European Sea Bass, *Dicentrachus labrax*

2

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Introduction

European sea bass (*Dicentrarchus labrax*) is a major marine fish species reared in Europe, particularly in the Mediterranean region, and production is expected to continue to increase in the near future. Current production is estimated to be about 45,000 tons, the major producing country being Greece, followed by Turkey, Italy and Spain. About 180 million juveniles are produced annually in hatcheries across Europe and transferred to grow out in marine cage farms in the Mediterranean. Very much appreciated by consumers, the price is about 5.5 Euros kg^{-1}. It is also a reasonable forecast that cultured sea bass will shortly predominate over wild-captured sea bass. The species has been fully domesticated for two or three decades, with all the different phases of production (controlled reproduction, larval culture, grow-out of juveniles to market size) well under control. Despite considerable research effort in recent years on the nutrition and feeding of these species, knowledge of the nutritional requirements is still limited.

Nutrient Requirements

Protein and amino acids

Initial studies (Alliot *et al.*, 1978; Métailler *et al.*, 1981) reported that European sea bass would have very high dietary protein requirements, ranging from 52 to 60%. Subsequently, it was shown that the dietary crude protein levels can be decreased to between 48 and 54% (Hidalgo and Alliot, 1988; Ballestrazzi *et al.*, 1994). More recent works (Pérez *et al.*, 1997; Dias *et al.*, 1998a) show that the optimum growth of sea bass can be achieved with diets having 43–45% protein. Dias *et al.* (1998a) found no growth differences in sea bass fed diets with either

43% or 52% protein, provided the dietary digestible energy levels are maintained above 21 MJ kg^{-1}.

Métailler *et al.* (1973) showed that European sea bass require the same ten essential amino acids (EAA) as the salmonids. Quantitative data on requirements for some of these EAA have been obtained in recent years (Table 2.1), based on dose–response curves using semipurified diets, for arginine (Tibaldi *et al.*, 1994), lysine (Tibaldi and Lanari, 1991), methionine and cysteine (Thébault *et al.*, 1985), tryptophan (Tibaldi *et al.*, 1993), and threonine (Tibaldi and Tulli, 1999). For other EAA, indirect estimations have been made using methods such as those based on overall body protein accretion and an ideal protein composition has been provided (Kaushik, 1998b).

The effect of water temperature on the protein requirements has been studied (15°C and 20°C by Hidalgo and Alliot, 1988; 18°C and 25°C by Peres and Oliva-Teles, 1999). In both studies, protein requirements were estimated to be 48–50% of the diet and found not to be affected by water temperature.

Data on the apparent digestibility coefficients (ADC) of some common feedstuffs for sea bass have been made available in recent years (Santinha *et al.*, 1996; da Silva and Oliva-Teles, 1998). Much as in other teleosts, the ADC of protein is generally high, while that of energy is slightly lower in some of the plant-protein sources, reflecting the variability in the availability of carbohydrates (Table 2.2).

Spyridakis *et al.* (1988) also determined the true and apparent digestibility coefficients for some ingredients in sea bass and found few differences between sources. However, the ADC of some amino acids were found to be different from that of the crude protein, suggesting the need for more systematic work on amino acid availability.

Currently, there are very few data on the energy requirements of European sea bass, either in terms of maintenance or for growth. Data based on oxygen consumption rates of sea bass under unfed conditions suggest that the maintenance requirements would be approximately 14–16 kJ kg^{-1} body weight (BW) per day. In terms of dietary protein-to-energy ratios, although early data indicated values above 22 mg digestible protein (DP) kJ^{-1} digestible energy (DE), the data from Dias *et al.* (1998a) suggest that the optimum protein-to-energy ratio of the diets for sea bass should be 19 mg kJ^{-1}, in diets with at least 21 MJ kg^{-1} DE, with the major portion of non-protein energy being supplied by dietary fats.

Table 2.1. Available data on the quantitative essential amino acid requirements (expressed as g per 16 g nitrogen) of European sea bass.

Amino acid	Requirement
Arginine	4.1
Lysine	4.8
Threonine	2.6
Tryptophan	0.5
Methionine + cystine	4.4

Table 2.2. Apparent digestibility coefficients (ADC) of selected protein sources in European sea bass.

		ADC (%)		
Ingredient	CP (%)	Protein	Energy	Reference
Fish-meal, Denmark	72.3	94.6	95.0	1
Fish-meal, Norway	74.9	96.0	94.5	2
Fish-meal, Portugal	70.1	89.5	86.2	2
Fish-meal, Peru	62.1	94.4	94.0	1
Fish soluble protein concentrate (CPSP G), France	71.7	96.5	94.6	2
Poultry-meat meal	62.2	97.3	96.5	1
Meat meal, defatted, steam-cooked	75.1	92.0	86.4	2
Blood meal	97.1	90.6	92.1	2
Dry brewer's yeast	48.0	88.6	85.0	1
Soybean meal	46.2	88.9	82.2	1
Soybean meal (solvent-extracted)	51.6	89.8	69.3	2
Soy protein concentrate	64.8	97.3	87.9	1
Rapeseed meal	35.6	93.4	78.1	1
Maize gluten meal	54.5	91.3	86.9	1
Wheat gluten	77.0	98.4	93.3	1
Extruded pea meal	24.5	92.5	84.2	1
Extruded lupin-seed meal	42.0	93.7	87.6	1

1, F. Tulli and E. Tibaldi (personal communication); 2, Da Silva *et al.* (1998); CP, crude protein; CPSP G, Concentré Protéique de Solubles de Poissons-Gras (Fish soluble protein concentrate – fat rich)

Lipids and fatty acids

Alliot *et al.* (1979b) observed higher growth rates in sea bass fed diets containing a dietary lipid level of 12% compared with fish fed a diet containing 8% lipid. Two later studies (Métailler *et al.*, 1981; Pérez *et al.*, 1997) with sea bass, however, did not show any beneficial effect from increasing the lipid level. Data of Dias *et al.* (1998a) and Lanari *et al.* (1999) suggest that an increase in dietary lipid up to 18–19% improves protein utilization in sea bass. However, Peres and Oliva-Teles (1999) suggest that very high levels (30% lipid) would lead to a growth depression in sea bass.

Although it is generally recognized that long-chain polyunsaturated fatty acids (PUFA) of the n-3 series, eicosapentaneoic acid (EPA) (20:5n-3), and docosahexaenoic acid (DHA) (22:6n-3), are considered essential for a marine fish such as the European sea bass, precise quantitative data have not been clearly established. Given the importance of PUFA during early embryonic and larval development (Bell *et al.*, 1996), much work has been undertaken with larval stages of sea bass fed PUFA-enriched live prey (Fukusho *et al.*, 1985). An attempt was made to determine the essential fatty acid (EFA) needs of sea bass using formulated dry diets (Coutteau *et al.*, 1996) and their data suggest a requirement of about 1% of n-3 PUFA for sea bass.

Supplementation with between 1 and 2% of phospholipids was also found by Geurden *et al.* (1997a,b) to bring about a significant improvement in the growth of juvenile sea bass, as well as in the retention of fatty acids. Ballestrazzi and Lanari (1996) observed that sea bass is capable of utilizing fatty acid calcium salts of herring oil as efficiently as fish oil.

The fatty acid composition of the neutral lipids in sea bass, as in many other teleosts, reflects that of the dietary fatty acid profile. However, sea bass are prone to have a high fat deposition in the liver. Given that marine oils rich in n-3 PUFA are susceptible to oxidation, the consequences in terms of hepatic enzyme activities as well as muscle peroxidation characteristics (Alvarez *et al.*, 1998) are worth taking into account.

Carbohydrates

European sea bass do not appear to have high digestive amylolytic activity. Digestibility of carbohydrates in sea bass is affected by the nature and complexity of the carbohydrate supplied. Extruded starch, maltose or glucose is better digested than crude starch. Use of precooked or pretreated plant products then becomes necessary for improving starch digestibility and hence DE supply. At the postabsorptive level, a prolonged hyperglycaemia is also reported in sea bass (Peres *et al.*, 1999), with postprandial patterns comparable to those observed in other species. Very early on, Alliot *et al.* (1979b) suggested a possible protein-sparing potential of dietary glucose in European sea bass. While some authors (Pérez *et al.*, 1997) found no growth differences in sea bass fed diets containing either crude or extruded starch, Dias *et al.* (1998a) observed better growth and feed utilization in sea bass fed extruded starch than in those fed crude starch. However, very high levels (above 30%) appear to induce some growth depression.

Vitamins and minerals

Data on quantitative vitamin requirements of European sea bass are extremely scarce. A dietary requirement for vitamin C below 50 mg kg^{-1} diet has been reported for sea bass. A recent work with juvenile sea bass (Fournier *et al.*, 2000) has indicated a much lower requirement for growth but higher needs for maximizing ascorbate concentration in the liver. There is also indirect but clear evidence that the requirements of European sea bass for most water-soluble vitamins would not differ from those established for the salmonids. Data from a recent study (Kaushik *et al.*, 1998) suggest that the recommendations on requirements for water-soluble vitamins established for salmonids (NRC, 1993) can be applied to European sea bass fed practical diets. Although no quantitative requirement data are available as regards fat-soluble vitamins, a dietary supply of vitamin E at levels of 500 mg kg^{-1} diet has been recommended as a measure of defence against peroxidative damage (Messager *et al.*, 1992).

There is a definite lack of data on the mineral requirements of European sea bass. Dietary phosphorus availability has received some attention (da Silva and Oliva-Teles, 1988; Santinha *et al.*, 1996), the bioavailability being higher in feedstuffs of animal origin than in those of vegetable origin. Unpublished data suggest that the requirements would be in the range of 0.6%. The possible improvement of the availability of phosphorus in plant feedstuffs by dietary exogenous phytase has also been demonstrated (Oliva-Teles *et al.*, 1998).

Practical Diets

Larval diets

As with most marine fish, first-feeding larvae of European sea bass are fed live prey items, such as the rotifers *Brachionus* sp. and *Artemia*. There is abundant literature on the beneficial effects of enrichment of these live prey with different nutrients (n-3/n-6 PUFA, vitamins, amino acids). Most of the recommendations as regards nutrient supply to larval sea bass have been obtained using variably enriched live prey (Bell *et al.*, 1996; Merchie *et al.*, 1996; Navarro *et al.*, 1997, 1998). After a period ranging from 25 to 40 days of growing the larvae with such live prey, they are gradually transferred to formulated dry diets. Although all hatcheries still follow the sequential supply of the live prey, there have been several research efforts to develop formulated diets for first-feeding larvae.

These works have shown that digestive enzyme activities are present even during early development of sea-bass larvae and that they are affected by dietary factors (Zambonino Infante and Cahu, 1994a,b; Péres *et al.*, 1996). Other studies have shown the beneficial effects of the use of protein hydrolysates instead of whole proteins in larval diets (Carvalho *et al.*, 1995; Zambonino Infante *et al.*, 1997; Cahu *et al.*, 1999). Similarly, studies by Geurden *et al.* (1997a,b) have identified the importance of dietary phospholipids for growth and tissue lipid composition of sea-bass larvae after transfer from live prey to compound dry diets. Cahu *et al.* (1998) were thus able to rear sea-bass larvae with a compound diet from first feeding onwards, although growth rates of these larvae were significantly lower than those fed *Artemia*. Our own, more recent, unpublished data indicate that it is possible to rear the larvae of European sea bass with formulated dry diets right from the first feeding onwards with equal growth rate and survival to those fed live prey. Given the continued interest and progress in this field of developing artificial diets as a total replacement for live prey, one can expect precise data on the requirements of sea-bass larvae for different nutrients in a short time, which will also require development of semipurified diets for first-feeding larvae.

Juvenile and grow-out stages

Diets for juvenile stages are generally rich in protein and those up to marketable size generally receive extruded dry diets with crude protein levels ranging from 43 to 50% and fat levels between 12 and 25%. Fish-meal remains the major protein source (Table 2.3), although even very early on studies were undertaken by Alliot *et al.* (1979a) to find alternatives to fish-meal. Current diets contain terrestrial plant products, such as soybean meal, maize gluten meal or wheat gluten, supplying anywhere between 30 and 40% of dietary protein. Partial or total replacement of fish-meal by plant ingredients in the diets have been attempted (Dias, 1999; Gouveia and Davis, 2000); however, poor growth performance of sea bass fed such diets has been linked to a reduction in voluntary diet intake. An improvement in voluntary diet intake by the addition of an amino acid mix as an attractant appears to hold promise (Gomes *et al.*, 1997). Addition of plant oils to a commercial diet for sea bass has reportedly decreased growth performance compared with addition of fish-oil (Yildiz and Sener, 1997). As with salmonids, culture of sea bass in the marine environment and how to minimize effects on environmental discharges need to be investigated more thoroughly (Ballestrazzi *et al.*, 1994). Sea bass exhibit postprandial ammonia excretion patterns comparable to those of other teleosts (Dosdat *et al.*, 1996) and the nutritional strategies for the reduction of nutrient loads into the environment are also similar (Kaushik, 1998a).

Brood-stock diets

A reduction of the dietary protein level from 51% to 34% was shown to reduce brood-stock performance in sea bass (Cerdâ *et al.*, 1994). Much emphasis has also been placed on the importance of both n-3 and n-6 highly unsaturated fatty acids (HUFA) for the reproductive performance of sea bass (Bell *et al.*, 1997; Navas *et al.*, 1998; Bruce *et al.*, 1999). Data indicate that marine fish-oils rich in long-chain HUFA are essential for improving the quality of eggs, much as in most other marine fish.

Table 2.3. Example of a practical diet based on fish-meal for European sea bass.

Ingredients	%
Fish-meal, CP > 70%	52.0
Extruded wheat	19.6
Soybean meal, CP 48%	9.5
Fish-oil	15.9
Binder	1.0
Mineral premix	1.0
Vitamin premix (NRC, 1993)	1.0

CP, crude protein.

Blazquez *et al.* (1995) found that a dietary supply of 17-α-methyltestosterone at 10 mg kg^{-1} diet from 126 to 226 days postfertilization was effective for masculinization of sea bass. More recent work by Chatain *et al.* (1999) demonstrated that even lower doses of a synthetic analogue, 17-α-methyldehydrotestosterone (0.5, 3.0 or 5.0 mg kg^{-1} diet), are sufficient to induce complete and permanent masculinization of sea bass, although a small proportion of males (10%) showed testicular deformities. Very few studies have reported that feeding purified diets to sea bass has led to growth rates comparable to those with fish-meal-based practical diets (Table 2.4).

Feeding Practices

Hatching and larval rearing of European sea bass are undertaken on land-based farms with a very good control of the physical and microbial environment. As mentioned above, enriched live prey (rotifers, *Artemia*) are used for rearing larvae during the first 4–6 weeks in circular, self-cleaning tanks. In order to avoid problems related to swim-bladder inflation, surface skimmers are necessary. They are slowly ‘weaned’ on to formulated dry diets. Juveniles (1–5 g) are transferred from hatcheries to rearing tanks and, after periods ranging from 3 to 6 months, transferred to grow-out cages in the sea. Cage culture is the major production system used for sea-bass culture in the Mediterranean area. The size of the cages is variable, with stocking densities ranging between 6 and 20 kg m^{-3}. There is also an increasing interest in land-based, thermoregulated, totally recirculated systems.

Some of the basic bioenergetic principles as applicable to marine fish feeding were provided recently (Kaushik, 1998a). Dias *et al.* (1998b) showed that, when there is a dilution of dietary nutrients by bulk agents, sea bass are capable of compensating by increasing their diet intake to a certain extent. However, as with salmonids, use of nutrient-dense diets for this species may be advisable. We have also recently shown that voluntary diet intake and feed : gain ratio are inversely related to dietary DE content (Boujard *et al.*, 2000).

Table 2.4. Example of a semipurified diet providing about 8% nitrogen (N) for studies on nutrient requirements of European sea bass.

	Diet	
Ingredients	1	2
Casein, vitamin-free	15.0	25.0
Fish-soluble protein concentrate	1.0	1.0
Dextrin	38.0	20.4
Agar	1.0	1.0
Vitamin mix	5.0	5.0
Mineral mix	5.0	5.0
Fish-oil + lecithin	11.0	11.0
Cellulose	5.0	5.0
Amino acid mix	19.0	26.6

Sea bass generally feed under daylight conditions. A feeding frequency of two to three meals during the light hours of the day is considered most efficient (Tsevis *et al.*, 1991). Recent studies (Boujard *et al.*, 1996; Azzaydi *et al.*, 1998) have also demonstrated that sea bass are capable of using demand feeders and that they exhibit a diel pattern of feeding activity rhythms. Sea bass also seem to exhibit a certain plasticity in their feeding rhythms in that they are capable of adjusting their feeding activity in response to diet availability. Compared with manual or automatic feeding, the use of demand feeders has the definite advantage of avoiding diet wastage and better feed efficiency (Coves *et al.*, 1998; Paspatis *et al.*, 1999), as well as reduced environmental loads (Paspatis *et al.*, 2000). Sea bass are able to adjust their diet intake in accordance with their nutritional needs.

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