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Effects of three diets on growth and body composition of gilthead sea bream, *Sparus aurata* (L.)

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Wild gilthead sea bream fingerlings (4.3±1.8 g) were reared to portion size (250 g) in an ambient seawater system with varying temperature (10.3-24.3°C) for 15.0-16.6 months. They were fed commercial crumbles and pellets alone (F1), or mixed with 35% chicken eggs (F2), or mixed with 35% blue mussel flesh (F3). The daily feeding rate, daily protein feeding rate, daily growth rate, feed efficiency (FE), protein efficiency ratio (PER), protein productive value (PPV) and specific growth rate (SGR) were calculated monthly after weighing. Fish fed diet F3 grew to 250 g significantly (P<0.05; ANOVA) faster than those fed F2 or F1, in 15.0 months rather than 16.6 months. The daily feeding rates significantly differed (P<0.05) between groups and was highest in group F3 (3.80±0.18%) and lowest in group F1 (1.72±0.34%). There were no significant differences in daily growth rate (P = 0.58-0.11). The daily growth rate, FE, PER and PPV were negative in winter. The final body composition of the tested fish had significantly less moisture (65.0-68.5%) and higher lipids (8.4-10.3%) than initially and than specimens from a native environment (73.6-76.1% and 0.6-3.7%, respectively).

Key words: *Sparus aurata*, juvenile, nutrition, growth, body composition

INTRODUCTION

The gilthead sea bream (*Sparus aurata*) is commonly farmed in countries bordering the Mediterranean Sea. Marine farming of *S. aurata* began in the 1980s and expanded rapidly in Spain, Italy, Turkey and, especially, Greece during the last decade. Since there are many hatcheries and fish farms in the Mediterranean, studies of artificial spawning and rearing in experimental conditions are numerous (KALOGEROPOULOS *et al*., 1992; KENTOURI *et al*., 1994; NAVARO & SARASQUETE, 1998; NENGAS *et al*., 1999; YUFERA *et al*., 1999; CANAVATE & FERNANDEZ-DIAZ, 2001; NAVARO *et al*., 2001; PAPANDROULAKIS *et al*., 2002; PITA *et al*., 2002; PEREIRA & OLIVIA-TELES, 2003).

Until recently, prepared diets were successfully used to establish the nutritional requirements of *S. aurata*. A number of authors (KISSIL *et al*., 1981, 1982, 2000; KISSIL & GROPP, 1984; KISSIL & KOVEN, 1987; PEREIRA, *et al.* 1987) researched amino acids, fatty acids and pyridoxines, food energy and their impact on growth and survival of this species.

Studies of the chemical composition of gilthead sea bream from the natural environment

are rare (WASSEF & SHEHATA, 1991). Some authors (KALOGEROPOULOS *et al*., 1992; NENGAS *et al*., 1999) studied the effect of long-term artificial food intake on the chemical tissue composition of the gilthead sea bream.

In the present study, the food conversion budget of *S. aurata* fingerlings, fed one of three diets, was studied. Hen eggs were used because of their good food fixing properties in previous studies (KRALJEVIĆ, 1984) and because the best growth rate of gilthead sea bream was obtained with diets that had an amino acid profile similar to that of hen eggs (KISSIL & KOVEN, 1987). Blue mussel meat was used because gilthead sea bream had the best growth and survival in an earlier study (KRALJEVIĆ, 1984, 1995). The daily feeding rate (f), daily protein feeding rate (f_p), daily growth rate (GR), feed efficiency (FE), protein efficiency ratio (PER), protein productive value (PPV) and specific growth rate (SGR) were calculated and gilthead sea bream tissue was chemically analyzed at the beginning and end of the experiment and compared with bream from the natural environment.

MATERIALS AND METHODS

A small number (ca 120) of wild gilthead sea bream juveniles were captured from the Makirina Cove (mideastern Adriatic coast) at the beginning of July with a small beach seine (50 m long, 2.5 m high, 8 mm wings and 4 mm sack mesh). The were allowed to adapt to aquaria conditions in a 250-l plastic tank, supplied with running sea water (36.7-37.9‰ NaCl) at ambient temperatures (17.1-19.3°C) under a natural photoperiod. The bream were fed commercial crumbles and pellets, together with mussels (*Mytilus galloprovincialis*) and fish (*Sardina pilchardus, Engraulis encrasicolus, Atherina hepsetus*). At catch, twelve bream died. The following day they were divided into two groups of six. Fragments of the head, central body muscle and tail muscle were taken from each fish for chemical tissue analysis. The fragments taken from each group were blended together for analysis in two replicates. Since differences in tissue components within the replicates or between groups were not statistically significant ($P>0.05$, *t*-test of proportion, SOKAL & ROHLF, 1969), results were presented as mean values. The experiment began on July 20.

Rearing conditions

Ninety survived juveniles averaging 6.9±0.9 cm (total length) and 4.3±1.8 g were randomly distributed into six aquaria, in groups of 15 per aquarium. Fish were placed in 250-l plastic tanks; on April 20, they were transferred to 1200-l plastic tanks. Both types of tanks were supplied with running sea water (34.6-39.5‰ NaCl) at ambient temperatures (10.3-24.3°C), under the natural photoperiod (44°30.5′N; 16°23.5′E). Dissolved oxygen was kept at 7.6±0.4 mg l^{-1}, while the seawater flow was maintained at about 0.7-3.1 l min^{-1} (approximately 4 changes per day; according to very low density). There were no incidences of pathogens, mortality or other adverse circumstances during the study, except those related to the quality of the different foods.

Dietary treatments

An artificial high-protein feed (supplied by ALMA Futter Ltd.) was used (Table 1). The crumbles and extruded pellets were given alone (diet F1) or mixed with 35% hen eggs (F2) or 35% blue mussel meat (F3). Before use, the hen eggs were homogenized and the mussel meat was minced.

Table 1. Composition of the commercial extruded crumbles and pellets (% wet weight)

Ingredient	Crumbles	Pellets
Moisture	10.0	9.6
Protein mix	42.5	42.0
Vitamin mix	1.0[a]	1.0[b]
Lysine	3.5	3.3
Lipids[c]	9.5	9.5
Crude fiber	2.0	2.8
Ashes	12.0	12.5
NFE	19.5	19.3
Mineral mix[d]	0.2	0.2

[a] Vitamins supplied per kg mix: vitamin A, 30,000 IU; vitamin D_3, 2000 IU; vitamin E, 100 mg; vitamin K, 4 mg; vitamin C (ascorbic acid), 250 mg; vitamin

B_1 (thiamin), 25 mg; vitamin B_2 (riboflavin), 15 mg; vitamin B_6 (pyridoxine), 4 mg; vitamin B_{12}, 80 mg; nicotinic acid, 60 mg; Ca-pantotenate, 20 mg; choline chloride, 300 mg; folic acid, 3 mg

[b] Vitamins supplied per kg mix: vitamin A, 25,000 IU; vitamin D_3, 2000 IU; vitamin E, 85 mg; vitamin K, 4 mg; vitamin C, 200 mg; vitamin B_1, 25 mg; vitamin B_2, 15 mg; vitamin B_6, 4 mg; vitamin B_{12}, 80 mg; nicotinic acid, 60 mg; Ca-pantotenate, 20 mg; choline chloride, 280 mg; folic acid, 3 mg

[c] Lipids supplied by cod liver oil (6.5%) and soybean oil (3.0%)

[d] Minerals supplied per kg mix: Mg, 60 mg; Zn, 40 mg; Fe, 18 mg; CuO, 12 mg; Mn, 7 mg; I, 0.5 mg; Se, 0.02; Co, 0.02 mg

The fingerlings were fed commercial crumbles at the beginning of the experiment. When they attained approximately 9.5 cm and 12.0 g, they were fed commercial extruded pellets with a diameter of 2 mm. The commercial crumbles and pellets contained adequate amounts of vitamins and minerals. The proximate composition of the diets is given in Table 2. The diets were prepared at ambient temperature and stored in a deep freeze (-20°C). Amounts needed for a feeding were thawed when needed.

The fish were fed by hand seven days a week, 3 times a day (usually at 8:00, 13:00 and 18:00) until satiation. During the winter (Dec 21-April 20), the fish were fed only twice a day (at 8:00 and 15:00). Each meal lasted about 15-20 min (25 in winter) according to APOSTOLOPOULOS & KLAOUDATOS (1986). The amount of food was weighed at the beginning and end of the feeding to calculate the weight of the food consumed. The experiment lasted until the end of a productive cycle (15.0-16.6 months) when the mean fish weight reached about 250 g (portion-size fish). Once a month, fish were slowly anesthetized (4-amino benzoic acid ethyl ester $C_9H_{11}NO_2$) and measured (total length and weight).

Growth parameters

The daily feeding rate (f), daily protein feeding rate (f_p), daily growth rate (GR), feed efficiency (FE), protein efficiency ratio (PER), protein productive value (PPV) and specific growth rate (SGR) were calculated according to the equations in Table 3. Values did not differ significantly between replicates.

Chemical tissue analysis

At the end of the experiment (after completion of one productive cycle, i.e., 15.0-16.6 months), the smallest, middle and biggest

Table 2. Proximate composition of the diets (% wet weight)

Component	F1 Commercial crumbles/ pellets (100%)	F2 Commercial crumbles/ pellets (65%) and hen eggs (35%)	F3 Commercial crumbles/ pellets (65%) and blue mussel flesh (35%)
Crude protein	41.4[a]	31.4[b]	31.9[b]
Crude lipid	10.2[a]	10.5[a]	7.8[b]
Moisture	6.3[a]	30.0[b]	30.1[b]
Ash	10.4[a]	7.2[b]	6.7[b]
Cellulose	2.5	1.4	1.6
Non-nitrogen materials	29.2	19.5	21.9

Values with the same superscript are not significantly different (P>0.05)

Table 3. Formulae for computing growth parameters in gilthead sea bream

Parameter	Abbreviation	Formula*
Daily feeding rate	f	$f = F \times 100/t[(W_o + W' + W_t)/2]$
Daily protein feeding rate	f_p	$f_p = p_{food} \times f$
Daily growth rate	GR	$GR = (W_t + W' - W_o) \times 100/t[(W_o + W' + W_t)/2]$
Food efficiency	FE	$FE = GR/f$
Protein efficiency ratio	PER	$PER = GR/f_p$
Protein productive value	PPV	$PPV = 100 \times (p_{fish} \times FE / p_{food})$
Specific growth rate	SGR	$SGR = (\ln W_t - \ln W_o) \times 100/days$

* F = total amount of food consumed (in g), t = experimental period (in days), W_o= total initial body weight (in g), W' = total body weight of dead fish (in g), W_t = total final body weight (in g), p_{food} = protein fraction in food, p_{fish} = protein fraction in fish

fish of each replicate were sampled for chemical body analysis. The body tissue (head, central body muscle, tail muscle) of the three fish from each group were mixed together for analysis in two replicates. Since there were no statistically significant differences (P<0.05) between the replicates, values are presented as the means for each dietary treatment. To compare the chemical composition with that of fish raised in nature, two *S. aurata* (ca 300 g) were caught from the natural environment near the Institute, samples were taken from the same three body locations as described above and the chemical composition was analyzed in the same way.

RESULTS

Changes in body length and weight and condition factor

Growth parameters are shown in Table 4. At the beginning of the experiment there were no significant differences (ANOVA; P>0.05) between lengths and weights. During the experiment, there were no significant differences (ANOVA; P>0.05) in length (F = 0.05-3.41; $F_{.05,1,30} = 4.17$; $F_{.05,1,21} = 4.32$, according to the later survival) or weight (F = 0.54-3.68) between replicates fed the same diet, but fish fed F3 differed (P<0.05, L_t-F = 3.89-8.84; W-F = 3.56-13.54; $F_{.05,2.68} = 3.15$) from those fed F1 or F2 from the first October until the end of experiment. The weight increase was higher in all three treatments during summer and autumn of the first (August 19-November 21) and second (July 21-October 20) years, gradually decreased as winter approached (November-December) and stagnated in January-April (Fig. 1a). The *S. aurata* on F3 diet reached 250 g 1.5 months earlier than fish fed the other diets. Fish fed diet F3 had the best survival. Throughout most of the experiment, the G-test of independence for total mortality (SOKAL & ROHLF, 1969) revealed significant differences (P<0.05) in survival between group F3 and the other groups.

The condition factor (Fig. 1b) followed temperature changes (Fig. 1a), with a lag of about 1.5 months. The difference between the condition factor measured in September-November of the first year (1.48) and that of the second year (1.59) suggests that it is influenced not only by temperature but also by fish size and is not an isometric length-weight relationship. In the winter (February-April), the fish grew relatively slower in weight than in length, especially in the F2 treatment where the condition factor was lower (1.29) than at any other time during the experiment, except the beginning (1.26). The highest condition factors were recorded in the first (1.46-1.48) and second (1.57-1.59) autumns. The condition factors for the F1 treatment were significantly lower (WILCOXON matched pairs test) than those of the F2 (P<0.001) and F3 (P<0.005) treatments, while it was lower for F2 than for F3 (P<0.001).

Table 4. Effects of feeding diets with different protein and lipid contents for 504 days on the growth and survival of juvenile gilthead sea bream, means±SEM (n)

	Diet		
Parameter	F1 Commercial crumbles and pellets	F2 Commercial crumbles and pellets (65%) with hen eggs (35%)	F3 Commercial crumbles and pellets (65%) with blue mussel flesh (35%)
Avg initial wt (g)	4.2±0.33 (30)[a]	4.6±0.29 (30)[a]	4.2±0.29 (30)[a]
Avg final wt (g)	250±11 (21)[a]	248±9 (26)[a]	268±8 (29)[b]
Wt gain (g)	245.8	243.4	263.8
Avg initial total length (cm)	6.8±0.16 (30)[a]	7.0±0.16 (30)[a]	6.8±0.14 (30)[a]
Avg final total length (cm)	25.1±0.30 (21)[a]	25.1±0.29 (26)[a]	25.7±0.24 (29)[b]
Length gain (cm)	19.0	18.1	18.9
Survival (%)	70.0[a]	86.7[b]	96.7[c]
Daily feeding rate (%)	1.72±0.34 (17)[a]	3.01±0.60 (17)[b]	3.80±0.18 (17)[c]
Daily protein feeding rate	0.71±0.14 (17)[a]	0.95±0.19 (17)[b]	1.21±0.24 (17)[c]
Daily growth rate (%)	0.75±0.20 (17)[a]	0.73±0.21 (17)[a]	0.87±0.23 (17)[a]
Food efficiency	0.39±0.05 (17)[a]	0.12±0.07 (17)[b]	0.19±0.02 (17)[b]
Protein efficiency ratio	0.94±0.12 (17)[a]	0.38±0.22 (17)[b]	0.59±0.06 (17)[b]
Protein productive value	18.1±2.4 (17)[a]	7.3±4.2 (17)[b]	11.3±1.2 (17)[b]
Specific growth rate (%)	0.79±0.22 (17)[a]	0.77±0.24 (17)[a]	0.90±0.25 (17)[a]

Values with the same superscript are not significantly different (P>0.05)

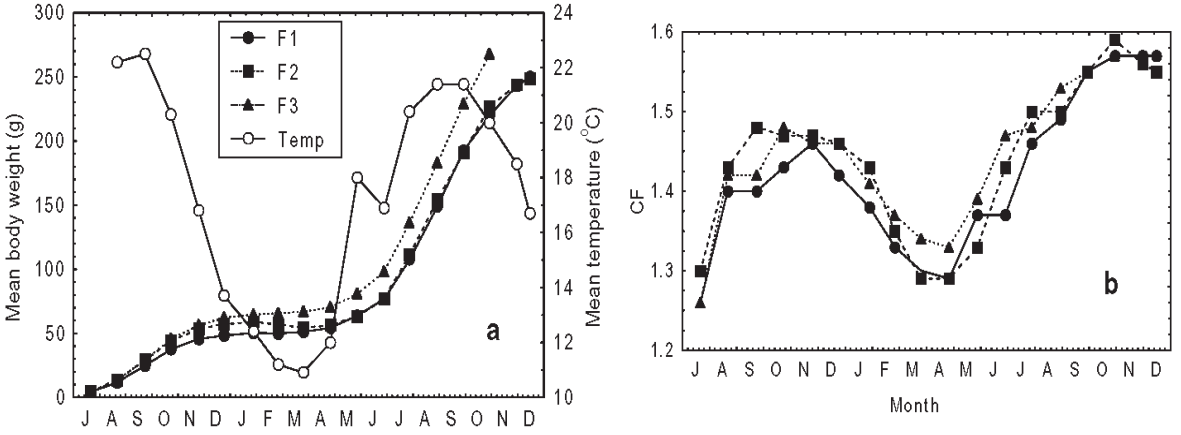

Fig. 1. Body weight (a) and condition factor (b) of Sparus aurata *reared on different foods*

Effect of diet on growth parameters

At the beginning of the experiment, the daily feeding rate (f) was highest for the F3 diet (11.74% of the mean body weight), and lowest for the F1 (4.35%; Fig. 2a). The WILCOXON matched pair test showed that the difference in daily feeding rates for diets F1 and F2 was statistically significant (P<0.001) as were the differences between F1 and F3 (P<0.001) and F2 and F3 (P<0.01). The daily protein feeding rate (f_p) had a similar curve as the daily feeding rate, but was one-third to one-half (Fig. 2b) the value throughout the experimental period. The WILCOXON matched pair test showed statistically significant differences in daily protein feeding rate between all diets (P<0.01).

There were no significant differences in daily growth rate (Fig. 2c) between diets F1 and F2 (P = 0.58), F1 and F3 (P = 0.17) or F2 and F3 (P = 0.11). The highest values (3.50, 3.31, 3.15%) were measured at the beginning of the experiment and the lowest were negative (-0.03, -0.04, -0.08%) in February and March. Daily GR values were very similar to the daily feeding rate (Fig. 2a) and daily protein feeding rate (Fig. 2b) and followed the temperature curve (Fig. 1a) throughout the experiment. The overall SGR was lower for diets F1 and F2 than for diet F3, but not significantly (P = 0.36, 0.39, 0.09). The monthly SGR, like fish weight, followed the temperature curve in all three treatments.

There were significant differences in FE (Fig. 3a) between diets F1 and F2 (P<0.001) and F1 and F3 (P<0.02). According to the WILCOXON matched pairs test, FE did not significantly differ (P = 0.36) between diets F2 and F3. The same statistical results were obtained for PER (Fig. 2b) and PPV (Fig. 2c), i.e., there were no significant differences (P = 0.28) between diets F2 and F3, while PER differed significantly between F1 and F2 (P = 0.001) and F1 and F3 (P = 0.002) and PPV differed significantly between F1 and F2 (P = 0.001) and F1 and F3 (P = 0.006). The curves of FE, PER and PPV were similar to those of f, f_p and GR, with minimums in February-March.

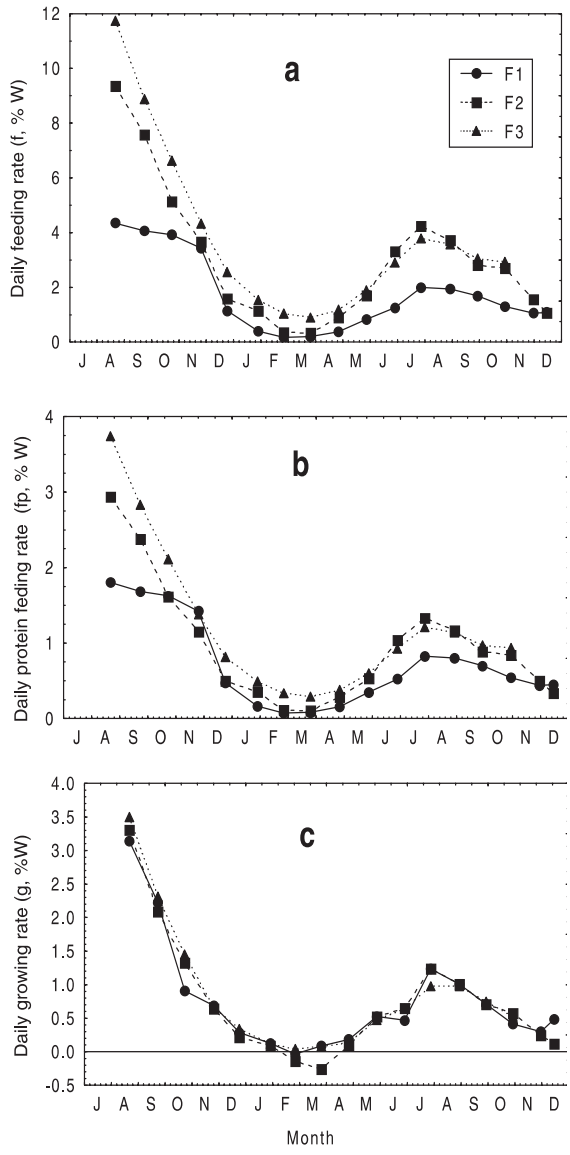

Fig. 2. Daily feeding rate (a), daily protein feeding rate (b) and daily growth rate (c) of Sparus aurata *reared on different foods*

Chemical tissue analysis

The chemical analysis of the body tissue at the beginning and end of the experiment were measured and compared with specimens from the wild (Table 5). The composition of the experimentally-fed fish did not significantly

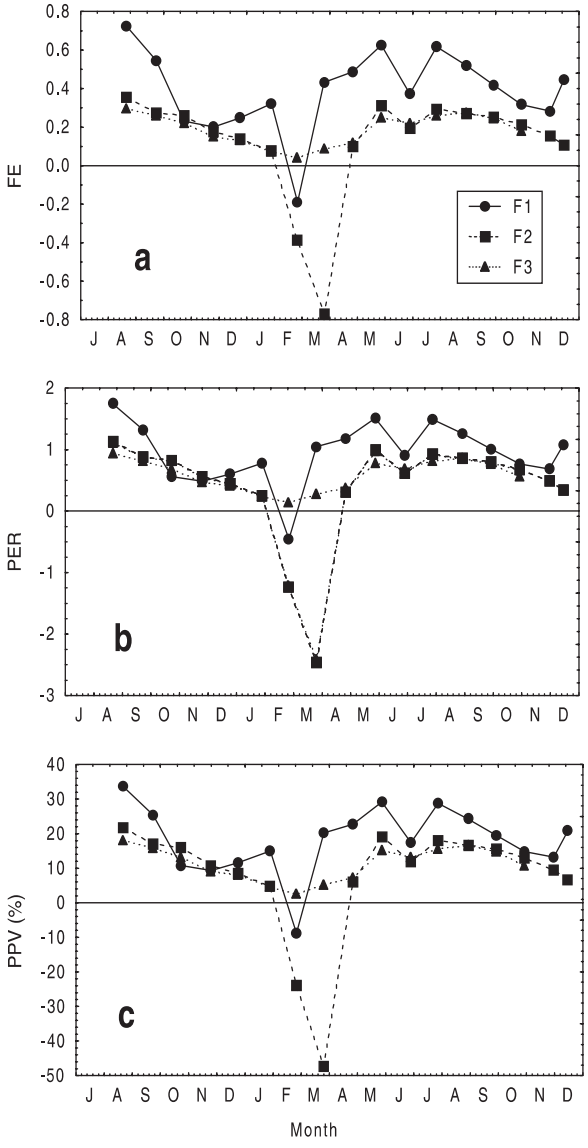

Fig. 3. Food efficiency (a), protein efficiency ratio (b) and protein production value (c) of Sparus aurata *reared on different foods*

differ from those of the initial (0.8-year-old juveniles) or 300 g gilthead sea bream from the natural environment (2.2-year-old; K1, K2) in protein, carbohydrate or ash but moisture was significantly lower and fat and energy significantly higher in the experimentally-fed fish. The moisture content rose with the level of moisture in the diets, while proteins, fat and energy dropped. All diets satisfied the nutrient needs of the gilthead sea bream.

DISCUSSION

WASSEF & SHEHATA (1991) studied the chemical composition of wet tissue from gilthead sea bream of different sizes and sexes from the natural environment of the southern Mediterranean, near Alexandria, at the different times of the year. Their results perfectly match ours for juvenile (initial) and two-year-old (K1, K2) gilthead sea bream from the natural Adriatic environment. Our results for fish fed commercial pellets strikingly differ from the natural results but are similar to those cited for the same species, experimentally fed with commercial artificial food (KALOGEROPOULOS *et al*., 1992; NENGAS *et al*., 1999), demonstrating that short (84 days) and long-term (150-504 days) artificial nutrition modifies chemical body tissue composition. If artificial nutrition has such an impact on *S. aurata* tissue (muscles), it probably affects other artificially reared fish in the same way.

In our experiment, the F1 diet had a significantly larger proportion of protein and ash and less moisture than the F2 and F3 diets. Likewise, the body tissues of the fish fed F1 had higher fat, ash and protein contents and less moisture than those fed F2 and F3. The diet consisting of 100% commercial pellets (F1) contained more protein than the diets containing pellets plus hen eggs (F2) or blue mussel flesh (F3). This is probably the reason why the fish fed F1 contained slightly more fat than the others, as confirmed by KALOGEROPOULOS *et al*.,(1992) and NENGAS *et al*., (1999). The fish fed F1 and, to a lesser degree, the fish fed F2 had a higher amount of stored mesenteric fat in the abdomen. A similar occurrence was recorded by DENDRINOS & THORPE (1985) in the tissue of sea bass after 12 months of feeding on a trout pellet diet, at the constant temperature of 19°C and varying salinity (5-33‰ NaCl). DENDRINOS & THORPE (1985) determined similar levels in sea bass from the natural environment, as did STIRLING (1972). COWEY *et al.* (1972) found a similar composition of fat in the tissues of test-fed turbot *Scophtalmus maximus* (L.).

Table 5. Body composition (%) of Sparus aurata *fed experimental diets, sampled from the natural environment or taken from the literature*

	This study				From nature		Kalogeropoulos *et al.*, 1992		Nengas *et al.*, 1999		Wassef & Shehata, 1991
	Initial	F1	F2	F3	K1	K2	Initial	Experimental (150 days)	Initial	Experimental (84 days)	Nature
Moisture	76.1[a]	65.0[b]	67.5[b]	68.5[b]	75.9[a]	73.6[a]	74.5	66.7-70.1	74.5	67.7-73.0	71.2-78.8
Protein	19.3	22.5	21.4	21.1	21.4	20.7	15.6	17.6-19.4	16.7	15.3-17.7	17.6-22.5
Lipids	3.7[a]	10.3[b]	9.4[b]	8.4[b]	0.6[c]	1.5[c]	2.7	8.4-9.8	8.7	6.8-10.2	1.6-4.9
Carbohydrates	0.0	0.3	0.2	0.4	0.2	0.4	-	-	-	-	-
Ash	1.2	1.6	1.4	1.3	1.3	1.7	7.1	4.1-4.8	5.5	4.7-4.9	1.1-1-6
Chloride	-	0.3	0.3	0.2	-	-					
Energy (kJ/100 g)	464[a]	769[b]	715[bc]	676[c]	386[d]	404[ad]	-	-	-	-	-

Table 6. Food efficiency (FE), protein efficiency ratio(PER) and specific growth rate (SGR) of Sparus aurata *reared at different but constant temperatures, compared with the present trial*

Stage	Initial weight (g)	Temperature (°C)	Length of experiment (Days)	Parameter			Author
				FE	PER	SGR	
Fingerling	1.23	20.0±1.0	150	0.52-0.68	1.10-1.30[1]	1.43-1.61[2]	Kalogeropoulos *et al.*, 1992
Fingerling-adult	6.5-230.0	15.5 ~ 18.0	43/49	-	-	0.13-0.73[2]	Kentouri *et al.*, 1994
Older juvenile	100	18 & 22	112	0.94-1.05	-	-	Kaushik, 1998
Fingerling	1.55	22.0±0.5	84	0.43-0.69	0.89-1.40	1.56-2.40	Nengas *et al.*, 1999
Fingerling	4.3±1.8	10.3-24.3	504	0.12-0.39	0.38-0.94	0.77-0.90	This study - whole experiment
Fingerling	4.3±1.8	10.3-24.3	504	(-0.77)-0.72	(-2.46)-1.75	(-0.13)-3.88	This study - monthly values

[1] According to Tibaldi *et al.* (1996)
[2] Calculated by present authors

Juvenile *Dentex dentex* (TIBALDI *et al*., 1996), of the same family as *S. aurata* and reared on food with a much higher percentage of proteins (44.3-55.9%) and slightly higher percentage of lipids (11.7-17.5%) than ours, had a higher moisture content (70.5-71.8%) and lower protein content (18.0-18.9%). This can be explained by the lengths of the experiments; their experiment was only 60 days while ours was 504 days.

The lowest daily feeding rate was for diet F1, which had the highest protein content, and diet F3 had a higher feeding rate than diet F2. Although diets F2 and F3 had the same amount of protein, the diets differed in lipid content. It is known that, in fish, the voluntary intake of food with lower energetic value is higher than that of food with higher energetic value, i.e., the consumption of food is inversely proportional to the energetic value (MARAIS & KISSIL, 1979). PAGE and ANDREWS (1973) found that higher levels of energy and protein in foods result in lower food consumption. From the equation describing the relationship between feeding rate, temperature and body weight, it can be predicted that the maximum feeding rate will be reached for diet F1 at 20°C, for diet F2 at 23°C and for diet F3 at 27°C, and that gilthead sea bream would stop feeding at 11.8°C (KRALJEVIĆ, 1995).

The feed efficiency ratio of fish fed F1 was significantly higher than those of the other groups, although the lipid concentrations were relatively the same, because fish take most of the energy they need for maintenance from protein (GERKIN, 1955). The FE of all three diets was influenced more by temperature than by body weight, especially in the winter (February-March). FE depends on environmental conditions such as temperature and salinity (KINNE, 1960; KLAOUDATOS & APOSTOLOPOULOS, 1986) and increases with temperature (GOOLISH & ADELMAN, 1984; HIDALGO *et al*., 1987; RUSSEL *et al*., 1996), as in our experiment. FE decreases with fish size and age (PALOHEIMO & DICKIE, 1966; PANDIAN, 1967; PAULY, 1986), increased feeding frequency (TSEVIS *et al*., 1992), lower lipid contents (KALOGEROPOULOS *et al*., 1992) or higher lipid contents (PERES & OLIVA-TELES, 1999). GOOLISH and ADELMAN (1984) explained the lower FE at lower temperatures as the slowing down of all metabolic processes, which is confirmed by our negative values during winter. Energetically poor food results in a lower FE (MARAIS & KISSIL, 1979), which could explain the lower values for diets F2 and F3.

Our mean PER values were lower than those of the same species at similar weights (1.23, 1.55 g), reared at higher temperatures (20.0; 22.0°C) in other studies (Table 6). The negative PER in the winter (February-March) were comparable to the negative values (-2.9) of Nile tilapia with a similar body weight (KAUSHIK *et al*., 1995). Research on PPV value is very scarce in the literature.

Our SGR values differed from those reported for juveniles currently farmed in the Mediterranean area, such as gilthead sea bream (Table 6) and dentex (1.18-1.32, TIBALDI *et al*., 1996). HIDALGO and ALLIOT (1988) obtained similar results on sea bass (0.55-0.99) given practical diets and probably kept at a similar water temperature of 20°C. SGR in our study rapidly decreased in the first year and slowly decreased in the second year of the experiment, following the temperature curve and body weight. According to KAUSHIK (1995, 1998), the SGR decreased rapidly and parabolically with an increase in body weight especially in the earliest juvenile stages of sea bream, sea bass, rainbow trout, and common carp, agreeing with our results. SGR values of different species slowly increase with body weight, but the values differ depending on body size and species. The negative SGR in February and March were consistent with results of Nile tilapia (-0.1; KAUSHIK *et al*., 1995). The SGR has often been related to some diet components, mainly protein or fat (PÉREZ *et al*., 1997), but seawater temperature is a major environmental influence (BUREL *et al*., 1996) on metabolic rate and food intake (CHO, 1992), as confirmed by our low and negative SGR values in winter when the seawater temperature was less than 11.8°C, although we maintain that body weight is more influential than seawater temperature. The SGR

value positively correlated to the food intake (BUREL *et al*., 1996).

There was a significantly slower weight increase in November at the temperature of 15°C and growth was inhibited until April when the temperature began to rise. During that period, the length increase was greater than the weight increase, causing the condition factor to drop.

The results of the present experiment showed that diets F1 and F2 were less satisfactory for growth of gilthead sea bream juveniles than diet F3. Fish fed diet F3 had the best weight gain and survival. Obviously, the quantities of protein and fat were not responsible for the better performance of diet F3. Probably, the amino acid composition was much better in the diet containing 35% blue mussel flesh than in the other two diets.

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Učinci triju različitih vrsta hrane na rast i kemijski sastav tkiva komarče, *Sparus aurata* (L.)

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SAŽETAK

Divlja je mlađ komarče (L_t=6,9±0,9cm; W=4,3±1,8g) bila uzgajana u bazenima s otvorenim sustavom protočne morske vode pri promjenjivoj temperaturi (24,5-10,3°C) tijekom 15,0-16,6 mjeseci s tri različite vrste hrane. Komercijalni su starteri i peleti (F1) bili miješani s 35% kokošjega jaja (F2) i 35% usitnjenog mesa dagnje (F3). Riba uzgajana na F3 hrani je dobila 268g u 15,0, a ona na F1 i F2 hrani oko 250g u 16,6 mjeseci. Dnevna je stopa hranjenja (*f*) bila najviša u grupi F3 (11,74%), a najniža u grupi F1 (4,35%), dok su mjesečne krivulje vrijednosti dnevnih stopa uzimanja proteina (f_p) bile vrlo slične onima od dnevnih stopa hranjenja. WILCOXON matched pairs test je pokazao statistički značajnu razliku ($P < 0.001$-0.01) za oba izračunata čimbenika (*f*; f_p) između testiranih vrsta hrane. Međutim, ne postoji statistički značajna razlika ($P = 0.11$-0.58) u vrijednostima dnevnih stopa rasta (*g*) između ovih vrsta hrane. Razlike u ukupnoj učinkovitosti hrane (FE) između F1 i F2 grupe je statistički značajna ($P < 0.001$), upravo kao i između F1 i F3 (WILCOXON matched pairs test; $P < 0.02$). Neke su vrijednosti dnevne stope rasta (*g*), ukupne učinkovitosti hrane (FE), djelotvornosti ugradnje proteina (PER) i proizvodnje proteina (PPV) pokazale negativne vrijednosti u veljači i ožujku. Nije zabilježena statistički značajna razlika ($P = 0.09$-0.39) u vrijednostima specifične stope rasta (SGR) između testiranih vrsta hrane, dok su njihove mjesečne vrijednosti slijedile krivulju promjenjive godišnje temperature tijekom trajanja eksperimenta. Kemijski je sastav tkiva testiranih riba statistički značajno odstupao u nižem sadržaju vlage (65.0-68.5%) i višim sadržajem masti (8.4-10.3%) od onih iz prirodne sredine na početku (76.1; 3.7%) i kraju (73.6-75.9; 0.6-1.5%) eksperimenta.

Ključne riječi: *Sparus aurata,* mlađ, rast, kemijski sastav tkiva