion ratio = feed intake in dry basis (g) / weight gain (g)

SGR : Specific growth rate = 100 x [ln (final weight) - ln (initial weight) / 40 days]

Statistical analysis

Data were statistically analyzed by one-way analysis of variance (package super-ANOVA, Abacus Concepts, Berkeley, California, USA). Tukey test was employed to determine any significant difference among variable means (Zar, 1999). Probabilities of $P < 0.05$ were considered significant.

Results

The weight gain (WG), feed intake (FI), feed conversion ratio (FCR), and specific growth rate (SGR) of common carp fed with test diets are presented in Table 3. All SDBP-based diets except diet III performed similarly as the control diet. The lowest SGR (2.1±0.2%) was obtained in the group of fish fed with diet III, which included fish oil. Diet IV with added fish oil and vitamins also showed a significantly lower SGR than the control. Supplementation of SDBP alone to the basal diet, without vitamins and oil mixtures, could yield a better growth performance of the common carp. This was well reflected by diet I having the best results in terms of FI, FCR and SGR among the test diets. The inclusion of fish oil in diets lowered the FI of fish significantly.

The FCR of diets I and II showed an inverse correlation on SGR. Of these two diets, diet I met the nutritional requirements for growth of common carp since its FCR value was lower than 2 and deemed more favorable from the cost-efficient standpoint.

Discussion

A prepared SDBP diet (diet I) without added vitamins and/or oil could yield a good growth of the common carp tested. This indicates the potential utility of SDBP as a feedstuff for fish, although the usefulness of SDBP has previously been reported on chicken, pigs and cows (Mahfudz ***et al.***, 1996; Mahfudz ***et al.***, 1997; Ohtsuka ***et al.***, 1998).

Fish fed with diet I gained the largest WG with the least nutrient supplementation, thereby the least cost of the test diets, suggesting that SDBP might exert a growth-promoting effect or act as a feeding attractant. Those fed with diets II and IV had a relatively high FI, but lower SGR (Table 3). Diet III containing fish oil but no added vitamins produced the poorest fish growth. It has also been found that the addition of saturated lipid in feed for carp fingerlings little improved

their growth and feed conversion (Watanabe ***et al.***, 1975). Similarly, the protein digestibility in rainbow trout fed with a casein-based diet was not affected by the addition of 30% olive oil to the diet (Kitamikado ***et al.***, 1964). A study on the Siberian sturgeon, ***Acipenser baeri***, also showed no effect of lipid on protein digestibility of the fish (Médale ***et al.***, 1991).

Our findings suggest that oil inclusion had a lesser effect on the growth of common carp, possibly lowering the nutritive value of feedstuff. However, co-mixing with vitamins seems to have a compensatory role by improving the feed intake and growth of fish. Nevertheless, it is well established that dietary fat can have a profound effect on the energy balance and, ultimately, body weight of fish. Vitamins have a role for the growth of fish; the requirements of vitamins for different species varied greatly according to the capacity to synthesize them (Watanabe ***et al.***, 1970; NRC, 1993; De Silva and Anderson, 1995). The vitamin requirements for fish are affected by size, age and growth rates as well as by various environmental factors and nutrientinterrelationship (Halver, 1988). In this study, vitamin supplementation for SDBP diet increased only food consumption, but no corresponding effect on the growth of fish.

FCR is useful for aquaculture purposes because it estimates the amount of food and hence, the cost required for producing sufficient WG of cultured fish. The fish fed with diet III showed the highest FCR, but the lowest WG and SGR, among the test diets. This seems quite important in considering the cost efficiency and utility of waste material. Diet I serves as the best feed option for common carp.

It has been reported that the increased interaction and competition among the fish of similar size possibly resulted in growth retardation of fish (Baardvik and Jobling, 1990). The test fish used in this study were relatively size-sorted, with the least dispersion in the diet III group. However, there was no sufficient evidence to claim competitive effects on the low SGR in diet III, although some significant difference ($P<0.05$) was observed between this and other fish groups. Thus, it will be needed to further investigate the growth effect of nutrient interrelationship in diet formulation.

The evaluation of apparent digestibility coefficients of feedstuffs is one of the most important steps in formulating properly balanced diets to satisfy the nutrient requirements of fish (Cho, 1992). Expanding the time scale of the present experiment will build a more reliable basis in affirming the effects of SDBP diets on the food consumption and growth of fish.

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