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ORIGINAL ARTICLE

Evaluation of different commercial feeds on grow-out silver black porgy, *Sparidentex hasta* (Valenciennes), for optimum growth performance, fillet quality, and cost of production

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KEYWORDS

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Abstract The objective of the study was to find a cost-effective feed from three commercial feeds, namely, Arasco (Saudi Arabia), Skretting (Turkey), and Biomar (Greece) for commercially producing silver black porgy (sobaity bream), *Sparidentex hasta* in Kuwait. For confidentiality, these feeds were randomly given code names, diets 1, 2, and 3, which were known only to the investigating staffs. The trash fish (diet 4) was used as the control. The experiment was conducted for 28 wk with grow-out sobaity bream (210.0 ± 0.51 g) using a flow-through system consisting of twelve 1-m^3 tanks. There were three replicates for each treatment. Fish were fed two times daily at satiation level. The results showed that fish fed diet 2 resulted in significantly ($P > 0.05$) better growth performance, feed utilization, and higher fillet eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) content compared to other diets. A comparison of fillet quality of cultured and wild sobaity bream showed no significant ($P > 0.05$) difference between sensory attributes, except that of 'flavor' in cooked fillets of wild sobaity bream. A simple economic analysis showed that the cost per kilogram of fish production was significantly ($P > 0.05$) the lowest in diet 2 (USD4.13), followed by diet 1 (USD5.70), diet 4 (USD6.33), and diet 3 (USD6.92). Thus, based on growth performance, feed utilization, cost of production, and nutritional quality of fillet, it is concluded

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that diet 2 may be recommended for commercial culture of sobaity bream in Kuwait. However, future research should focus on how to improve fillet quality of the cultured fish at par with wild fish by manipulating the feed formulation.

1. Introduction

Kuwait fisheries satisfy only 30% of the country's demand for fish; while the other 70% is supplemented through imports. Despite management regulations, catches from the sea have continued to decline day by day. Fish importation is not a reliable solution, because it does not guarantee the sustainability of supply from regional countries, where supplier stock levels are decreasing as well. Therefore, aquaculture can play a major role in bridging the gap between demand and supply. The Aquaculture Program of the Environment and Life Sciences Research Center (ELSRC) of the Kuwait Institute for Scientific Research (KISR) has developed various technologies needed to culture silver black porgy, locally known as sobaity bream (*Sparidentex hasta)* from egg to a marketable size in tanks and cages (Teng et al., 1987; Abdullah et al., 1989). In the recent reorganization of KISR's programs, emphasis was given to the commercialization of culture technology developed by the institute for private sector entrepreneurs. In this regard, sobaity was considered as the first candidate for commercialization due to the huge amount of research data available for its successful culture (Teng et al., 1987; Abdullah et al., 1989; Al-Abdul-Elah et al., 2010).

The sobaity bream is native to the Arabian Gulf, western Indian Ocean, and the coast of India (Yousif et al., 2003). Sobaity bream is a shoreline surface fish, feeding in the wild by hunting small pelagic fishes. It is a silvery fish with tender flesh and a rich flavor. Sobaity bream has been a table delicacy for the Arabs for more than a century (Kitto, 2004).

Since the KISR's Aquaculture Program's objective emphasized the commercialization of sobaity culture in Kuwait, conducting research aimed at evaluating commercial diets for growth, fellet quality, and cost of production of sobaity was given a top priority. However, for any commercial fish farming, feed is often the single largest operating cost item and can represent over 50% of the operating costs in intensive aquaculture (El-Sayed, 1999). Therefore, any reduction in feed cost or improvement in feed efficiency would have a positive impact in reducing production cost and maximizing profit of the fish farming enterprise. Thus, cost-effective and high performing commercial feeds have been developed by various feed companies for culturing valuable marine species.

Since no fish meal is produced in Kuwait, use of imported fish meal in aquafeed in Kuwait may not be cost effective. Different commercial feeds available in the world market are being imported to Kuwait for fry rearing and grow-out operations by the Aquaculture Program at KISR. Hence, the immediate priority was given to find a cost-effective feed from the available commercial diets to start with the commercialization of sobaity. Since formulation, testing, and development of a new diet is a long process, this study evaluated three commercial feeds, namely, Arasco (Saudi Arabia), Biomar (Greece), and Skretting (Turkey), along with a local trash fish feed for commercial culturing of sobaity bream in Kuwait.

2. Materials and methods

2.1. Experimental system

The experiment was carried out in a flow-through system, consisting of twelve 1-m^3 round fiberglass tanks, each containing approximately 800 l of water. The inside of the tanks was blue in color, and the bottom had a 2° slope toward a 5-cm diameter central drainage stand pipe, which provided water drainage from the bottom. The tanks were covered with nets to prevent the fish from jumping out. Filtered and ultraviolet (UV)-treated seawater and groundwater were mixed and flowed through the tanks of an open flow-through system at a rate of approximately 15 min^{-1}. A continuous oxygen supply in the experimental tanks was maintained through air stones. Fluorescent lights were used to provide a natural photoperiod of 12 h light and 12 h dark, which was maintained throughout the study period.

2.2. Source of fish and acclimation and sampling

Uniform-sized grow-out sobaity bream (210.0 ± 0.51 g) were obtained from KISR's hatchery at Salmiya, Kuwait. There were three replicates for each treatment and the stocking density was 20 fish per tank. Before the start of the experiment, fish were acclimated to the experimental system for 1 wk. At the start of the experiment, individual fish in each tank was measured for length and weight. The experiment was conducted for 28 wk during the months from April to November 2013. Four-weekly bulk sampling was done using an electronic balance to monitor fish growth. During the sampling period, the water in each tank was reduced, and quinaldine was used to anesthetize the fish. All of the fish in each tank were bulk weighed using an electronic balance. During sampling, fish in the tanks were counted numerically, and each tank was cleaned and washed before the fish were released back into the tanks. Any mortality of fish was recorded. At the beginning of the experiment, five fish from the stock were collected as initial sample, and at the end of the experiment, three fish from each replicate tank were collected as final sample for proximate and fatty acid composition analysis. The skin and boneless fillets from both sides of the fish were separated, pooled, ground, and freeze-dried for chemical analysis. The rest of the fish were kept in their respective tanks, and feeding was continued until the organoleptic test was done to evaluate the fillet quality compared to that of the wild sobaity.

2.3. Experimental feeds and feeding

Three different commercial feeds such as Biomar (3.0 mm), Skretting (4.00 mm), and Arasco (1.9 mm) were procured from Greece, Turkey, and Saudi Arabia, respectively. For confidentiality, these commercial feeds were randomly given the code names diet 1, diet 2, and diet 3, which were known only to the investigating staffs. Since the feed pellet sizes were smaller compared to the fish size, they were repelleted to a size of 4.5 mm using a meat mincer with a 4.5-mm die. The trash fish was used as the control. The gizzard shad (*Nematolosa nasus*), locally known as 'youaf', was selected on the basis of availability and price and used as trash fish (diet 4). The trash fish were bought in bulk and kept deep frozen. Before being used as feed, the trash fish were thawed, beheaded, tail and fin removed, and cut into pieces using a sharp knife. The fish were hand-fed twice daily at 900 and 1400 h at satiation level. Feed pellets were dropped slowly from the surface so that the fish could easily eat the pellets. Care was taken to ensure that all fish were sufficiently fed, and that no feed was left uneaten at the bottom of the tank.

2.4. Water quality parameters

The water quality parameters, such as water temperature, pH, and dissolved oxygen, were monitored daily throughout the experimental period. Total ammonia and salinity were measured weekly. All the parameters are found to be suitable for fish growth and survival. The ranges were: temperature 24.0–28.5 °C, pH 6.8–7.7, dissolved oxygen 5.8–7.0 mg L^{-1}, salinity 4.0–4.2 g L^{-1}, and total ammonia 0.040–0.071 mg L^{-1}.

2.5. Organoleptic test

The organoleptic test was performed at the end of the growth trial. The organoleptic properties of fish fillets of both wild and cultured sobaity bream from different treatments were evaluated for color, flavor, or odor, texture, and taste by a simple 'ten-member panel'. Both fresh and cooked fillets were evaluated organoleptically. The panel was a non-professional' panel formed by researchers and KISR personnel, who were familiarized with the procedure before the final evaluation. The session was conducted in the meeting room at KISR, Salmiya. Samples were given secret code numbers and served simultaneously. Similar-sized wild sobaity bream were procured from Sharq fish market, Kuwait. Skinless dorsal fillets from both sides of the fish were used for sensory evaluation. For the cooked samples, fillets were individually wrapped in an aluminum foil and cooked in an electric oven for 10 min. The sensory evaluation was performed according to the Torry Scheme (Howgate, 1982). Different parameters, such as color, flavor, or odor, texture, and taste, were assigned different attributes with numerical scores (1–5) in a questionnaire supplied to each panelist. The overall acceptance of the fillet quality was evaluated by numerical scores of up to 5, where score 1 = very bad, 2 = bad, 3 = average, 4 = good, and 5 = very good. The scores of the ten panelists were averaged to get a mean score of the panel. Data obtained were subjected to a one-way analysis of variance (ANOVA, Duncan, 1955) followed by Tukey's test to see the significance ($P > 0.05$) between treatment means.

2.6. Economic analysis

A simple economic analysis was performed to estimate the cost of production and net profit in different treatments. The production cost was based on the 2013 market price of the inputs used. The initial cost of fish was considered at USD1.50 each. The sale price of sobaity bream was considered at USD14.00 kg^{-1}. The capital cost, including the cost of electricity and water, was not included. An additional 7.5% on total cost was included as operational cost (ADCP, 1983).

2.7. Analytical methods and statistical analysis

The proximate composition of commercial feeds, trash fish, and fish samples were analyzed in triplicates according to the standard procedure (AOAC, 2000). Lipid content of samples for fatty acid analysis was extracted by the Bligh and Dyer (1959) method. Fatty acid composition was determined by preparing methyl esters and analyzing them by gas chromatography (AOCS, 1992). An HP 6890 gas chromatograph (Hewlett-Packard, Palo Alto, CA, USA) equipped with a Chrompack column (CP-Sil 88 50 m, ID 0.25 mm, Varian Inc, Palo Alto, CA, USA) was used for the analysis.

Data were processed to calculate the growth and feed utilization parameters according to Castell and Tiews (1980), as follows:

- Weight gain (WG) = final mean weight (g) – initial mean weight (g).
- Daily weight gain (DWG, g/fish/d) = total weight gain/number of fish/day.
- Specific growth rate (%/d) = 100 × [in (final body weight) – in (initial body weight)/experimental period (d)].
- Condition factor (CF) = (W/L^3), where W = weight (g) and L = length (g) of fish.
- Hepatosomatic index (HSI) = (liver weight/fish weight) × 100
- Daily feed intake (%) = feed intake (dry matter) × /100/[(initial fish weight + final fish weight) × days fed/2].
- Feed conversion ratio (FCR) = dry feed fed/live weight gain.

Table 1 Proximate composition of the experimental diets (% dry matter basis).

Parameter	Diet 1	Diet 2	Diet 3	Diet 4
Dry matter	95.72	95.39	95.99	27.99
Protein	49.42	48.88	47.37	59.04
Lipid	13.74	14.01	13.88	20.70
Ash	6.54	10.49	6.90	10.02
Crude fiber	4.42	4.51	4.12	1.01
NFE[1]	25.88	22.11	27.73	10.24
Gross energy (kJ g^{-1})[2]	21.54	20.87	21.43	23.87
P:E ratio[3]	22.94	23.41	22.10	24.73

[1] Nitrogen-free extract (NFE) calculated as 100 – % (protein + lipid + ash + crude fiber).
[2] Estimated according to NRC (1993) using the values of 23.6, 39.5, and 17.2 kJ g^{-1} for protein, lipid, and total carbohydrate, respectively.
[3] Protein to energy ratio (P:E) in mg protein kJ g^{-1} of gross energy.

Table 2 Fatty acid composition (% of total fatty acids) of experimental diets.

Fatty acid	Diet 1	Diet 2	Diet 3	Diet 4
C14	4.7 ± 0.11	5.60 ± 0.09	3.12 ± 0.12	10.49 ± 0.14
C15	0.28 ± 0.04	0.52 ± 0.05	0.24 ± 0.02	5.08 ± 0.08
C16	16.21 ± 0.34	18.04 ± 0.54	13.80 ± 0.36	34.02 ± 0.48
C17	0.45 ± 0.03	0.72 ± 0.05	0.36 ± 0.02	1.62 ± 0.06
C18	2.66 ± 0.07	4.2 ± 0.08	2.68 ± 0.06	5.65 ± 0.12
C20	0.32 ± 0.03	0.59 ± 0.05	0.36 ± 0.02	0.44 ± 0.03
C16:1	4.02 ± 0.09	6.48 ± 0.13	4.44 ± 0.10	18.02 ± 0.13
C17:1	0.32 ± 0.2	0.49 ± 0.04	1.02 ± 0.04	2.24 ± 0.07
C18:1n-9	31.02 ± 0.26	23.64 ± 0.32	33.08 ± 0.44	13.42 ± 0.23
C20:1	ND[1]	ND	ND	0.40 ± 0.04
C22:1n-9	5.48 ± 0.08	4.96 ± 0.11	4.87 ± 0.09	ND
C24:1	0.40 ± 0.02	0.26 ± 0.01	0.28 ± 0.03	ND
C18:2n-6	12.96 ± 0.12	11.60 ± 0.13	16.54 ± 0.15	2.36 ± 0.06
C18:3n-3	8.24 ± 0.09	4.48 ± 0.07	8.10 ± 0.11	0.36 ± 0.03
C18:3n-6	0.18 ± 0.02	0.22 ± 0.03	0.16 ± 0.03	0.13 ± 0.02
C20:3n-3	0.62 ± 0.03	0.96 ± 0.07	0.44 ± 0.02	0.38 ± 0.03
C20:3n-6	0.18 ± 0.01	0.16 ± 0.02	0.20 ± 0.02	0.14 ± 0.01
C20:5n-3, EPA[2]	4.60 ± 0.09	7.56 ± 0.11	3.48 ± 0.08	1.26 ± 0.05
C22:6n-3, DHA[3]	6.48 ± 0.10	7.48 ± 0.09	4.98 ± 0.07	1.20 ± 0.02
∑SFA[4]	24.03	29.67	20.56	58.20
∑MUFA[5]	41.84	35.38	43.69	34.08
∑PUFA[6]	33.26	32.38	34.40	5.83
∑n-3	19.94	20.40	17.50	3.2
∑n-6	13.32	11.98	16.90	2.63
n-3/n-6 ratio	1.50	1.70	1.04	1.22
DHA/EPA ratio	1.40	0.99	1.43	0.95

[1] ND = not detected.
[2] EPA = eicosapentaenoic acid.
[3] DHA = docosahexaenoic acid.
[4] SFA = saturated fatty acid.
[5] MUFA = mono-saturated fatty acid.
[6] PUFA = polyunsaturated fatty acids.

- Protein efficiency ratio (PER) = live weight gain/crude protein fed.
- Apparent net protein utilization (ANPU %) = (final fish body protein – initial fish body protein/(total protein fed) × 100.
- Lipid retention (LR %) = 100 × (lipid gain/lipid intake).
- Energy retention (ER %) = 100 × (energy gain/energy intake).

Data were tested for statistical significance using a one-way ANOVA (Duncan, 1955) followed by Tukey's test to see the significance difference between treatment means.

3. Results

The analyzed proximate composition of the experimental diets is presented in Table 1. The results showed almost similar values of protein and lipid levels of commercial diets, which varied between 47.37% and 49.42%, and 13.74% and 14.01%, respectively. However, the protein (59.04%) and lipid (20.70%) content (% dry matter basis) of the trash fish was very high compared to that of the commercial diets. The gross energy contents of the three commercial diets were almost iso-energetic, which ranged between 20.87 and 21.54 kJ g^{-1}, but the gross energy value in trash fish diet was slightly higher (23.87 kJ g^{-1}) than the rest.

The analyzed fatty acid composition of the experimental diets is shown in Table 2. Among the saturated fatty acids (SFA), palmitic acid (C16) was the most dominant fatty acid ranging from about 14% to 34%, whereas, C18:1n-9 was the most dominant monounsaturated fatty acid (MUFA), accounting for 13– 33% of the total fatty acids. Trash fish had the highest level of ∑SFA and the lowest level of ∑MUFA. On the other hand, the commercial diets had higher levels of polyunsaturated fatty acids (PUFA), which ranged between 23% and 34%, whereas it was only about 6% in the trash fish feed. Among the experimental diets, diet 2 had the highest levels of eicosapentaenoic acid (EPA, 7.56%) and decosahexaenoic acid (DHA, 7.48%), whereas trash fish had the lowest levels of EPA (1.26%) and DHA (1.20%). The ∑n-3/n-6 ratio ranged between 1.04 and 1.70, with diet 2 showing the highest, and diet 3 showing the lowest value.

The average final weight of fish in different treatments ranged between 471.93 g and 701.07 g (Table 3). Fish fed with diet 2 showed significantly ($P < 0.05$) the highest final weight, weight gain, and specific growth rate (SGR) among all the dietary treatments. There were no significant ($P > 0.05$) differences between the final weight, weight gain, and SGRs of fish fed diet 1 and diet 4, but these values were significantly ($P < 0.05$) higher than those of diet 3. Fish fed diet 2 had significantly ($P < 0.05$) the highest condition factor (CF). There was no significant ($P > 0.05$) difference between the

Table 3 Growth performance and feed utilization in sobaity bream fed experimental diets.[1]

Parameter	Diet 1	Diet 2	Diet 3	Diet 4
Initial weight (g)	210.23^{a} ± 0.28	209.93^{a} ± 0.83	209.87^{a} ± 0.60	209.83^{a} ± 0.61
Final weight (g)	585.70^{b} ± 24.36	701.07^{a} ± 32.17	471.93^{c} ± 15.81	564.27^{b} ± 19.01
Weight gain (g)	375.47^{b} ± 24.23	491.14^{a} ± 28.17	262.06^{c} ± 16.22	354.44^{b} ± 19.09
DWG (g/fish/d)[2]	1.92^{b} ± 0.12	2.50^{a} ± 0.16	1.34^{c} ± 0.08	1.81^{b} ± 0.10
SGR (% d^{-1})[3]	0.52^{b} ± 0.02	0.62^{a} ± 0.02	0.41^{c} ± 0.02	0.51^{b} ± 0.02
CF[4]	1.84^{b} ± 0.03	1.96^{a} ± 0.02	1.84^{b} ± 0.06	1.69^{c} ± 0.01
HSI[5]	1.29^{a} ± 0.11	1.28^{a} ± 0.02	1.46^{a} ± 0.17	0.76^{b} ± 0.06
DFI (%)[6]	1.30a^{b} ± 0.10	1.27^{b} ± 0.03	1.44^{a} ± 0.02	1.23^{b} ± 0.03
FCR[7]	2.23^{b} ± 0.06	1.85^{c} ± 0.04	3.19^{a} ± 0.19	1.86^{c} ± 0.05
PER[8]	0.89^{b} ± 0.04	1.12^{a} ± 0.05	0.63^{c} ± 0.03	0.86^{c} ± 0.04
ANPU[9]	20.40^{b} ± 0.31	23.55^{a} ± 0.43	13.97^{d} ± 0.41	18.32^{c} ± 0.57
LR[10]	20.95^{a} ± 1.67	22.47^{a} ± 1.89	16.97^{b} ± 1.23	16.77^{b} ± 1.12
ER[11]	15.80^{b} ± 0.83	18.89^{a} ± 1.13	12.81^{c} ± 0.49	15.00^{b} ± 0.53
Survival (%)	98.3^{a} ± 2.9	98.3^{a} ± 2.9	100.0^{a} ± 0.0	80.0^{b} ± 5.0

[1] Values in a row with different superscripts are significantly different as determined by ANOVA followed by Tukey's test ($P < 0.05$).
[2] DWG: daily weight gain (g/fish/d).
[3] Specific growth rate (% d^{-1}) = 100 × [in (final body weight) – in (initial body weight)/experimental period (d)].
[4] CF: condition factor = W/L^3 where, W = weight of fish (g), L = length of fish (cm).
[5] HSI: hepatosomatic index = (liver weight/fish weight) × 100.
[6] DFI: daily feed intake (%) = feed intake (dry matter) × /100/[(initial fish weight + final fish weight) × days fed/2].
[7] FCR: feed conversion ratio = dry feed fed/live weight gain.
[8] PER: protein efficiency ratio = live weight gain/crude protein fed.
[9] ANPU: apparent net protein utilization (%) = (final fish body protein – initial fish body protein)/(total protein fed) × 100.
[10] LR: lipid retention (%) = 100 × (lipid gain/lipid intake).
[11] ER: energy retention (%) = 100 × (energy gain, kJ/energy intake, kJ).

heptosomatic index (HSI) values of fish fed diets 1, 2, and 3, but these values were significantly ($P < 0.05$) higher than those of fish fed diet 4.

Fish fed diet 3 showed significantly ($P < 0.05$) the highest daily feed intake (DFI %) but there were no significant ($P > 0.05$) differences between the DFIs of fish fed diets 1, 2, and 4. The feed conversion ratios (FCR) of the different diets ranged between 1.85 and 3.19 with diet 3 resulting in the highest (3.19), i.e., the worst FCR. Diets 2 and 4 resulted in significantly ($P < 0.05$) lower FCRs than those of diet 1. The PER values showed a similar trend like those of FCRs, which ranged between 0.63 and 1.12. Fish fed diet 2 had significantly ($P < 0.05$) the highest PER and apparent net protein utilization (ANPU%) values among the diets. The lipid retention (LR%) values ranged between 16.77% and 22.47%, and the LR% values of fish fed diets 1 and 2 were significantly ($P < 0.05$) higher than those fed diets 3 and 4. The ER% values ranged between 12.81% and 18.89% with fish fed diet 2 resulting in the highest ER value. The survival of fish ranged between 80% and 100%. Fish fed diet 4 had significantly ($P < 0.05$) the lowest survival rate (80.0%), and there were no significant ($P > 0.05$) differences between the survival rates of fish fed diets 1, 2, and 3, which ranged between 98.3% and 100%. The low survival rate in fish fed the trash fish diet could be related to the parasitic infestation of the fish in the trash fish tanks in the latter part of the trial, although routine prophylactic treatment with formalin and freshwater treatment were provided to all of the dietary groups. The source of parasitic contamination in treatment 4 tanks could be the trash fish used.

Among the diets, fish fed diet 4 had significantly ($P > 0.05$) the highest, and diet 3 had the lowest fillet moisture content (Table 4). There was no significant ($P > 0.05$) difference between the fillet moisture content of the fish fed diets 1 and 2, and these values were significantly lower than those fed diet 4. There were no significant ($P > 0.05$) differences between the fillet protein content of the fish fed different experimental diets, which ranged between 20.31% and 20.73%. There was no significant ($P > 0.05$) difference between the fillet lipid contents of fish fed diets 1, 2, and 3, but these values were significantly ($P < 0.05$) higher than those fed diet 4.

Palmitic acid was the dominant SFA amounting to about 23–31% of total fatty acids (Table 5). Fish fed diet 4 had significantly ($P < 0.05$) higher C16 than those fed other diets. Among the MUFAs, C18:1n-9 was the most dominant MUFA ranging from 19% to 29% with fish fed diet 1, having significantly ($P < 0.05$) higher C18:1n-9 than those of others. Among the PUFAs, C18:2n-6 was the dominant fatty acid, and fish fed diet 2 had significantly higher C18:2n-6 than those fed other diets. Fish fed diet 2 had significantly ($P < 0.05$) higher EPA, whereas the fillets of wild sobaity bream had significantly higher DHA. The DHA level in wild sobaity bream fillet was almost double than those of the cultured sobaity bream fillets. However, among the cultured sobaity fillets, fish fed diet 2 had significantly higher ($P < 0.05$) DHA level. The $\sum$n-3 level was also significantly higher in the wild sobaity bream fillet than those of the cultured sobaity bream. Again, among cultured sobaity bream fillets, fish fed diet 2 had significantly higher $\sum$n-3 level than those fed other diets.

Table 6 shows the mean sensory evaluation scores of the raw fillets of cultured and wild sobaity bream. Statistically, there were no significant ($P > 0.05$) differences between the mean scores of different attributes. However, in general, fillets from fish fed diet 2 and the wild sobaity bream had higher

Table 4 Fillet proximate composition (% fresh matter basis) of sobaity bream at the start and at the end of the experiment.[1]

Parameter	Initial (all fish)	Diet 1	Diet 2	Diet 3	Diet 4
Moisture	74.88	$71.61^{b} \pm 0.74$	$72.28^{b} \pm 0.23$	$70.59^{c} \pm 0.07$	$73.49^{a} \pm 0.44$
Protein	19.20	$20.67^{a} \pm 0.51$	$20.73^{a} \pm 0.06$	$20.41^{a} \pm 0.15$	$20.31^{a} \pm 1.06$
Lipid	3.05	$5.38^{a} \pm 0.56$	$5.02^{a} \pm 0.52$	$5.81^{a} \pm 0.25$	$3.64^{b} \pm 0.53$
Ash	1.61	$1.57^{a} \pm 0.12$	$1.47^{a} \pm 0.11$	$1.81^{a} \pm 0.18$	$1.58^{a} \pm 0.11$

[1] Values (mean ± SD) in rows with different superscripts are significantly different as determined by ANOVA, followed by Tukey's test ($P < 0.05$).

Table 5 Muscle fatty acid composition (% of total fatty acids) of cultured and wild sobaity bream.[1]

Fatty acid	Initial (all fish)	Diet 1	Diet 2	Diet 3	Diet 4	Sobaity muscle (wild)
C14	5.01	$5.30^{c} \pm 0.09$	$6.11^{b} \pm 0.13$	$3.64^{e} \pm 0.05$	$8.32^{a} \pm 0.11$	$4.34^{d} \pm 0.05$
C15	0.45	$0.39^{d} \pm 0.02$	$0.60^{c} \pm 0.05$	$0.40^{d} \pm 0.04$	$2.38^{a} \pm 0.05$	$0.91^{b} \pm 0.03$
C16	27.42	$22.50^{e} \pm 0.52$	$24.17^{d} \pm 0.14$	$25.88^{c} \pm 0.15$	$31.25^{a} \pm 0.14$	$28.57^{b} \pm 0.13$
C17	2.71	$5.84^{c} \pm 0.11$	$7.30^{b} \pm 0.12$	$4.47^{e} \pm 0.06$	$9.78^{a} \pm 0.15$	$4.98^{d} \pm 0.07$
C18	4.39	$3.64^{d} \pm 0.06$	$4.22^{c} \pm 0.03$	$3.71^{d} \pm 0.08$	$5.87^{b} \pm 0.06$	$8.79^{a} \pm 0.08$
C20	0.36	$0.26^{a} \pm 0.03$	$0.28^{a} \pm 0.04$	$0.23^{a} \pm 0.03$	$0.30^{a} \pm 0.02$	$0.29^{a} \pm 0.02$
C16:1	5.41	$0.20^{c} \pm 0.03$	$0.22^{c} \pm 0.01$	$0.25^{c} \pm 0.02$	$0.43^{b} \pm 0.03$	$0.60^{a} \pm 0.04$
C17:1	0.36	$0.54^{a} \pm 0.05$	$0.57^{a} \pm 0.03$	$0.32^{c} \pm 0.03$	$0.58^{a} \pm 0.04$	$0.45^{b} \pm 0.03$
C18:1n-9	25.42	$28.96^{a} \pm 0.37$	$24.78^{c} \pm 0.20$	$28.32^{b} \pm 0.16$	$20.98^{d} \pm 0.17$	$19.20^{d} \pm 0.13$
C20:1	0.89	$0.18^{b} \pm 0.13$	$0.20^{b} \pm 0.03$	$0.31^{a} \pm 0.02$	$0.26^{a} \pm 0.03$	$0.31^{a} \pm 0.03$
C22:1n-9	0.78	$0.96^{b} \pm 0.06$	$0.48^{c} \pm 0.07$	$1.10^{a} \pm 0.04$	$0.57^{c} \pm 0.03$	$0.49^{c} \pm 0.04$
C24:1	0.20	$0.23^{b} \pm 0.03$	$0.14^{c} \pm 0.01$	$0.12^{c} \pm 0.02$	$0.48^{a} \pm 0.04$	$0.10^{c} \pm 0.01$
C18:2n-6	11.48	$12.44^{b} \pm 0.22$	$13.45^{a} \pm 0.07$	$10.60^{c} \pm 0.13$	$6.02^{d} \pm 0.09$	$5.83^{d} \pm 0.08$
C18:3n-3	2.12	$4.34^{b} \pm 0.08$	$3.05^{c} \pm 0.09$	$6.07^{a} \pm 0.10$	$2.50^{d} \pm 0.05$	$2.95^{c} \pm 0.03$
C18:3n-6	0.40	$0.31^{b} \pm 0.03$	$0.25^{b} \pm 0.04$	$0.59^{a} \pm 0.03$	$0.25^{b} \pm 0.02$	$0.57^{a} \pm 0.04$
C20:n-3	0.38	$0.33^{d} \pm 0.33$	$0.52^{b} \pm 0.04$	$0.40^{c} \pm 0.03$	$0.48^{b} \pm 0.03$	$2.99^{a} \pm 0.05$
C20:n-6	0.20	$0.26^{b} \pm 0.02$	$0.21^{c} \pm 0.03$	$0.39^{a} \pm 0.02$	$0.20^{c} \pm 0.01$	$0.22^{c} \pm 0.02$
C20:4n-6	0.24	$0.38^{a} \pm 0.04$	$0.19^{b} \pm 0.02$	$0.22^{b} \pm 0.04$	$0.13^{c} \pm 0.01$	$0.20^{b} \pm 0.03$
C20:5n-3, EPA[2]	3.88	$4.01^{b} \pm 0.07$	$4.31^{a} \pm 0.04$	$3.71^{c} \pm 0.08$	$2.96^{d} \pm 0.08$	$3.68^{c} \pm 0.06$
C20:6n-3,DHA[3]	4.29	$5.07^{d} \pm 0.10$	$6.43^{b} \pm 0.12$	$5.85^{c} \pm 0.09$	$3.12^{e} \pm 0.03$	$10.64^{a} \pm 0.07$
$\sum$SFA[4]	40.34	$37.93^{d} \pm 0.47$	$42.68^{c} \pm 0.51$	$38.33^{d} \pm 0.32$	$57.90^{a} \pm 0.12$	$47.88^{b} \pm 0.21$
$\sum$MUFA[5]	33.06	$31.07^{a} \pm 0.39$	$26.39^{b} \pm 0.18$	$30.42^{a} \pm 0.53$	$23.30^{c} \pm 0.21$	$21.15^{d} \pm 0.10$
$\sum$PUFA[6]	22.99	$27.14^{c} \pm 0.33$	$28.41^{a} \pm 0.11$	$27.83^{b} \pm 0.18$	$15.66^{d} \pm 0.10$	$27.08^{c} \pm 0.17$
$\sum$n-3	10.67	$13.75^{d} \pm 0.21$	$14.31^{c} \pm 0.15$	$16.03^{b} \pm 0.05$	$9.06^{e} \pm 0.08$	$20.26^{a} \pm 0.16$
$\sum$n-6	12.32	$13.39^{a} \pm 0.30$	$14.10^{a} \pm 0.06$	$11.80^{b} \pm 0.13$	$6.60^{c} \pm 0.06$	$6.82^{c} \pm 0.11$
$\sum$n-3/$\sum$n-6	0.87	$1.03^{c} \pm 0.03$	$1.02^{c} \pm 0.02$	$1.36^{b} \pm 0.02$	$1.37^{b} \pm 0.02$	$2.97^{a} \pm 0.02$
DHA/EPA	1.10	$1.26^{d} \pm 0.04$	$1.49^{b} \pm 0.11$	$1.58^{b} \pm 0.05$	$1.05^{c} \pm 0.02$	$2.89^{a} \pm 0.04$

[1] Values (mean ± SD) in rows with different superscripts are significantly different as determined by ANOVA followed by Tukey's test ($P < 0.05$).
[2] EPA = eicosapentaenoic acid.
[3] DHA = docosahexaenoic acid.
[4] SFA = saturated fatty acid.
[5] MUFA = mono-unsaturated fatty acid.
[6] PUFA = polyunsaturated fatty acids.

scores for color, texture, and overall acceptance than those fed other diets.

The scores for flavor of the cooked fillets fed diet 2 and wild sobaity bream were significantly ($P < 0.05$) higher than those of fish fed diet 4 (Table 7). However, there were no significant ($P > 0.05$) differences between the scores in the flavor of fillets from fish fed diets 1, 2, 3, and wild sobaity bream fillets. No significant ($P > 0.05$) differences were found between the respective texture, taste, and overall acceptance scores of cultured and wild sobaity bream fillets. However, in general, fillets from fish fed diet 2 and the wild sobaity bream had higher scores for texture, taste, and overall acceptance.

A simple economic analysis was performed based on the 2013 market price of the inputs used (Table 8). The costs per kilogram (kg^{-1}) of the feeds, including transport cost were USD1.87, 1.27, 1.77, and 0.45 for diets 1, 2, 3, and 4, respectively. The total feed cost per tank in diets 1 and 3 were significantly ($P < 0.05$) higher than those of diets 2 and 4. The feed cost (kg^{-1}) of fish production differed significantly ($P < 0.05$) among treatments. The feed costs (kg^{-1}) of fish production were USD 2.77, 1.67, 3.26, and 2.55 for diets 1, 2, 3, and 4, respectively. Like the feed cost, the total production cost per tank in diets 1 and 3 were also significantly ($P < 0.05$) higher than those of diets 2 and 4. The total fish production ranged

Table 6 Sensory evaluation scores of raw muscles of cultured and wild sobaity bream.

Treatment	Sensory attributes[1]			
	Color (1–5)[2]	Texture (1–5)	Odor (1–5)	Overall acceptance (1–5)
Diet 1	4.2 ± 0.8	3.4 ± 0.5	4.4 ± 0.9	3.9 ± 0.6
Diet 2	4.5 ± 0.7	3.7 ± 0.5	4.8 ± 0.4	4.2 ± 0.4
Diet 3	4.5 ± 0.9	3.0 ± 0.5	4.7 ± 0.5	4.1 ± 0.6
Diet 4	4.1 ± 0.9	3.5 ± 0.7	4.4 ± 0.7	4.1 ± 0.7
Wild sobaity	4.4 ± 0.8	3.7 ± 0.7	4.6 ± 0.5	4.2 ± 0.7

[1] Not significantly different at ($P > 0.05$).
[2] Score ranges as follows: score 1 = very bad, 2 = bad, 3 = average, 4 = good, and 5 = very good.

between 9.03 and 13.78 kg tank^{-1}, with diet 2 producing significantly ($P < 0.05$) the highest yield, and diets 3 and 4, the lowest. The total cost (kg^{-1}) of fish production was significantly ($P < 0.05$) the highest in diets 3 and the lowest in diet 2. The result showed that diet 2 generated significantly the highest net profit per tank (i.e., m^{-3}) of USD135.99, followed by diet 1 (USD98.39), diet 4 (USD69.25), and diet 3 (USD66.80). The net profit per cubic meter in diet 2 was almost double compared to that of diet 3.

4. Discussion

The results of the study showed that fish fed diet 2 resulted in significantly ($P < 0.05$) higher growth performance compared to other diets. Fish fed diet 2 resulted in the highest final weight of 701 g, whereas it was only 586, 564, and 472 g, in diets 1, 3, and 4, respectively. The SGR values (0.41–0.62) in the present study were lower than those (2.16–2.39) obtained with sobaity bream fry (Hossain et al., 2014), which could be related to fish size. Usually, the SGR values would decrease with fish size. The initial weight of fish in the present study was 210.0 ± 0.51 g; whereas, it was 6.40 ± 0.06 g in sobaity fry (Hossain et al., 2014). The CF of the fish, often used for monitoring husbandry and nutritional settings, was significantly ($P < 0.05$) higher in the fish fed diet 2, reflecting the better performance of these fish than the groups fed other diets. The HSI provides an indication on the status of the energy reserve and metabolic activity of an animal (Pyle et al., 2005). Fish with poor growth usually have a smaller liver with less energy reserve in the liver. Fish fed commercial diets had significantly ($P < 0.05$) higher (1.28–1.24) HSI compared to those of fish fed the trash fish diet (0.76). In general, the FCR values in the present study were seen to be higher than those obtained with sobaity bream fry (Hossain et al., 2014).

Table 7 Sensory evaluation scores of cooked fillets of cultured and wild sobaity bream.

Treatment	Sensory attributes			
	Texture (1–5)[1]	Taste (1–5)	Flavor (1–5)	Overall acceptance (1–5)
Diet 1	4.0^{a} ± 0.5	3.8^{a} ± 0.9	4.0^{ab} ± 0.5	4.1^{a} ± 0.7
Diet 2	4.0^{a} ± 0.4	4.2^{a} ± 0.6	4.6^{a} ± 0.5	4.3^{a} ± 0.5
Diet 3	3.9^{a} ± 0.6	4.0^{a} ± 0.9	4.0^{ab} ± 0.9	4.0^{a} ± 0.7
Diet 4	3.8^{a} ± 0.4	3.7^{a} ± 0.5	3.5^{b} ± 0.6	3.7^{a} ± 0.5
Wild sobaity	4.0^{a} ± 0.5	4.0^{a} ± 0.8	4.3^{a} ± 0.8	4.3^{a} ± 0.8

Values in a column with different superscripts are significantly different as determined by Tukey's test ($P < 0.05$).
[1] Score ranges as follows: score 1 = very bad, 2 = bad, 3 = average, 4 = good, and 5 = very good.

In the present study, fish fed diet 2 with low intake of protein, in terms of per unit body weight, resulted in the highest ANPU and energy retention. It is generally observed in fish that protein retention efficiency increases with low protein intake (Cho et al., 2001), so less of the dietary protein is either excreted or used as energy substrate. High dietary lipid level in diet 4 (20.70%) did not improve protein retention, indicating that no protein sparing effect occurred. Similarly, no protein sparing by dietary lipid was also reported in gilthead sea bream (Company et al., 1999) and white sea bream (Ozorio et al., 2006).

The proximate composition of fish is affected by the composition of their food (Orban et al., 2007). In the present study, there were no significant ($P > 0.05$) differences between the fillet protein levels of fish fed different experimental diets. The muscle protein level (20.3–20.73%) in the present study was found slightly higher than those (19.20–19.59%) found in sobaity fry (Hossain et al., 2014). The fillet lipid levels in fish fed commercial diets were significantly higher than those fed trash fish. The lipid levels (3.64–5.81%) in the present study were higher than those reported for sobaity bream fry (2.40–3.42%) by Hossain et al. (2014).

Marine fish generally show a good growth when EPA and DHA are supplied at a combined rate of between 0.8 and 2.0% (NRC, 1993). In the present study, the combined absolute dietary level of EPA and DHA in diets 1, 2, and 3 were 1.52%, 2.11%, and 1.17%, respectively, which are within the reported requirement level for marine fishes. The fillet fatty acid composition reflected the dietary fatty acid content, particularly EPA and DHA, which were significantly ($P < 0.05$) higher in fish fed diet 2, followed by diets 3, 1, and 4. Nonetheless, the DHA levels (3.12% to 6.43%) in cultured sobaity bream fillet were significantly ($P < 0.05$) lower than those of wild sobaity bream (10.64%). Compared to initial muscle composition, the deposits of DHA in fish fed commercial diets were higher than EPA. Similar results of higher incorporation of DHA into body lipid have been reported in gilthead bream (Kalogeropoulos et al., 1992).

In general, wild fish are characterized by higher n-3/n-6 ratios (van Vliet and Katan, 1990; George and Bhopal, 1995). In contrast, Orban et al. (2003) and Mnari et al. (2007) reported a higher n-3/n-6 ratio in cultured gilthead bream compared to that of the wild. In the present study, n-3/n-6 ratios in wild sobaity muscle were significantly ($P < 0.05$) higher than those of the cultured. Hossain et al. (2012) also obtained a higher n-3/n-6 ratio in wild sobaity bream compared to the cultured ones, although the contribution of DHA as n-3 PUFA was much higher in the cultured fish. The higher n-3/n-6 ratio in wild sobaity bream might be related to the health status of the fish, as it was collected during the pre-spawning season when the fish have the highest level of fat. The lower level of n-3/n-6 ratio in cultured sobaity bream fillet might be due to the higher proportion of n-6 fatty acids present in the fillet, in particular C18:2n-6.

Table 8 Economic analysis of the cost of production (in USD) of sobaity bream using different commercial feeds.

Parameter	Feed			
	Diet 1	Diet 2	Diet 3	Diet 4
Fish cost ($tank^{-1}$)[1]	30.00	30.00	30.00	30.00
Feed cost $fish^{-1}$	$1.64^{a} \pm 0.14$	$1.15^{b} \pm 0.20$	$1.54^{a} \pm 0.01$	$1.15^{b} \pm 0.07$
Total feed cost $tank^{-1}$	$32.80^{a} \pm 2.35$	$23.0^{b} \pm 3.11$	$30.80^{a} \pm 0.49$	$23.00^{b} \pm 1.24$
Feed cost (kg^{-1}) of fish production	$2.77^{b} \pm 0.10$	$1.67^{d} \pm 0.15$	$3.26^{a} \pm 0.09$	$2.55^{c} \pm 0.05$
Operational cost[2]	$4.71^{a} \pm 0.24$	$3.91^{b} \pm 0.31$	$4.56^{a} \pm 0.05$	$4.17^{b} \pm 1.75$
Total production cost ($tank^{-1}$)[3]	$67.51^{a} \pm 4.17$	$56.98^{b} \pm 3.35$	$65.36^{a} \pm 0.53$	$57.17^{b} \pm 1.75$
Total fish production(kg) $tank^{-1}$	$11.85^{b} \pm 0.43$	$13.78^{a} \pm 0.66$	$9.44^{c} \pm 0.32$	$9.03^{c} \pm 0.73$
Total cost of fish (kg^{-1}) production	$5.70^{c} \pm 0.23$	$4.13^{d} \pm 0.24$	$6.92^{a} \pm 0.13$	$6.33^{b} \pm 0.36$
Gross income ($tank^{-1}$) from fish sale[4]	$165.95^{b} \pm 6.02$	$192.97^{a} \pm 9.18$	$132.16^{c} \pm 4.45$	$126.42^{c} \pm 10.25$
Net profit $tank^{-1}$ (i.e., m^{-3})[5]	$98.39^{b} \pm 4.05$	$135.99^{a} \pm 6.81$	$66.80^{c} \pm 3.78$	$69.25^{c} \pm 9.47$

Values (mean ± SD) in rows with different superscripts are significantly different as determined by ANOVA, followed by Tukey's test ($P < 0.05$).

[1] Cost of per fish stocked considered as USD1.50.

[2] Operational cost is considered as 7.5% of the total cost (ADCP, 1983).

[3] No cost was considered for capital cost including electricity and water.

[4] Sale price of fish (kg^{-1}) = USD14.00.

[5] Net profit $tank^{-1}$ (i.e., m^{-3}) = gross income from fish sale – total production cost.

Sensory evaluation scores of raw and cooked muscles of cultured and wild sobaity did not differ significantly except that of the 'flavor' of the cooked muscle. The panelists found significant difference only in the flavor of the cooked muscle from fish fed diet 2 and wild sobaity, which were significantly ($P < 0.05$) better than those fed trash fish. Although there were reports that wild and cultured fish differ significantly in their organoleptic properties (Sylvia et al., 1995; Grigorakis et al., 2003), the average scores showed that the panelists in the present study could not find any significant difference between the cultured and wild muscles. However, the cultured fish were found to have slightly more whitish appearance compared to their wild counterpart. The impression of fillets originating from wild fish looked slightly darker, which might be related to the higher proportion of the dark muscle in them. The dark muscles are used for continuous swimming motion, whereas white muscles help rapid energy burst (Venugopal and Shahidi, 1996). This could explain why wild fish have a slightly darker appearance. Also, the higher fat content in cultured fish fillets may have contributed to its white appearance.

The total production of fish in different dietary treatments ranged between 9.03 and 13.78 kg m^{-3} and fish fed diet 2 resulted in significantly the highest total production (Table 8). A simple economic analysis showed that the cost of fish production (kg^{-1}) was significantly ($P < 0.05$) the lowest in diet 2 (USD4.13), followed by diet 1 (USD5.70), diet 4 (USD6.33), and 3 (USD6.92). The estimated highest (USD135.99 m^{-3}) net profit generated in diet 2 clearly demonstrated that diet 2 is the best low-cost diet for the commercial culture of sobaity bream. In the present study, the better performance of diet 2 in sobaity growth might be related to its better nutritional composition of the diet, in particular, better EPA and DHA levels.

In the present study, the fatty acid profile comparisons showed that the proportion of DHA levels in wild sobaity were significantly higher than that of the cultured sobaity. Nonetheless, in the present study, wild sobaity used for comparison was collected during the pre-spawning season when the fish is in its best health condition, i.e., it contains the highest level of fat. But in the other seasons of the year, wild sobaity bream and gilthead bream contain less fat or lipid compared to the cultured ones (Hossain et al., 2012; Orban et al., 2003; Mnari et al., 2007). The lipid composition of farmed fish is more constant and less affected by seasonal variation than that of the wild fish, because it is largely dependent on the fatty acid composition of their diets. However, as farmed fish generally have higher total lipid levels than wild fish, 100 g of farmed fish fillet can provide a higher amount of n-3 PUFAs (especially EPA and DHA) than 100 g of wild fish.

Based on the growth performance, feed utilization, survival rate, cost of production, and nutritional quality of fish fillets, it is concluded that diet 2 in the present study may be recommended for the culture of sobaity in Kuwait. Future research should focus on improving fillet quality of the cultured fish at par with wild fish by manipulating the feed formulation.

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