Gilt-head Sea Bream, *Sparus aurata*

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Introduction

The natural habitat of the gilt-head sea bream (*Sparus aurata*) ranges from the Mediterranean and Black Sea to the eastern Atlantic Ocean from Senegal to the UK (Kissil *et al.*, 2000a). This species is generally found in shallow lagoons along the coast but moves into deeper waters to spawn after late autumn. In many commercial rearing conditions, the larvae emerging after hatching deplete the yolk-sac after 3–4 days of endogenous feeding. At this stage, the eyes are pigmented and the mouth open, allowing the larvae to feed on rotifers (e.g. *Brachionus plicatilis*). At 12–15 days posthatching, the rapidly growing larvae are fed mostly on *Artemia* nauplii as well as rotifers through the onset of metamorphosis to the end of larval rearing (32–35 days posthatching). Prior to being fed to the larvae, rotifers and *Artemia* are routinely enriched with commercial lipid preparations to enhance their levels of essential fatty acids, which are critical for normal larval growth, development and survival. After metamorphosis, fish from 5 to 10 mg are rapidly weaned from *Artemia* to a dry high-protein (50–60%) formulated diet. At 1–3 g, the juveniles are stocked in sea cages and grown to market size (400–500 g) over 12–14 months, using high-energy extruded diets (Kissil *et al.*, 2000a). At present, sea-cage culture is more economical than land-based production systems (ponds and raceways), which need high capital investment and energy input (constant aeration and continual pumping of sea water). On the other hand, cage farming is limited to sites protected from inclement weather and may pose an environmental problem from the nutrient effluent of the fish.

Nutrient Requirements: Larval Fish

The determination of the nutrient requirements of larval sea bream has focused almost entirely on the lipids and essential fatty acids necessary to promote good growth and survival. This is primarily due to the almost exclusive use of rotifers

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and *Artemia* as experimental diets, which are generally limited to the manipulation of their lipid content and composition. Practical diets or microdiets, which would offer a more diverse tool for nutritional research, have not been sufficiently developed as a live-food alternative, although great strides in their application have been made in recent years.

Lipids and fatty acids

In the gilt-head sea bream, the dietary requirement for the n-3 highly unsaturated fatty acids (HUFA), primarily eicosapentaenoic acid (EPA) (20:5n-3) and docosahexaenoic acid (DHA) (22:6n-3), has been established (Koven *et al.*, 1989, 1990, 1992a,b; Mourente *et al.*, 1993; Rodríguez *et al.*, 1993). These fatty acids, in their phospholipid (PL) form, function as critical structural and physiological components of the cell membrane in most tissues (Gurr and Harwood, 1991; Sargent *et al.*, 1993a). The n-3 HUFA requirement in first-feeding sea-bream larvae ranged from 8.4 (Koven *et al.*, 1990) to 55 mg n-3 HUFA g^{-1} dry weight (DW) rotifer (Rodríguez *et al.*, 1998a). This discrepancy may be explained by the rotifer EPA : DHA ratio, which varied among studies, affecting the larval n-3 HUFA requirement. Rodríguez *et al.* (1997) found that, for a constant level of n-3 HUFA, growth was negatively correlated with the rotifer EPA : DHA ratio (0.71 : 1 to 3.6 : 1). This suggested that DHA had higher nutritional value and contributed more to growth than EPA (Mourente *et al.*, 1993; Rodríguez *et al.*, 1997).

Koven *et al.* (1992b) found an age-dependent relationship in gilt-head sea bream, where DHA was preferentially assimilated into the tissue phospholipid, phosphatidylethanolamine (PE), and was highly correlated with larval growth, while EPA in PE was poorly associated with this parameter. Unlike other tissues, neural tissue, particularly the brain and retina, is richer in PE than in the main phospholipid, phosphatidylcholine (PC). The higher biological value to larvae of DHA compared with EPA could be derived from its presence in tissues involved in visual acuity. Presumably, this would influence prey-hunting success and net energy gain (Koven *et al.*, 1992b; Sargent *et al.*, 1993b; Bell *et al.*, 1995).

Rodríguez *et al.* (1998a) concluded that 15 mg n-3 HUFA g^{-1} DW rotifer with an EPA : DHA ratio of 0.71 : 1 promoted good growth during the first 2 weeks of larval development. These results agreed well with the 17 mg (Mourente *et al.*, 1993) and 20 mg n-3 HUFA g^{-1} DW of rotifers (Salhi, 1997) with a low EPA : DHA ratio. During *Artemia* feeding, Koven *et al.* (1992a) obtained best growth in 22–36-day-old gilt-head sea-bream larvae when fed the 30 mg n-3 HUFA g^{-1} DW *Artemia*.

Unlike EPA and DHA, arachidonic acid (AA) (20:4n-6) is not a structural membrane lipid and instead is involved, as a precursor in eicosanoid synthesis, in various areas of cellular regulation, including fluid and electrolyte fluxes, the cardiovascular system, the reproductive function and the neural system (Mustafa and Srivastava, 1989). Bessonart *et al.* (1999) found that AA-supplemented

(18 mg AA g^{-1} DW) microdiets were more effective in improving survival than growth in 17–31-day-old gilt-head sea-bream larvae if provided in the presence of a low dietary EPA : DHA ratio. Similarly, Koven *et al.* (2001a) found that dietary AA (2.7 mg g^{-1} DW rotifer) fed to sea-bream larvae prior to handling stress improved survival more effectively than when fed following handling stress (4.6 mg AA g^{-1} DW *Artemia* nauplii). These findings imply the requirement of AA in early larval development, as it affects later larval and juvenile survival during the stress of metamorphosis, weaning, crowding and grading.

Practical Diets

A great deal of interest has been generated in developing an artificial larval diet or microdiet (MD) as a live-food alternative. However, in general, MDs are consumed much less than live food and are frequently sufficient only as a maintenance ration (Tandler and Kolkovski, 1991). On the other hand, the MD performance was markedly improved when co-fed with live *Artemia* nauplii (Tandler and Kolkovski, 1991; Fernández-Díaz and Yúfera, 1997; Kolkovski *et al.*, 1997a; Rosenlund *et al.*, 1997). This suggested the presence of certain nutrients in live food that elicit physiological responses in the larvae, which should be considered in larval diet development.

Kolkovski *et al.* (1997a) found that the MD ingestion rates in sea-bream larvae increased up to 120% in the presence of different concentrations of *Artemia* nauplii. These authors indicated that the free amino acids (FAA) alanine, glycine, arginine and betaine secreted by *Artemia* nauplii were responsible for stimulating food ingestion (Kolkovski *et al.*, 1997a). In a later study, the inclusion of these nutrients in an MD based on the gelatin encapsulation of liposomes improved the MD ingestion rate in 7-day-old sea-bream larvae (Koven *et al.*, 2001b).

The phospholipid PC in the diet was also shown to have a stimulatory effect on sea-bream larval feeding, while this was not observed with PE (Hadas, 1998; Koven *et al.*, 1998). Larvae fed a PC-supplemented MD had 35% higher ($P < 0.05$) ingestion rates compared with the unsupplemented MD in 21–26-day-old gilt-head larvae, although this effect diminished in 28–31-day-old larvae (Hadas, 1998; Koven *et al.*, 1998). Further studies suggested that dietary PC has a postprandial physiological influence as well, occurring in parallel or in tandem with its appetite-stimulating properties. Koven *et al.* (1993) showed a significant effect of dietary lecithin on the incorporation of labelled free fatty acid (FFA) in body neutral lipid and phospholipid (PL) in 21–45-day-old larvae. Hadas (1998) and Salhi *et al.* (1999) concluded that dietary PL contributes to lipoprotein production, thereby enhancing the efficiency of lipid transport from the enterocytes lining the digestive tract to the body tissues.

In sea-bream larvae ingesting MD supplemented with a porcine pancreatic extract (0.05%), Kolkovski *et al.* (1993) found a 30% increase in assimilation and significantly improved growth. This suggested that live food could enhance digestion by contributing enzymes to facilitate the digestion process. In contrast,

Cahu *et al.* (1995) and Moyano *et al.* (1996) found no evidence of rotifers or *Artemia* supplying proteases for digestion in various ages of marine larvae. An alternative interpretation of the contribution of live food to larval digestion is that certain factors are released from the prey upon ingestion that stimulate the conversion of indigenous zymogens to active enzymes and/or an endocrine response, which regulates digestion and nutrient assimilation. The digestive hormone bombesin influences digestion by activating the peristaltic movement of the gut and the release of hydrochloric acid (HCl) as well as increasing blood circulation to the gut wall (McDonald *et al.*, 1979). Kolkovski *et al.* (1997b), comparing the postprandial stimulation of bombesin in live food and MD, found the level of bombesin increased by 300% when *Artemia* nauplii were given as the sole food to sea-bream larvae compared with levels that were found in larvae offered only an MD. However, the nutrient factors in *Artemia* responsible for eliciting this endocrine response remain unclear.

Feeding Practices

Rotifers (e.g. *B. plicatilis*) are fed as a first food (ten rotifers ml^{-1}) to sea-bream larvae and are continually offered throughout the 32–35-day larval rearing period. Prior to being fed to larvae, rotifers previously fed baker's yeast (*Saccharomyces cerevisiae*) and/or algae (e.g. *Nannochloropsis* sp.) are enriched (500 rotifers ml^{-1}) for approximately 8 h on commercial preparations designed to increase their levels of EPA and DHA. Algae are added together with the rotifers to the rearing tanks ($\pm 0.2 \times 10^6$ algal cells ml^{-1}) to improve rotifer survival as well as imparting to the larvae unidentified metabolites that are reputed to contribute to larval health.

Instar III *Artemia* nauplii (*Artemia franciscana*), which are fed (one nauplius ml^{-1}) to larvae from approximately 18 days old to the end of larval rearing, are previously enriched (100–300 nauplii ml^{-1}) at the instar II stage (12 h posthatching from decapsulated cysts) for 18–24 h on commercial preparations, mainly to boost their levels of EPA and DHA. Apart from the essential fatty acids, other nutrients, including vitamins A, E and C and pigments, are frequently included in commercial enrichment products (Lavens and Sorgeloos, 1996).

Nutrient Requirements: Juvenile and Grow-out Fish

Proteins and amino acids

The feeding of juveniles to market weight in many commercial species represents up to 50% of the operating costs of production (Kissil *et al.*, 1997). The protein fraction of the food, which approximates 40–50% of the diet, is responsible for about 48% of the total feed price and is largely contributed by the fish-meal component (≥ 44% of feed protein) (Kissil *et al.*, 1997). The highest growth rates were reported in sea bream fed 55% protein in fish-meal-based diets in 0.8–3.0 g

(Vergara *et al.*, 1996a) and 9–63 g (Santinha *et al.*, 1996) juveniles. However, fish-meal is a diminishing resource that is destined to become more expensive and scarce as resource fisheries begin to dwindle. Alternative protein sources such as rape-seed and soybean are cheaper, before processing, than quality fish-meal (kg^{-1} protein basis) (Higgs *et al.*, 1995) and are currently being evaluated.

Kissil *et al.* (2000b) fed sea bream diets that replaced 30, 60 and 100% of fish-meal with soybean-protein concentrate (SPC) or rape-seed-protein concentrate (RPC). The diet intake and weight gains were inversely related to the inclusion levels of plant proteins, possibly due to reduced palatability (e.g. phytic acid), deficiencies in essential amino acids and/or the presence of antinutritional factors. Robaina *et al.* (1995), however, found that diet intake was not significantly affected by a 10, 20 and 30% partial replacement of sardine fish-meal with soybean meal (SBM) and lupin-seed meal. On the other hand, a marked reduction in trypsin activity and protein digestibility with increasing SBM may have been attributable to dietary phytic acid. These authors concluded that lupin meal is the preferred protein alternative to SBM in diets for gilt-head sea bream and a level of up to 20% replacement of fish-meal on an equal nitrogen basis was suggested.

Kissil *et al.* (2000b) found that the efficiency of protein utilization appeared similar for diets containing increasing levels of SPC and RPC, which replaced fish-meal, except in the 100% SPC diet. They indicated that a significant depression of the protein production value in the 100% SPC diet reflected a deficiency of one or more essential amino acids, such as methionine. The poor performance of sea-bream diets based on high inclusion levels (75–100% of protein) of poultry meals was similarly attributed to deficiencies in lysine and possibly methionine (Nengas *et al.*, 1995, 1999). On the other hand, Kissil *et al.* (2000b) reported that the RPC diet, even at the 100% level, was as efficiently utilized as that of the fish-meal control, suggesting that the RPC protein quality was similar to that of fish-meal.

Robaina *et al.* (1997) reported that the growth, feed efficiency, protein efficiency ratio and protein production values were not significantly affected by the partial substitution (20, 30 and 40%) of fish-meal with corn (maize)-gluten meal (CGM) or meat and bone meal (MBM). However, delayed and increased levels of nitrogen excretion were evident in fish fed the CGM and MBM diets. This suggests an increase in deamination activity and the amount of ammonia released into the water. A similar observation was reported in SBM- and lupin-meal-containing diets, indicating that plant proteins tend to be digested more slowly and inefficiently, particularly SBM (Robaina *et al.*, 1995). In fish fed diets containing more than 20% MBM, an increase in hepatic deposition of lipids, nuclei polarization and isolated necrotic foci were observed. This may have been caused by an unfavourable ratio of saturated fatty acids and polyunsaturated fatty acids in this food component (Robaina *et al.*, 1997). These authors also found a negative correlation between dietary ash content and dietary protein digestibility in the MBM diets recommending a 30 and 20% substitution of fish-meal by CGM and MBM, respectively.

Lipids and fatty acids

Juvenile sea bream, as in larvae, have a dietary requirement for n-3 HUFA. Ibeas *et al.* (1994, 1996) found that with an EPA : DHA ratio of 1 : 2, 19 mg and 10 mg n-3 HUFA g^{-1} DW diet promoted the best growth of 42.5 g and 11.5 g sea bream, respectively. Kalogeropoulos *et al.* (1992) obtained best growth in 1 g fish fed 9 mg of EPA and DHA g^{-1} DW despite the lower EPA : DHA ratio of 1 : 1 in this study. These results suggest that, unlike in larval nutrition, in which DHA has better nutritional value than EPA, these two essential fatty acids appear to have similar nutritional input for juveniles. Ibeas *et al.* (1996) claimed that the optimum EPA : DHA ratio of 1 : 1.5 in larvae may be increasing to 1 : 1 or 2 : 1 in juveniles and adults.

Energy

Despite the growing body of information on protein sparing by dietary lipid in the gilt-head sea bream, there remain discrepancies in the results reported in the literature. Gilt-head sea bream that were fed to satiation on high-quality fish-meal diets containing 470–480 g crude protein kg^{-1} diet and 220 or 270 g lipid kg^{-1} diet exhibited markedly higher growth than fish fed similar diets containing 150 g lipid kg^{-1} diet (Caballero *et al.*, 1999). In contrast, fish fed a 497 g crude protein kg^{-1} diet containing a lower-quality fish-meal demonstrated improved growth only at 270 g lipid kg^{-1} diet (Caballero *et al.*, 1999). This suggests a possible effect of impaired essential amino acid (EAA) availability on protein sparing by dietary lipid. Vergara *et al.* (1996b) recommended a diet containing 460 g protein and 150 mg lipid kg^{-1} diet for sea-bream juveniles fed at levels approaching satiation. In these studies, a consequence of feeding close to or at satiation is an increase in body and/or liver lipid content. Company *et al.* (1999) claimed that, in order to maximize a protein-sparing effect, restricted feeding must be employed to avoid excessive fat deposition and impaired growth performance.

The main factor determining voluntary-consumption feeding in gilt-head sea bream and other fish species is the digestible energy (DE) content of the diet (Jobling and Wandsvik, 1983; Kentouri *et al.*, 1995; Paspatis and Boujard, 1996; Lupatsch *et al.*, 2001). Lupatsch *et al.* (2001) found that the efficiency of utilization (above maintenance) of daily DE in sea bream was constant at 0.50, regardless of energy intake. However, the efficiency of utilization of digestible protein (DP) varied between 0.33 to 0.60, with an optimum value of 0.47. At high dietary DP : DE ratios, the protein utilization efficiency is about 0.35, as protein is being catabolized for energy. An increase of the DE content by raising the non-protein energy fraction improved the protein efficiency by sparing protein catabolized as an energy source (Lupatsch *et al.*, 2001).

Lupatsch *et al.* (2001) calculated the energy and protein requirements for gilt-head sea bream, according to the growth potential for a specific weight and water temperature, and these are presented as a practical feeding table in Table 5.1.

Table 5.1. Recommended dietary energy and protein supply for growing *Sparus aurata* (modified from Lupatsch *et al.*, 2001).

Energy and protein requirements for different body weights						
Body weight (g per fish)	10		100		250	
Weight gain (g per fish day^{-1})*	0.25		1.00		1.82	
DE_m (kJ per fish day^{-1})†	1.22		8.25		17.66	
DE_g (kJ per fish day^{-1})‡	3.33		17.36		35.19	
DE_{m+g} (kJ per fish day^{-1})§	4.55		25.61		52.85	
DP_m (g per fish day^{-1})‖	0.034		0.172		0.326	
DP_g (g per fish day^{-1})¶	0.096		0.398		0.694	
DP_{m+g} (g per fish day^{-1})§	0.130		0.570		1.019	
Food formulation at two DE levels						
DE level of diet (MJ kg^{-1})	16	20	16	20	16	20
Diet intake (g per fish day^{-1})	0.284	0.228	1.60	1.28	3.30	2.69
DP content (g kg^{-1})	455	569	345	432	309	387
FCR	1.14	0.91	1.60	1.28	1.80	1.44
DP : DE (g MJ^{-1})	28.5	28.5	21.6	21.6	19.3	19.3

* Predicted growth for *Sparus aurata*.
† Digestible energy required for maintenance = 55.8 kJ $kg^{-0.83}$ day^{-1} (Lupatsch *et al.*, 1998).
‡ Digestible energy required for growth using energy efficiency of 0.50.
§ Digestible protein required for maintenance and growth.
‖ Digestible protein required for maintenance = 0.86 g BW $kg^{-0.70}$ day^{-1} (Lupatsch *et al.*, 1998).
¶ Digestible protein required for growth using protein efficiency of 0.47.
FCR, feed conversion ratio.

Carbohydrates

Carnivorous fish such as the gilt-head sea bream have a limited ability to use dietary carbohydrate, due to low amylolytic enzyme activity (Vergara and Jauncey, 1993). In sea bream carbohydrate digestibility was less than 77% regardless of source (Vergara and Jauncey, 1993; Lupatsch *et al.*, 1997) and increasing levels of dietary fibre further decreased the digestibility (Vergara and Jauncey, 1993). Morris and Davies (1995b) reported that lipid and carbohydrate could not be interchanged according to their metabolic energy values. Therefore, in sea-bream diets, lipids provide the majority of non-protein energy, resulting in carbohydrate accounting for less than 150 g carbohydrate kg^{-1} DW diet (Morris, 1997).

Vitamins and minerals

The requirement of gilt-head sea bream for these nutrients has concentrated on vitamins since minerals in formulated diets are generally inexpensive. Morris *et al.* (1995) characterized the pathologies of gilt-head sea-bream juveniles

associated with dietary deficiencies of many of the B vitamins, including thiamine, riboflavin, pyridoxine, niacin and pantothenic acid, and demonstrated a requirement of this species for all these vitamins. Morris and Davies (1995a) determined the nicotinic acid requirement to be 63–83 mg kg^{-1} diet, while Morris and Davies (1995b) showed that a thiamine (vitamin B_1) supplement of 10 mg kg^{-1} gave significantly better growth, food conversion and apparent net protein utilization than a thiamine-deficient diet. Kissil *et al.* (1981) found that the minimum level of pyridoxine (B_6) necessary for good growth was 1.97 mg kg^{-1} dry diet. In another study, Kissil (1981) found no suppression of growth or histopathological signs in sea bream fed graded levels of biotin. However, based on the activity of pyruvate carboxylase in the liver, a dietary biotin level between 0.21 and 0.37 mg kg^{-1} DW diet appears to be required for maximum activity of this enzyme.

Ascorbic acid cannot be synthesized by most teleosts (Henrique *et al.*, 1996) and a deficiency in a number of fish species induces a variety of symptoms, including scoliosis, lordosis, haemorrhages, distorted gill filaments, fin erosion, anaemia and increased mortality (Halver, 1989). Alexis *et al.* (1997) reported many of these symptoms in gilt-head sea bream as well as granulomatous disease in the kidney and suppression of the wound-healing response.

Nutrient Requirements: Brood-stock

The gilt-head sea bream is a continuous spawner, having a short vitellogenic period (Zohar *et al.*, 1995). Over the 3–4-month spawning season, brood-stock continue to feed while a spawning female will produce a total egg biomass of 0.5–2 kg kg^{-1} body weight (BW). Consequently, the nutrient composition of the eggs is highly influenced by diet and to a much lesser extent by the endogenous body stores (Tandler *et al.*, 1995).

Proteins and amino acids

The reproductive performance of gilt-head sea bream was greatly improved when fed a diet based on a squid-meal composition (Harel *et al.*, 1992; Tandler *et al.*, 1995; Fernández-Palacios *et al.*, 1997), which is well known as a good protein and lipid source. It has been suggested that the superior performance of squid protein was related to its EAA composition, which resembles that of sea-bream egg protein (Tandler *et al.*, 1995). Tandler *et al.* (1995) reported that dietary protein influences egg quality by regulating the synthesis and selective uptake of yolk constituents. The lowest level of vitellogenin (Vg)-binding capacity was observed in oocytes from brood-stock fed diets where wheat gluten was the protein source. The supplementation of specific EAA so that dietary protein was similar to sea-bream egg protein markedly increased the level of oocyte Vg-binding sites mg^{-1} membrane protein. However, the highest level of Vg-binding sites was in oocytes from brood-stock fed squid-meal-based diets.

Lipids and fatty acids

Lipid is the main dietary constituent of brood-stock diets that directly influence the composition of the eggs and larvae (Watanabe, 1985; Mourente and Odriozola, 1990; Tandler *et al.*, 1995; Almansa *et al.*, 1999). Fernández-Palacios *et al.* (1995) reported that EPA in the eggs was more sensitive to a dietary change in n-3 HUFA than was egg DHA and that EPA as well as arachidonic acid influenced the egg fertilization rate. A low level of brood-stock dietary n-3 HUFA resulted in decreased fecundity, hatching rate and egg viability (Fernández-Palacios *et al.*, 1995; Rodríguez *et al.*, 1998b; Almansa *et al.*, 1999). It also induced a 34% decrease in larval growth and a reduction in swim-bladder inflation from 85% to 55% (Tandler *et al.*, 1995). However, excessive levels of n-3 HUFA in the brood-stock diet (31.5 g kg^{-1} DW) were associated with lower egg fecundity and yolk-sac hypertrophy in recently hatched larvae (Fernández-Palacios *et al.*, 1995). Fernández-Palacios *et al.* (1995) recommended that brood-stock diets should contain 16 g n-3 HUFA kg^{-1} DW for improved spawning performance. This agrees well with Rodríguez *et al.* (1998b), who found better egg quality from broodstock fed 18 g n-3 HUFA kg^{-1} DW diet, while Tandler *et al.* (1995) suggested that brood-stock diets must include 15 g n-3 HUFA kg^{-1} DW diet.

Practical Diets

The determination of the nutritional requirements of the gilt-head sea bream during the juvenile and grow-out stages has been a continuous research effort over the last 25 years and is summarized in Table 5.2. These studies have enabled the production of quality juveniles as well as feeds that offer faster growth, better conversion efficiency and decreased feeding costs to the farmer, allowing the industry to expand dramatically in the last few years. Today, there is a tendency to feed high-energy (up to 20% lipid) extruded diets at levels according to established feeding tables. Sea-bream production in Europe produced 57,000 tons in 1999 and is projected to reach 60,000 tons in the year 2000.

Feeding practices: brood-stock

Sea-bream culture in the Mediterranean is carried out in cages except in the Canary Islands, southern Portugal and Italy, which employ large land-based tanks or earthen ponds (Smart, 1996). Many farms use hand-feeding during grow-out to closely monitor any changes in fish appetite and health conditions. Recently, a number of farms have employed computer-controlled automatic feeders, where feeding frequency and the amount of diet can be programmed for each cage according to feeding tables and the numbers of juveniles stocked. New approaches, adopted primarily from the salmon industry, using Doppler technology and cameras placed in cages to accurately detect satiation feeding levels are currently being tested.

Table 5.2. Summary of known nutritional needs of the gilt-head sea bream during juvenile and grow-out stages (modified from Kissil *et al.*, 2000b).

Protein	• Total dietary level	% of DW diet
	Juvenile	50–60
	Grow-out	45–50
	• Amino acids (AA)	% of dietary protein
	Arginine	< 2.6
	Lysine	5.0
	Methionine + cysteine	4.0
	Tryptophan	0.6
	• Estimates of remaining AA*	
	Histidine	1.7
	Isoleucine	2.6
	Leucine	4.5
	Valine	3.0
	Phenylalanine + tyrosine	2.9
	Threonine	2.8
Lipid	• Total dietary level	% of DW diet
	Grow-out	12–24[cf]
	• (n-3) HUFA (EPA + DHA)	
	Juveniles (1–11 g)	≥ 0.9
	(12–30 g)	1
	Grow-out	1.5–2.7[cf]
Carbohydrate		% of DW diet
		20
Energy	• Daily maintenance	55.8 kJ × BW (kg)$^{-0.83}$
	• Growth requirement	23 MJ kg^{-1} live weight
Vitamins		mg kg^{-1} diet
	Pyridoxine (B_6)	3–5
	Biotin	0.37
	Nicotinic acid	63–83
	Thiamine (B_1)	> 5.0
	Riboflavin, pantothenic and ascorbic	Levels unknown
Minerals†		Commercial premixes[rv]
DP : DE ratios		28–19 g DP MJ^{-1} DE

rv, recommended values; cf, values found in commercial diets for sea bream.
* Estimates of AA based on ratios of whole-body AA to total AA.
† No information.

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