

# ヒゴイ *Cyprinus carpio* L. 餌料としての焼酎蒸留廃液(SDBP)の有用性

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## Utility of *Shochu* Distillery By-products (SDBP) as a Feedstuff for the Carp *Cyprinus carpio* L.

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**Abstract:** *Shochu* distillery by-products (SDBP) is an underutilized liquid waste of a popular liquor, locally called “*shochu*”, a fermentative product from sweet potato in Kagoshima, Japan. Growth performance of the common carp *Cyprinus carpio* L. fed with different levels of SDBP was examined. Test diets including 1%, 2%, 3% and 4% SDBP as dry weight in a commercial carp feed were formulated. The commercial feed without SDBP was used as the control. On addition of SDBP no marked change was observed in total protein contents of the diets. The weight gain, feed intake and specific growth rate of fish fed with SDBP diets for 40 days increased with increased SDBP. In these three parameters diets with higher levels of SDBP were significantly different ( $P < 0.05$ ) from those with lesser ones. However, the food conversion ratio of fish reduced with increased SDBP. This suggests that SDBP might have nutritive and economic potentials to be used as a feedstuff for carp.

**Key words:** *Shochu* distillery by-products; Carp; *Cyprinus carpio*; Alternative fish diet; Nutrition; Feeding; Growth

The high cost of commercial fishmeal necessitates an optimization of protein in the diet. Alternative ingredients that reduce feed costs to maintain adequate production of fish can have a marked impact on the profitability of the industry. Since feed costs represent 40–70% of the total production costs, it is important to search for alternative protein sources to reduce or stabilize the cost of production<sup>1-4</sup>.

Recently, technological advances have made possible the recycling of many industrial waste products into feed ingredients. However, the total protein level in formulated diets must be kept at the optimum requirements of fish not only to maximize fish growth but also to protect water quality. A major cause of environmental impacts in fish farming has been attributed to the loss of non-ingested feeds, feces and

end-products of metabolism to natural environments<sup>5</sup>. Therefore, any improvement in diet quality and feed management is a major step to reduce the pollutive effects of intensive fish farming<sup>6</sup>.

The dietary protein content of expensive commercial fishmeal appears to be one of the most important factors in increasing common carp production. In order to improve the yield and nutrient values, there have been used less expensive sources of plant protein, including *shochu* distillery by-products (SDBP), to partially or totally replace commercial fishmeal. SDBP are underutilized by-products of a very popular liquor, locally called “*shochu*”, a fermentative product from sweet potato in Kagoshima, Japan. These distillery by-products is a tremendous waste output, but its utilization as an

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animal feedstuff has drawn some experimental interests. However, little is known on fish, although there have been some studies on the favorable effects of SDBP-based diets on the growth of chicken and pigs<sup>7-9</sup>.

Fish species, such as carp, can ingest many nutrients from decaying organic matter in addition to any artificial diets. SDBP appear to be an alternative potential feedstuff for fish because of their accessibility and relatively low cost. Therefore, it is necessary to determine their nutritive value and dietary potential for fish production<sup>10-12</sup>. The present study deals with the growth performance of common carp *Cyprinus carpio* L., which received different levels of SDBP diets.

## Materials and Methods

### Experimental diets

*Shochu* distillery by-products (SDBP) were obtained from a *shochu* production company in Kagoshima Prefecture, Japan. SDBP samples were adjusted from pH 4.0 to 7.0 with 4 N sodium hydroxide and then stored in a freezer at  $-30^{\circ}\text{C}$  prior to use.

The compositions of the test diets are shown in Table 1, with a commercial feed (Nippon Formula Feed Co., Tokyo) as the control diet. Commercial wheat flour (Nisshin Seifun Co.,

Tokyo) was added to make sticky dough. Four types of diets were formulated by changing the SDBP contents from 1 to 4% that corresponds to 18.8 to 75.0 mL of liquid waste. The dry weight equivalent of liquid SDBP corresponds to the weight of the residue after drying the liquid samples in an oven at  $100^{\circ}\text{C}$ . To reduce variability, the SDBP samples were randomly obtained from a well-mixed volume. Each experimental diet was prepared by thoroughly mixing the dry ingredients with the desired volume of liquid SDBP until dough was produced. The dough was then passed through a hand-made pipe-pelletizer. For the SDBP, 4% (7.5 mL) was apparently the maximum quantity possible to produce sticky dough.

Five fish were placed in each of 25 rectangular tanks ( $50 \times 62 \times 86$  cm) filled with 150-L aerated dechlorinated freshwater at  $27 \pm 0.1^{\circ}\text{C}$ . Five tanks then formed each diet group. In the tanks, fish were provided with diets *ad libitum* twice a day (morning and afternoon) for 40 days. The test fish achieved apparent satiation one hour after feeding since, as visually observed, most of them ceased ingesting the supplied pellets. The amounts of feeds consumed by fish in each tank were recorded daily by noting the number of pellets (1.0 g wet weight/piece) ingested. The feed consumption was calculated as the dry weight of feed consumed for 40 days.

### Feeding condition

Juvenile common carps, *Cyprinus carpio* L. were obtained from Kaneko Hatchery, Yamaguchi Prefecture, Japan and kept in the above mentioned rectangular indoor tanks. One-third of the water in tanks was replaced every morning throughout the study period. Four diets with different levels of SDBP were formulated (Table 1). Before the feeding experiment, all fish were conditioned for one week, wherein they were adjusted to the pelleted diets and standardized environmental conditions. At the end of acclimation period, the fish were weighed and then started on the respective experimental diets for 40 days to evaluate the effects of dietary SDBP levels on the growth

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

Ingredient	Diet (g/100 g)				
	Control	I	II	III	IV
Commercial fish feed* <sup>1</sup>	49.75	48.45	47.40	46.35	45.30
Commercial wheat flour* <sup>2</sup>	49.75	50.00	50.00	50.00	50.00
SDBP* <sup>3</sup>	0	1.05	2.10	3.15	4.20
Vitamin mixture* <sup>4</sup>	0.50	0.50	0.50	0.50	0.50

\*<sup>1</sup> Crude protein, 39.00%; crude oil, 3.00%; crude fiber, 5.00%; crude ash, 15.00%; calcium, 1.50%; phosphorus, 1.30%; moisture 35.20%; energy, 268.80 kcal/g.

\*<sup>2</sup> In 100g: crude protein, 12.00 g; crude lipid, 1.80 g; crude fiber, 69.00 g; crude ash, 1.40 g; moisture, 15.80 g; energy, 368.30 kcal/g.

\*<sup>3</sup> Crude protein, 37.80%; crude lipid, 15.20%; crude ash, 3.60%; crude fiber, 22.60%; Nitrogen-Free Extract (NFE) 19.70%; moisture 1.10%; energy 442.60 kcal/g.

\*<sup>4</sup> In 1000 g: vitamin A, 400,000 IU; B<sub>1</sub>, 10.00 g; B<sub>2</sub>, 1.50 g; B<sub>6</sub>, 1.20 g; B<sub>12</sub>, 0.90 g; C, 14.00 g; D<sub>3</sub>, 80,000 IU; E, 8.00 g; K, 0.05 g; nicotinic acid amide, 1.00 g; calcium pantothenate, 5.00 g; folic acid, 0.30 g; biotin, 2.00 mg; choline chloride, 20.00 g; inositol, 3.00 g.

and feed utilization of carps. Each tank was randomly assigned to dietary treatments. Then, fish were transferred to each experimental tank. The average weight of fish (mean  $\pm$  SD) was  $23.3 \pm 0.7$  g for the control group,  $23.1 \pm 0.7$  g for Diet I,  $23.2 \pm 0.4$  g for Diet II,  $23.2 \pm 0.7$  g for Diet III and  $23.5 \pm 0.9$  g for Diet IV. All dietary treatments were tested in three replicate groups of fish with uniform size.

Proximate compositions of the test diets are shown in Table 2. Moisture and crude ash contents<sup>13)</sup> were determined by heating in a muffle furnace at 105 and 550 for 12 hours, respectively, crude lipids by a Soxhlet extraction method<sup>14)</sup>, and crude proteins ( $N \times 6.25$ ) by a semi-micro Kjeldahl method<sup>14)</sup>.

#### Water quality

Water temperature, pH and dissolved oxygen were recorded daily in the morning before the tank water was changed. Unionized ammonia in the tanks was determined once a week based on Strickland and Parsons<sup>15)</sup>.

#### Statistical analysis

Statistical evaluation of the data was conducted using package super-ANOVA (Abacus

Concepts, Berkeley, California, USA). ANOVA was used to identify any statistical differences ( $P < 0.05$ ) in weight resulting from each test diet formulation. A Tuckey test<sup>16)</sup> was subsequently used to determine any significant difference among variable means for selected parameters.

## Results

All fish survived during the feeding experiment. Diets I-V appeared palatable to the fish tested. The commercial fish feed was reduced as the SDBP level increased (Table 1), but there was no marked variation in the proximate compositions of diets (Table 2).

The significant difference from the control was neither found in average weight (AW) for Diets II and III, nor in feed intake (FI) for Diets I and II. Diets I-III, each of which included 1, 2, or 3% SDBP, did not give any significant effects on specific growth rate (SGR) of fish (Table 3). However, growth performance was noted significantly low in Diet IV with 4% SDBP.

All fish groups showed different FI values, which might be caused by different palatability and acceptance of fish for each diet. The FI values varied significantly with different SDBP formulations in diets and increased as the content of SDBP increased (Table 3). The fish with the highest content of SDBP showed the best growth.

Food conversion ratio (FCR) values also differed significantly among the groups of fish. They generally decreased with increased SDBP.

**Table 2.** Proximate compositions of the test diets

	Diet (g/100 g)				
	Control	I	II	III	IV
Crude ash	6.56	6.35	6.40	6.52	6.58
Crude lipid	4.40	4.55	4.37	4.27	4.46
Crude protein	32.64	32.64	32.65	32.66	32.72
Crude fiber	56.40	55.45	54.48	53.40	52.04

**Table 3.** Growth performance of common carp fed different levels of SDBP for 40 days

Diet	Weight (g)		Average weight <sup>*1</sup> (g)	Feed intake <sup>*2</sup> (g)	Feed conversion ratio <sup>*3</sup>	Specific growth ratio <sup>*4</sup> (%/day)
	Initial	Final				
Control	23.3 $\pm$ 0.7	64.9 $\pm$ 2.1 <sup>b</sup>	41.7 $\pm$ 2.2 <sup>b</sup>	76.2 $\pm$ 4.2 <sup>a</sup>	1.9 $\pm$ 0.2 <sup>a</sup>	2.6 $\pm$ 0.3 <sup>a</sup>
I	23.1 $\pm$ 0.7	53.2 $\pm$ 2.4 <sup>a</sup>	30.1 $\pm$ 2.5 <sup>a</sup>	73.0 $\pm$ 3.2 <sup>a</sup>	2.5 $\pm$ 0.2 <sup>b</sup>	2.3 $\pm$ 0.1 <sup>a</sup>
II	23.2 $\pm$ 0.4	62.3 $\pm$ 2.3 <sup>b</sup>	40.0 $\pm$ 1.9 <sup>b</sup>	74.6 $\pm$ 2.7 <sup>a</sup>	1.9 $\pm$ 0.1 <sup>a</sup>	2.5 $\pm$ 0.2 <sup>a</sup>
III	23.2 $\pm$ 0.7	66.5 $\pm$ 1.7 <sup>b</sup>	43.3 $\pm$ 1.5 <sup>b</sup>	80.5 $\pm$ 2.1 <sup>b</sup>	1.8 $\pm$ 0.4 <sup>a</sup>	2.7 $\pm$ 0.2 <sup>a</sup>
IV	23.5 $\pm$ 0.9	72.6 $\pm$ 2.1 <sup>c</sup>	48.9 $\pm$ 2.1 <sup>c</sup>	86.0 $\pm$ 2.2 <sup>c</sup>	1.8 $\pm$ 0.5 <sup>a</sup>	2.9 $\pm$ 0.3 <sup>b</sup>

\*<sup>1</sup> Final weight-initial weight.

\*<sup>2</sup> Cumulative feed consumption for 40 days (g).

\*<sup>3</sup> Feed intake in dry basis (g)/average weight (g).

\*<sup>4</sup>  $100 \times [\ln(\text{mean final weight}) - \ln(\text{mean initial weight})/40 \text{ days}]$ .

Average values are means  $\pm$  SD of triplicate tanks for each dietary treatment. Values in the same column with different superscripts (a, b, and c) are significantly different ( $P < 0.05$ ) when analyzed using ANOVA with a Tuckey test.

The fish fed with 1% SDBP showed the highest FCR values. A superior FCR ( $< 2$ ) was obtained for the rest of diets with 2-4% SDBP and control. SGR values increased with increased SDBP, but no statistical difference ( $P < 0.05$ ) in SGR was observed among all diets except for Diet IV.

Throughout the experiment, water temperature ranged 27.1-27.5 °C, pH 7.1-7.4, DO 6.8-7.2 mg/L, and unionized ammonia 8.0-9.5  $\mu\text{g-N/L}$ .

## Discussion

Development of an alternative protein source for the partial or direct replacement of fishmeal for fish species has been studied, with marginal success<sup>4</sup>. In this study, the addition of SDBP seemed useful for the growth of common carp from the nutritive point of view. The protein contents of test diets agreed well with those recommended for common carp<sup>17-19</sup>. In particular, the protein requirement for growing common carp was estimated to be 31-38%. This suggests that a partial replacement of commercial fishmeal by SDBP might be possible to achieve a similar growth performance in fish. As such, the relatively lower cost and greater accessibility of SDBP could reduce feeding costs, thus improving the economic efficiency of fish production. In addition to being an excellent source of energy, SDBP have an advantage in maximizing the growth of fish, since higher growth rates were obtained with an increase of SDBP in their diets.

This study also demonstrated that the SDBP could replace the commercial fish feed up to 4% on dry weight basis without compromising the growth performance. The addition of SDBP in diets increased WG, FI and SGR but decreased FCR (Table 3). Reducing the proportion of dietary protein by replacing it with SDBP resulted in a significant improvement in FCR. In spite of this, FCR was noted to decrease with an increased dietary protein content<sup>20</sup>. The level of SDBP in diets was the main factor that affected fish growth, although the level of dietary SDBP must be high enough to effect significantly higher growth. The fish fed with Diet IV gave

a relatively high WG, FI and SGR, suggesting a growth-promoting effect of SDBP.

Lowering of the SDBP contents resulted in lower SGR, which correlated with lower FI or lowered palatability leading to the retardation of growth. It has been reported that the freshwater prawn *Macrobrachium rosenbergii* exhibited a favorable growth when fed a diet containing 4% distiller's grains with solubles (DGS), which are solid by-products from ethanol extraction of corn<sup>21</sup>. Webster *et al.*<sup>4</sup> mentioned in their reviews that diet with 8% DGS could be fed to the lake trout *Salvelinus namaycush* without adverse effects on growth, whereas 7.5-15% DGS could be added to a 36% protein diet for the channel catfish *Ictalurus punctatus*. Hence, a much higher level of DGS is recommended to achieve a more flexible and economical formulations of the diet<sup>4</sup>. It has been shown that poultry by-product meal (PBM) could successfully replace about 40% of the protein content of fish meal for the juvenile African catfish *Clarias gariepinus*<sup>22</sup>.

Since, in this study, the common carp with a high level of SDBP increased WG, FI and SGR, SDBP could be utilized as an alternative ingredient in fish diets. However, as in the DGS, the optimal amount of SDBP in formulated diets might vary according to species. As a by-product of an expansive liquor industry in Japan, the low cost and high accessibility of SDBP may potentially increase the economic benefits to be derived from fish production. Hence, the use of SDBP in aquaculture as a replacement for commercial feed appears to be viable and important, but the digestibility of the protein, amino acids, lipid and energy components in relation to the different size classes of fish must be further determined to fully evaluate the dietary potential of SDBP.

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## ヒゴイ *Cyprinus carpio* L. 餌料としての 焼酎蒸留廃液 (SDBP) の有用性

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イモ焼酎は、鹿児島地方の主要な産品の一つであるが、その製造過程で排出される多量の焼酎蒸留廃液または焼酎蒸留副産物 (SDBP) の利用法については、未利用な部分が多く、その扱いに苦慮している。そこで、本研究では SDBP の利用拡大を図るために、水産生物餌料としての有用性を試験した。

市販のコイ配合餌料に SDBP 濃度が 1, 2, 3 および 4% になるように添加した後、ヒゴイ *Cyprinus carpio* L. に 40 日間給餌した。総蛋白量では、SDBP の添加によって特に顕著な変化はみられなかった。餌料中の SDBP 量が増加すると、試験魚の増重量、摂餌量および比成長速度も増加した。SDBP 添加量の高い餌料を与えたものでは、上記 3 餌料成績に有意の差 ( $P < 0.05$ ) が認められたが、SDBP 添加量の増加は、餌料転換効率の低下を起こした。

かように、SDBP は栄養学的に優れており、また経済性も高いことから、コイ餌料としての使用は可能なものと考えられる。