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Preliminary Studies on the Effects of Dietary Genetically Modified Soya and Corn on Growth Performance and Body Composition of Juvenile Olive Flounder (*Paralichthys olivaceus*) and Rockfish (*Sebastes schlegeli*)

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Two feeding experiments were conducted to investigate the effects of dietary genetically modified (GM) soya and corn on growth performance, feed utilization and body composition of juvenile olive flounder, *Paralichthys olivaceus* and rockfish, *Sebastes schlegelii.* For each fish species, four isonitrogenous (50% crude protein) and isocaloric (4.1 kcal/g) diets (designated as nGM soya, GM soya, nGM corn and GM corn) were formulated to contain 20% non-GM (nGM) and GM soya and corn. Thirty olive flounder (initial body weight, 15.4 ± 0.4 g) and fifty rockfish (initial body weight, 3.1 ± 0.02 g) were distributed in each 400 L tank (200 L water) in a flow through system. Each experimental diet was fed to triplicate groups of fish to visual satiation, twice a day (9:00 h and 17:00 h) for 6 weeks. Growth performance was measured every three weeks. No effects of GM feedstuffs on survival were observed. Dietary inclusion of GM feedstuffs did not affect growth performance and feed utilization of fishes, except for rockfish fed GM corn. Rockfish fed the GM corn diet showed higher weight gain, daily feed intake and daily protein intake than did fish fed the nGM corn diet, but no significant differences were observed in final body weight between the dietary treatments. Condition factor, hepatosomatic index, visceral somatic index and body composition were not altered by the inclusion of GM feedstuffs. These results indicate that dietary inclusion of GM soya and corn could have no effects on growth performance and feed utilization of juvenile flounder and rockfish. Lower weight gain and feed intake in flounder and rockfish fed the diets containing 20% soya were likely due to anti-nutritional factors, rather than transgenic factors in the feedstuffs. Dietary inclusion of GM soya and corn at the level tested did not alter the body composition of fishes. Further studies to investigate the effects of GM feedstuffs on health conditions and the development of fishes, as well as those of residue of transgenic fragments in ambient environments and in animals are necessary for safe use of the ingredients in aquaculture.

Key words: Olive flounder, *Paralichthys olivaceus*, Rockfish, *Sebastes schlegelii*, GM soya, GM corn, Growth, Body composition

Introduction

Given the shortage and roughly increasing price of fish meal, the inclusion of alternative protein sources originating from plants, such as soybean, cottonseed and rapeseed meals in aquaculture feeds is increasing (FAO, 2005). Genetically modified (GM) feedstuffs

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are in used in aquaculture industry in some countries. However, the effects of such feedstuffs on growth performance, feed utilization, whole body composition, health conditions and the development of fish have not been well investigated. Glencross et al. (2003) reported that dietary inclusion of methionine-enhanced genetically manipulated lupin did not affect growth performance and feed utilization of marine fish (*Pagrus auratus*). For Atlantic salmon (*Salmo salar*), studies (Sanden et al., 2004; Hemre et al., 2005; 2007; Sanden et al., 2006; Frøystad et al., 2007; Sissener et al., 2009) have been conducted to investigate the effects of GM soybean and maize on growth performance, feed utilization, health status and gene expression of fish at different developmental stages. Hemre et al. (2005) reported no significant differences in growth performance, feed utilization and body composition between fish fed the diets containing 130 g/kg non-GM (nGM) and GM soybeans. Immune responses and blood parameters were also equivalent between dietary treatments. Conversely, lower feed intake, specific growth rate and final body weight were reported for Atlantic salmon fed the diets containing GM maize (Hemre et al., 2007). Thus different GM feedstuffs may differentially affect to growth performance and feed intake of farmed fish.

Olive flounder (*Paralichthys olivaceus*) and rockfish (*Sebastes schlegelii*) are important marine aquaculture fishes in Korea. Feed producers are increasingly considering the inclusion of GM feedstuffs such as soybeans and corn feeds for these fish species. However, the impacts of such ingredients on growth performance, feed utilization, and health status for these fish species are not well understood. In addition, undesirable impacts on aquatic environments (*e.g.*, transmission of GM gene fragments into the environment) are an important concern with respect to the use of GM products for fish farming (Douville et al., 2009). As part of a long-term project to address the safety issues of GM feedstuffs in aquaculture, the following preliminary feeding trials were conducted to investigate the effects of dietary GM soya and corn on growth performance, feed utilization, and body composition of juvenile olive flounder and rockfish.

Materials and Methods

GM and nGM soybean and corn

GM soybean and corn were imported from the United States by private companies. nGM soybean and corn were domestic strains administered by National Agricultural Cooperative Federation (NACF, Korea) and are available at the Eomgung agricultural market, Busan (Korea) (http://www.eomgung-market.busan.kr/). Their GM statuses were confirmed by PCR typing and/or immunostrip assay of the selected GM genes that were used in the genetic modification of soybean or corn, according to the procedure described by the Korea Food and Drug Administration (KFDA; see 2008 Guideline and Rules for Genetically Modified Food; http://gmo.kfda.go.kr/pds/pds.jsp?cc=4).

Experimental diets

For each fish species, four isonitrogenous (50% crude protein) and isocaloric (4.1 kcal/g dry matter) diets (designated as nGM soya, GM soya, nGM corn, and GM corn) were formulated to contain 20% nGM and GM soya and corn. Ingredients and proximate composition of the experimental diets are presented in Tables 1 and 2, and the proximate composition of the main ingredients is presented in Table 3. Soya and corn were finely ground prior to their being added to the experimental diets. To avoid contamination between nGM and GM feedstuffs, all equipment was carefully washed with tap water. Dried ingredients were thoroughly mixed with 30% distilled water. Pellets were prepared using a moist pelleting machine and dried at room temperature for 48 h. The experimental diets were stored at -25°C until use.

Fish and feeding trials

Juvenile flounder and rockfish were transported from a private hatchery (Taean-gun, Chugcheong-nam-do, Korea) to the Marine Biology Center for Research and Education at Gangneung-Wonju National University and acclimated to laboratory conditions by feeding commercial pellets for 2 weeks. After this conditioning period, juvenile flounder (body weight, 15.4±0.5 g) and rockfish (body weight, 3.1±0.02 g) were randomly distributed in twelve 400 L fiberglass reinforced tanks (200 L seawater each) at a density of 30 and 50 fish per tank, respectively. Each experimental diet was fed to triplicate groups of fish to visual satiation twice a day (9:00 h and 17:00 h) for 6 weeks. All tanks were operated as flow-through, receiving 7 L/min, and were continuously aerated. Seawater temperature, specific gravity, dissolved oxygen concentration and pH were 17.9±2.3°C, 1.024±0.001, 7.5±0.07 (mg/L) and 7.7±0.2, respectively.

Growth performance

At the beginning and the end of the feeding trials,

Table 1. Ingredients and proximate composition (% dry matter) of the experimental diets containing genetically modified soya and corn for juvenile olive flounder

	Diets			
	nGM soya	GM soya	nGM corn	GM corn
Ingredients				
Fish meal[1]	60.0	60.0	65.0	65.0
nGM soya	20.0			
GM soya[2]		20.0		
nGM corn			20.0	
GM corn[2]				20.0
Dextrin	16.0	16.0	9.0	9.0
Squid liver oil	2.0	2.0	4.0	4.0
Vitamin premix[3]	0.9	0.9	0.9	0.9
Mineral premix[4]	1.0	1.0	1.0	1.0
Choline chloride (50%)	0.1	0.1	0.1	0.1
Proximate composition				
Dry matter	86.4	86.0	87.0	86.4
Crude protein	51.5	51.9	50.8	49.2
Crude lipid	9.5	9.9	10.1	9.3
Ash	4.1	3.9	3.9	4.0
Gross energy (kcal/g)	4.1	4.1	4.1	4.1

[1]Provided by Fisheries Co-op Feeds Co., Ltd. Gyeongsannamdo, SouthKorea.
[2]Imported from United States.
[3]Vitamin premix contained the following amount which were diluted in cellulose (g/kg premix): L-ascorbic acid, 121.2; DL-α-tocopheryl acetate, 18.8; thiamin hydrochloride, 2.7; riboflavin, 9.1; pyridoxine hydrochloride, 1.8; niacin, 36.4; Ca-D-pantothenate, 12.7; myo-inositol, 181.8; D-biotin, 0.27; folic acid, 0.68; p-aminobenzoic acid, 18.2; menadione, 1.8; retinyl acetate, 0.73; cholecalciferol, 0.003; cyanocobalamin, 0.003.
[4]Mineral premix contained the following ingredients (g/kg premix): $MgSO_4 \cdot 7H_2O$, 80.0; $NaH_2PO4 \cdot 2H_2O$, 370.0; KCl, 130.0; Ferric citrate, 40.0; $ZnSO_4 \cdot 7H_2O$, 20.0; Ca-lactate, 356.5; CuCl, 0.2; $AlCl_3 \cdot 6H_2O$, 0.15; KI, 0.15; $Na_2Se_2O_3$, 0.01; $MnSO_4 \cdot H_2O$, 2.0; $CoCl_2 \cdot 6H_2O$, 1.0.

Table 2. Ingredients and proximate composition (% dry matter) of the experimental diets containing genetically modified soya and corn for juvenile rockfish

	Diets			
	nGM soya	GM soya	nGM corn	GM corn
Ingredients				
Fish meal[1]	55.0	55.0	60.0	60.0
nGM soya	20.0			
GM soya[2]		20.0		
nGM corn			20.0	
GM corn[2]				20.0
Dextrin	18.0	18.0	13.0	13.0
Squid liver oil	5.0	5.0	5.0	5.0
Vitamin premix[3]	0.9	0.9	0.9	0.9
Mineral premix[4]	1.0	1.0	1.0	1.0
Choline chloride (50%)	0.1	0.1	0.1	0.1
Proximate composition				
Dry matter	83.5	86.0	85.1	86.9
Crude protein	49.0	47.9	46.5	45.2
Crude lipid	10.6	9.2	10.1	10.0
Ash	4.1	4.4	4.1	3.9
Gross energy (kcal/g)	4.1	4.1	4.1	4.1

[1]Provided by Fisheries Co-op Feeds Co., Ltd. Gyeongsannamdo, South Korea.
[2]Imported from United States.
[3]Vitamin premix contained the following amount which were diluted in cellulose (g/kg premix): L-ascorbic acid, 121.2; DL-α-tocopheryl acetate, 18.8; thiamin hydrochloride, 2.7; riboflavin, 9.1; pyridoxine hydrochloride, 1.8; niacin, 36.4; Ca-D-pantothenate, 12.7; myo-inositol, 181.8; D-biotin, 0.27; folic acid, 0.68; p-aminobenzoic acid, 18.2; menadione, 1.8; retinyl acetate, 0.73; cholecalciferol, 0.003; cyanocobalamin, 0.003.
[4]Mineral premix contained the following ingredients (g/kg premix): MgSO4·7H2O, 80.0; $NaH_2PO4 \cdot 2H_2O$, 370.0; KCl, 130.0; Ferric citrate, 40.0; $ZnSO_4 \cdot 7H_2O$, 20.0; Ca-lactate, 356.5; CuCl, 0.2; $AlCl_3 \cdot 6H_2O$, 0.15; KI, 0.15; $Na_2Se_2O_3$, 0.01; $MnSO_4 \cdot H_2O$, 2.0; $CoCl_2 \cdot 6H_2O$, 1.0.

Table 3. Proximate composition (% dry matter) of dietary ingredients[1]

	Fish meal	nGM soya	GM soya	nGM corn	GM corn
Dry matter	94.2	88.0	89.0	87.5	86.6
Crude protein	69.5	37.5	37.0	11.1	7.4
Crude lipid	8.3	19.7	20.5	5.4	3.6
Ash	16.0	5.2	4.9	1.7	1.1
Carbphydrate[2]	6.2	37.6	37.6	81.8	87.9

[1]Values presented are mean of two replications.
[2]Calculated = 100 – (crude protein + crude lipid + ash).

fish in each tank were collectively weighed and counted after being fasted and anaesthetized in MS-222 solution (100 ppm) to calculate growth rate, feed utilization, and survival. Total length, whole body, liver and visceral weights of three fish per tank were measured to calculate condition factor, and hepatosomatic and visceral somatic indices. Weight gain, feed utilization, condition factor, and hepatosomatic and visceral somatic indices were calculated according to the following equations:

Weight gain (%) = [final body weight (g) – initial body weight (g)] × 100/initial body weight (g)
Specific growth rate (%) = [ln (final body weight (g)) – ln (initial body weight (g))] × 100/days reared
Daily feed intake (%) = feed intake (g) × 100/ [(initial body weight (g) + final body weight (g) + dead fish weight (g)) × days reared/2]
Daily protein intake (%) = protein intake (g) × 100/ [(initial body weight + final body weight + dead fish weight) × days reared/2]
Feed efficiency (%) = wet weight gain (g) × 100/feed intake (g)
Protein efficiency ratio = wet weight gain (g) / protein intake (g)
Condition factor (%) = [fish weight (g) / fish length $(cm)^3$] × 100
Hepatosomatic index (%) = [liver weight (g) / body weight (g)] × 100
Viscera somatic index (%) = [viscera weight (g) / body weight (g)] × 100
Survival (%) = (number of surviving fish ×100 / total number of fish)

Proximate composition analysis

At the end of the feeding trials, seven fish per tank were sampled and stored at -25°C for proximate composition analysis. Proximate composition was analyzed according to standard methods (AOAC, 1995). Crude protein was determined using the Kjeldahl method with the Auto Kjeldahl System (Buchi, Flawil, Switzerland). Crude lipid content was analyzed with ether extraction in a soxhlet extractor (SER 148, VELP Scientifica, Milano, Italy), and moisture was determined using a dry oven at 105°C for 12 h. Ash content was determined after combustion at 550°C for 4 h in a muffle furnace.

Statistical analysis

Independent-sample *t*-tests were used to assess the significance of differences in growth performance, feed utilization, and whole body composition of juvenile olive flounder and rockfish. All statistical analyses were conducted using SPSS Version 11.0 (SPSS, Chicago, IL, USA).

Results and Discussion

At the end of the feeding trial, low survival in flounder fed diets containing nGM and GM soya was due to diseases manifestation. No significant differences were observed in final body weight, weight gain and feed utilization between flounder fed the experimental diets containing nGM and GM soya (Table 4). Survival, final body weight, weight gain, feed utilization and survival were not significantly different between flounder fed the GM and nGM corn diets (Table 5). For rockfish, no significant differences were found in weight gain, feed utilization and survival between fish fed the experimental diets containing nGM and GM soya (Table 6). Weight gain was low (42-45%) in fish fed the nGM and GM soya diets. Survival of fish fed nGM corn was slightly higher than that of fish fed the GM corn (Table 7). Fish fed the diet containing GM corn showed higher weight gain and daily feed intake than did fish fed the diet containing nGM corn.

These results suggested that the inclusion of GM soya did not affect growth performance and feed utilization of flounder and rockfish. These results were in accordance with the findings of Hemre et al. (2005) who reported that up to 130 g/kg GM soybean protein can be safely used in diets for Atlantic salmon. Poor growth performance and feed utilization of flounder and rockfish fed the soya diets in the present studies were likely due to excessive level of anti-

Table 4. Growth performance and feed utilization of juvenile olive flounder fed the experimental diets containing genetically modified soya for 6 weeks[1]

	Diets		*P value*
	nGM soya	GM soya	
Initial body weight (g, IBW)	15.3 ± 0.3	15.4 ± 0.4	0.80
Final body weight (g, FBW)	20.0 ± 0.7	18.7 ± 0.5	0.21
Weight gain (%)[2]	31.1 ± 6.8	21.6 ± 0.5	0.12
Specific growth rate (%)[3]	0.64 ± 0.12	0.47 ± 0.01	0.24
Daily feed intake (%)[4]	1.5 ± 0.18	2.0 ± 0.12	0.25
Daily protein intake (%)[5]	0.80 ± 0.10	1.0 ± 0.06	0.14
Feed efficiency (%)[6]	27.3 ± 5.9	19.9 ± 4.7	0.13
Protein efficiency ratio (%)[7]	0.53 ± 0.11	0.38 ± 0.09	0.38
Survival (%)[8]	40.0 ± 15.0	75.6 ± 9.5	0.36

[1]Values presented are mean ± SE of three replications.
[2](FBW (g) – IBW (g)) × 100/IBW (g).
[3](ln (FBW (g)) - ln (IBW (g))) × 100/days reared.
[4]Feed intake (g) × 100/ [(IBW (g) + FBW (g) + dead fish weight (g)) × days reared/2].
[5]Protein intake (g) × 100/ [(IBW + FBW + dead fish weight) × days reared/2].
[6]Wet weight gain (g) × 100/feed intake (g).
[7]Wet weight gain (g) × 100/protein intake (g).
[8]Numer of surviving fish × 100/initial total number of fish.

Table 5. Growth performance and feed utilization of juvenile olive flounder fed the experimental diets containing genetically modified corn for 6 weeks[1]

	Diets		*P value*
	nGM corn	GM corn	
Initial body weight (g, IBW)	16.0 ± 0.3	15.2 ± 0.6	0.27
Final body weight (g, FBW)	42.6 ± 2.1	38.1 ± 0.4	0.10
Weight gain (%)[2]	165.0 ± 7.6	152.2 ± 11.2	0.91
Specific growth rate (%)[3]	2.3 ± 0.1	2.2 ± 0.1	0.40
Daily feed intake (%)[4]	1.46 ± 0.13	1.49 ± 0.22	0.39
Daily protein intake (%)[5]	0.74 ± 0.07	0.73 ± 0.11	0.92
Feed efficiency (%)[6]	124.8 ± 1.6	118.7 ± 2.5	0.92
Protein efficiency ratio (%)[7]	2.46 ± 0.03	2.41 ± 0.05	0.11
Survival (%)[8]	70.0 ± 10.7	72.2 ± 15.6	0.52

[1]Values presented are mean ± SE of three replications.
[2](FBW (g) – IBW (g)) × 100/IBW (g).
[3](ln (FBW (g)) - ln (IBW (g))) × 100/days reared.
[4]Feed intake (g) × 100/ [(IBW (g) + FBW (g) +dead fish weight (g)) × days reared/2].
[5]Protein intake (g) × 100/ [(IBW + FBW + dead fish weight) × days reared/2].
[6]Wet weight gain (g) × 100/feed intake (g).
[7]Wet weight gain (g) × 100/protein intake (g).
[8]Numer of surviving fish × 100/initial total number of fish.

nutritional factors (ANFs). Generally, ANFs such as trypsin inhibitor and phytic acid in soya can be inactivated and/or eliminated by thermal and extraction treatments. The inclusion of up to 20% of raw soya without any treatments can result in excessive level of ANFs above tolerance level of fish, resulting in pathological changes of the digestive system and reducing growth performance and feed utilization. Previous studies suggest that the presence of ANFs is a major limiting factor for the inclusion of the plant originating feedstuffs in fish feeds (Lee et al., 1991; Bjerkeng et al., 1997; Boonyaratpalin et al., 1998; Francis et al., 2001; Lim et al., 2004). Determination of tolerable ANF levels in experimental diets and pathological changes of the digestive system is necessary.

We found that weight gain (194-82%), specific growth rate (2.6-3.2%), and feed efficiency (99-109%) were within the normal ranges reported for rockfish (Lim et al., 2004). No significant differences were observed in the final body weights between fish fed the GM and nGM corn diets. The lower growth performance concurrent with a reduction of feed intake in rockfish fed the nGM corn compared with fish fed the GM corn indicates that differences in weight gain were likely to due to the differences in

Table 6. Growth performance and feed utilization of juvenile rockfish fed the experimental diets containing genetically modified soya for 6 weeks[1]

	Diets		*P value*
	nGM soya	GM soya	
Initial body weight (g, IBW)	3.14 ± 0.05	3.10 ± 0.05	0.56
Final body weight (g, FBW)	4.57 ± 0.13	4.38 ± 0.16	0.42
Weight gain (%)[2]	45.4 ± 1.8	41.6 ± 6.0	0.33
Specific growth rate (%)[3]	0.89 ± 0.03	0.83 ± 0.10	0.58
Daily feed intake (%)[4]	2.27 ± 0.10	2.00 ± 0.08	0.56
Daily protein intake (%)[5]	1.11 ± 0.05	0.95 ± 0.04	0.09
Feed efficiency (%)[6]	36.2 ± 2.3	38.1 ± 4.6	0.05
Protein efficiency ratio (%)[7]	0.74 ± 0.05	0.79 ± 0.10	0.74
Survival (%)[8]	97 ± 1.8	93 ± 2.4	0.64

[1]Values presented are mean ± SE of three replications.
[2](FBW (g) – IBW (g)) × 100/IBW (g).
[3](ln (FBW (g)) - ln (IBW (g))) × 100/days reared.
[4]Feed intake (g) × 100/ [(IBW (g) + FBW (g) + dead fish weight (g)) × days reared/2].
[5]Protein intake (g) × 100/ [(IBW + FBW + dead fish weight) × days reared/2].
[6]Wet weight gain (g) × 100/feed intake (g).
[7]Wet weight gain (g) × 100/protein intake (g).
[8]Numer of surviving fish × 100/initial total number of fish.

Table 7. Growth performance and feed utilization of juvenile rockfish fed the experimental diets containing genetically modified corn for 6 weeks[1]

	Diets		*P value*
	nGM corn	GM corn	
Initial body weight (g, IBW)	3.09 ± 0.03	3.14 ± 0.02	0.32
Final body weight (g, FBW)	9.11 ± 0.81	11.99 ± 0.78	0.06
Weight gain (%)[2]	194.1 ± 22.9	282.0 ± 22.9	0.01
Specific growth rate (%)[3]	2.55 ± 0.18	3.18 ± 0.14	0.05
Daily feed intake (%)[4]	2.18 ± 0.04	2.37 ± 0.04	0.05
Daily protein intake (%)[5]	1.02 ± 0.02	1.07 ± 0.02	0.03
Feed efficiency (%)[6]	99.0 ± 2.2	108.5 ± 4.0	0.14
Protein efficiency ratio (%)[7]	2.13 ± 0.05	2.40 ± 0.09	0.11
Survival (%)[8]	98 ± 0.7	90 ± 1.1	0.06

[1]Values presented are mean (SE) of three replications.
[2](FBW (g) - IBW (g)) × 100/IBW (g).
[3](ln (FBW (g)) - ln (IBW (g))) × 100/days reared.
[4]Feed intake (g) × 100/ [(IBW (g) + FBW (g) +dead fish weight (g)) × days reared/2].
[5]Protein intake (g) × 100/ [(initial weight + final weight + dead fish weight) × days reared/2].
[6]Wet weight gain (g) × 100/feed intake (g).
[7]Wet weight gain (g) × 100/protein intake (g).
[8]Numer of surviving fish × 100/initial total number of fish.

feed intake. Hemre et al. (2007) reported that the various factors such as amylase: amylopectin ratio or other qualitative and/or quantitative differences in the starch fiber fractions and different content of secondary metabolites which influence gastrointestinal tract physiology might be attributable to the differences in growth performances and feed utilization of fish. Further analysis of the nutrient digestibilties and secondary metabolites contents in GM and nGM corn could provide deeper insight to the effects of the feedstuffs on growth performance and feed utilization of rockfish.

Dietary inclusion of GM soya and GM corn did not alter the morphological parameters and body composition of flounder and rockfish. Flounder fed the diet containing GM soya showed a slight decrease in condition factor (CF) and an increase in hepatosomatic index (HSI), but these values were not significantly different from those in fish fed the nGM soya diet (Table 8). No significant differences were observed in CF, HSI and visceral somatic index (VSI) between fish fed the diets containing nGM corn and GM corn (Table 9). Sanden et al. (2006) found a significantly lower HSI in Atlantic salmon fed the diet containing Pioneer 1 maize. In later study, Hemre et al. (2007) reported that Atlantic salmon fed the GM

Table 8. Morphological parameters of juvenile olive flounder fed the experimental diets containing genetically modified soya for 6 weeks[1]

	Diets		*P value*
	nGM soya	GM soya	
Condition factor (%)[2]	0.83 ± 0.12	0.69 ± 0.01	0.29
Hepatosomatic index (%)[3]	0.92 ± 0.17	1.36 ± 0.23	0.19

[1]Values presented are mean ± SE of three replications.
[2][Fish weight (g)/fish length (cm)^3] × 100.
[3](Liver weight/body weight) × 100.

Table 9. Morphological parameters of juvenile olive flounder fed the experimental diets containing genetically modified corn for 6 weeks[1]

	Diets		*P value*
	nGM corn	GM corn	
Condition factor (%)[2]	0.84 ± 0.01	0.83 ± 0.02	0.61
Hepatosomatic index (%)[3]	2.04 ± 0.11	2.06 ± 0.03	0.90
Viscera somatic index (%)[4]	4.45 ± 0.52	4.68 ± 0.15	0.69

[1]Values presented are mean ± SE of three replications.
[2](Fish weight (g)/fish length (cm)^3) × 100.
[3](Liver weight/body weight) × 100.
[4](Viscera weight/body weight) × 100.

maize diet for 82 days showed higher HSI, spleen somatic, head kidney and distal intestine somatic indices in compared with the those fed the nGM maize. Differences in the sizes of the organs were also observed between Atlantic salmon fed the GM and nGM soya (Sissener et al., 2009). Such discrepancies between the studies are likely due to differences in maize varieties such as quality, processing and strain.

Body composition of flounder was not affected by dietary inclusion of GM soya and corn (Tables 10 and 11). Similar results were observed for rockfish fed the diets containing GM and nGM corn (Table 12 and 13). These results indicate that dietary inclusion of GM feedstuffs does not influence the body composition of fishes. This is in accordance with the results reported for Atlantic salmon (Hemre et al., 2007; Sissener et al., 2009).

Based on the preliminary findings, it was suggested that dietary inclusion of GM soya and corn could have no effects on growth performance and feed utilization of juvenile flounder and rockfish. Lower weight gain and feed intake in flounder and rockfish fed the diets containing 20% full-fat soya were likely due to the excessive content of anti-nutritional factors, rather than transgenic factors in the feedstuff. Dietary inclusion of GM soya and -corn at the level tested did not alter body composition of

Table 10. Body proximate composition (% dry matter) of juvenile olive flounder fed the experimental diets containing genetically modified soya for 6 weeks[1]

	Diets		*P value*
	nGM soya	GM soya	
Moisture	77.9 ± 0.92	78.4 ± 0.52	0.69
Crude protein	54.7 ± 5.87	60.1 ± 6.36	0.57
Crude lipid	13.7 ± 0.72	14.2 ± 0.71	0.60
Ash	18.1 ± 0.80	18.8 ± 0.40	0.49

[1]Values presented are mean ± SE of three replications.

Table 11. Body proximate composition (% dry matter) of juvenile olive flounder fed the experimental diets containing genetically modified corn for 6 weeks[1]

	Diets		*P value*
	nGM corn	GM corn	
Moisture	76.2 ± 0.24	76.7 ± 0.69	0.49
Crude protein	66.6 ± 2.84	64.5 ± 5.17	0.74
Crude lipid	12.6 ± 0.41	12.8 ± 1.43	0.88
Ash	15.6 ± 0.52	16.4 ± 0.30	0.25

[1]Values presented are mean ± SE of three replications.

Table 12. Body proximate composition (% dry matter) of juvenile rockfish fed the experimental diets containing genetically modified soya for 6 weeks[1]

	Diets		*P value*
	nGM soya	GM soya	
Moisture	75.5 ± 0.75	74.9 ± 0.93	0.62
Crude protein	46.4 ± 4.14	50.3 ± 3.78	0.52
Crude lipid	15.1 ± 0.34	15.5 ± 0.75	0.67
Ash	17.8 ± 0.51	18.0 ± 0.83	0.84

[1]Values presented are mean ± SE of three replications.

Table 13. Body proximate composition (% dry matter) of juvenile rockfish fed the experimental diets containing genetically modified corn for 6 weeks[1]

	Diets		*P value*
	nGM corn	GM corn	
Moisture	74.5 ± 0.60	74.6 ± 0.85	0.97
Crude protein	56.2 ± 1.47	50.2 ± 3.81	0.22
Crude lipid	19.9 ± 0.65	21.9 ± 1.15	0.21
Ash	15.6 ± 0.92	14.0 ± 0.38	0.19

[1]Values presented are mean ± SE of three replications.

fishes. Further studies investigating the potential effects of GM feedstuffs on health status and development of fishes (*i.e.*, altered profiles at transcription and/or translation levels) would be valuable. Furthermore, potential residues of modified gene fragments in ambient environment as well as in animal should be carefully examined to further address safety issues with respect to use of GM feedstuffs for aquaculture.

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