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学位論文全文に代わる要約
Extended Summary in Lieu of Dissertation

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学位論文題目：
Title of Dissertation

Improvement of Nutritional Quality of Soy Protein Concentrate (SPC) for Red Sea Bream (*Pagrus major*)
（マダイに対する濃縮大豆タンパク質の栄養価改善）

学位論文要約：
Dissertation Summary

Red sea bream (*Pagrus major*) is one of the most important farmed fish, and it is the second largest production in Japan. Food habits of this fish species is a strict carnivore, and its optimum dietary protein and lipid needs have been reported as being 52% and 15% in diets. Fish meal has been used as the main protein source for red sea bream due to its high palatability and high nutritional value of protein namely digestibility and amino acid profile. Fish meal as a main protein source in aquafeeds becomes unsustainable supply. Soy protein concentrate (SPC) is a purified soy product that has low anti-nutrient factors, thus it considered as a good candidate of fish meal replacer of aquaculture feeds. However, a high inclusion of SPC in diets results in reduction of feed intake and growth performance.

Fish meal is highly favored for aquafeeds and aquafeed production is under increasing pressure due to limited supplies and increasing price. Therefore, this research aimed to develop a fish meal-free soy protein concentrate (SPC)-based diet without any animal product as a protein source in diet for sustaining aquaculture. Therefore, it is necessary to enhance feed intake of SPC diet to red sea bream and clarify the reasons for low growth in red sea bream fed a fish meal- free SPC-based diet to accomplish sustainable red sea bream aquaculture.

Chapter 1, plasma free amino acids (FAAs) and protein digestibility were examined in red sea bream fed either fish meal (FM as a control) or SPC diets. FAAs levels of SPC group were higher than that of FM group. Protein digestibility of SPC fed fish was comparable to that of FM ($p > 0.05$). The results indicate that red sea bream could digest and utilize soy protein concentrate as a sole protein in SPC diet, suggesting that low growth in SPC fed fish is not associated with protein digestibility and absorbability.

Chapter 2, the same diets as Chapter 1 were fed to 3 groups of red sea bream; for example, FM-sat and SPC groups were fed FM and SPC diets, respectively, until satiation; FM-pair group was fed the same amount of

FM diet as that of SPC group for 6 weeks. Daily feeding rates (DFR) of SPC and FM-pair groups were significantly lower than FM-sat group (p <0.05). Growth, feed utilization and lipid accumulation of FM-sat and FM-pair were significantly higher than those of SPC group (p <0.05). It was concluded that low growth in SPC fed fish was not simply due to low feed intake but also lipid utilization.

Chapter 3, effect of feeding stimulants either synthetic (SFS diet) or natural (NFS diet) which was fish meat hydrolysate (FMH) on digestive enzyme secretion was examined in 2 trials. Trial 1: a significantly higher lipase activity in pyloric and intestinal digeta of SFS group (p <0.05) indicates that SFS has a potential to stimulate digestive enzyme secretion of SPC fed fish. Trial 2: the higher activities of trypsin in intestinal digesta; and lipase in pyloric and intestinal digesta were significantly found in NFS group (p <0.05). It was concluded that NFS is more effective than SFS.

Chapter 4, four kinds of diets including SPC diet (Basal), Basal diet with FMH (FHM), FMH with glutamic acid (glu; FMHG) and FM diet were fed to red sea bream for 8 weeks. DFR, growth rate, and feed utilization of FM and FMHG groups were similar which was better than those of Basal and FMH groups (p <0.05). No significant difference in digestive enzyme activities between SPC- and FM-fed fish (p >0.05). A comparable growth rate of FMHG group to that of FM group was mainly due to increasing feed intake by a combination of FMH and glu. Feeding stimulants did not trigger digestive enzyme secretion.

Chapter 5, as feed utilization of FM fed fish was slightly better than FMHG group in previous chapter, a paired-feeding experiment was conducted by feeding the same amount of diets (Basal, FMHG and FM diets) to all treatments with triplicates for 8 weeks to find out whether improved growth in SPC fed fish by FMH and glu supplementation was due to enhancing feeding intake only or/and feed utilization. Growth rate, feed utilization, whole body lipid content, visceral fat somatic index and lipid retention of SPC fed fish (Basal and FMHG groups) were significantly lower than those of FM fed fish (p <0.05). FMH and glu supplementation did not improve feed utilization; and low growth in SPC fed fish was related to poor lipid retention that may be associated with low lipid digestion resulting from insufficient bile salts.

Chapter 6, effect of emulsification reagents namely soybean lecithin (SBL) and a commercial product (F160) on growth and feed utilization was examined. Red sea bream fed Basal, SBL, F160 and FM diets for 6 weeks. Feed intake, growth rate and feed utilization of SBL and FM groups were significantly higher than those of Basal and F160 groups (p <0.05). Growth improvement in SBL group was due to increased feed utilization, possibly lipid utilization. The cause of low lipid digestion of SPC fed fish needs to be further investigated.

In conclusion, low growth in SPC fed fish is not simply due to low feed intake but also feed utilization.

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Based on the findings of this research, it is possible to use SPC as a sole protein source in diet, without inclusion of any animal product as a protein source, for red sea bream. To culture red sea bream which comparable growth rate to that fed FM diet by FM-free SPC diet, the nutritional quality of SPC could be improved by supplementation of synthetic (L-alanine, L-proline, L-glutamic acid, inosine 5'-monophosphate) and natural (fish meat hydrolysate) feeding stimulants in addition to by supplementation of soybean lecithin to enhance lipid utilization.

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