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Recent advances in nutritional aspects of *Seriola dumerili*

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SUMMARY – The existing knowledge about the nutritional aspects of the Mediterranean yellowtail (*Seriola dumerili*, Risso 1810) are reviewed in this presentation. Data about natural food and feeding habits of young and adult fish are presented due to its potential application for developing farming techniques. Commercial experiences carried out on the culture of *S. dumerili* have usually been based on the use of raw fish as food. Research trials conducted at our laboratory using moist and soft-dry pellets as food for young *S. dumerili* have resulted in better growth and conversion factor and even survival rate than raw fish. Use of formulated feed is becoming popular in Japan for the rearing of Japanese yellowtail (*S. quinqueradiata*, Temmick and Schlegel), where actually 16 feed companies are producing such kind of food. So, a similar development is expected in the Mediterranean area. For the practical diet formulation, some experiences with the use of different protein and lipid sources in extruded diets for *S. dumerili* have also been carried out in collaboration with other Spanish research centres and will be commented. Regarding nutritional studies, very scarce data about macronutrient (protein, lipids and carbohydrate), vitamin, essential fatty acid and mineral requirement are available. Preliminary trials about protein and lipid and the protein/energy rate requirements carried out in collaboration with the Universidad Politécnica de Valencia are presented. Finally, future prospects and research topics will be pointed out and compared with the present trends in Japan.

Key words: Mediterranean yellowtail, nutrition, feeding, diet formulation, nutrient requirements.

RESUME – *"Progrès récents concernant les aspects nutritionnels de la* Seriola dumerili*". Dans cette présentation sont révisées les connaissances sur les aspects nutritionnels de la sériole méditerranéenne (*Seriola dumerili*, Risso 1810). Les données sur l'alimentation naturelle et les habitudes alimentaires des sérioles jeunes et adultes se présentent vis-à-vis de leur application potentielle pour le développement des techniques d'élevage. Les expériences commerciales menées sur l'élevage de* S. dumerili *ont été normalement basées sur l'utilisation de poisson haché comme aliment. Les expériences menées dans notre laboratoire avec l'utilisation de mélange et d'aliment composé sec (soft-dry) pour jeunes* S. dumerili *ont abouti à une meilleure croissance et conversion de l'aliment, et survie en comparaison avec le poisson haché. L'utilisation d'aliment formulé a commencé à être populaire au Japon pour l'élevage de la sériole japonaise (*S. quinqueradiata*, Temmick et Schlegel), où aujourd'hui il existe 16 entreprises alimentaires qui produisent ce type de nourriture. Partant, un développement similaire est envisageable sur la Méditerranée. Pour la formulation pratique des régimes, on a mené des expériences sur l'utilisation de différentes sources de protéines et lipides dans les granulés extrudés pour* S. dumerili*, en collaboration avec d'autres centres espagnols de recherche. Au regard des études nutritionnelles, on dispose seulement de très peu de données sur les besoins en macronutriments (protéines, lipides et carbohydrates), en vitamines, acides gras essentiels et minéraux. Les résultats préliminaires des expériences menées en collaboration avec la Universidad Politécnica de Valencia sur les besoins en protéines et lipides, et le rapport protéine/énergie sont présentés. Finalement, ont cite les prospections pour l'avenir ainsi que les filières de recherche, et on les compare avec les tendances actuelles menées au Japon.*

Mots-clés : *Sériole, nutrition, alimentation, formulation des régimes, besoins nutritionnels.*

Food and feeding habits

Knowledge of the natural diet of *S. dumerili* might be useful in developing artificial diet for its farming. Several papers have been published regarding the food and feeding habits of young and adult *S. dumerili* (Lazzari and Barbera, 1988, 1989a; Grau *et al*., 1992; Mazzola *et al*., 1993; Badalamenti *et al.*, 1995; Matallanas *et al.*, 1995; Pipitone and Andaloro, 1995). As it has been reported for many fish species (Nikolsky, 1963; Wooton, 1991), *S. dumerili* undergoes a marked diet shift during development. Badalamenti *et al*. (1995) reported that individuals up to 80 mm standard length (SL) feed mainly on the zooplankton community (Copepoda and Crustacean decapoda larvae),

fish between 80 to 120 mm SL continues to feed on zooplankton, but benthic and nektonic items also become important and those greater than 120 mm SL feed mainly on nektonic and nektobenthic items. Similar results were obtained by Mazzola *et al*. (1993) and Pipitone and Andaloro (1995). It seems that juvenile *S. dumerili* are active predators from their earliest life stages, feeding on large preys (Grau *et al*., 1992) and becoming piscivorous after only a short planktivorous phase lasting no more than three months (Badalamenti *et al*., 1995), as in others Carangidae species (Sudekum *et al*., 1991; Jobling, 1995). The diet shift have also been related to the habitat change that *S. dumerili* undergoes at a size about 20 cm when they abandon offshore waters to come closer to the coast in shallow waters (Pipitone and Andaloro, 1995).

Regarding juveniles and adult *S. dumerili*, teleost fish are usually the main food. *Trachurus trachurus, Scomber scombrus, Engraulis encrasicholus, Sardina pilchardus* and *Merluccius merluccius* frequently accompanied with cephalopoda (*Loligo vulgaris* and *Sepiola* sp.) and occasionally Crustacea (*Squilla mantis*) have been found in their stomachs (Lazzari and Barbera, 1988, 1989a; Matallanas *et al.*, 1995).

Types of food used for the rearing of *S. dumerili*

As for the Japanese yellowtail (*S. quinqueradiata*, Temmick and Schlegel), the very few commercial farming experiences of *S. dumerili* have been based on frozen, low cost raw fish, such as *Sardinella aurita, Boops boops, Trachurus trachurus, Scomber scombrus, Engraulis encrasicholus* and *Sardina pilchardus.* Also many research studies about on-growing of *S. dumerili,* in tanks as in cages, have used raw fish as food (Giovanardi *et al*., 1984; Navarro *et al*., 1987; Cavaliere *et al*., 1989; Lazzari and Barbera, 1989b; Grau, 1992; Boix *et al*., 1993; García, 1993a; García *et al*., 1993; Greco *et al*., 1993; Mazzola *et al*., 1993; Porrello *et al*., 1993). Fish fed *ad libitum* with raw fish have a food conversion rate of 5-7. Growth in weight and length, daily growth rate and specific feeding rate according to the age are summarised in Table 1. Growth and feeding parameters are influenced by the fish age and water temperature (Figs 1 and 2) (García, 1993c), as in *S. quinqueradiata* (Harada, 1965). García *et al.* (1993) suggested a lesser feeding rate than the satiation one for young *S. dumerili* at optimal water temperature (20-25°C).

Table 1. Growth and feeding parameters of captive *S. dumerili* fed with raw fish (modified from García, 1993c)

Age	Weight (g)	Length (cm)	DGR[†,†††]	SFR[††,†††]
1	1000-1100	35-45	0.8-1.1	1.7-5.6
2	3000-3200	60-65	0.3-0.4	0.4-2.6
3	5000-5200	70-75	0.2	
4	8000-10000	85-95		
5	11000-13000	95-105		

[†]DGR = Daily growth rate (%).
[††]SFR = Specific feeding rate (%).
[†††]DGR and SFR varies with the seawater temperature.

The use of such kind of food have several disadvantages: the *S. dumerili* production is heavily dependent on locally available raw fish. Moreover, feeding raw fish for densely cultured fish frequently results in deterioration of environmental waters in terms of loading nitrogen, phosphorous and oxygen consuming substances due to their loss from the diets, leading to eutrophication and occurrence of various fish diseases (Watanabe *et al*., 1991). Raw fish also have an unstable nutritive value, poor hygienic condition and its preparation and storage require labour and facilities (Shimeno, 1991).

Until 1985, frozen raw fish were used in Japan as the main food for yellowtail culture (Nakada and Murai, 1991; Shimeno, 1991). Practical formulated feeds, such as the Oregon moist pellet (OMP), single moist pellet (SMP), "soft-dry" pellet (SDP) and extruded pellet (EP) have been developed and the last two recently used. OMP is prepared by mixing raw fish and formulated mash, which usually contains fish meal, fish oil and a vitamin-mineral mixture. In the Mediterranean area, OMP have also been successfully

used for the rearing of *S. dumerili* (Di Bella *et al*., 1991, 1994; García, 1993a,b; Greco *et al*., 1993), specially at low temperatures (under 15°C) when they usually stop feeding (García, 1993a,b). Moreover, *S. dumerili* fed on OMP have resulted in lesser mortality rate and more homogenous growth than those fed on raw fish (García, 1993a,b; García *et al*., 1995; González *et al*., 1995).

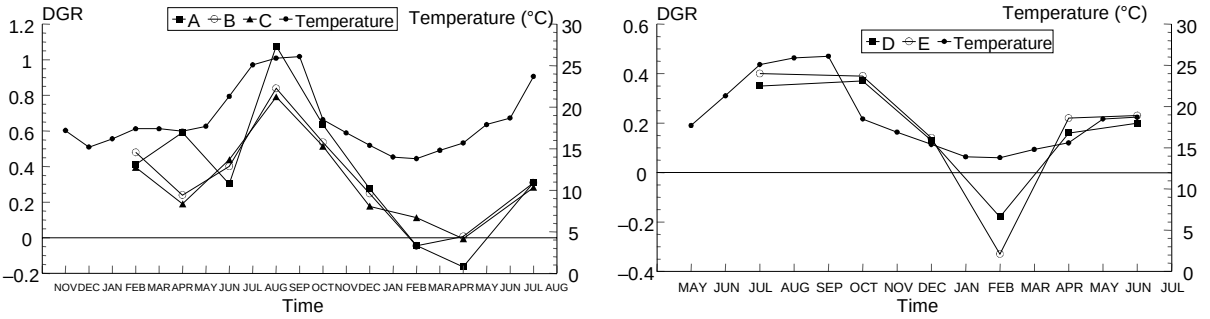

Fig. 1. Daily growth rate (DGR) variation in three groups (A, B and C) of 0+ age class and two groups (D and E) of 1+ age class young *S. dumerili*, fed with raw fish, according to the average sea water temperature in the rearing tanks (modified from García, 1993c).

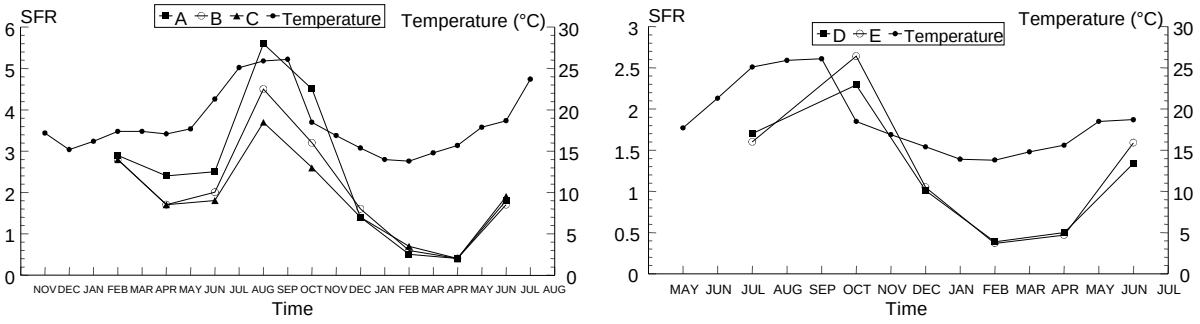

Fig. 2. Specific feeding rate (SFR) variation in three groups (A, B and C) of 0+ age class and two groups (D and E) of 1+ age class young *S. dumerili*, fed with raw fish, according to the average sea water temperature in the rearing tanks (modified from García, 1993c).

The disadvantages of moist pellet are that it can not be produced in a suitable size for fish over 5-6 kg, because pellets of a suitable size for larger fish do not retain their shape in water. In addition, it is difficult to maintain the proper calorie-protein balance in a large size pellets and at present they do not supply sufficient energy required by larger fish (Nakada and Murai, 1991). Also OMP has the disadvantage of requiring facilities and labour for its preparation and storage (Shimeno, 1991).

SMP is also a moist pellet prepared with a pellet mill from a mixture comprised of a powdered formulated diet, freshwater and oil (10:4:1 in general). This pellet has the same advantages as those of OMP, but in addition has stable nutritive value and is hygienic because it does not require fresh fish as raw material. However, SMP can not be fed in low temperature seasons (Shimeno, 1991).

SDP and EP are pellet with 8-12 and 7-10 moisture respectively, processed by a cooking-extrusion technique, which are well accepted by *Seriola* spp. because are softer than ordinary hard pellets (Watanabe *et al*., 1991). This new type of food has been put into the market for yellowtail culture since 1988. Nowadays 16 feed companies are producing such kind of food for jacks (J. Kleine Staarman, Yamaha-Nutreco Co., pers. comm.). EP is very promising because is cheaper, more nutritive, less polluting and requires less labour and facilities for its preparation and storage than the other ones (Nakada and Murai, 1991; Shimeno, 1991). Other advantages is that EP is high in calories to meet the nutritional need of *Seriola* spp., water stable, and do not deteriorate at normal temperatures, making possible the full-scale automatisation of production in off-shore ocean sites (Nakada and Murai, 1991).

SDP and EP have been successfully used in Japan, not only for the on-growing of *S. quinqueradiata* (Watanabe *et al*., 1991, 1992, 1993; Viyakarn *et al*., 1992; Shimeno *et al*., 1993a, 1997); but also as a broodstock diet (Mushiake *et al*., 1995; Watanabe *et al*., 1996; Verakunpiriya *et al*., 1996, 1997).

Since 1993, some experimental feeding trials using EP diets, formulated and prepared at the Universidad Politécnica de Valencia (E Spain), as food for *S. dumerili* have been carried out at the Instituto Español de Oceanografía (IEO) facilities in Puerto de Mazarrón (Murcia, SE Spain). Firstly, an EP pellet with physical and organoleptic characteristics suitable for *S. dumerili* was developed and tested. In 1996 four EP diets were tested containing two levels of protein (45 and 50%) and two levels of lipid (14 and 17%). Results indicates that an optimal growth of *S. dumerili* can be obtained with EP diets, at least similar to those with raw fish and moist pellets (García, 1993a,b). Another feeding trial with 1+ age class *S. dumerili* were made using a commercial food for *S. quinqueradiata* (EWOS Canada Ltd., unpublished data) containing a high lipid content (24% fat), which also resulted in a very good growth. More details of these researches will be presented in the next section: Nutrients requirements.

Owing to limitations regarding sustainability and availability of raw materials of marine origin (principally fish meal and fish oil) in the fish feed industry, many aquaculture researchers are exploring the use of alternative raw materials which meet the requirement for the efficient cost-effective production of farmed fish (Talbot, 1998). Several papers are published dealing with the partial substitution of fish meal protein by other animal and plant protein sources in practical diets for *S. quinqueradiata*. Thus, animal proteins from meat meal, meat-and bone meal; together with plant protein mostly from soybean meal but also from corn gluten meal, rapeseed meal and malt protein flour have been tested (Takii *et al*., 1990; Lee *et al*., 1991; Shimeno *et al*., 1991, 1992a,b, 1993a,b,c,d,e, 1994, 1995a,b; Masumoto *et al*., 1996; Ruchimat *et al*., 1997). Regarding soy protein, which seems to be the most useful alternative protein source, some studies have been performed to check the improvement of nutritive value and digestibility of this plant meal for *S. quinqueradia* diets through different treatment like fermentation, defattening, heating and purification (Shimeno *et al*., 1992a,b, 1993a,b,c,d,e, 1995a,b). The nutritive value of various oils for *S. quinqueradiata* diets have been less investigated (Deshimaru *et al*., 1982a,b).

There are not any papers in the literature about the use of alternative protein and lipid sources for *S. dumerili* diets. Actually, we are undertaking this kind of research in collaboration with the Universidad Politécnica de Valencia (Spain) and the NUTRECO Aquaculture Research Centre (Norway). Furthermore, a research study was recently carried out, together with the Canarian Institute of Marine Science (ICCM) (Spain), on the nutritional use of different lipid sources in extruded diet for *S. dumerili* (El-Sayed Aly, 1999). The dietary utilisation by *S. dumerili* of three lipid sources (fish oil, sunflower oil and animal tallow) and their influence on growth, feeding rate and meet quality were investigated. Results indicated that sunflower oil may be used as a partial replace of fish oil for on-growing *S. dumerili.* On the contrary, fish oil substitution by animal tallow proved to have a negative effect in the culture of *S. dumerili*, showing a lower DGR and higher conversion index (CI) than the other two diets tested. This can be concluded at least at the percentage of replacement used in the experiment (over 60%), probably due to the lower digestibility and n-3 high unsaturated fatty acids (HUFA) content and higher saturated fatty acid contents than the other fish oil and sunflower oil based-diets (El-Sayed Aly, 1999).

Nutrients requirements for *S. dumerili*

Few data are available in the literature for this specie. In contrast, many papers have been published regarding the nutrient requirement of the close related species *S. quinqueradiata* (Shimeno, 1991; Takeuchi *et al.*, 1992a,b; Furuita *et al.*, 1996; Shimeno *et al.*, 1996). Compared with other fish species, *S. quinqueradiata* has a low ability to utilise carbohydrates and a high ability to utilise protein and lipid because of their carnivorous nature; whilst the vitamin and mineral requirement of the fish are also slightly different (see review in Shimeno, 1991). In general, a diet containing about 50% of protein and 15-20% of lipid (including 1.6 to 3.1% HUFA) results in a good feed efficiency (Shimeno, 1991; Takeuchi *et al.,* 1992a,b).

In 1996, a study was performed at our facilities on the growth of *S. dumerili* fed with extruded diets containing different levels of protein and lipid (Jover *et al.,* 1997, 1999). Two levels of protein (45 and 50% crude protein, CP) and two levels of lipid (14 and 17%) were tested. The effect of lipid level was

not significant, but growth of fish feed with 50% CP was higher than 45% CP (Fig. 3). Nutritional parameters likes food intake rate, food conversion ratio and protein efficiency ratio were 1.3-1.4, 2.8-3.2 and 2.4-2.5 respectively and were not significantly affected by the diets. Body composition and nutrient retention of fish were similar for all diets. Digestibility trials also were performed for these diets and results being analysed. Recently, a new experiment has started by comparing four diets with 50 and 55% CP and again 14 to 17% lipid.

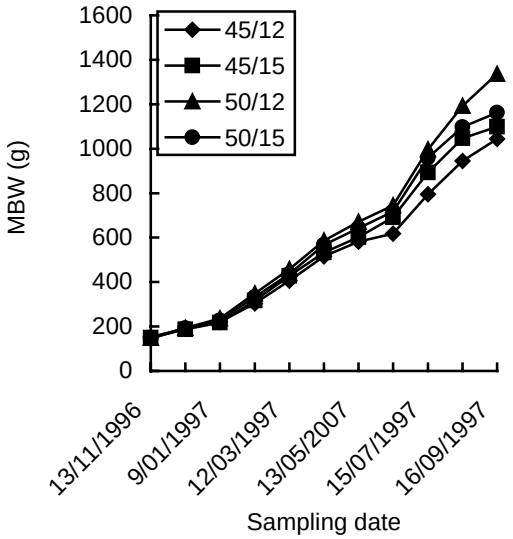

Fig. 3. Growth of *S. dumerili* fed with extruded diets containing different levels of protein and lipid (from Jover *et al*., 1999). MBW: mean body weight.

High energy diets (with different digestible protein/digestible energy rate) have resulted in better growth and body composition in salmonid species (Talbot, 1993). In 1998, a study was performed with over one year old *S. dumerili* (1.6 kg average body weight) in order to compare a commercial high lipid content containing 43% CP and 24% lipid (EWOS yellowtail L type) and a control food (50% CP and 15% lipid). EWOS diet resulted in better fish growth (Fig. 4) and conversion rate and similar feeding rate compared to the control diet (DGR: 0.41 versus 0.22; CI: 1.55 versus 3.07; and SFR: 0.90 versus 0.85 respectively). It should be pointed out that the control diet were manufactured by an experimental extruder machine from the Universidad Politécnica de Valencia. Then, both diet had different appearance and raw material content, so it is hard to get definitive conclusions on this trial.

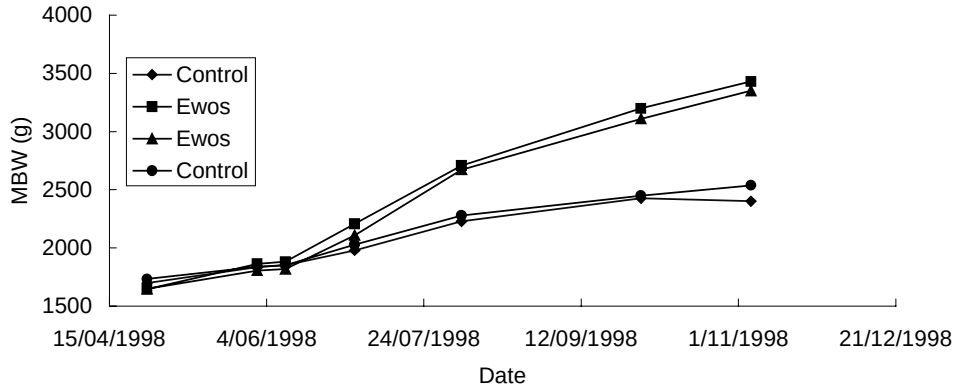

Fig. 4. Growth of young *S. dumerili* (1+ age class) fed with high energy (EWOS Ltd.) and a control extruded diets (unpublished data). MBW: mean body weight.

Currently, a wider range of protein/energy ration and raw material composition are being investigated together with the NUTRECO Aquaculture Research Centre for developing a commercial diet.

Future prospects and research topics

When the Mediterranean aquaculture industry will have available enough supply of *S. dumerili* fingerlings, the next point will be to have available a practical diet which covers their nutritional requirement, optimises commercial cost-effectiveness, maximises growth rate and reduces conversion rate, and lowers the feed cost. Therefore, future studies should be focused on adjusting the nutritional requirement of *S. dumerili* in a low cost formulated diet using common raw materials, check the use of alternative protein and lipid sources for *S. dumerili* diets, thereby providing a reduction of cost without comprising a good growth performance, by growth and feeding tests together with digestibility trials. Finally, studies need to be performed about the use of palatability enhancers on feed intake and growth (such as minerals, vitamins, amino acids and other chemicals) which are now used in diets for other marine fish.

Another future research topic could be the study of feeding behaviour, which will involve conducting research dealing with natural feeding rhythms at different environmental conditions and fish age. This will help the fish farmers to develop a proper feed management (feed allowance, meals per day, etc.) for improving its production.

These trends are similar to those followed by most of the Universities and Research Centres in Japan. So, taking into account the applicability of results obtained between both species (*S. dumerili* and *S. quinqueradiata*), strengthening the collaboration between Japan and Mediterranean researchers and institutions is recommended. Moreover, a close relationship with the private industry (fish farmers and feed companies) will be helpful to achieve the common objective, the diversification of aquaculture production by introducing a good quality fish like *S. dumerili.*

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