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Effect of stocking density and protein/fat ratio of the diet on growth of Dover sole (*Solea solea*)

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ABSTRACT: 250 soles (30g initial weight) were randomly placed in 12 experimental tanks at the Discizia's aquaculture marine station. They were reared at 2 different stocking densities (2.3 and 1.3kg/m^2 corresponding to 40% and 25% of the bottom surface area covered by fish) and fed on 2 diets with different protein/fat ratio (50% and 54% crude protein and 21% and 18% total lipid, respectively for diets A and B) with triplicate tanks per treatment.
The trial lasted 120 days. Fish stocked at the lower density resulted in significantly higher weight gain than fish reared at 2.3 kg/m^2 (29.0±7.3 g *vs* 20.3±8.0g; P<0.01) with a specific growth rate (SGR) of 0.54±0.09 and 0.42±0.13, respectively. Feed conversion rate (FCR) was improved at the lower density (1.8 *vs* 2.4, P<0.01).
The chemical composition of the test diets significantly affected the growth performance of sole. Diet B led to a higher final weight (59.7 *vs* 50.8g; P<0.01) and better feed utilisation (FCR: 1.8 *vs* 2.4, P<0.01). These results confirm the necessity to ensure an adequate space for the growing sole and suggest the need for high protein diets to meet sole's requirements.

Key words: Dover sole, Stocking density, Diet, Productive performance.

INTRODUCTION – The large demand for flatfish species in the European market, makes Dover sole (*Solea solea*) one of the most actractive new species for marine aquaculture. The interest in farming Dover sole has been stimulated by the need for the existing marine fish farming industry to diversify its production (Howell, 1997). Since the end of the 60's, attempts at reproduction of *Solea solea* in captivity have produced encouraging results (Shelbourne, 1968; Ramos, 1977; Salvatori, 1986; Devauchelle *et al*., 1987), although the production of juveniles of a satisfactory quality was obtained only after 2000 (Bertotto *et al*., 2001; Tibaldi *et al*., 2002; Zannella *et al*., 2004; Paolini *et al*., 2005). However, in order to start a commercial scale production of sole, it is necessary to improve survival rate at weaning and to define suitable rearing densities in the on-growing phase. In fact, due to its benthonic behaviour, the breeding of this species at high densities may represent a problem (Howell, 1998). In this study we investigated the effects of stocking density and protein/fat ratio of the diet on the growth performance of *Solea solea*.

MATERIAL AND METHODS – The trial was carried out at the Discizia's aquaculture recirculating marine water station, using 250 soles from the company "Orbetello Pesca Lagunare". They had an initial average weight of 30g and, after a brief period of adaptation in quarantine tanks, they were randomly divided among 12 experiment tanks, according to a factorial design combining two different initial stocking densities (2.3 *vs* 1.3kg/m^2, corresponding to 40% and 25% of the bottom surface area covered by fish) and two different diets (A *vs* B), with triplicate tanks per treatment. The chemical composition of the two diets, analysed following the methods of AOAC, (2000), was 50% and 54% crude protein, 21% and 18% total lipid, 21.84 and 21.77 (MJ/Kg) gross energy, for diets A and B, respectively. The experiment lasted 120 days. Water temperature was kept at 17.1±0.8°C and salinity at 30‰ throughout the experiment. During the trial, fish were fed at 1% biomass/day. The feed was administered twice a day over the whole surface of the water in the tanks to render it accessible simultaneously to all fish.

The tanks were inspected once daily for mortality and dead fish were removed immediately from the tanks after detection. On day 1 (stocking) and day 120 (end of the trial), fish from each tank were weighed in bulk to determine weight gain and specific growth rate (SGR) per tank as follows: SGR=100x (ln final weight - ln initial weight)/days. Data were processed by the analysis of variance using the GLM procedure of SAS (SAS, 2000).

RESULTS AND CONCLUSIONS – During the experiment, mortality was quite low (1.6%) and not related to the density or diets. No significant interaction was found between density and diet for the various response parameters. The growth performance and the feed efficiency of sole ordered by main factors are shown in Table 1.
The weight gain of fish stocked at the lower density (29.0±7.3g) was significantly higher than that of fish kept at 2.3kg/m^2 (20.3±8.0g) with a specific growth rate of 0.54±0.09 and 0.42±0.13, respectively. SGR values in this trial were lower than those reported by Schram *et al*. (2006) for sole of similar body weight and stocking density but kept under different culture conditions (water temperature 20.9°C, feed given at 2.0 and 1.5% biomass/day). It is probable that reduced growth in this trial resulted from lower water temperature and feeding rate, even if uneaten feed was observed in all the tanks throughout the experiment. However, for sole the presence of uneaten feed in the tanks may not be a signal of overfeeding since other authors (Schram *et al*., 2006) observed that uneaten pellets lying on the bottom of the tank for over 10min were not eaten later on. These results, according to other authors (Howell, 1998; Tibaldi *et al*., 2002; Schram *et al.*, 2006), confirm the need for sole to have adequate room at its disposal in order to give better productive responses. Also the different chemical composition of the diet influenced the growth performance of soles. Diet B, with a higher content of crude protein and a lower fat level, resulted in a higher weight gain (final weight: 59.7g *vs* 50.8g; P<0.01) with a specific growth rate of 0.55±0.09 and 0.41±0.12 (P<0.01) and led to a better feed utilisation (FCR: 1.8 *vs* 2.4, P<0.01). Nevertheless, due to difficulties of determining the real feed intake, it was not possible to state to what extent Diet B produced a better performance because it met more closely the requirements of sole or due to a higher palatability which led to a higher feed intake. In conclusion, these results, even if obtained using a limited number of fish, appear to be of great interest because they confirm the possibility of rearing this fish species under intensive farming systems, even if the weight gain reduction with increased stocking density needs further research. It appears evident that in order to obtain a commercial scale production of sole, farming systems that allow suitable stocking density without penalizing growth performance and efficiency, have to be developed. In our opinion, further research has to investigate the feeding behaviour of sole to

Table 1. Main performance of *Solea solea* during the experimental period (120 days).

	Initial Density		Diets	
	2.3 kg/m^2	1.3 kg/m^2	A	B
Tanks (n)	6	6	6	6
Initial Weight (g)	29.8±1.6	31.5±1.8	30.5±1.9	30.8±0.9
Final weight (g)	50.1±8.2^A	60.5±8.5^B	50.8±9.2^A	59.7±7.2^B
Weight gain (g)	20.3±8.0^A	29.0±7.3^B	20.3±8.5^A	28.9±6.7^B
SGR	0.42±0.13^A	0.54±0.09^B	0.41±0.12^A	0.55±0.09^B
FCR	2.4±0.8^A	1.8±0.4^B	2.4±0.8^A	1.8±0.4^B

A.B: *P*<0.01;
SGR (specific growth rate) = 100 × (ln final weight – ln initial weight)/days;
FCR (feed conversion rate) = g administered feed /g live weight gain.

minimize the effects of competition between subjects and maximize feed intake in order to find new technological and farming solutions which allow a greater breeding density and productivity.

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