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RESEARCH ARTICLE

Effects of high salinity on the growth of juveniles and pre-adult European sea bass (*Dicentrarchus labrax*)

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Abstract. Diversifying aquaculture in Saudi Arabia with the inclusion of finfish species already reared in the Mediterranean Sea requires a sufficient understanding of the preferences and limits of cultured fish under local conditions. Two trials involving European seabass, *Dicentrarchus labrax* (L.) juveniles of 126 g and pre-adult fish of 313 g were carried out in Saudi Arabia. The trials tested four locally available commercial feeds for 84 and 80 days to determine the growth performance of fish in local high salinity 42-45‰ conditions. The average final weight in juveniles was not significantly different among treatments. The weight gain was smaller in Diet 3, while the specific growth rate was highest in Diet 1 and smallest in Diet 3. The feed conversion ratio was similar in all diets. The average final weight in pre-adult fish showed no significant differences in final body weight, weight gain, or feed intake. The growth results appear to be in line with related research. Improvement of nutritional characteristics of the feed is expected to improve the performance of the fish.

Keywords: *Dicentrarchus labrax*, nutrition, growth rate, feed conversion ratio, aquaculture, high salinity

Introduction

The current major mariculture fish species in Saudi aquaculture industries are Asian sea bass *Lates calcarifer* (Bloch), gilthead bream, *Sparus aurata* L., and Sabaki tilapia, *Oreochromis spilurus* (Günther) (Food and Agriculture Organization of the United Nations 2022). Due to potential market demand, the fisheries authority selected European seabass, *Dicentrarchus labrax* (L.) as the target species of mariculture development projects, while the commercial culture of European seabass had not been developed in Saudi Arabia (Young et al. 2021, Dickson 2022). Moreover, mariculture in Saudi Arabia faces several challenges, such as extreme salinity. On the coastline of Jeddah, West Saudi Arabia, the salinity of seawater is 42-45‰ during the production period (Young and AlMoutiri 2022, Young and Shaikhi 2022).

European seabass is one of the most relevant species farmed in the Mediterranean Sea. Its eurythermal (5-28°C) and euryhaline (salinity from 3 to 33‰) characteristics make this fish particularly adaptable either in full seawater, lagoons, or estuary migrations to the open sea observed during unfavorable climatic conditions. Farming European seabass in warmer waters shows high potential due to slow growth paces observed during the winter season in the Mediterranean Sea and the market seasonality of

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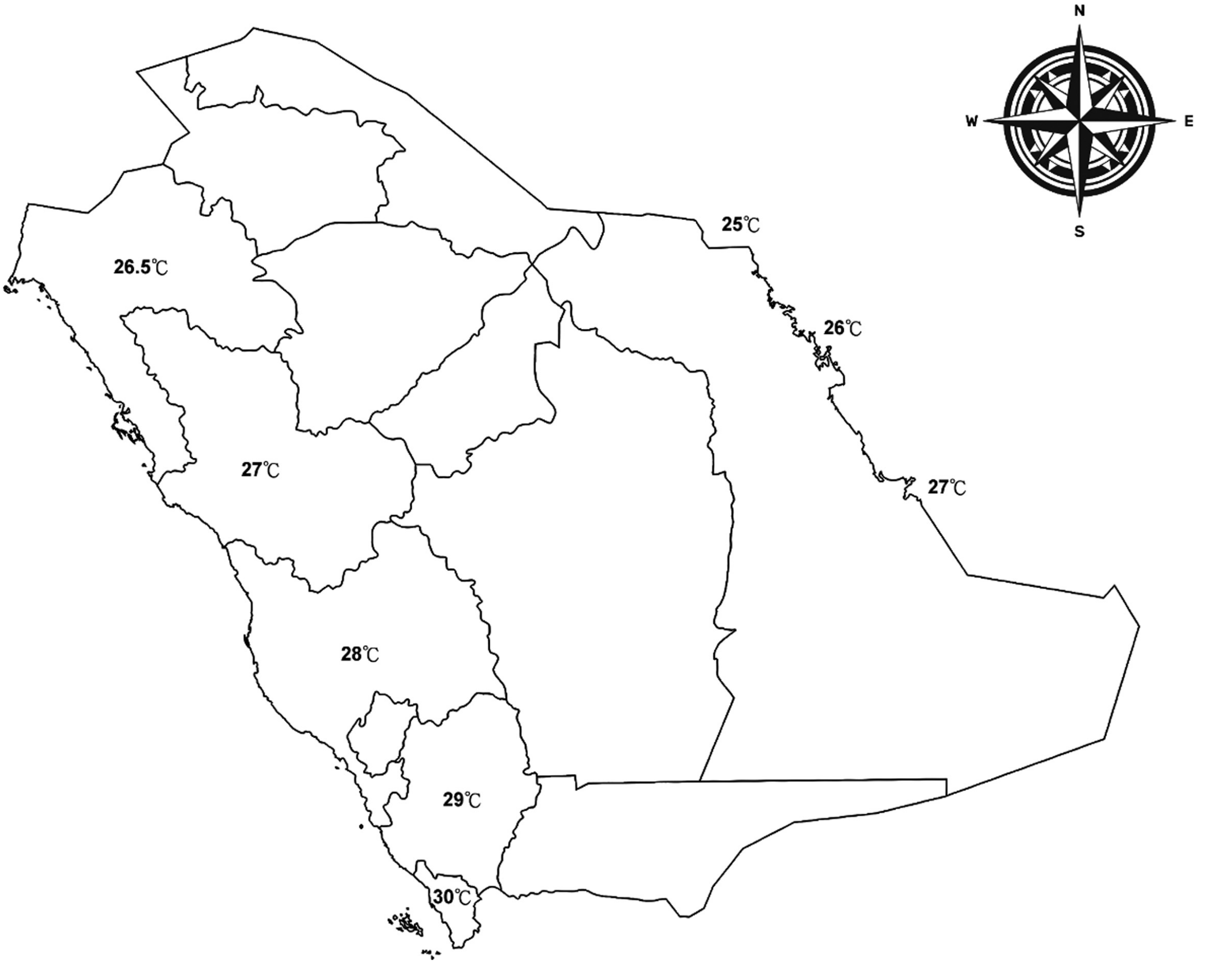

Figure 1. The average water temperature at locations of primary aquaculture companies in Saudi Arabia (Source: Young and Shaikhi 2022).

fish that see an oversupply of seabass in summer and autumn to avoid slack seasons (Rad 2007).

With its long coastline and different climatic conditions, Saudi Arabia is particularly advantaged in developing mariculture through warmer waters to improve productivity, particularly in the winter. However, most European seabass farms are in northern Saudi Arabia to avoid high water temperatures (Fig. 1). Although the conditions of previous related research (Eroldoğan et al. 2000, Ercan et al. 2015, Yilmaz et al. 2019) indicate higher salinities (40‰) than those measured in the Mediterranean Sea (33‰), there is a need to improve the knowledge of the growth responses of European sea bass at higher salinities and temperatures typically occurring in the Red Sea (42-45‰). The scope of this research was to test the growth performance of European sea bass fed different commercial diets under conditions of high salinity.

Materials and Methods

The research aimed to test different commercial feeds during two consecutive cycles involving juvenile (1 April 2019 – 23 June 2019) and pre-adult fish (4 November 2019 – 23 January 2020) of European sea bass executed at the King Abdullah University of Science and Technology, Saudi Arabia.

European seabass fingerlings were obtained from a commercial farm in Saudi Arabia. The fish were grown in indoor holding tanks of 2,200 l and fed the same commercial feed until the fish reached the juvenile and pre-adult sizes required for the feeding trials. At the beginning of each trial, fish were stocked in 1-ton capacity round tanks (1.2 m diameter: 0.9 m height), each holding 850 L of water. Weight and length were determined for each fish. To ensure uniformity of fish sizes between tanks, nonsignificant variability of fish size among tanks was verified with a statistical test.

For the first experiment involving juveniles (Run 1), 32 juveniles with an average weight of 126.59 ± 23.30 g (mean ± SD) and length of 22.19 ± 1.44 cm were stocked in triplicate in each tank at 4.2 kg m^{-3}. For the second experiment (Run 2), the same tank setting was maintained with 16 pre-adult fish with an average weight of 313.96 ± 66.06 g and length of 29.77 ± 2.26 cm, resulting in a stocking density of 5.9 kg m^{-3}.

The tanks were supplied with filtered and sterilized seawater (42-45‰) through a flow-through system delivering a flow rate of 5 l min^{-1}. Continuous aeration was also provided in each tank to maintain dissolved oxygen close to saturation. The tanks were maintained by conducting daily flushing of drain valves and siphoning of wastes at the tank bottom and cleaned fortnightly during sampling. The photoperiod was set at a 12 h:12 h light/dark regime. The duration of the experiments was 84 days for Run 1 and 80 days for Run 2.

Fish were fed four different commercial feeds commonly marketed in Saudi Arabia: Maram 6 mm (Maram Feed Plant for Concentrates and Cubes, Saudi Arabia), Biomar-1 4.5 mm (Biomar Group, Denmark), Arasco 6 mm (Arasco Feed Company, Saudi Arabia), and NAQUA 6 mm (National Aquaculture Group, Saudi Arabia). The same feeds

Table 1

Proximate composition and amino acid profile (g × 100 g^{-1} dry matter) of the commercial diet used in the experiment

	Diet 1	Diet 2	Diet 3	Diet 4
Crude protein	46.88	48.13	47.50	42.23
Crude fat	13.80	14.03	11.83	19.88
Ash	10.20	9.80	10.30	7.00
Dry matter	90.50	97.50	95.70	92.90
Starch	7.60	7.95	8.15	8.97
Amino acid				
Arginine	2.26	2.30	1.28	2.86
Histidine	1.22	2.14	n.d.	1.40
Isoleucine	1.99	2.03	1.83	1.58
Leucine	3.63	5.48	3.80	2.81
Lysine	3.10	3.93	2.44	3.73
Methionine	1.16	2.05	1.16	1.15
Phenylalanine	2.16	2.69	1.91	1.75
Threonine	1.94	2.0	1.69	1.74
Valine	2.23	2.30	2.22	1.84
Alanine	2.68	3.22	2.58	2.02
Aspartic acid	6.67	6.38	5.58	5.11
Cystine	0.43	0.27	0.34	0.51
Glutamic acid	9.0	11.12	8.19	6.43
Glycine	2.93	2.32	2.24	2.56
Proline	1.67	3.21	1.87	1.79
Serine	2.25	2.70	1.91	1.62
Tyrosine	n.d.	2.05	n.d.	1.42
Calculated				
Gross energy[1]	21.55	21.75	21.14	23.16
P/E ratio[2]	21.75	22.13	22.47	18.23

[1]Estimated using the following caloric values: CHO=17.3 MJ kg^{-1}; protein=23.6 MJ kg^{-1}; lipid=39.5 MJ kg^{-1}
[2]MJ kg^{-1}
n.d.: not detected.

were used for both trials. Due to confidentiality, feeds were randomly named Diet 1, Diet 2, Diet 3, and Diet 4 to undisclosed their identity (Table 1). Fish were hand-fed at libitum daily twice a day (9:00 and 15:00), except for the days of sampling when the fish were under starvation. Pellets were released slowly to allow fish to easily chase the food and to eat evenly. Consumption was recorded daily, and uneaten pellets recovered from the tanks were air-dried and weighed to calculate the actual feed intake of the fish.

The main water parameters, such as temperature, dissolved oxygen, pH, and salinity, were monitored twice daily during all trial periods. Values (mean ± SD) for Run 1 were 26.98 ± 1.02°C, 7.64 ± 0.35 mg l^{-1}, and 8.20 ± 0.22, respectively; for Run 2, they were 25.88 ± 1.77°C, 7.77 ± 0.35 mg l^{-1}, and 8.22 ± 0.08, respectively, with Knudsen water salinities of 42-45‰.

Sampling was conducted every two weeks to determine growth and survival. Fish were anaesthetized using clove oil (25 µl l^{-1}) before sampling and were allowed to recover in a holding tank before being returned to their allocated tank after sampling. During sampling, the feeding was discontinued until the following day. In the final sampling at the end of each trial, the body length was also measured to determine the condition factor of each fish. Data from sampling were used to calculate growth parameters:

- Survival (S, %) = 100 × (final number of fish) × (initial number of fish)$^{-1}$;
- Weight gain (WG) = (final body weight) – (initial body weight);
- Specific growth rate (SGR, % d^{-1}) = [(ln (W2–W1)) × 100] × Δt^{-1}, where W1 represents the initial wet fish weight at stocking, W2 represents the final wet fish weight, and t represents the grow-out period;
- Feed conversion ratio (FCR) = (weight of feed consumed) × (fish weight gain)$^{-1}$;
- Protein efficiency ratio (PER) = (weight gain) × (protein intake)$^{-1}$.

The results were analyzed using Predictive Analytics Software version 18.0 (IBM, Armonk, New York) using analysis of variance and Duncan's multiple range test for post hoc comparison of the means. $P < 0.05$ was considered significant.

Results

The average final weight in Run 1 (Table 2) was not significantly different among treatments ($P > 0.05$). The specific growth rate was highest ($P < 0.05$) in the Diet 1 group (0.65) and lowest in the Diet 3 group (0.51). The feed intake was significantly higher ($P < 0.05$) in the Diet 1 group than in the other groups, which was similar. The feed conversion ratio was significantly higher ($P < 0.05$) in the Diet 3 group (1.97), which was affected by the reduced weight gain obtained.

Table 2

Survival, initial and final body weight, final total length, specific growth rate, feed intake and protein efficiency ratio of juvenile European seabass fed the different commercial diets for ten weeks under 42-45‰

Parameters	Diet 1	Diet 2	Diet 3	Diet 4
Survival (%)	100 ± 0.00^{a}	98.81 ± 1.46^{a}	96.43 ± 2.53^{a}	100 ± 0.00^{a}
Initial body weight (g)	125.85 ± 2.50^{a}	126.44 ± 3.60^{a}	127.99 ± 1.70^{a}	126.08 ± 0.74^{a}
Final body weight (g)	209.74 ± 8.10^{a}	200.23 ± 9.45^{a}	191.18 ± 1.47^{a}	198.17 ± 4.29^{a}
Final total length (cm)	26.02 ± 0.17^{a}	25.74 ± 0.48^{a}	25.57 ± 0.12^{a}	25.49 ± 0.05^{a}
Specific growth rate (%/ day^{-1})	0.65 ± 0.06^{a}	0.56 ± 0.05^{b}	0.51 ± 0.04^{c}	0.55 ± 0.05^{b}
Feed conversion ratio	1.73 ± 0.14^{a}	1.74 ± 0.12^{a}	1.97 ± 0.21^{b}	1.76 ± 0.13^{a}
Feed intake (g/ day^{-1})	1.89 ± 0.08^{a}	1.64 ± 0.09^{a}	1.59 ± 0.02^{a}	1.59 ± 0.06^{a}
Protein efficiency ratio	1.21 ± 0.04^{b}	1.20 ± 0.04^{b}	1.07 ± 0.01^{b}	1.37 ± 0.02^{c}

In each column, different letters indicate a significant difference ($P < 0.05$).

Table 3
Survival, initial and final body weight, final total length, specific growth rate, feed intake and protein efficiency ratio of pre-adult European seabass fed the different commercial diets for ten weeks under 42-45‰

	Diet 1	Diet 2	Diet 3	Diet 4
Survival (%)	97.92 ± 2.55[a]	100.00 ± 0.00[a]	97.92 ± 2.55[a]	100 ± 0.00[a]
Initial body weight (g)	308.48 ± 2.51[a]	309.10 ± 10.07[a]	318.79 ± 7.52[a]	319.46 ± 2.06[a]
Final body weight (g)	432.49 ± 12.13[a]	457.90 ± 2.30 [a]	416.90 ± 38.91[a]	427.56 ± 33.98[a]
Final total length (cm)	32.93 ± 0.06[a]	33.13 ± 0.33[a]	32.77 ± 0.44[a]	32.89 ± 0.36[a]
Specific growth rate (%/ day^{-1})	0.41 ± 0.15[a]	0.52 ± 0.04[b]	0.35 ± 0.06[c]	0.45 ± 0.14[a]
Feed conversion ratio	1.56 ± 0.20[a]	1.55 ± 0.18[a]	2.48 ± 0.20[b]	1.57 ± 0.21[a]
Feed intake (g/ day^{-1})	2.87 ± 0.13[a]	3.13 ± 0.09[a]	2.91 ± 0.34[a]	2.54 ± 0.43[a]
Protein efficiency ratio	1.23 ± 0.07[a]	1.31 ± 0.05[a]	0.91 ± 0.23[a]	1.30 ± 0.24[a]

In each column, different letters indicate a significant difference ($P < 0.05$).

Run 2 showed no significant differences ($P > 0.05$) for final body weight, final total length, or feed intake. The specific growth rate and feed conversion ratio showed significant differences in pre-adult fish (Table 3).

Discussion

This study shows that the growth performances of European seabass under conditions of high salinity obtained from juveniles and pre-adults are comparable to the results from other research for same-sized fish. For both Run 1 and Run 2, the final body weight and total length were statistically similar in all diets. However, for Run 1, the weight gain and SGR showed a bias between Diet 3 and the remaining diets in this research. The diets used were in line with the standard nutritional parameters of commercial feed for European seabass. The crude protein values of the experimental diets were in the upper range (42-48%) of the common levels of proteins (38-48%) normally used in commercial diets for fish weighing 60-300 g (Kousolaki et al. 2015).

This study showed that the growth performance of European seabass is comparable to other research carried out at lower temperatures or salinities. In Run 1, the FCR ranged between 1.73-1.76 for Diets 1, 2, and 4 and 1.97 for Diet 3, with the latter being significantly different from the others. Similarly, the SGR ranged between 0.65 of Diet 1, the lower values of 0.58-0.59 of diets 2 and 4, and the less performing Diet 3 settled at 0.51. Similar results were obtained by Eroldoğan et al. (2000) and Tibaldi et al. (2015) with SGR 0.52-0.58 and FCR 1.30-1.69, values obtained with both 40‰ or freshwater conditions in fish growing from 108 g to 290 g. However, Eroldoğan et al. (2000) in trials with 30 g fish noted that final biomass in fish was lower ($P < 0.05$) for salinities above 30‰. The experimental results obtained were comparable to Güroy et al. (2006), which showed an SGR of 0.7 and an FCR of 1.79 using an extruded diet of 47% protein fed three times a day to 170 g fish reared in tanks at 24°C and 24‰. Nevertheless, the Run 1 results were underperforming compared to Person-Le Ruyet et al. (2004), who reared fish at both 25°C and 29°C with 44% protein and 22% crude fat diets and achieved SGR 1.35 and 1.2, respectively, and FCR 1.05-0.95. Notably, European seabass growth is higher when temperatures do not drop below 25°C, although the FCR seems not to be affected. Diets with 16.5% inclusion of chickpea (Adamidou et al. 2009) could also achieve higher growth (SGR 1; FCR 1.24) than those in Run 1. Pre-adult fish in Run 2 increased their biomass from 310 g up to 458 g and achieved statistically similar SGR (0.35-0.52) and FCR (1.55-2.48) with an average temperature of 26.9°C. The results obtained were better than the growth observed by Di Turi et al. (2009), who reared 323 g fish up to 584 g, achieving an SGR of 0.32 and an FCR of 2.88, or Mladineo et al. (2010), who achieved an SGR of 0.27 and an FCR of 2.2 in a recirculating aquaculture system (RAS).

This study shows that the growth performances of European seabass under conditions of high salinity obtained from juveniles and pre-adults are comparable to the results from other research for same-sized fish. For both Run 1 and Run 2, the final body weight and total length were statistically similar in all diets. However, for Run 1, the weight gain and SGR showed a bias between Diet 3 and the remaining diets.

This study found that the maximum salinity endured during the survival and growth of European seabass was 42‰. Our results indicate that juvenile and pre-adult European seabass culture is feasible under high salinity conditions. However, growth performance showed significant differences among diets in specific growth rates in both culture periods. These research results can be utilized to inform further research and aquaculture development in higher salinity regions.

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Author contributions. B.C.Y. contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. A.A.S. corrected the paper and approved the final manuscript.

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