無魚粉飼料への段階的なタウリン添加がブリ幼魚の成長と生理に及ぼす影響

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Effects of graded levels of taurine supplement to the no-fishmeal diet on the growth and physiology in juvenile yellowtail *Seriola quinqueradiata*

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Abstract: A feeding experiment was conducted in juvenile yellowtail to examine the effects of six graded levels of supplementation taurine (0, 1, 2, 3, 4 and 5%) to a soy protein concentrate based no-fishmeal diet for 10 weeks. The final body weight and tissue (red muscle and liver) taurine concentrations in fish fed 0% diet were the lowest among the dietary treatment but they were significantly improved by a diet supplemented with 1% taurine. Furthermore, a diet supplemented with 1% taurine improved tissue seine concentration, and hematocrit value. On the other hand, dietary supplementation level of 3% was necessary to improve plasma osmotic pressure and prevent green liver. Therefore, even though the tissue taurine concentration could be saturated with supplementation level at 1% (0.8% content in a diet), more than 3% taurine supplementation (2.4% content in a diet) to no-fishmeal diet is necessary to maintain the normal physiology of yellowtail used in this study. Yellowtail might not increase dietary taurine requirement even soybean protein is a dietary protein source.

Key words: Yellowtail; No-fishmeal diet; Soy protein concentrate; Taurine

A global decline in catching fisheries and an increase in the demand in aquaculture for fish have severely limited the availability of fishmeal. Thus fishmeal has become scarce and expensive. Therefore, it is inevitable to reduce fishmeal content in diets by utilizing alternative protein sources such as plant-derived ingredients to sustain the aquaculture industry (Hardy 2010).

Yellowtail *Seriola quinqueradiata* is one of the most widely cultured and economically important aquaculture fish species in Japan. A high level of inclusion of plant ingredients in the yellowtail diet reduced the growth rate and exhibited abnormal physiology such as green liver syndrome and anemia but these abnormalities were prevented by a dietary taurine supplementation (Takagi et al. 2006a).

Taurine is a sulfur-containing amino acid naturally found in animal tissues, whereas terrestrial plants are devoid of it. The de novo synthetic capacity of taurine varied among fish species. Further, taurine is now considered as an essential nutrient in fish with low capacity such as yellowtail. Taurine deficiency is likely to cause low hematocrit value and low osmotic pressure in yellowtail (Takagi et al. 2006a) and hepatic cellular metabolism alternations in Florida pompano *Trachinotus carolinus* (Salze et al. 2016). These physiological defects were overcome by dietary taurine supplementation. Although the dietary taurine requirement in yellowtail is reported as more than 1% (Matsunari et al. 2005) or 4.5% (Takagi et al. 2006a), there are

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large differences in these reported values. One of the possible reasons for such discrepancies may be a difference in dietary protein sources. The authors in the former study used fishmeal as a protein source, but those in the latter study used soy protein concentrate (SPC). Feeding soy protein to cats has been reported to decrease plasma taurine levels via the excretion of bile acids (Kim et al. 1995). This suggests that soybean protein drains taurine-conjugated bile acids leading to reduction in taurine storage in the body. Thus, dietary taurine requirement increases to offset the loss. If dietary soy protein content influences dietary taurine requirement in yellowtail, taurine supplementation level should be adjusted according to the soy protein content in the diet. It is important to reevaluate taurine requirement in yellowtail not only for growth but also from the physiological perspective.

The aim of the present study was to clarify the effects of graded taurine levels in a soy protein-based diet on yellowtail. Six dietary taurine levels were used to study to determine the optimum taurine level to prevent growth retardation and physiological abnormalities.

Table 1. Formulation and proximate composition of the experimental diets

	Diets						
	FM	T0	T1	T2	T3	T4	T5
Ingredients (g / kg)							
Soy protein concentrate[1]	0	720	720	720	720	720	720
Fish meal	700	0	0	0	0	0	0
Fish oil[2]	60	120	120	120	120	120	120
Starch	40	40	40	40	40	40	40
Feeding stimulant[3]	0	4	4	4	4	4	4
Vitamin and mineral[4]	10	10	10	10	10	10	10
Calcium phosphate	10	10	10	10	10	10	10
Guar gum	5	5	5	5	5	5	5
CMC-Na[5]	25	25	25	25	25	25	25
L- Lysine HCl	0	10	10	10	10	10	10
DL- Methionine	0	5	5	5	5	5	5
Cellulose	150	51	41	31	21	11	1
Taurine	0	0	10	20	30	40	50
Proximate composition (dry g / kg)[6]							
Crude protein	48.8	49.2	48.9	47.2	48.6	48.8	49.1
Crude lipid	11.2	11.5	11.6	11.8	10.8	11.3	11.5
Crude ash	7.4	3.2	3.4	3.4	3.1	3.6	4.0
Taurine (mg / g)	6.1	0.0	7.5	17.4	24.4	37.3	49.7

[1] Crude protein 67 %
[2] Fish oil (Riken, Tokyo, Japan)
[3] Supplied the following (g/kg): L-proline, 354: L-alanine, 232: Inosine-5'mono phosphate, 414.
[4] Vitamine mixture containing (mg/100g dry diets) : thiamine HCl, 2.4; riboflavin, 4.4; pyridoxine HCl, 2.4; folic acid, 2.4; nicotinic acid, 7.2; calcium pantothenate, 14; biotin, 7.0; inositol, 169; choline chloride, 1168; calcium ascorbate, 178; cyanocobalamin,1.6; vitaminA palmitate, 4.0; vitamin D_3, 0.0045; vitamin E (DL-α-tocopherol), 176; menadione-$NaHSO_4$, 5.13 Mineral mixture containing (mg/100g dry diets) : KH_2PO_4, 412; Ca $(H_2PO_4)_2.H_2O$, 618; calcium lactate, 282; iron proteinate, 166; $ZnSO_4.H_2O$, 9.99; $MnSO_4.\ H_2O$, 6.3; $CuSO_4.\ H_2O$, 2.0; $CoSO_4.\ 7H_2O$, 0.05; KIO_3, 0.15.
[5] CMC-Na: sodium carboxymethyl cellulose.
[6] By analysis.

Materials and Methods

Experimental diet

Six no-fishmeal SPC based diets with graded taurine levels at 0% (T0), 1% (T1), 2 % (T2), 3% (T3), 4% (T4) and 5% (T5) and a fishmeal (FM) based diet as a control were prepared in the present study (Table 1). The analyzed taurine concentrations of the diets (mg/g dry matter) were not detectable (T0), 7.5 (T1), 17.4 (T2), 24.4 (T3), 37.3 (T4), 49.7 (T5), and 6.1 (FM), respectively. Experimental diets were prepared in a laboratory. All ingredients including taurine were mixed thoroughly in a food mixer. Thereafter, fish oil was added and mixed. Finally, water was added to the mixture to obtain dough for pelleting. The dough was pelleted by passing through 2.5 mm die in a meat grinder. Pellets were packed and stored −30°C until used.

Experimental condition and sampling

Growth study

The experiment was carried out at the Usa Marine Biological Institute, Kochi University (Kochi, Japan). Nine juvenile yellowtails (average body weight 53.8 g) were randomly distributed into each of 14 (seven treatments with two replications) indoor polyvinyl chloride tanks with a holding capacity of 200 *l*. Fish were hand-fed the experimental diets at a fixed ration of 3.3% body weight at 9:00 AM for 10 weeks. The feeding amount was adjusted every two weeks after body weight measurement. Dissolved oxygen and water temperature were monitored daily and ranged from 6.6 to 7.9 mg/*l* and from 25.1 to 26.5°C during the experiment, respectively. At the beginning and every two weeks thereafter, all fish were weighed. The fish were not fed 48 h before measuring their individual body weights. At the end of the experiment, four fish from each tank were randomly collected and anesthetized with phenoxyethanol and blood was withdrawn via the caudal vein with 1 m*l* syringes pre-filled with heparin as an anticoagulant. An aliquot of the blood sample was used to determine the hematocrit value within 2 h after taking blood and the remainder was centrifuged to obtain plasma. Hematocrit value was measured in a capillary glass tube by centrifugation at 10,000 rpm for 10 min. The rest of the blood sample was centrifuged at 15,000 rpm for 5 min to separate plasma. The plasma samples were immediately stored in a freezer at −30°C. After collecting the blood sample, two fish were then dissected to take the liver, gallbladder and dorsal muscle. The dorsal muscle was collected the area between the dorsal fin and the lateral line (2 cm × 3 cm) and separated into red (dark) and white (ordinary) muscles. The former and the latter samples were used to determined free taurine and serine concentrations, respectively. The serine concentration was measured as an indication of taurine sufficiency (Matsunari et al. 2005). All samples were stored in a freezer at −30°C until they were analyzed individually. The incidence of green liver was visually examined for the four sampled fish.

Postprandial plasma taurine study

Five fish (average body weight 35.3 g), which had been fed a commercial diet, were randomly distributed into each of the 15 tanks (five treatments in three tanks) with a holding capacity of 500 *l*. The experimental diets of FM, T0, T1, T2 and T3 were fed until apparent satiation to each triplicate tank for 7 days. Then fish were deprived of feed for 2 days, fed again and blood samples were collected at 0 (before feeding) 3, 6, and 12 h after feeding. One fish per tank was taken at each sampling time (3 fish / treatment / sampling time), and the blood samples were immediately centrifuged as described in the growth study to obtain plasma. The plasma samples were deproteinized with 5% trichloroacetic acid and clear supernatant after centrifugation at 10,000 rpm for 10 min was used for plasma taurine determination.

The integrated plasma taurine concentration during 12 h after feeding was calculated as follows.

$$T = (B + C + D) - 3A$$

where T is the taurine concentration at 12 h after feeding, and A, B, C, and D are the plasma taurine concentrations at 0, 3, 6 and 12 h after feeding, respectively.

Analytical methods

Plasma osmotic pressure was determined with a vapor pressure osmometer (VAPRO 5520 Hyland Scientific, USA). The plasma cholesterol concentration was analyzed using a commercial automatic analyzer (Dri-chem 3500V, Fujifilm, Tokyo, Japan). Taurine in the liver, red muscle, plasma and experimental diets was extracted with 5% trichloroacetic acid and quantified by high-performance liquid chromatography (L-2000, Hitachi, Japan) with a fluorescence spectrophotometer detector (F-1000, Hitachi, Japan) set at 340 nm excitation and 455 nm emission. An analytical column (150 × 4.60 mm i.d.) and a pre-column (50 × 4.6 mm i.d.) were packed with Wakosil 5C18 reverse-phase resin with a particle size of 5 μm (Wako Pure Chemical Co, Japan). Taurocholic acid (TCA) and chenodeoxycholic acid (CDC-T) concentrations in the bile juice were measured according to the method of Goto et al. (1996). Free serine concentration of the white muscle was determined using an automatic amino acid analyzer (L-8500 Hitachi, Japan) after the samples were extracted with 5% trichloroacetic acid. The proximate compositions of the experimental diets were analyzed according to the AOAC methods (AOAC, 1990).

Statistical analysis

Data were analyzed using a one-way analysis of variance. Statistical differences between groups were assessed using a Tukey- Kramer test and significance was based on a 5% level of probability.

Results

Growth study

Final body weight, specific growth rate (SGR), and feed efficiency of fish fed no-fishmeal diets (T0-T5) irrespective of the taurine supplementation levels, were significantly lower than those of FM diet fed fish (Table 2). Among the no-fishmeal diet fed groups, the final body weight of fish fed T0 was the lowest and those of T1 and T5 fed fish were significantly higher than fish fed T0 ($P < 0.05$). SGR of T0 fed fish was lower than that of fish fed all the taurine supplemented diets fed fish but significant differences were not detected. Although a daily feeding rate was originally set at 3.3%, the overall value was in the range of 3.5 to 4.0% and there was no statistically significant difference among treatments. The green liver rate was the highest at 88% in fish fed T0 diet followed by 13% in fish fed T1. However, the green liver was not found in FM and T2 to T5 diets fed fish (Table 2). Survival rate was not 100% owing to accidental stop in inlet water supply and loss after improper handling during body weight measurement within 4 weeks from the initiation of the experiment. These mortalities were not related to dietary treatments. Hematocrit value of T0 fed fish was significantly lower than FM fed fish ($P < 0.05$) but no statistical differences were seen between T1, T4 and T5 and FM fed fish. Moreover, no statistical differences were seen between T0 to T5 fed fish (Table 3). Plasma osmotic pressure values of T0 and T1 fed fish were significantly lower than those of FM fed fish ($P < 0.05$) and no significant differences were detected between FM and T3 to T5 fed fish. Plasma total cholesterol concentrations of fish fed T0 to T5 diets fed fish were significantly lower than those of FM fed fish and no statistically significant differences were found in T0 to T5 fed fish. The taurine concentrations of the liver and red muscle of fish fed T0 were significantly lower than those of fish fed FM and no statistically significant differences were found between fish fed FM and T1 to T5. On the other hand, the white muscle free serine concentration of T0 fed fish was significantly higher than that of FM fed fish ($P < 0.05$), but no statistically significant differences were found between fish fed FM and T1 to T5 (Table 4). There was no statistically significantly difference among dietary treatments in biliary TCA concentrations. On the other hand, the CDC-T concentration of T0 fed fish was significantly lower than that of FM fed fish ($P < 0.05$) and there were no significant differences between FM and T1 to T5 fed fish (Table 5).

Table 2. Performance of yellowtail fed the experimental diets for 10 weeks

	Diets						
	FM	T0	T1	T2	T3	T4	T5
Initial body weight (g)	53.3 ± 1.13	54.1 ± 1.34	53.6 ± 0.71	51.1 ± 2.12	55.6 ± 0.64	53.3 ± 0.42	53.8 ± 1.06
Final body weight (g)	116.7 ± 8.01^{a}	58.3 ± 0.12^{c}	79.2 ± 11.55^{b}	62.0	69.4 ± 2.24^{bc}	70.3 ± 0.59^{bc}	75.4 ± 6.76^{b}
Feed efficiency (%)	39.5 ± 3.03^{a}	3.6 ± 1.53^{b}	20.3 ± 10.16^{b}	8.7	11.5 ± 2.14^{b}	13.2 ± 0.80^{b}	16.9 ± 6.04^{b}
Dairy feeding rate (%)	3.5 ± 0.1	3.8 ± 0.1	3.6 ± 0.4	4.1	3.6 ± 0.0	3.8 ± 0.2	3.7 ± 0.1
Specific growth rate (%)	1.45 ± 0.09^{a}	0.14 ± 0.06^{b}	0.71 ± 0.30^{b}	0.36	0.41 ± 0.08^{b}	0.51 ± 0.0^{b}	0.62 ± 0.2^{b}
Survival (%)	92	100	75	50	100	100	92
Green liver (%)	0	88	14	0	0	0	0

Values are means ± SD of two tanks except T2. Values with different alphabets are significantly different ($P < 0.05$).

Table 3. Blood components of yellowtail

	Diets						
Parameter	FM	T0	T1	T2	T3	T4	T5
Hematocrit (%)	41.4 ± 3.4^{a}	29.4 ± 7.2^{c}	36.9 ± 3.7^{ab}	33.3	35.1 ± 2.4^{bc}	36.8 ± 3.1^{ab}	38.0 ± 2.3^{ab}
Osmotic pressure (mosm/kg H_2O)	393.3 ± 6.5^{a}	354.0 ± 5.5^{c}	373.4 ± 1.1^{bc}	375.0	375.1 ± 4.1^{ab}	383.6 ± 1.4^{ab}	379.1 ± 1.6^{ab}
Total cholesterol (mg/100 m*l*)	248.2 ± 1.5^{a}	88.6 ± 2.9^{b}	78.8 ± 5.3^{b}	86.2	83.5 ± 1.2^{b}	87.8 ± 9.2^{b}	82.7 ± 3.3^{b}

Values are mean ± SD two replicates except T2. Values with different alphabets are significantly different ($P < 0.05$).

Table 4. Taurine and serine concentration of fish fed the experimental diets for 10 weeks

	Diets						
	FM	T0	T1	T2	T3	T4	T5
Taurine concentration (mg / g wet weight)							
Liver	5.45 ± 0.34[a]	0.32 ± 0.12[b]	6.80 ± 1.26[a]	5.41	6.23 ± 0.78[a]	6.37 ± 2.25[a]	5.30 ± 0.74[a]
Red muscle	8.91 ± 1.02[a]	4.25 ± 1.97[b]	8.38 ± 2.80[a]	9.49	11.1 ± 1.20[a]	9.93 ± 2.25[a]	9.81 ± 2.35[a]
Serine concentration (mg / 100g wet weight)	4.4 ± 0.8[b]	7.1 ± 0.8[a]	3.2 ± 0.4[b]	4.0	3.8 ± 0.3[b]	4.5 ± 0.9[b]	3.5 ± 0.3[b]

Values are mean ± SD two replicates except T2. Values with different alphabets are significantly different ($P < 0.05$).

Table 5. Bile acid composition of fish fed the experimental diets for 10 weeks

	Diets						
	FM	T0	T1	T2	T3	T4	T5
TCA (μmol / m*l*)	175.6 ± 27.5	150.2 ± 14.7	226.8 ± 61.4	238.4	178.2 ± 20.9	154.3 ± 45.9	200.2 ± 37.1
CDC-T (μmol / m*l*)	39.9 ± 11.2[a]	15.1 ± 0.4[b]	27.1 ± 8.1[ab]	34.3	23.6 ± 7.6[ab]	39.1 ± 1.6[ab]	32.2 ± 2.5[ab]

Values are mean ± SD two replicates except T2. Values with different alphabets are significantly different ($P < 0.05$).
TCA : Taurocholic acid.
CDC - T : Taurochenodeoxycholic acid.

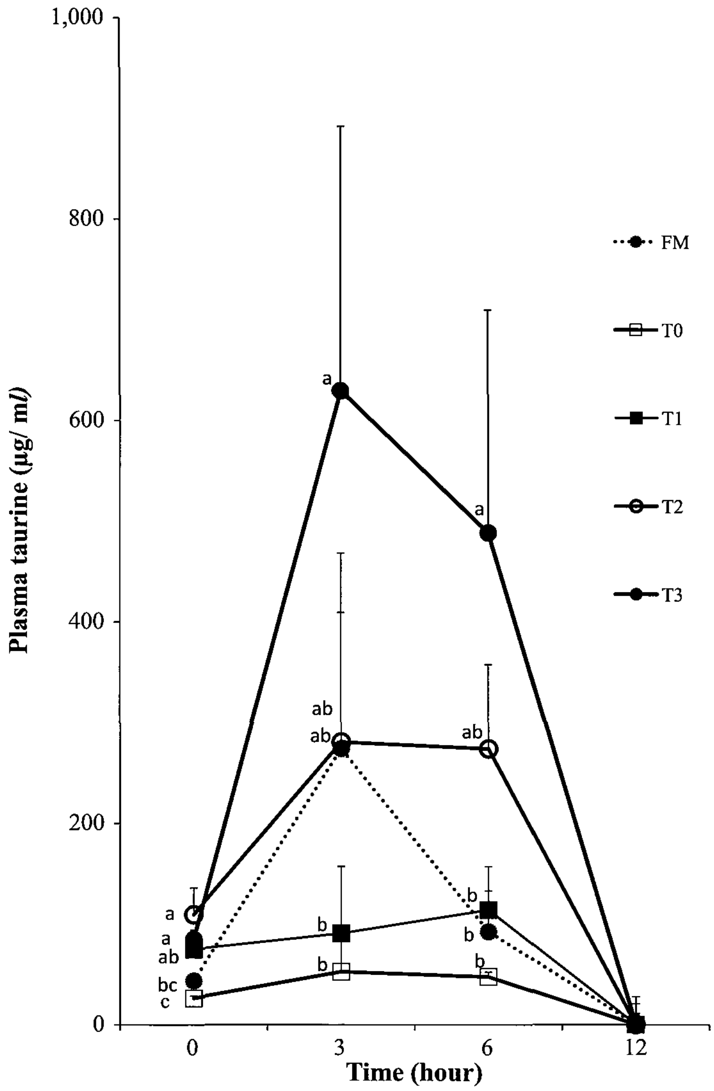

Fig. 1. Plasma taurine concentration of fish fed different dietary taurine supplementations. Values are means ± SD of three fishes. Values with different alphabets at each sampling time are significantly different ($P < 0.05$). Samples are identified by the following symbols: Dash line with ●, fish meal; □, taurine 0%; ■, taurine 1%; ○, taurine 2%; ●, taurine 3 %

Postprandial plasma taurine concentration

Plasma taurine concentrations of T0 and T1 fed fish did not show apparent changes during sampling (Fig. 1). On the other hand, the plasma taurine concentrations of fish fed FM, T2 and T3 had peaks at 3 h after feeding and those of fish fed T3 were significantly higher than those of the other dietary treatments examined. The integrated plasma taurine concentration (μg/m*l*) during the 12 h after feeding was T0 (1.24) < T1 (2.2) < FM (2.30) < T3 (6.36).

Discussion

The effects of graded level of taurine on growth performance of yellowtail fed no-fishmeal SPC-based diet were examined. The final body weight of fish fed T0 was the lowest among dietary treatments but it was improved with a taurine concentration more than 0.8% in the diet. Similarly, the taurine requirement of yellowtail (Matsunari et al. 2005) has been estimated at 1.0% when fish were fed a diet with fishmeal as the sole protein source. This implies that taurine requirement does not change irrespective of the dietary protein source. On the other hand, Takagi et al. (2006a) reported that the taurine requirement of yellowtail was 4.5% after 40 weeks of feeding trial. The dietary taurine requirement of yellowtail may increase with growth. Green liver is a prominent symptom of dietary taurine insufficiency in some fish species such as red sea bream *Pagrus major* (Goto et al. 2001; Takagi et al. 2006b), yellowtail (Takagi et al. 2006a), and yellowtail king fish *Seriola lalandi* (Bowyer et al. 2012). Takagi et al. (2006a) reported that taurine level at 3% in the diet could prevent a severe green liver in yellowtail with an initial body weight of 250 g, although they did not set a dietary taurine level less than 3%. In the present study, green liver was observed at a high rate in fish fed T0, whereas it was not observed in fish fed diet with taurine levels higher than 1.7% in the diet. This indicates that a taurine level at least 1.7% is necessary to completely prevent the green liver in fish size (initial weight c.a. 54 g) used in the present study.

Anemia or a reduction of red blood cell number has been reported as a sign of typical taurine insufficiency in yellowtail (Takagi et al. 2005). In the present study, hematocrit value, which is a criterion of anemia, of fish fed T0 diet was the lowest and it was significantly improved by diet containing 0.8% taurine (T1). In addition, the plasma osmotic pressure of T0 fed fish was the lowest but it was improved by diets containing higher than 2.4% taurine (T3-T5). A hypotonic solution with low osmotic pressure is known to lyse red blood cells and an important role of amino acids in osmoregulation has been reported in fish (Assem and Hanke 1983). Thereby, the reduction of plasma taurine concentration would have strong effects in osmolality. In fact, taurine has been suggested to have an important role in maintaining the osmotic pressure in yellowtail plasma (Takagi et al. 2006a). A low plasma taurine content in fish fed T0 might have induced hemolysis and resulted in lower red blood cell volume, i.e., a low hematocrit value. Therefore, a dietary taurine concentration of 2.4% is necessary to prevent anemia in yellowtail at the growth stage examined in the present study.

Taurine concentrations of the red muscle and liver of T0 fed fish were the lowest among dietary treatments and those of fish fed diets supplemented with taurine at more than 0.8% in the diet reached plateau levels. Similarly, the taurine concentration in the muscle of juvenile yellowtail was steady at more than 1.3% in the diet (Matsunari et al. 2005). Their study and the present result suggest that these tissues of young yellowtail were saturated with taurine levels less than 1.7% in the diet. Postprandial plasma taurine levels in the present study revealed that they increased as dietary taurine levels increased. This indicates that the saturated tissue taurine levels in fish fed diets with higher dietary taurine levels are not due to the restriction of absorption from the intestine.

An increase of free serine content in the white muscle of yellowtail (Matsunari et al. 2006; Khaoian et al. 2014) and red sea bream (Matsunari et al. 2008) has been reported when they were fed diets with low taurine concentrations. It has been suggested that an accumulation of serine in tissues is due to the low enzyme activity of an enzyme involved in taurine biosynthesis, although the exact mechanism of the accumulation has not been elucidated, yet (Matsunari et al. 2005). In the present study, the serine concentration in the white muscle of T0 fed fish was significantly higher than that of FM fed fish but decreased without significant differences in fish fed diets with taurine concentration higher than 0.8% in the diet. This result is in accordance with the tissue taurine concentrations in the study of red sea bream, showing a steady concentration at higher than 1% in the diet (Matsunari et al. 2008). These results suggest that dietary taurine concentration at least 1% is necessary to maintain a normal taurine status of fish in the present study.

One of the important physiological functions of taurine is the conjugation of bile salts. Bile acids need to conjugate with glycine or taurine to increase polarity before they are dissolved in the bile juice (Tuchweber et al. 1996). In yellowtail, non-conjugated bile salt has not been found in the biliary bile juice and the conjugation of bile salt has been reported to be exclusive with taurine (Goto et al. 1996). In the present study, more than 80% of biliary bile salts of yellowtail were TCA and the rest was CDC-taurine, which is a similar result with previous reports in yellowtail (Goto et al. 1996; Khaoian et al. 2014). Low dietary taurine concentration has been known to affect biliary bile salt composition in yellowtail (Goto et al. 2007; Khaoian et al. 2014), Japanese flounder *Paralichthys olivaceus* (Kim et al. 2008), and Korean rockfish *Sebastes schlegelii* (Kim et al. 2015). In the present study, the biliary CDC-taurine concentration was the lowest in T0 fed fish and increased at higher dietary taurine concentrations although there were no statistically significant differences between T0 and the other taurine supplemented diets fed groups. A dietary taurine concentration higher than 0.8% in the diet may be necessary to normalize the bile salt composition of yellowtail.

The decrease in plasma cholesterol concentrations in fish fed diets with plant protein has been reported in several fish species including yellowtail (Nguyen et al. 2011). In the present study, the plasma cholesterol concentrations of all SPC-based diets fed fish were significantly lower than those of FM fed fish, regardless dietary taurine levels. This result indicates that dietary taurine level is not a direct cause of low plasma cholesterol level.

The final body weight, SGR and feed efficiency were improved by supplementation of taurine, however, these parameters were still significantly inferior to FM fed fish indicating there is another factor(s), other than taurine insufficiency, that reduces the growth of no-fishmeal diet fed fish. Further studies are necessary to elucidate the factor for development of no-fishmeal diets for yellowtail.

In conclusion, a taurine level of 0.8% in the no-fishmeal SPC based diet saturated the red muscle and liver taurine concentrations in juvenile yellowtail. Furthermore, it improved the final body weight, tissue serine concentration, and hematocrit value. On the other hand, a taurine concentration of 2.4% in the diet was necessary for the improvement of plasma osmotic pressure and prevention of green liver. Therefore, more than 2.4% taurine concentration in the SPC-based no-fishmeal diet is necessary to maintain the normal physiology of yellowtail used in the present study. Yellowtail may not increase dietary taurine requirement even soybean protein is a dietary protein source.

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無魚粉飼料への段階的なタウリン添加が
ブリ幼魚の成長と生理に及ぼす影響

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ブリ幼魚におけるタウリンの添加効果を調べるため，濃縮大豆タンパク質主体の無魚粉飼料にタウリンを段階的に添加した飼料（0, 1, 2, 3, 4 および 5%）および魚粉対照飼料を10週間与えた。最終魚体重では，0%添加飼料区が試験区間で最も低かったが，1%添加飼料区で有意に改善した。肝臓と赤筋のタウリン濃度も 0%添加飼料区が他区に比べて有意に低かったが，1%以上の添加区で有意に高くなった。また 1%以上の添加区間に有意差は無かった。白筋のセリン含量は 0%添加飼料区が最も高く，1%以上区で有意に低くなり，タウリン添加区間に差はなかった。一方，緑肝症の完全な抑制や血漿浸透圧の正常化にはタウリン添加濃度 3%以上の添加が必要であった。以上の結果から，1%の添加（飼料含量0.8%）で組織タウリン含量は飽和に達するが，正常な生理状態の維持には少なくとも 3%（飼料含量2.4%）の添加が必要と考えられた。