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Growth Performance of Nile Tilapia *Oreochromis niloticus* Juveniles fed Sweet Potato and Soy Sauce By-product Meal Diet in a Flow Through System

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Abstract: A 6-week feeding trial was conducted to evaluate the potential to use sweet potato and soy sauce by-product as an ingredient in the diet of *Oreochromis niloticus* juveniles. Five experimental diets D1－D5 were formulated with 0, 10, 20 and 30% sweet potato, and a mixture of 10% soy sauce by-product and 20% sweet potato, respectively. A commercial extruded pellet diet was used as the control (D6). *O. niloticus* juveniles with an initial weight of about 3 g were reared in 30 *l* aquariums illuminated by overhead fluorescent lights to maintain a constant photoperiod of 12 h light and 12 h dark cycle. Water temperature was maintained at 25±0.5℃. The control commercial diet showed the best growth performance. Among the formulated experimental diets, D1 had the best growth performance and D5 had the lowest growth performance in terms of the growth parameters measured. Whereas there was no significant difference between D2 and D3, but the performance in both diets was much better than D4 and D5. These results demonstrated that a 10－20% inclusion of sweet potato meal could be used as a replacement of wheat meal in practical diets for juvenile *O. niloticus*. With an appropriate recycling method, soy sauce by-product can be used as a fish food ingredient if the offensive odours are removed.

Key words: *Oreochromis niloticus*; Growth performance; Sweet potato; Soy sauce by-product

Aquafeed production is currently one of the fastest growing agricultural industries, with an annual estimated growth rate of 30% per year (De Silva and Anderson 1994). Feed occupied majority of the principal cost in finfish aquaculture (Cowey 1992). The search for alternative feed resources in aquafeed is gaining more attention since conventional ingredients are becoming more costly, less affordable and less available (Alexis et al. 1985; Olvera-Novoa et al. 1990; Fontaínhas-Fernandes et al. 1999; El-Sayed 1999; Naylor et al. 2000; Middleton et al. 2001; Rinchard et al. 2002; Ali et al. 2003; Adewolu 2008). The use of alternative ingredients that reduce feed costs yet maintain adequate levels of growth and production can have a marked impact on the sustainability and profitability of aquaculture industry. The inclusions of unconventional plant ingredient sources depend on other factors such as the nutrient content of the plant, processing conditions and economic feasibility (El-Sayed 1999). Tilapia is one of the most cultured freshwater fish in the world and can be grown year round with some variability in fish yields depending upon seasonal differences (Green et al. 1990). Moreover, tilapia is capable of digesting high levels of carbohydrate in its diet (Brett and Groves 1979; Anderson et al. 1984; National Research Council 1993). It also effectively utilizes alternative feed ingredients such as rice, cocoa, various flours, and soya-nut oil (Jackson et al. 1982; Brown 1983).

The sweet potato, *Ipomoea batatas* L. is cultivated in over 100 countries and ranks

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fifth among the most important food crops in tropical areas (An 2004). The carbohydrate of sweet potato is highly digestible and soluble. It is low in fibre and consists predominantly of starch with 4 – 7% of it occurring as sugar (Oyenuga 1978), which consists of a large extent of non-protein nitrogen. According to Fuller and Chamberlain (1982), sweet potato amino acid profile shows good nutritional quality although lower level of tryptophan and total sulphur when compared to the reference amino acid profile. Sweet potato is moderately high in ascorbic acid, carotene and also contains other vitamins such as thiamine, riboflavin and niacin (Fuller and Chamberlain 1982). The nutritive quality of sweet potato is reduced by the effect of anti-nutritive factors, which can be reduced by oven drying, sun drying or hot air drying during feed ingredient processing.

With the advancement in technology more efficient ways to reuse food by-products have been developed. The production of soy sauce usually gives rise to the production of soy sauce cake. It has been reported that soy sauce cake is a useful by-product containing good nutritive rich fat, high anti oxidant fat-soluble vitamin E as well as vitamin K_1 which is indispensable for blood coagulation and a lot of isoflavone that is antioxidant and acts like female hormone (Luh 1994; Esaki et al. 2004). It is usually discarded but with an improved dehydration method it can be dried after fermentation without losing its nutritional qualities.

Although these materials are available, little or no information exists on their use as fish feed ingredient. This study was conducted to evaluate the potential use of sweet potato and soy sauce by-product in the practical diet of juveniles *O. niloticus* through their growth performance.

Materials and Methods

Sweet potato

The sweet potatoes used for this experiment were collected from Indonesia. This variety is mainly cultivated for starch production with a high root yield and high starch content. Freshly harvested sweet potatoes were collected, sorted out, washed, chopped into pieces and hot air dried to reduce the effect of trypsin and then ground into a powder.

Soy sauce by-product

Soy sauce by-product was produced at Yamasa Corporation and processed by Nippon Formula Feed Mfg. Co. Ltd. After the fermentation of soybean and soy sauce extraction, the residual cake was collected, dried and recycled by dehydration to reduce the moisture to a very low level.

Experimental diets

The diets used in this experiment were manufactured and produced at the Laboratory of Formula Feed Mfg. Co. Ltd. Five experimental diets D1 – D5 were formulated with sweet potato of 0, 10, 20 and 30% and a mixture of 10% soy sauce by-product and 20% sweet potato, respectively. These diets were formulated as shown in Table 1 and pelleted using an extruder machine (DNDG-62; Buhler AG, Switzerland). A commercial extruded pellet diet was used as the control (D6).

Experimental conditions and fish rearing

The experiment was carried out at the Laboratory of Fish Culture, Tokyo University of Marine Science and Technology, Japan. A freshwater flow-through system with filtered and dechlorinated tap water at 9 *l*/h was used for the study. This consists of twelve 30 *l* aquariums and water temperature was maintained at

Table 1. Formulation of the experimental diet for juveniles *O. niloticus*

Ingredients	Diet code					
	D1	D2	D3	D4	D5	D6
Wheat meal	46.0	36.0	26.0	16.0	17.8	Commercial diet
Sweet potato	0.0	10.0	20.0	30.0	20.0	
Soybean meal	10.0	10.0	10.0	10.0	10.0	
Corn gluten meal	5.7	5.7	5.7	5.7	5.7	
Fish meal	30.0	30.0	30.0	30.0	30.0	
Soybean oil	4.0	4.0	4.0	4.0	3.0	
Vitamin premix*[1]	0.5	0.5	0.5	0.5	0.5	
Chorine chloride (50%)	0.5	0.5	0.5	0.5	0.5	
Mineral premix*[2]	3.3	3.3	3.3	3.3	3.3	
Soy sauce by-product	-	-	-	-	10.0	
Total	100.0	100.0	100.0	100.0	100.0	-

*[1] Ogino and Yang (1978).
*[2] Ogino et al. (1979).

25±0.5℃ using electric heaters. The aquariums were provided with continuous aeration through an air blower. Illumination was supplied by overhead fluorescent lights to maintain a constant photoperiod of 12 h light and 12 h dark cycle (8:00−20:00) throughout the experiment. The water temperature and dissolved oxygen in the system were monitored weekly.

The tilapia *O. niloticus* juveniles (average weight: 2.9 g) used for this experiment were obtained from pure-bred tilapia broodstock, held at the laboratory. Twenty fish were stocked in each 30 *l* aquariums with a flow through system for six weeks. Fish were weighed individually at the beginning and thereafter at two-week intervals using an electronic balance (EB-3200D; Shimadzu Corporation, Kyoto, Japan) to observe the growth changes and feed performance.

Biochemical analyses

The experimental diets were subjected to chemical analysis. Proximate analysis and lipid analysis were carried out according to the methods of Takeuchi (1988) and Folch et al. (1957). For fatty acid profile analysis, crude lipid was saponified using 50% ethanol to prepare methyl esters with 7% boron trifluoride in a methanol solution (BF_3-methanol). The fatty acid profile was determined using gas liquid chromatography (GC-14A; Shimadzu Corporation, Kyoto, Japan). An amino acid auto analyzer (JLC-500V; JOEL Ltd., Tokyo, Japan) was used to determine the constitutional amino acids of the diets in accordance with the method described by Simpson et al. (1976).

Evaluation of growth parameters

Growth performance and diet nutrient utilization were analyzed in terms of weight gain (WG), feed efficiency (FE), specific growth rate (SGR), feed intake (FI) and protein efficiency ratio (PER). The following formulas were used:

Weight gain (%) =
 (final weight (g) − initial weight (g)) / initial weight (g) × 100

Feed efficiency (%) =
 (weight gained (g) / feed fed (g)) × 100

Specific growth rate (%) =
 ((ln final weight (g) − ln initial weight (g)) / feeding period (day) × 100

Feed intake (mg/fish/day) =
 dry feed (mg) fed / number of fish / feeding period (day)

Protein efficiency ratio =
 wet body weight gain (g) / protein intake (g)

Statistical analyses

Data were analyzed using a one way analysis of variance (ANOVA) using SPSS, version 11.0 (SPSS Inc., Illinois, USA). Differences between treatments were compared by Tukey's multiple comparison test. Level of significance was tested at $P < 0.05$.

Results and Discussion

Except for D6 (control), which is a commercial diet, all the formulated diets used in the present study were isonitrogenous. The chemical composition of the diets indicates increase in the inclusion level of sweet potato in D2, D3, and D4 led to an increase in the level of starch content, while inclusion of 20% sweet potato and

Table 2. Proximate composition of the diets (%) and constitutional amino acid content of the experimental diets fed juveniles *O. niloticus* for 42 days (g/100 g)

Diet code	D1	D2	D3	D4	D5	D6
Proximate composition						
Crude protein	39.70	38.89	37.17	35.37	38.04	52.00
Crude lipid	8.33	8.27	8.51	7.93	8.23	12.26
Starch	37.13	22.31	22.68	28.41	15.89	18.20
Ash	8.27	9.04	9.07	8.94	8.42	12.20
Moisture	6.50	6.64	6.85	6.24	6.61	6.76
Essential amino acid						
Arginine	2.65	2.92	2.82	2.74	2.58	3.15
Lysine	4.23	4.28	4.20	4.16	4.80	4.31
Histidine	1.72	1.53	1.73	1.72	1.84	1.70
Phenylalanine	2.37	2.61	2.44	2.32	2.40	2.51
Leucine	2.55	3.00	2.68	2.43	2.53	3.98
Isoleucine	3.10	3.26	3.09	3.09	3.02	2.23
Methionine	1.07	1.06	0.89	0.11	1.09	1.51
Valine	2.30	2.26	2.29	2.05	2.22	2.54
Threonine	3.26	3.20	3.31	3.09	3.30	3.49
Tryptophan	0.63	0.50	0.66	0.54	0.99	1.04
Non-essential amino acid						
Taurine	0.09	0.08	0.08	0.07	0.11	0.50
Alanine	1.84	2.18	1.96	1.85	1.90	3.36
Glycine	1.57	1.85	1.60	1.60	1.71	3.25
Glutamic acid	5.91	6.81	5.81	5.17	5.52	7.49
Serine	1.41	1.67	1.47	1.37	1.49	2.24
Aspartic acid	3.65	3.20	3.84	3.83	3.88	4.85

Table 3. The results of growth performances of juvenile *O. niloticus* in the 42 days feeding

Diet code	Av. body weight (g)		Body weight gain (%)	Specific growth rate (%)	Total feed intake (g/fish)	Feed efficiency (%)	Protein efficiency ratio
	Initial	Final					
D1	2.90±0.04	20.9 ± 2.0^{cd}	620.7 ± 2.0^{cd}	5.47 ± 0.23^{cd}	16.1 ± 2.10^{b}	111.9 ± 2.5^{b}	3.11±0.02
D2	2.91±0.01	18.6 ± 0.4^{bc}	539.2 ± 0.4^{bc}	5.15 ± 0.08^{bc}	14.6 ± 0.38^{ab}	107.3 ± 0.2^{ab}	3.10±0.01
D3	2.97±0.01	19.2 ± 0.3^{bc}	456.5 ± 0.3^{bc}	5.19 ± 0.05^{bc}	15.6 ± 0.67^{b}	104.5 ± 2.7^{ab}	3.15±0.04
D4	2.96±0.04	16.7 ± 0.5^{ab}	464.2 ± 0.5^{ab}	4.81 ± 0.04^{ab}	13.8 ± 0.04^{ab}	99.3 ± 3.3^{a}	3.24±0.03
D5	2.94±0.04	14.7 ± 1.4^{a}	400.0 ± 1.5^{a}	4.47 ± 0.03^{a}	11.4 ± 0.34^{a}	103.2 ± 0.6^{ab}	3.16±0.02
D6	2.93±0.03	22.4 ± 0.7^{d}	664.5 ± 0.7^{d}	5.65 ± 0.05^{d}	14.3 ± 0.93^{ab}	136.4 ± 4.4^{c}	3.00±0.01

Mean±S.D. (n=2).
Values in the same column with different super script letters are significantly different ($P<0.05$) from each other.

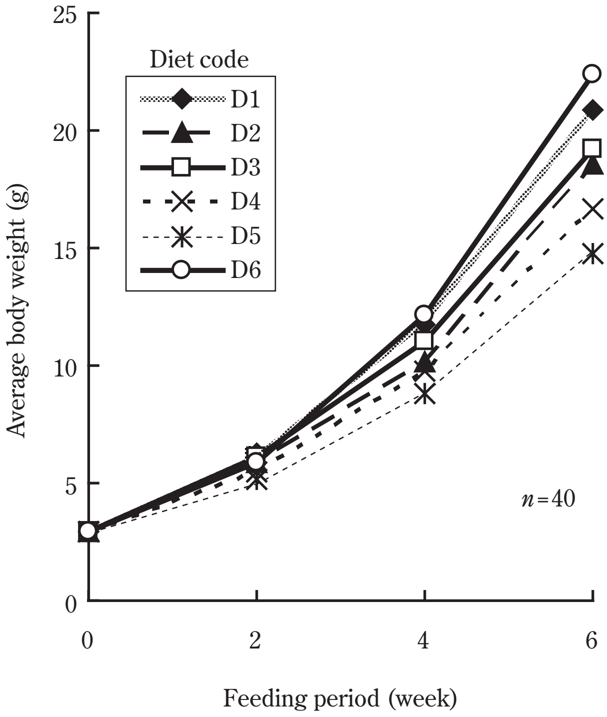

Fig. 1. Growth curves of juveniles *O. niloticus* during the 6-week feeding trial.

10% soy sauce in D5 had lower starch content. This further affirms that soy sauce ingredient is not a starchy material. Carbohydrate is the least expensive form of dietary energy for both human and domestic animals, but their utilization by fish varies and the potential for their use in diets remains unclear (Shiau 2002). It has been reported that starch utilization by tilapia is significantly higher than glucose (Shiau 2002). Studies also show that tilapias have relatively long digestive tract that allows the establishment of polysaccharide, hence its ability to effectively utilize starch materials. However in the context and the result of this study show that among the formulated diets the high starch content in the diet may not be the only reason for the weight gain since D2 and D3 did better than D4, which has higher starch content.

The food quality of a diet is directly proportional to its ability to support growth, and its dietary content is of paramount importance. One of the limiting growth factors in fish is protein, and it is well known that 10 standard amino acids are essential for building new tissues (Lu et al. 2002). Table 2 compares the constitutional essential amino acid (EAA) composition of the diets with the minimum quantitative requirement of *O. niloticus* reported by Santiago and Lovell (1988). The good growth of tilapia fed the diets in this study indicated that the EAA values of these diets were sufficient despite being lower than the recommended EAA requirement levels for *O. niloticus* except for D4, which was very low in methionine and tryptophan. The richness of these diets in the essential amino acids is evident in the growth performance of fish fed the experimental diets. Therefore a progressive reduction in the growth performance in accordance with the inclusion level may not be necessary due to deficiency of amino acid in the diets. This is in agreement with El-Sayed (1999) that most plant sources of ingredient in tilapia feeds may usually not be deficient in EAA but in minerals. The fatty acid compositions of the experimental diets agree with the minimum requirements of essential fatty acid for tilapia according to Takeuchi (1997).

The growth performances of juvenile *Oreochromis niloticus* in terms of WG, SGR, FE, FI and PER are shown in Table 3 and Fig. 1. Juvenile *O. niloticus* fed the commercial diet (D6, control) gave the best growth performance.

Among the formulated experimental diets, juvenile *O. niloticus* fed on D1 had the highest WG, SGR and FI while D5 had the lowest WG, SGR, and FI. However, there was no significant ($P <$ 0.05) difference among D1, D2 and D3.

FE decreased with increase of the inclusion level of sweet potato. There was no significant difference between D2 and D3, D5, however obviously it was much better than D4. This indicates that D5 has a high nutritive content and its low intake may be responsible for low in WG and SGR. This result is similar to the findings of Gerpacio et al. (1978) where two-week old broilers (chickens) were fed sweet potato root meal replacing 0, 50, 75 and 100% of corn for six weeks. The growth performance of the birds fed sweet potato decrease with increase in sweet potato inclusion but can be used as a good source of ingredient in the diets of the birds. Olukunle (2006) reported that increasing the inclusion of sweet potato peels in the diet of advance fry of *Clarias gariepinus* reduced their growth performance. When the PER was compared with the control, there was no significant difference among treatments ($P > 0.05$).

No fish mortality was recorded during the feeding trial in all the treatments. Moreover, all the experimental fish remaining in the tanks were morphologically normal at the end of the feed trial. The water temperature 25±0.5℃ and the dissolved oxygen 6.6 – 8.3 mg/*l* were within the acceptable range for tilapia culture (Balarin and Hatton, 1979).

In summary, the growth performance of *O. niloticus* fed diet with sweet potato and soy sauce by product as presented in Table 3 shows that there was no feed rejection during the experiment, the diets were accepted and ingested feeds actively by the fish, although the acceptability differs among the treatment as could be seen in their total feed intake. When plant materials are used in fish diets, one common problem is the palatability of the diet (Rodriguez-Serna et al. 1996). The inclusion level of sweet potato does not affect the palatability of the diet as the fish fed better on D3 than D2. There was no significant difference between D2 and D4. The unpalatable odour from the inclusion of soy sauce by-product might be responsible for the lowest FI of D5. The strong offensive smell was attributable to the production of the soy sauce through fermentation, which the dehydration process during recycling process could not remove. Proper processing of feed ingredients usually increases the palatability of a diet (Fagbenro 1999; Francis et al. 2001; Siddhuraju and Becker 2003). Another factor may be the use of high salt content during soy sauce production, according to Hano et al. (2004) one of the major constrain of using soy sauce cake for livestock feeding is the presence of high salt content found in the cake, since chlorine in the soy sauce cake is usually as high as 5 – 7%, this may have likely affect the ability of the fish to feed effectively on the diet. The high FI obtained in this study may be ascribed to the processing technique employed during the feed formulation with extrusion process. This may have reduced the effect of anti-nutritive factors in the sweet potato roots. In conclusion, the results of this study demonstrate that 10 – 20% of sweet potato can be used to replace wheat meal in the fish diet, and can also be used effectively as an ingredient in the practical diet of juvenile *Oreochromis niloticus*. However, a method should be developed to reduce the unpleasant smell that characterizes the high-nutritive soy sauce ingredients.

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References

Adewolu, M. A. (2008) Potentials of sweet potato (*Ipomoea batatas*) leaf meal as dietary ingredient for *Tilapia zilli* fingerlings. *Pakistan J. Nutr.*, **7**, 444–449.

Ali, A., N. A. Al-Asgah, S. M. AL- Ogaily and S. Ali (2003) Effect of feeding different levels of alfalfa meal on the growth performance and body composition of Nile tilapia (*Oreochromis niloticus*) fingerlings. *Asian Fish. Sci*., **16**, 59–67.

An, L. V. (2004) Sweet potato leaves for growing pigs. Biomass yield, digestion and nutritive value. Doctor's thesis, Swedish University of Agriculture Sciences, Uppsala. pp. 47

Anderson, J., A. J. Jackson, A. J. Matty and B. S. Capper (1984) Effects of dietary carbohydrate and fibre on the tilapia *Oreochromis niloticus* (Linn.). *Aquaculture*, **37**, 303–314.

Alexis, M. N., E. Papaparaskeva-Papoutsoglou and V. Theochari (1985) Formulation of practical diets for rainbow trout (*Salmo gairdneri*) made by partial or complete substitution of fish meal by poultry by-products and certain plant by products. *Aquaculture*, **50**, 61–73.

Balarin, J. D. and J. P. Hatton (1979) Tilapia: A guide to their biology and culture in Africa. Unit of Aquatic Pathobiology. University of Stirling, Scotland. 174p.

Brett, J. R. and T. D. D. Groves (1979) Physiological energetic. In: "*Fish Physiology, Bioenergetics and Growth Vol. 8*" (ed. by W. S. Hoar, D. J. Randall, J. R. Brett), Academic Press, New York, pp. 279–352.

Brown, E. E. (1983) World Fish Farming: Cultivation and Economics. 2nded. AVI publishing, Connecticut, 397p.

Cowey, C. B. (1992) Nutrition: Estimating requirements of rainbow trout. *Aquaculture*, **100**, 177–189.

De Silva, S. S. and T. A. Anderson (1995) Fish Nutrition in Aquaculture. Chapman and Hall, London, 319 pp.

El-Sayed, A.-F. M. (1999) Alternative dietary protein sources for farmed tilapia, *Oreochromis* spp. *Aquaculture*, **179**, 149–168.

Esaki, H., R. Watanabe, N. Hishikawa, T. Osawa and S. Kawakishi (2004) Utility of isoflavone preparation from soy sauce cake as antioxidant materials. *Nippon Shokuhin Kogaku Kaishi*, **51**, 47–53.

Fagbenro, O. A. (1999) Comparative evaluation of heat-processed winged bean (*Psophocarpus tetragonolobus*) meals as partial replacement for fish meal in diets for the African catfish (*Clarias gariepinus*). *Aquaculture*, **170**, 297–305.

Fontaínhas-Fernandes, A., E. Gomes, M. A. Reis-Henriques and J. Coimbra (1999) Replacement of fish meal by plant proteins in the diet of Nile tilapia: digestibility and growth performance. *Aquacult. Int*. **7**, 57–67.

Folch, J., M. Lees and G. H. Sloane-Stanley (1957) A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem*., **226**, 497–509.

Francis, G., H. P. S. Makkar and K. Becker (2001) Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects on fish. *Aquaculture*, **119**, 197–227.

Fuller, M. F. and A. G. Chamberlain (1982) Protein requirements of pigs. In "*Recent Advances in Animal Nutrition*" (ed by W. Haresign), Butterworths, London, p. 176.

Gerpacio, A. L., F. S. Pascual, L. J. Querubin, A. F. Vergel De Dios and C. I. Mercado (1978) Evaluation of tuber meals as energy sources. 1. Sweet potato and cassava based rations for broilers. *Philippine Agriculturalist*, **61**, 395–410.

Green, B. W., D. R. Teichert-Coddington and R. P. Phelps (1990) Response of tilapia yield and economics to varying rates of organic fertilization and season in two Central American countries. *Aquaculture*, **90**, 279–290.

Hano, T., M. Hirata and H. Takanashi (2004) Approch to zero emission processes in food industry − Case study for soy-sauce production process −. *J. Water Environ. Tech*., **2**, 1–7.

Jackson, A. J., B. S. Capper and A. J. Matty (1982) Evaluation of some plant proteins in complete diets for the tilapia, *Sarotherodon mossambicus. Aquaculture*, **27**, 97–109.

Lu, J., G. Yoshizaki, K. Sakai and T. Takeuchi (2002) Acceptability of raw *Spirulina platensis* by larval tilapia *Oreochromis niloticus. Fish Sci*., **68**, 51–58.

Luh, B. S. (1994) Industrial production of soy sauce. *J. Indust. Microbio*., **14**, 467–471.

Middleton, T. F., P. R. Ferket, L. C. Boyd, H. V. Daniels and M. L. Gallagher (2001) An evaluation of co-extruded poultry silage and culled jewel sweet potatoes as a feed ingredient for hybrid tilapia (*Oreochromis niloticus* × *O. mossambicus*). *Aquaculture*, **198**, 269–280.

Naylor, R. L., R. J. Goldburg, J. H. Primavera, N. Kautsky, M. C. M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney and M. Troell (2000) Effect of aquaculture on world fish supplies. *Nature*, **405**, 1017–1024.

National Research Council (1993) Nutrient Requirements of Fish. National Academy Press, Washington, DC, 114 pp.

Ogino, C. and G. Y. Yang (1978) Requirement of rainbow trout for dietary zinc. *Nippon Suisan Gakkaishi*, **44**, 1015–1018.

Ogino, C., L. Takeuchi, H. Takeda and T. Watanabe (1979) Availability of dietary phosphorus in carp and rainbow trout. *Nippon Suisan Gakkaishi*, **45**, 1527–1532.

Olukunle, O. (2006) Nutritive potential of sweet potato peel meal and root replacement value for maize in diets of African catfish (*Clarias gariepinus*) advanced fry. *J. Food Tech*., **4**, 289–293.

Olvera-Novoa, M. A., S. G. Campos, M. G. Sabido and C. A. Martinez-Palacios (1990) The use of alfalfa leaf protein concentrates as a protein source in diets for tilapia (*Oreochromis mosssambicus*). *Aquaculture*, **90**, 291–302.

Oyenuga, V. A. (1978) Nigeria's Foods and Feeding Stuffs 3rd Ed. Ibadan University Press, Ibadan, pp. 4–8.

Rodriguez-Serna, M., M. A. Olvera-Novoa and C. Carmona-Osalde (1996) Nutritional value of animal by-product meal in practical diets for Nile tilapia, *Oreochromis niloticus* (L.) fry. *Aquacult. Res*., **27**, 67–73.

Santiago, C. B. and R. T. Lovell (1988) Amino acid requirements for growth of Nile tilapia. *J. Nutr*., **118**, 1540–1546.

Shiau, S. Y. (2002) Tilapia, *Oreochromis* spp. In: "*Nutrient Requirements and Feeding of Finfish for Aquaculture*" (ed. by C. D. Webster and C. E. Lim), CABI Publishing, Oxford, pp. 273–292.

Siddhuraju, P. and K. Becker (2003) Comparative nutritional evaluation of differentially processed mucuna seeds (*Mucuna pruriens* (L.) DC. var. *utilis* (Wall ex Wight) Baker ex Burck), on growth performance, feed utilization and body composition in Nile tilapia (*Oreochromis niloticus* L.). *Aquacult. Res.*, **34**, 487–500.

Simpson, R. J., M. R. Neuberger and T. Y. Liu (1976) Complete amino acid analysis of proteins from a single hydrolysate. *J. Biol. Chem.*, **251**, 1936–1940.

Takeuchi, T. (1988) Laboratory work- Chemical evaluation of dietary nutrients. In: "*Fish Nutrition and Mariculture. JICA Textbook, the General Aquaculture Course*" (ed. by T. Watanabe), Kanagawa International Fisheries Training Centre, Japan International Cooperation Agency, Tokyo, pp. 179–233.

Takeuchi, T. (1997) Essential fatty acid requirements of aquatic animals with emphasis on fish larvae and fingerlings. *Rev. Fish. Sci.*, **5**, 1–25.

ティラピア *Oreochromis niloticus* 稚魚の成長に対する飼料用甘薯および醤油粕添加飼料の有効性

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ティラピア *Oreochromis niloticus* 稚魚用飼料への飼料用甘薯と醤油粕の添加効果を検討するために，5種類の試験飼料を用いて6週間の飼育試験を行った。飼料はタンパク質35%，脂質7.5%に調整したものを使用し，試験区 D1－D5 には甘薯0%，10%，20%，30%（D1－D4），甘薯20%と醤油粕10%（D5）を添加した5種類の試験飼料を，対照区には市販飼料を給与した。飼育試験は，魚体重約3gのティラピア稚魚を30 *l* 水槽に収容し，水温25℃，照明12L：12D で行った。飼育終了時の増重率，餌料効率，成長率，摂餌量は，対照区で最も高い値を示した。試験飼料を給餌した区では，D1 で最も高い値を示し，D5で最も低い値を示した。また，D2 と D3 の間に有意差は認められず，D4 や D5 よりも高い値を示した。これらの結果から，小麦を甘薯で10－20%代替できることが明らかとなり，ティラピア稚魚の飼料として飼料用甘薯が使用可能であると考えられた。また，醤油粕は独特の臭いを取り除くことが出来れば使用できると考えられた。