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The Influence of Stocking Density on Growth and Feed Efficiency in Gilthead Seabream, *Sparus aurata*

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Abstract: The effects of the stocking density on growth performance and feed efficiency in gilthead seabream *Sparus aurata* were investigated at cage culture conditions. Three stocking density (36, 40 and 44 fish m^{-3}) were tested in the experiment lasted eleven months (from 1 January to 5 December 2006). Replication number was three in low stocking density group (36 fish m^{-3}) two in medium density group (40 fish m^{-3}) and three in high density group (44 fish m^{-3}). A total of 2000 gilthead seabreams with a mean initial body weight of 36.4±0.4 g (mean±SE) were used in the experiment. Feeding regime was applied with commercial feeds as *ad libitum*. Weight gain, specific growth rate, thermal-unit growth coefficient increased linearly, daily feed intake, feed conversion rate decreased quadratically and protein efficiency rate increased quadratically with increasing stocking density in the range of 36-44 fish m^{-3}. Results indicated that stocking density of 44 fish m^{-3} cause to improve on growth, feed efficiency and gross benefit compared to stocking densities of 36 and 40 fish m^{-3} in gilthead seabreams.

Key words: Gilthead seabream (*Sparus aurata*), stocking density, growth performance, feed efficiency, cage culture, gross benefit

INTRODUCTION

The eficiency and profitability of fish culture can be maximized by increasing the stocking densities. This may vary according to fish species, ranges of stocking densities and different environment and/or environmental conditions. Even in the same species, different growth performance and feed efficiency could be seen at different stocking densities. Thus, determining of the best density of stocking according to different environment/ environmental condition is very important. Gilthead seabream (*Sparus aurata*) is one of the most important marine fish species for Mediterranean aquaculture. Gilthead seabream production reached up to 128.943 tonnes in 2008 with major suppliers from Greece (47%), Turkey (21%), Spain (19%) and Italy (7.4%) (FEAP, 2009). Gilthead seabream was cultured mainly in West Mediterranean and Aegean regions of Turkey. Farmers generally stock the gilthead seabream to wooden cages (dimensions, 5×5×5 m) at three different densities (4500-5000-5500 fish $cage^{-1}$). However, it is not clear which stocking density is best. In the present study, we aimed to determine the effects of the stocking densities of 36, 40 and 44 fish m^{-3} on growth performance, feed efficiency in gilthead seabream at cage culture conditions.

MATERIALS AND METHODS

Fish, rearing conditions and experimental design: The study was conducted at Nurya Marine Fish Cage Culture Co., Ltd., Ziraat Adasi, Milas, Mugla, Turkey. Gilthead seabreams (mean initial weight 2.4 g) used in the experiment were obtained from Egemar Marine Fish Hatchery (Akbük-Aydin, Turkey) at 30 August 2005. Gilthead seabreams were stocked to cages (dimensions 5×5×5 m) at the 80 fish m^{-3} density, till 01 January 2006. Gilthead seabreams, arriving to ~35 g, were distributed to eight treatment cages (dimensions 2×2×3 m, active volume 10 m^3) randomly for determining the effects of stocking density on growth. The study which three stocking densitiy (36, 40 and 44 fish m^{-3}) were tested, lasted 11 months (from 1 January to 5 December 2006). Replication number was three in Low Stocking Density group (LSD, 36 fish m^{-3}, final density 11.9 kg m^{-3}), two in Medium Density group (MSD, 40 fish m^{-3}, final density 13.2 kg m^{-3}) and three in High Density group (HSD, 44 fish m^{-3}, final density 14.5 kg m^{-3}, respectively). A total of 2000 gilthead seabreams with a mean initial body weight of 36.41±0.4 g (mean±SE) were used in the experiment. Fish were reared between 13.31 and 27.56°C water temperature (mean, 19.95°C) under natural light

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Table 1: Chemical composition of the diets used in the experiment

Chemical composition	Gilthead seabream (2 mm)	Gilthead seabream (3-6 mm)
Moisture (max %)	10.0	10.0
Crude protein, (min %)	50.0	45.0
DE (kcal kg^{-1})	4400.0	4354.0
Ether extracts (min %)	19.0	20.0
Crude ash (max %)	10.0	10.0
Crude fibre (max%)	1.5	2.5

regime. The O_2 concentration was above 6 ppm. Nets, used in the experiment (mesh size; 16 mm), were cleaned regular intervals.

Feed and feeding: Commercial extrude feeds of gilthead seabreams were provided from Blacksea Fish Feed Manufacturer, Sea Ball®. Chemical composition of the extruder diets used in the experiment which was 3-5 mm at phase was shown in Table 1.

Before treatment, meals were supplied to fish manually four times daily. When water temperature decreased to 15°C, meals were decreased to three and two (Mid November 2005). In treatment phase, two meals were provided to fish manually. Feed was supplied in small quantities, assuring that fish ate to satiation and no feed was wasted. The amount of feed given per meal and per day was recorded. Dead fish were removed from the cages after recording the weight. Biometric measurements, taking at the initiation and end of the experiment, were used in the predictions.

Calculations: In the study, the following predictions were used (Bascinar *et al*., 2008; Cho, 1 992). The Weight Gain (WG, g) calculated as:

$$\text{WG} = \text{Last biomass-first biomass}$$

The Specific Growth Rate (SGR% day^{-1}) was calculated as:

$$\text{SGR} = 100\times\left(\frac{(\ln w_2 - \ln w_1)}{\text{Feeding days}}\right)$$

The Daily Feed Intake (DFI%) was calculated as:

$$\text{DFI} = 100\times\left(\frac{\frac{\text{Feed consumed (g)}}{\text{Feeding days}}}{\text{Fish number}}\right)\left(\frac{\text{Initial biomass (g)} + \text{Final biomass (g)}}{2}\right)$$

The Feed Conversion Rate (FCR) was calculated as:

$$\text{FCR} = \frac{\text{Feed consumed}}{(\text{Increase in biomass} + \text{dead fish biomass})}$$

Thermal-unit Growth Coefficient (TGC) calculated as:

$$\text{TGC} = \frac{\text{Final body weight } (g^{1/3}) - \text{Initial body weight } (g^{1/3})}{\sum \text{water temperature } (°C \times \text{Day}) \times 100}$$

Protein Efficiency Rate (PER) calculated as:

$$\text{PER} = \frac{\text{Increase in biomass (g)}}{\text{Protein consumed (g)}}$$

Coefficient of Variation (CV, %) calculated as:

$$\text{CV} = 100 \times \left(\frac{\text{Standard deviation}}{\text{Mean weight}}\right)$$

Statistical analysis: The data were analyzed by one-way ANOVA and significant differences were determined by Duncan's Multiple Range Test at 5% level. Arc Sinus angular transformation was applied to percentage data before analyses. Linear or non-linear regression was analysed using SPSS Statistical Package Program (SPSS, 2008) 17.0, released version, www.spss.com). For curve fitting, treatment means were used.

RESULTS AND DISCUSSION

Growth: Growth performance data of the treatments were given in Table 2. The weight gain, specific growth rate and thermal-unit growth coefficient levels of HSD group were highest and significantly different from MSD (except TGC value) and LSD treatment groups ($p<0.05$). Weight gain, specific growth rate and thermal-unit growth coefficient increased linearly with increasing stocking density (Table 3).

Feed efficiency and mortality: Feed efficiency and mortality data of the treatments were shown in Table 2. Daily feed intake was lowest in HSD group and ranged from 0.74-0.80% among groups and was significantly influenced by stocking density (Table 2 and 3). Decreasing in feed conversion rate in HSD group was significantly different from MSD and LSD groups (Table 2). Protein efficiency rate increased in HSD group, and was significantly different from the other groups ($p<0.05$, Table 2).

Daily feed intake and feed conversion rate decreased quadratically and protein efficiency rate increased quadratically with increasing stocking density (Table 3). Mortality was highest in MSD group and ranged from 1.5-3.2% among groups and was

Table 2: Coefficient of variations of initial and last weights. Growth performance, feed efficiency and mortality in experimental groups (mean±standard error)

	Treatments, stocking density (fish m^{-3})			
Parameters	LSD (36)	MSD (40)	HSD (44)	Main effect*
Weight				
IW (g CV %)	37.4 (1)	36 (3.9)	35.7 (4.7)	-
LW (g CV %)	330.3 (0.9)	337.15 (2)	348.8 (1)	-
Growth				
WG (g)	292.9±1.64[b]	301.05±3.85[b]	313.13±2.97[a]	L
SGR (%)	0.643±0.001[b]	0.659±0.004[ab]	0.673±0.009[a]	L
TGC	0.000511±1.25E-06[b]	0.000523±4.01E-07[ab]	0.000537±6.03E-06[a]	L
Feed efficiency				
DFI (%)	0.805±0.006[a]	0.807±0.032[a]	0.742±0.002[b]	Q
FCR	1.51±0.009[a]	1.49±0.059[a]	1.38±0.006[b]	Q
PER	1.30±0.008[b]	1.33±0.053[b]	1.44±0.011[a]	Q
Mortality	0.015±0.004[b]	0.032±0.005[a]	0.021±0.002[ab]	NS

LSD: Low Stocking Density, MSD: Medium Stocking Density, HSD: High Stocking Density. IW: Inital Weight, LW: Last Weight, CW: Coefficient of Variation, WG: Weight Gain, SGR: Specific Growth Rate, TGC: Thermal-unit Growth Coefficient, DFI: Daily Feed Intake, FCR: Feed Conversion Rate, PER: Protein Efficiency Rate, [a, b]Different letter superscripts indicate statistically significant differences among means (ANOVA, $p<0.05$), *L: Linear effect ($p<0.05$), Q: Quadratic effect ($p<0.05$), NS: Non Significant ($p<0.05$)

Table 3: Regression equations and coefficients (R^2) of stocking density on growth performance and feed efficiency

Main regression models	R^2	Adjusted R^2	p-value
WG = 201.358 + 2.5292 SDensity	0.854	0.830	0.001
SGR = 0.5080 + 0.038 SDensity	0.700	0.650	0.010
TGC = 0.0004 + 3 E-06 SDensity	0.812	0.780	0.020
DFI = -2.1491 + 0.1557 Sdensity-0.0020 SDensity^2	0.773	0.682	0.025
FCR = -3.0826 + 0.2454 Sdensity-0.0033 SDensity^2	0.794	0.710	0.019
PER = 5.3137-0.2169 Sdensity + 0.0029 SDensity^2	0. 824	0.750	0.012

WG: Weight Gain, SGR: Specific Growth Rate, TGC: Thermal-unit Growth Coefficient, DFI: Daily Feed Intake, FCR: Feed Conversion Rate, ER: Protein Efficiency Rate, SDensity: Stocking Density

insignificantly influenced by stocking density (Table 2). The results of the present study with gilthead seabreams indicated that stocking density of 44 fish m^{-3} improved the growth and feed efficiency compared to stocking densities of 36 and 40 fish m^{-3}. It has been reported that high stocking density has caused to different responses in varous fish species and even in the same fish species. The finding agrees with growth studies reported for sea bass (Papoutsoglou *et al*., 1998), Arctic charr (Wallace *et al*., 1988; Jorgensen *et al*., 1993). On the other hand, high stocking density decreased the growth in some fish species due to different factors such as decreased food consumption and social interactions (Wedemeyer, 1997), decreased water quality (Pickering and Stewart, 1984; Kebus *et al*., 1992) hormonal and metabolic calterations (Leatherland and Cho, 1985; Schreck *et al*., 1985; Vijayan and Leatherland, 1988).

Previous studies with stocking density of gilthead seabreams were focused on growth and welfare status, (Canario *et al*., 1998; Roncarati *et al*., 2006), vitamin E, C and essential fatty acid deficiency/support, (Montero *et al*., 1999a; 2001a, b), stress response (Montero, 1999b) and hormonal mechanism (Rotllant *et al*., 2000). Some of the researchers reported that growth decreased with increasing stocking density (Canario *et al*., 1998; Roncarati *et al*., 2006). However, other studies with gilthead seabream in tank conditions showed that increasing stocking density didn't affect the growth performance (Montera *et al*., 1999a, b; 2001a, b). Previous studies except one (Roncarati *et al*., 2006, in raceways) performed in tank conditions and restricted feeding regime was applied. In the present study, treatment was performed in cage conditions and thus dissolved oxygen concentration and nitrogenous metabolic wastes were not limiting factor. Unlike previous researches, feeding regime was selected as *ad libitum* for clearing the feed efficiency and preventing the competitive interactions (Andrew *et al*., 2002). Andrew *et al*. (2004) reported that feeding regime influenced competition for feed amongst gilthead seabream and this in turn could influence feeding behavior and feeding efficiency. Restricted feeding regime application in previous studies may mask the feed intake and growth performance.

Daily feed intake was significantly the lowest in HSD group ($p<0.05$). Some researchers also reported that feed intake decreased in higher stocking densities (Leatherland, 1993; Alanara and Brannas, 1996). Weight gain increased by 3.8-6.7% in the HSD group compared to the MSD and LSD groups. Additionally feed conversion rate decreased by 7.4-8.6% in the HSD group compared to MSD and LSD groups. These differences in weight gain and feed conversion rate in treatment groups probably associated with differences in energy costs. Likewise, because of the significant decreasing in protein efficiency rate in MSD and LSD groups ($p<0.05$), it can be expected that in lower stocking density (36-40 fish m^{-3}) groups needs to more energy. This situation can not be attributed to waste feeds as feed was supplied in small quantities, assuring that fish ate to satiation (*ad libitum*) and almost no feed was wasted. When we take into consideration the coefficient of variation, similar to Canario *et al*. (1998) report, stocking density didn't affect the size variation and size variation decreased in all treatment groups in the end of experiment (Table 2).

These results indicated that the growth differences were unlikely to be directly caused by intraspecific competition for feed and/or space. Significantly higher protein efficiency rate in HSD group may show that the fishes in this group could save the energy more efficiently.

In the sea bass, the other important cultured fish species of Herskin and Steffensen (1998) reported that the tail beat frequency of individual fish 9-14% lower when at the rear of a school than when at the front, corresponding to a 9-23% reduction in oxygen consumption rate and this was a potential important energy saving mechanism for fish cruising in schools.

On the other hand, Montero *et al*. (1999b) reported that gilthead seabreams in higher densities (40 kg m^{-3}) followed a strategy for increasing oxygen carrying capacity of blood during periods of high energy demand without suppressing the growth. For better understanding of the effect of schooling intensity and feeding behavior on energy in cage conditions, there is need to further research. Although, stocking density range was narrow and was in fish welfare densities (20 kg m^{-3}, Roncarati *et al*., 2006) in the present study, the results of economic analyses of groups were very different. The gross benefit of HSD group was 25 and 18% higher than MSD and LSD groups, respectively.

CONCLUSION

In this study, weight gain, specific growth rate, thermal-unit growth coefficient increased linearly, daily feed intake, feed conversion rate decreased quadratically and protein efficiency rate increased quadratically with increasing stocking density in the range of 36-44 fish m^{-3}. In these ranges, stocking density was not a limiting factor.

The results of the present study with gilthead seabream show that the stocking density of 44 fish m^{-3} cause to improve in growth and feed efficiency and gross benefit compared to stocking densities of 36 and 40 fish m^{-3}.

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