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Consumer preferences for seafood inform aquaculture development in the United Arab Emirates

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ABSTRACT

Stated and revealed preferences for fish and attributes of fish products important to consumers and prospective aquaculture development in the United Arab Emirates (UAE) were evaluated by consumer surveys, focus groups, key informant interviews, and sensory evaluation (taste, texture and overall liking). Consumers of seafood in the UAE prefer hamour (*Epinephelus coiodes*) and kanaad (*Scomberomorus commerson*) above all other species commonly offered at UAE retail outlets. These preferences, which guide consumer-appropriate aquaculture in the UAE, were similar among nationalities (Emiratis and other nationalities), purchasers of fish at seafood retailers, and consumers of fish at restaurants throughout the UAE.

Fresh whole fish are preferred over fillets or frozen product because consumers can assess freshness and they consider whole fish to be better value for money. Among other product attributes shown to be important elsewhere, country of origin, wild vs cultured fish, and eco-labels were considered relatively unimportant by UAE respondents.

Five prospective species for aquaculture were evaluated through sensory evaluation. Differing from stated preferences, barramundi (*Lates calcarifer*) (also marketed as Asian seabass) was clearly preferred as having superior taste, texture, and overall liking (over hamour; shaeri, *Lethrinus nebulosus*; safi, *Siganus canaliculatus*; and cobia, *Rachycentron canadum*). Of the candidate species, only hamour is successfully grown in the UAE albeit on a relatively small scale (< 1000 t annually). Prospects for increasing aquaculture production of fish in the UAE will most likely depend on recirculating aquaculture systems (RAS) effectiveness as the harsh environmental conditions prohibit other grow out systems (e.g. pond culture).

1. Introduction

Residents of the United Arab Emirates (UAE) have relatively high seafood consumption rates (~26 kg/person/year) (Squalli, 2020). A growing, ethno-culturally diverse and high-income population is driving further increases in demand for a range of seafoods in the UAE. However, the UAE is increasingly reliant on imports (~ 72 %) to meet demand for seafood (FAO, 2017; James Cook University and UAE University, 2021). Supplies of fish have diminished in the UAE because of overfishing and habitat degradation: stocks of hamour (*Epinephelus coioides*) have declined to less than 5 % of historical stock size (Al Blooshi et al., 2017; Wabnitz et al., 2018; Squalli, 2020). Similarly, stocks of kanaad (*Scomberomorus commerson*) have decreased by more than 60 % compared with average stock levels (2005–2018) (EAD, 2021). These trends underlie a national food security strategy supporting investments in aquaculture aimed at supporting local consumption but with options for export of value-added processed seafood. However, aquaculture development is challenged by the harsh climatic conditions in the country: this prohibits pond culture of many popular species. Accordingly, farming of popular species such as shrimp, nile tilapia,

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catfish, milkfish, European sea bream, European sea bass and carp are unlikely to be economically viable compared with cheaper imports from large-scale production in east/south Asia. Furthermore, biological and practical limitations render farming of valuable species such as lobster, tuna and kingfish(kanaad) difficult and economically unviable (James Cook University and UAE University, 2021).

The UAE's strategic intent to increase aquaculture production tenfold (above the current annual production of 3200 t) will depend on economic efficiency (cost of production versus willingness to pay by UAE consumers) and choice of species that can be cultured profitably in the UAE whilst meeting consumer demand including, potentially, export markets (Aquaculture Pulse, 2020).

Two grow-out systems are practically feasible in the UAE: recirculating aquaculture systems (RAS) and sea-cage culture. RAS typically involves 5–10 t production tanks connected to a solid removal device and a biological filter to remove toxic residue (ammonia and nitrite) through nitrification (Bregnballe, 2015; Ahmed and Turchini, 2021; Qui and Hadley, 2022). RAS requires a higher level of management than sea-cage systems because of the water quality issues associated with high stocking densities and their complex mechanics (Bregnballe, 2015; Ahmed and Turchini, 2021). RAS, although comparatively expensive (with a dependence on land-based infrastructure) offers advantages in that the growth of fish can be controlled from egg to market-ready favouring premium product (Bregnballe, 2015; Eurofish Magazine, 2021). Of current aquaculture operations in the UAE, fish are mostly grown in RAS (UAE Aquaculture Pulse, 2020, James Cook University and UAE University, 2021).

Other than practical issues, consumer preference will influence the choice of species for intensive aquaculture. Furthermore, a value proposition which offsets price with preferred product attributes is likely to influence buying decisions (Carlucci et al., 2015; Cantillo et al., 2020). Using a combination of stated (survey) and revealed (sensory evaluation) preference methods, this study aimed to assess consumer preferences for the most prevalent fresh fish species retailed for home consumption, with particular emphasis on elucidation of favourable attributes of local marine species for aquaculture.

2. Methods

2.1. Consumer surveys

Surveys involved households across the UAE to capture attitudes and purchasing behaviour relating to fish available in the UAE. Surveys were stratified by Emirate to reflect the population and questionnaires were made available in English, Arabic, and Urdu languages in hard copies but were mostly undertaken online. Respondents were recruited via email and social media (WhatsApp and Instagram are the most widely used platforms in the UAE) consistent with accepted ethical procedures (Ethical Approval no. ERS_2020_6197 by the United Arab Emirates University Ethical Committee). The survey considered the UAE population's diverse demographics (e.g., national versus non-national, ethnicities, as well as other socio- economic and demographic factors including household income, Emirate of residence, family size, and levels of income and education of the head of the household).

Importantly, respondents were chosen as experienced seafood consumers (who purchase or consume fish at least once a week). They were also assumed to be familiar with the range of fish species offered by seafood retailers in the UAE. Thus, the survey sought to identify preferences of species based on consumer's purchasing patterns at seafood retail outlets. Such preferences would therefore mostly reflect consumer choice for eating fish at home. Qualitative information was also sought from focus groups and key informant interviews to explore preferences of fish consumed outside the home e.g., at restaurants.

2.2. Focus groups and key informant interviews

Five Focus groups evaluation sessions targeting the identification of factors influencing seafood consumer choice were conducted during mid-October to early November 2021. Volunteer participants were recruited as knowledgeable consumers selected on the basis of regular seafood consumption (eat seafood at least twice a week, including more than one species). Participants were chosen to represent different genders, nationalities, Emirate of residence, and socio-economic profiles. Five focus groups involved 4 to 9 participants each from the Emirates of Dubai, Abu Dhabi (Abu Dhabi and Al Ain), Sharjah and the collective other Northern Emirates.

Key informant interviews were undertaken to explore other factors affecting consumer preference for seafood in the UAE (e.g., in restaurants and seafood retail outlets). Interviews were conducted in person with local fish farmers, seafood retailers, restaurant proprietors, chefs, hotel managers, and marketing personnel in Abu Dhabi, Dubai and Sharjah in March 2022.

2.3. Sensory evaluation

Sensory evaluation procedrure was approved by Social Science Ethical Commitee of UAE university with reference number ERS_2021_8379. Consumer panellists were selected according to demographics, age distribution, nationality, gender, and potential consumption of fish/fish products. Fresh whole fish (supplied within 24 h of capture) of five selected species were provided by a local seafood retailer (in Al Ain, Abu Dhabi) for sensory evaluation. Boneless and skinless pieces of similar size (20 to 25 g) from each species were prepared. Pieces were placed in ceramic containers with a lid before cooking for a predetermined period of time (between one minute 40 s and 2 min and 20 s in a microwave oven at a uniform power setting (440 watts). There were no additives (e.g., salt) added.

Cooked samples were assigned to randomly-numbered coded plates before transfer to individual booths/tables (within 1–2 min of cooking) for sensory evaluation by panellists. All panellists were instructed on the objectives and method of completing the preference and Hedonic tests. They were not provided with any specific attributes or information on the species of fish being evaluated. The order of presentation of the five species to tasters (one at a time to testing booths) varied randomly. Hedonic test applied to rank taste, texture, and overall acceptance as they are considered to work well when consumer panellists have limited reading and or comprehension skills (English was a second language for most of the participants) (Lawless and Heymann, 2010).

The sensory evaluation consisted of ranking scores from 1 (least preferred) to 9 (most preferred), for the attributes like Taste, Texture, and Overall liking. Due to the type of data and its distribution, a non-parametric test (Friedmans) was conducted to assess significant differences in median rank among the five species evaluated within each Emirate/city. Consequently, a nonparametric pairwise multiple comparison test was conducted to assess which species' was different from the other. In addition, all data for each of the five candidate species regardless of origin, were analysed together for Overall liking and Species Taste Rank (a score from 1, most preferred, to 5, Least preferred), to assess which species were most liked in the sensory evaluation across the UAE.

Data analysis was undertaken using R (R Core Team, 2020) using the packages 'ca' (Nenadic and Greenacre 2007) and 'vegan' (Oksanen et al. 2020).

3. Results

3.1. Consumer surveys

Consumer surveys were completed in September 2022. Survey respondents ($n = 1001$) were mostly from the Emirates of Abu Dhabi (including the cities of Abu Dhabi and Al Ain) (49 %) and Dubai (37 %). However, respondents were surveyed in other Emirates i.e., Ras Al Khaimah (5.5 %), Sharjah (3.6 %), Ajman (3.4 %), and Umm Al Quwain (0.6 %). Respondents were mostly aware of the species presented (to determine preferences), particularly hamour, kanaad and threadfin bream (locally named: Sultan Ibrahim: *Nemipterus bipunctatus*) (> 85 % of all respondents) but they were less familiar with barramundi (*Lates calcifer*), Gilthead seabream (or European seabream: *Sparus aurata*) and cobia (*Rachycentron canadum*) (< 70 % of all respondents).

In general, awareness reflected consumer preference (Fig. 1), particularly kanaad, hamour, and Sultan Ibrahim. Less familiar species (barramundi, European seabream, and cobia) were also less preferred by survey respondents (Fig. 1). These most preferred species (hamour and kanaad) were similar among non-nationals and Emiratis (Fig. 2). However, the third most preferred species (nile tilapia) among non-nationals was least preferred by Emiratis. Notably, many of the respondents from Dubai were from the Middle East and Africa (38 %), and this influenced the preference for nile tilapia. Similarly, Emiratis showed a preference for safi, whereas this species was ranked low in preference by non-nationals (Fig. 2). Both Emiratis and non-nationals showed low preferences for barramundi, European seabream and cobia (Fig. 2).

Of all the attributes of seafood determining preferences, freshness was by far the most important. This was equally true for Emiratis and non-nationals (Fig. 3). Product form (whole vs. fillets), species, and price were also important for both Emiratis and non-nationals (Fig. 3). The least important attributes were country of origin and whether fish were cultured or wild-caught (Fig. 3).

Consumers in the UAE were generally motivated to purchase fish because of perceived health benefits, including the cleanliness of the seafood retail outlet (Fig. 4). The cleanliness of the seafood retail outlet was ranked higher for Emiratis than by non-nationals (Fig. 4). Of opinions influencing fish consumption, fish availability (at retail outlets) and cheap protein source were the lowest for all respondents (Fig. 4).

When purchasing fish, fresh fish was overwhelmingly preferred (77 % of respondents) over frozen or canned product. Similarly, whole fish (38 % of respondents) were preferred over processed fish i.e., fillets, gilled and gutted (21 % of respondents), or processed ready-to-eat (19 %). Most consumers purchased fish from specialised seafood markets (41 %) or from supermarkets (31 %). Online sales were preferred by only 2 % of respondents.

3.2. Focus groups and key informant interviews

Five focus group discussions were completed with representatives from all Emirates. Focus group participants generally preferred whole fish at the point of sale as they could identify particular species, and evaluate the freshness of the fish at the time of purchase, and they considered whole fish to be more cost-effective. However, some participants stated that they purchased whole fish according to custom. They also noted that many retail outlets in the UAE would process whole fish into products (e.g., fillets) on-site at no extra cost.

Some respondents indicated that consumers prefer fillet/pieces/cuts for their readiness and ease of preparation and cooking compared to whole fish. This was often the case when fish was consumed by an individual (i.e., seeking convenience) rather than by families and household consumption (i.e., seeking a nutritious, cost-effective family meal).

The strong preference for fresh fish over frozen fish shown by consumer survey respondents was reinforced by focus group participants who considered frozen fish to be imported and of uncertain provenance and product age.

Dubai was covered more intensively than the other Emirates with nine participants (two male, seven female, ages 22 to 45, with 7 Emiratis, 1 Sudanese, and 1 Filipino). Even so, the general findings were similar among all five focus groups across the UAE. This is despite the relatively high value of seafood consumption in Dubai, reflecting the strong tourism sector. Many focus group participants stated a preference for wild over cultured fish. However, participants also admitted that they could not differentiate between wild or cultured fish at the retail outlet. This is particularly the case when eating out (in restaurants) where product provenance is not stated. Moreover, fish species in restaurants cannot often be discerned because of preparation method and presentation (fillets or pieces). Stated preference among some focus group participants reflected perceived nutritional value (unadulterated wild species). Notably, some participants stated that they would favour UAE-cultured fish over imported fish as they were confident that the UAE government would impose suitable standards for production, resulting in a superior product.

Although the consumer survey focused exclusively on fish preferences, focus group participants also revealed a preference for crustaceans (shrimp, lobster, crabs), but these were not consumed as regularly as fish. Some participants revealed allergies to crustacea, and others considered eating crustaceans only on special occasions. In any case, many participants revealed that if the price was not an issue, then they would consume more crustaceans. In this regard, non-UAE nationals

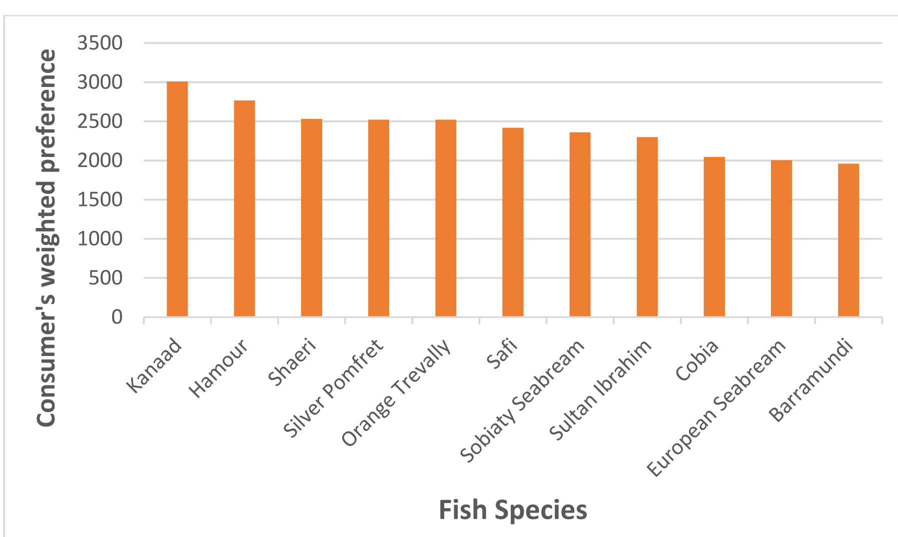

Fig. 1. Preferred species weighted by preference score. Data are total scores after weighting of stated preferences (1 to 5) were applied ($n = 1001$).

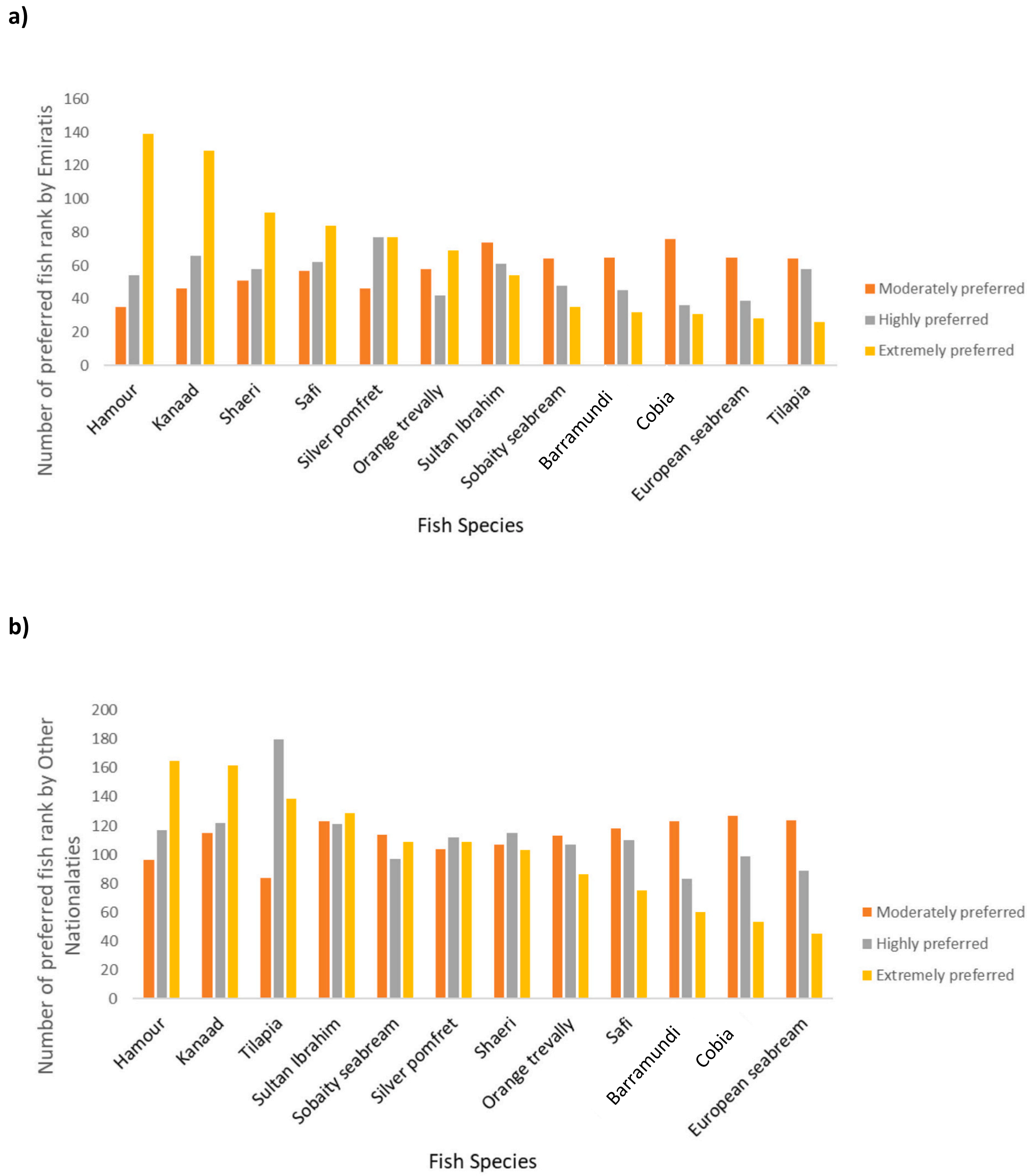

Fig. 2. Comparison of species preference for Emiratis (a) vs other nationalities (b).

were generally more price sensitive compared with UAE nationals.

A total of 33 key informant interviews was completed. Key informants included seafood retail outlets, including shops and markets (24), hotel (1), restaurant managers/chefs (7), and a fish farmer (1). Most respondents noted that whole fish was preferred over fillets, consistent with the findings of consumer surveys and focus group discussions. However, stated preferences varied with species. For example, shaeri is preferred as a fillet, whereas other species such as hamour, are preferred whole. Respondents noted that consumers also respond favourably to discounts on fillets or ready-to-cook fish.

Managers at retail outlets (shops and markets) noted consumer preference for European seabream, European seabass (*Dicentrarchus labrax*), and hamour in that order. Notably, these preferences differed from the findings of the consumer surveys that ranked European seabream well below hamour. However, consistent with consumer surveys, respondents stated that fresh fish is preferred over frozen or preserved fish. Retailers noted that consumers check for signs of freshness, including eye and gill colour.

Generally, at seafood retail outlets, fresh fish is sold on the day and are not retained at seafood retail outlets. Restaurant managers noted that reliability of supply was important so as to consistently present fresh fish to their customers. However, they also noted that frozen seafood was often used (particularly shrimp). Chefs at restaurants noted that customers rarely enquire about the origin of the seafood: particular dishes are more important. Both wild-caught and cultured products are served. Product quality is by far the most important consideration in

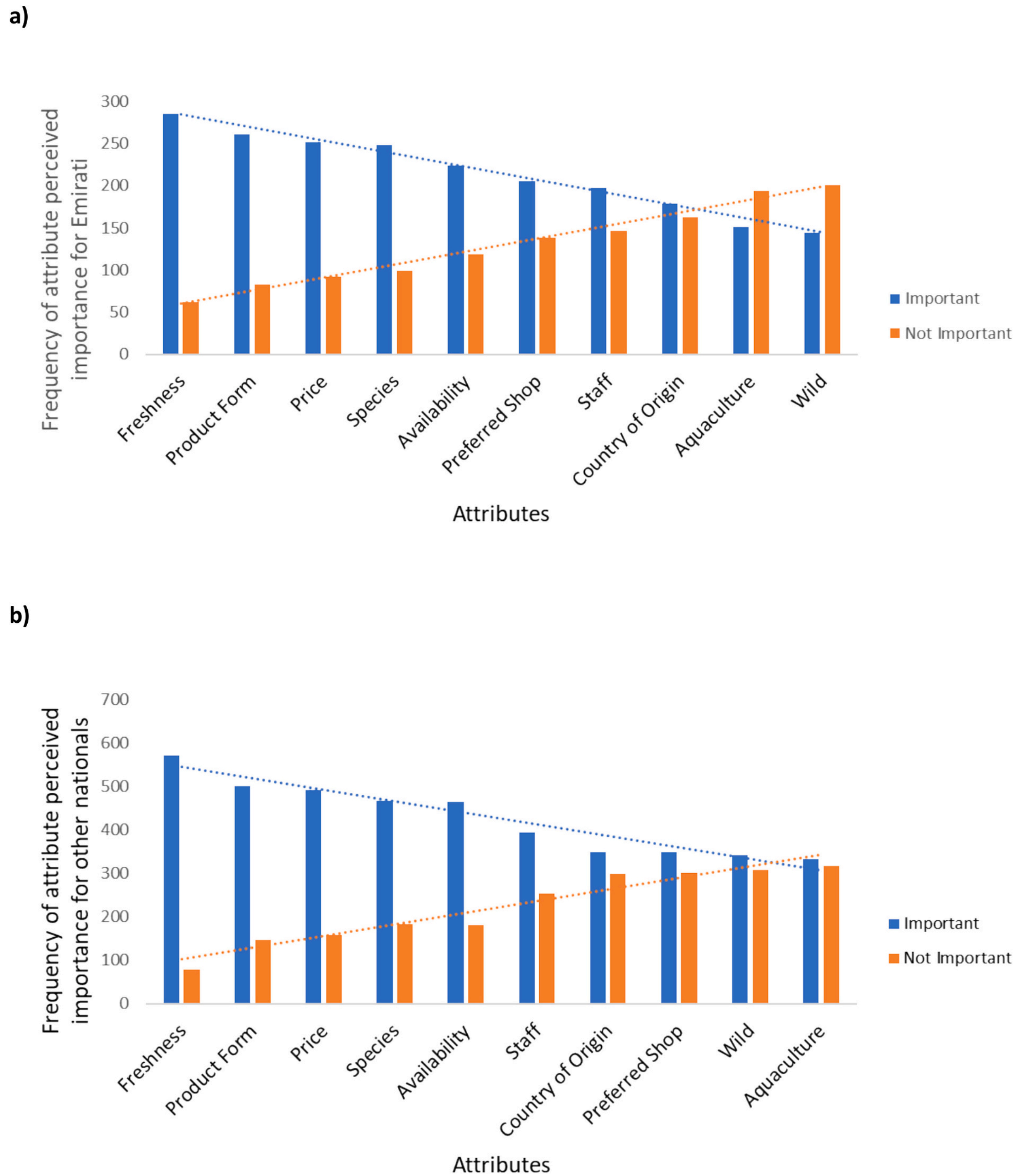

Fig. 3. Importance of seafood product attributes as reported by Emiratis (a) and other nationalities (b) Data are frequency of attributes perceived as important.

preparing seafood for consumption, particularly among restaurants specializing in seafood.

Interviewees noted seasonal patterns in seafood consumption. In the UAE, fish abundance is generally high in winter compared with summer months, and this correlates with reduced prices and higher consumption. Similarly, demand for seafood during Ramadan is low but high after (particularly during the Eid holiday).

Most key informants noted consumer preference for wild-caught fish. However, they also noted that if locally-produced fish were available from aquaculture, then consumers would respond favourably. Furthermore, interviewees believed that knowledgeable consumers would be willing to pay a premium for fresh, locally-produced seafood and that aquaculture presents an opportunity to provide reliable supply of high-quality fish product available throughout the year. Seafood suppliers noted that cultured fish was already imported from Turkey, Oman, Tunisia, and India. Demand for crustaceans (shrimp, lobster, crabs) is high, particularly in Dubai, where tourism promotes demand at restaurants and hotels. Restaurant managers and chefs noted that high-priced seafood (e.g., lobsters) was prepared (specific recipes) to satisfy demand, particularly by East Asian consumers. Prices paid for crustaceans vary seasonally according to supply. However, most shrimp is sourced from imported aquaculture supply.

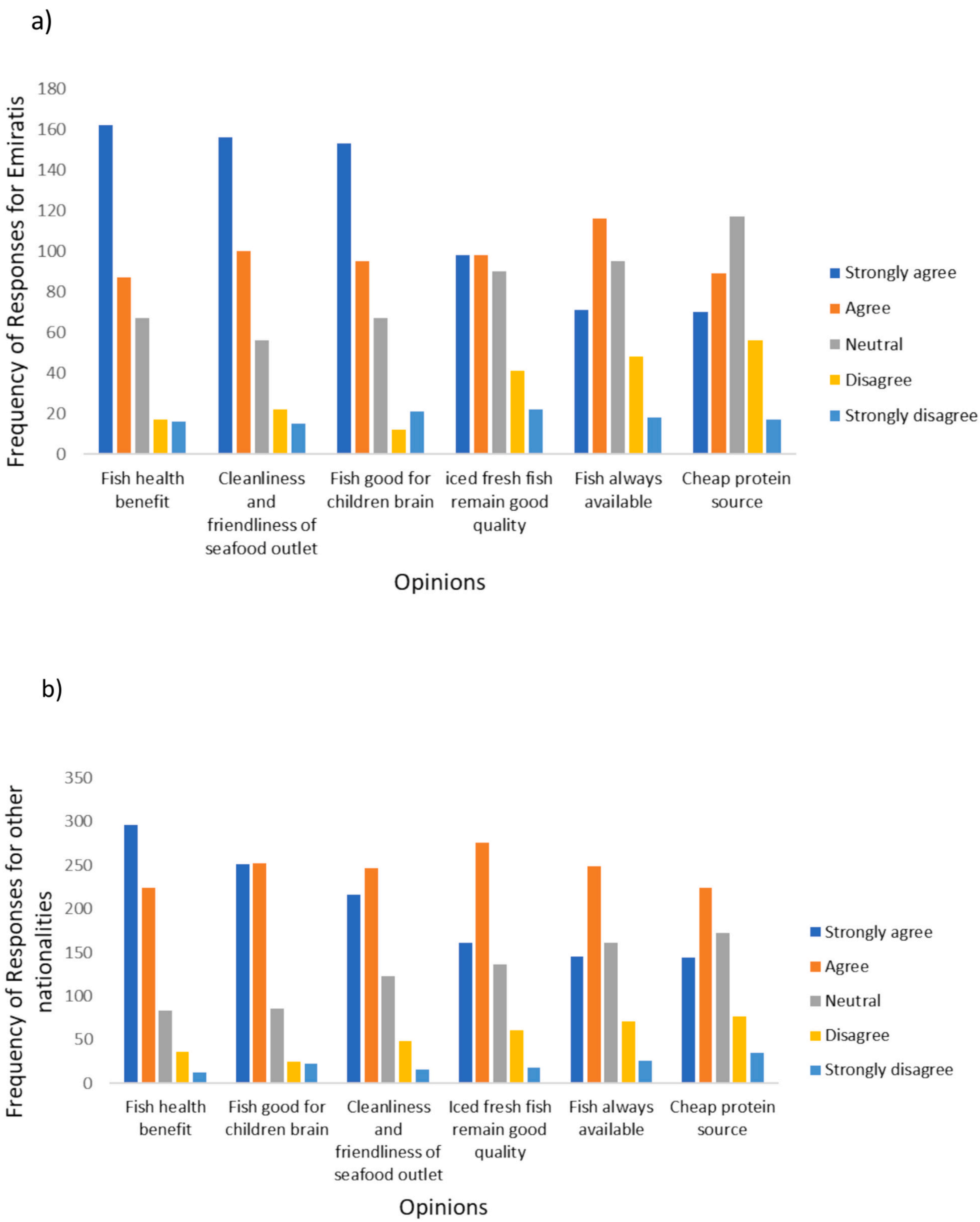

Fig. 4. Factors influencing purchase and consumption of fish. Data are shown as percent responses from Emiratis (a) and other nationalities (b).

3.3. Sensory evaluation

In selecting candidate species for sensory evaluation, the following factors were considered to be important:

- preferred by UAE consumers;
- opportunity to differentiate as a UAE premium product;
- amenable to economically-viable aquaculture.

Candidate species for intensive commercial aquaculture in the UAE reflecting stated preferences from consumer surveys include hamour, shaeri, and safi. Testing more than five species at a time risks panellists' fatigue and erroneous assessment (Lawless and Heymann, 2010).

In contrast to consumer surveys, seafood retailers in the UAE stated customer preferences for European seabream and European seabass. These species are intensively cultured outside the UAE and, although in demand by UAE consumers, are not unique to the UAE and are otherwise widely available on global seafood markets. Two other candidate species included cobia and barramundi, high yielding and salinity-tolerant species amenable to sea-cage culture but less familiar to UAE consumers.

A total of 335 panellists' participated in sensory evaluation trials in three Emirates: Dubai, Sharjah, and Abu Dhabi (including trials in the major cities of Abu Dhabi and Al Ain). Panellists comprised Emiratis (18 %), non-Emirati Arab (38 %), Asian (33 %), African (7 %), and Western (4 %) nationalities. Most panellists were male (74 %) and had attained at least a high school education (88 %). The panellists consumed fish more than once per week (46 %), at least once per week (37 %) or at least once per month (17 %). Most panellists (75 %) were between 26 and 50 years of age.

Rank preferences based on taste, texture, and overall liking varied among participants from different Emirates (cities). Panellists from Abu Dhabi and Sharjah revealed differences in taste, texture, and overall liking among the five species evaluated ($P < 0.001$ Friedmans test (Figs. 5 and 8). In contrast, panellists from Al Ain, and Dubai showed no difference in preferences in taste, texture, or overall liking ($P > 0.05$) (Figs. 6 and 7). Notably, of the five species evaluated, none were disliked (median scores >6), although combined hedonic scores for safi and cobia showed a range extending to 4 (Fig. 9).

Multiple comparisons following Friedmans tests for ordinal preference data showed that significant differences for Abu Dhabi and Sharjah were due to a higher overall preference for barramundi above the other species. Panellists from Arab and Asian countries, together with Emiratis, clearly preferred barramundi over the other species (Fig. 10), although Africans preferred hamour. Similarly, panellists from Abu Dhabi and Sharjah preferred barramundi (Fig. 10). Shaeri was preferred by panellists from Al Ain and hamour was preferred by panellists from Dubai (Fig. 10). However, given the variability in scores across taste, texture and overall liking, it is unlikely that these differences are significant. In terms of overall ranking, panellists clearly preferred barramundi over the other four species evaluated (Fig. 11).

4. Discussion

Much of the literature on seafood preference is derived from European studies, given the importance of seafood consumption and choice factors in the European market. Such studies are not as widespread in Middle Eastern countries but factors important in influencing consumer choice for seafood in the UAE are revealed here.

Consumer preferences favour wild caught over farmed fish, reflecting perceptions of superior freshness, taste, and health benefits (FAO, 2011; Lawley et al., 2012; Fernandez-Polanco et al., 2013; Claret et al., 2016; Cantillo et al., 2020; Pulcini et al., 2020). For example, in European markets, wild-caught gilt-head seabream attracts a considerable price premium compared with farmed seabream (Fernandez-Polanco et al., 2013). However, empirical studies show that production methods are less important to consumers than other attributes (particularly sensory factors) (Lawley et al., 2012). Moreover, consumer knowledge of fish and aquaculture practices is generally low (Zander et al., 2018; Pulcini et al., 2020), and perceptions of lower quality of farmed fish may not translate into purchase decisions (Risius et al., 2019).

Negative perceptions of farmed fish do not appear to be based on sensory attributes (Claret et al., 2016; Pulcini et al., 2020). Even so, consumers living in coastal areas not surprisingly prefer wild-caught fish given the availability, variety, and freshness of wild-caught products (Verbeke et al., 2007; Carlucci et al., 2015). The availability of preferred species such as kanaad (*Scomberomorus commerson*) is low in summer in the Gulf region (Al-Balushi et al., 2016), and this can influence consumer choice (e.g. of other species) (Yousuf et al., 2019).

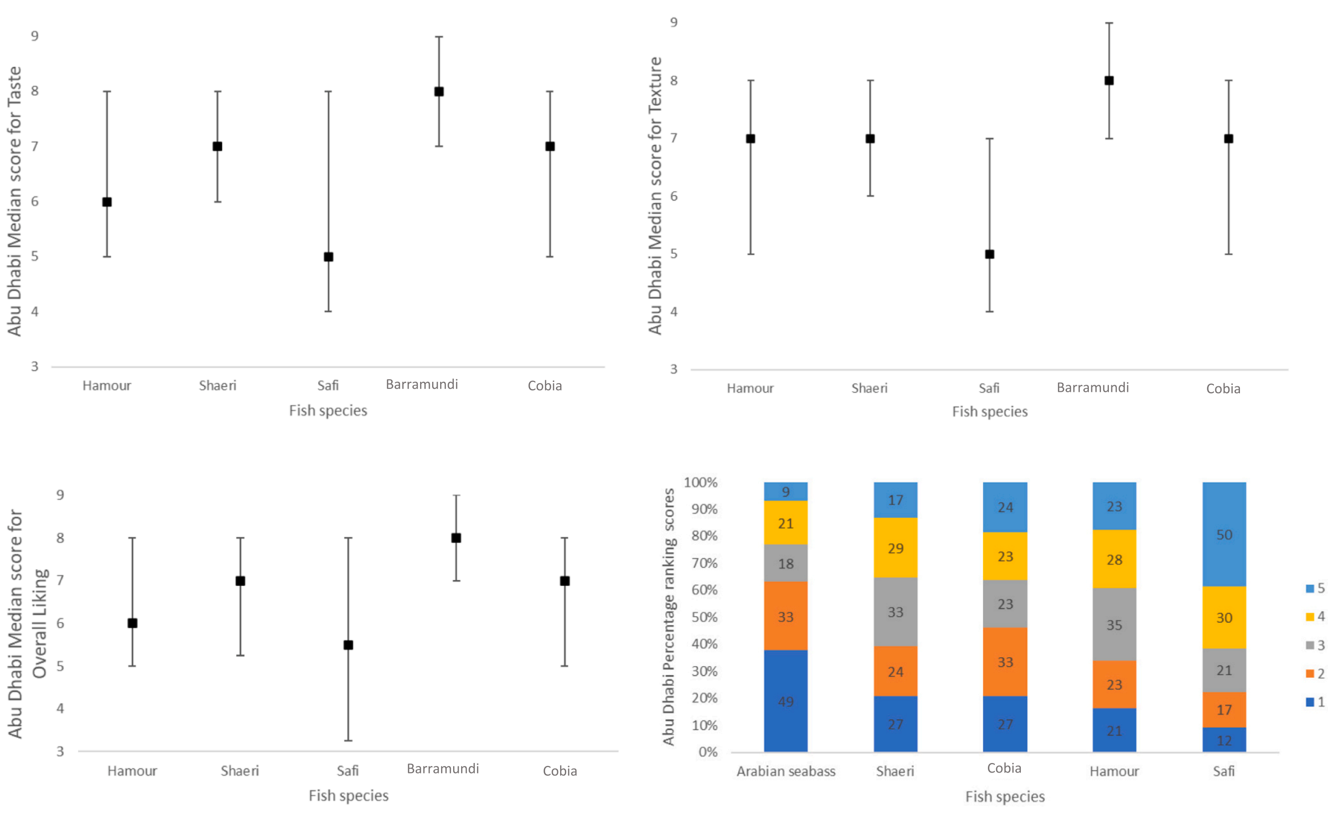

Fig. 5. Sensory evaluation of candidate species Abu Dhabi. Data for taste (top left), texture (top right) and overall liking (bottom left) are median and interquartile range plots. The bottom right figure presents percentage ranking scores (1 = most preferred, 5 = least preferred).

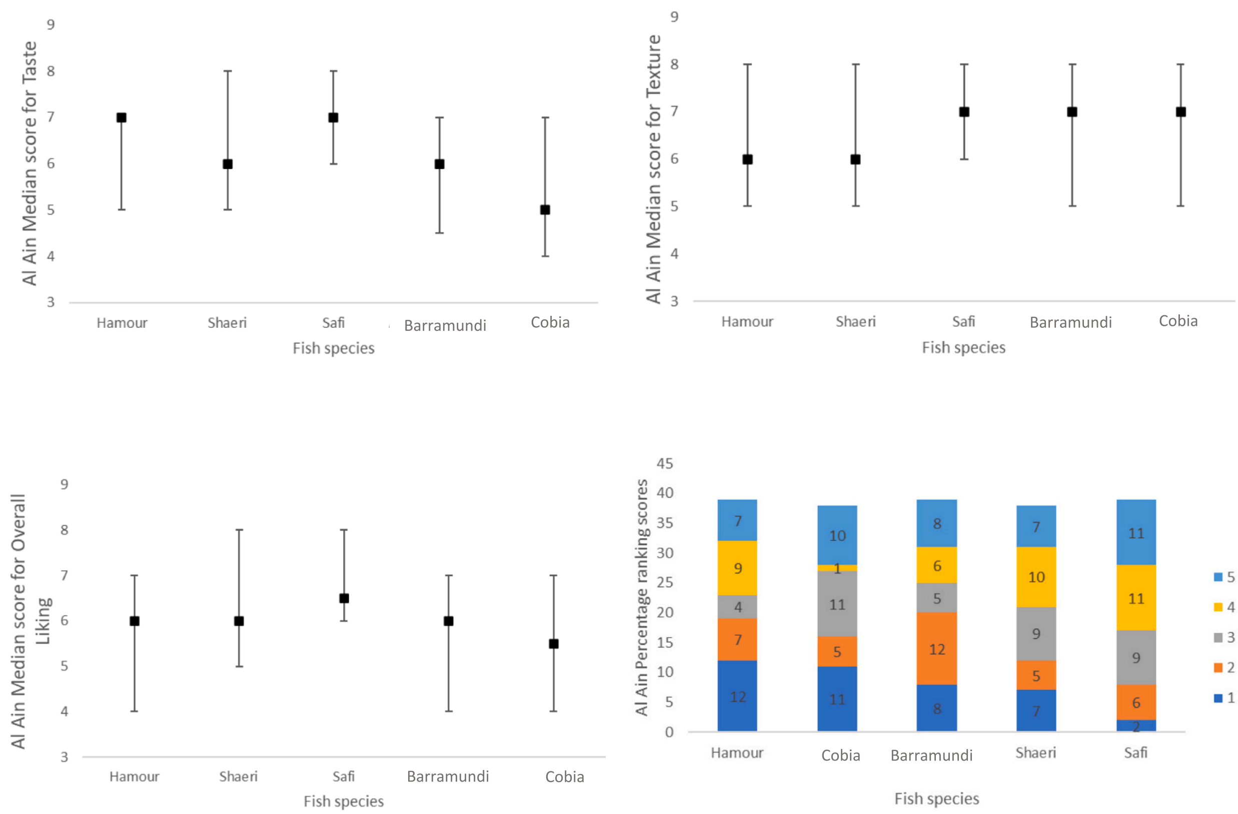

Fig. 6. Sensory evaluation of candidate species Al Ain (Abu Dhabi). Data for taste (top left), texture (top right) and overall liking (bottom left) are median and interquartile range plots. The bottom right figure presents percentage ranking scores (1 = most preferred, 5 = least preferred).

The UAE has an ethnically and culturally diverse population (national versus expatriate). Nearly half the population of the UAE originate from South Asia (India 25 %, Pakistan 12 %, Bangladesh 7 %). Consumers of South Asian origin tend to consume less seafood than those East Asian consumers (Nurul Izzah et al., 2016): consumers from Bangladesh prefer freshwater fish (Thapa et al., 2015). Filipinos make up 5 % of the UAE population and prefer seafood (particularly pelagic fish such as tuna) (Thapa et al., 2015). The UAE also has a substantial population of expatriates from western countries and other Arab states. However, other than a non-national preference for nile tilapia, consumer preferences for finfish in the UAE were similar among residents.

Consumers usually prefer fish caught in their home country (Carlucci et al., 2015; Cantillo et al., 2020; Olsen et al., 2021). This also applies to the UAE with strong preferences for traditional wild-caught species such as hamour, kanaad, shaeri, and safi. However, most of these species are no longer sourced from the UAE but instead imported (e.g. from Oman or Sri Lanka). The diversity of fish products on sale in the UAE suggests a wealth of choice for seafood consumers. Information on the country of origin is not generally available at the point of sale in the UAE, which imports most of its seafood (FAO, 2011). However, more recently, seafood outlets in the UAE have commenced labelling seafood with flags denoting country of origin. Socio-cultural factors such as origin, religion and traditional food preferences have a large influence on food preferences for consumers in Arab countries (Musaiger, 1993), including seafood (Yousuf et al., 2019).

Although price is a key determinant of seafood preference for both Emiratis and other nationalities, it ranked below freshness, species, and product form (e.g., whole vs. fillets vs. frozen) among UAE consumers. Freshness often ranks above taste in species attributes among fish consumers (Alam and Alfnes, 2020). Consumption of seafood clearly varies among nationalities (e.g., South Asians generally consume much less seafood (5 kg/person/year) than those from the UAE (26 kg/person/year)) (Thapa et al., 2015; Squalli, 2020). However, only consumers who regularly ate or purchased seafood were interrogated in the present study. Thus, the preferences recorded here reflect the choice of experienced seafood consumers rather than the general UAE population.

For fish chosen at seafood retail outlets for consumption at home, Emiratis show similar preferences for seafood to non-nationals: kanaad and hamour. This was generally true among consumer survey respondents, information from focus groups and key informant interviews. Although less preferred, shaeri and safi were favoured by Emiratis whereas less expensive species, particularly nile tilapia (*Oreochromis niloticus*) and Sultan Ibrahim (*Nemipterus delagoae*) were highly preferred by non-UAE nationals probably because these fish are available at a lower price. Furthermore, many respondents (particularly in Dubai) were from African or Middle Eastern countries where nile tilapia are widely available and evidently preferred.

Unlike seafood retail outlets, consumer preferences for seafood eaten at restaurants or at hotels were not as clear although key informants noted that hamour (as whole fish) was popular among locals particularly in Dubai as was kanaad. Notably, European seabream and European seabass were also popular among restaurant diners (Dubai and Abu Dhabi) as was nile tilapia but less so at seafood retail outlets.

Chefs stated that these latter species are more likely to be served as pieces rather than whole fish. Higher-priced seafood, particularly lobster, crab and shrimp was also popular among restaurant diners particularly tourists from east Asia (China, Japan, Korea). By value, consumers spend more on crustacea (shrimp, crab, lobster) (46 %) than on fish (40 %) even though most seafood consumed in the UAE is fish.

Country of origin and wild vs. aquaculture were the least important attributes influencing seafood preference for both Emiratis and non-nationals (in contrast to Thapa et al., 2015, Nurul Izzah et al., 2016, Ministry for Primary Industries (New Zealand), 2019). Notably, the most preferred species in sensory trials in the present study, barramundi, was

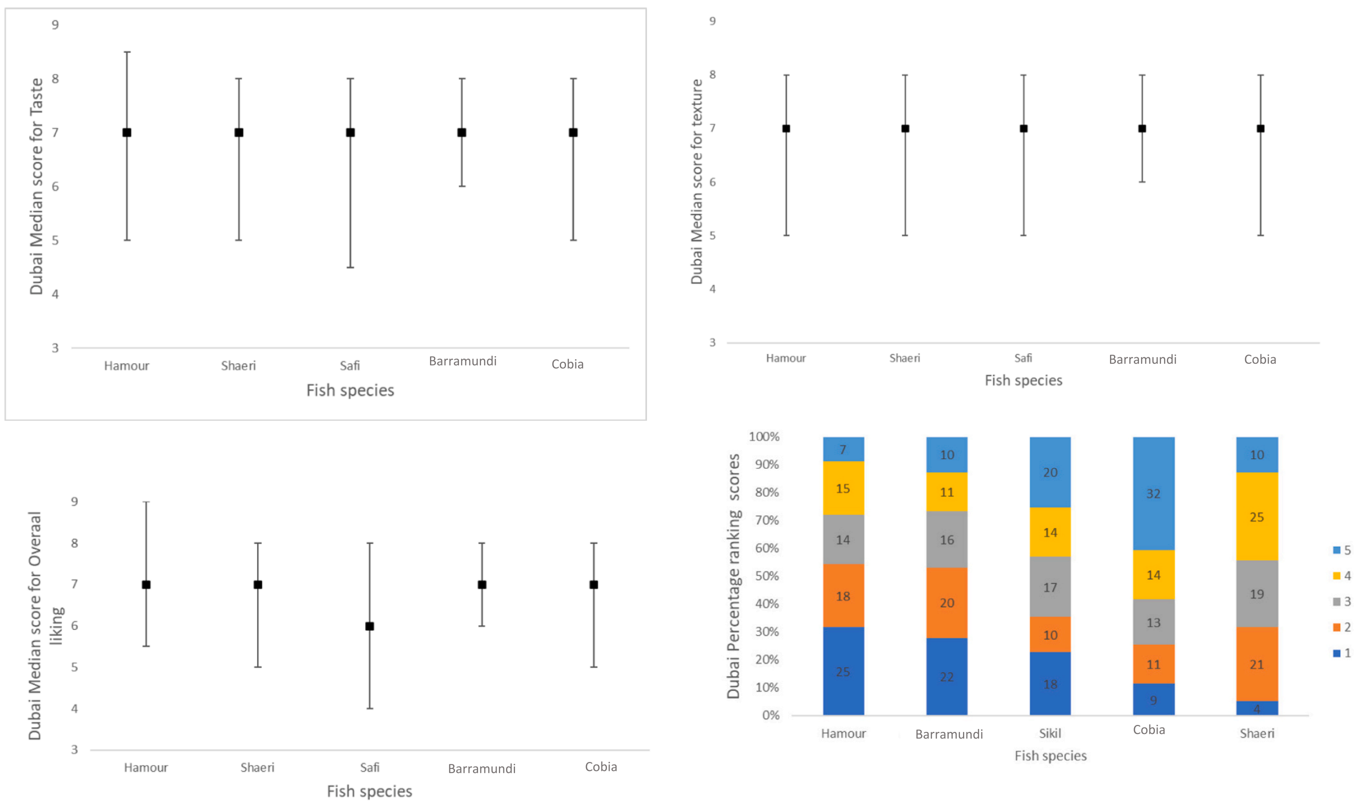

Fig. 7. Sensory evaluation of candidate species Dubai. Data for taste (top left), texture (top right) and overall liking (bottom left) are median and interquartile range plots. The bottom right figure presents percentage ranking scores (1 = most preferred, 5 = least preferred).

farmed in Saudi Arabia. In any case, key informant interviews showed that consumers were generally unaware of whether fish purchased was cultured or wild. Accordingly, production source was deemed to be relatively unimportant (cf. Verbeke et al., 2007; Stefani et al., 2012). This finding is in contrast to studies outside the UAE where consumer preferences apparently choose wild caught over farmed fish, reflecting perceptions of superior freshness, taste, and health benefits (FAO, 2011; Lawley et al., 2012; Fernandez-Polanco et al., 2013; Claret et al., 2016; Cantillo et al., 2020; Menozzi et al., 2020; Pulcini et al., 2020). However, consumer knowledge of fish and aquaculture practices is generally low (Zander et al., 2018; Oksanen et al., 2020) and evident among UAE consumers from responses from focus groups and key informant interviews in this study. Perceptions of lower quality of farmed fish may not translate into purchase decisions (Risius et al., 2019) although most species preferred in the present study by UAE consumers were all wild-caught (e.g., kanaad, hamour, shaeri, and safi). Exceptions included nile tilapia that were preferred by non-nationals (particularly Africans and consumers from other Arab nations such as Egypt and Jordan).

Focus groups and key informant interviews revealed that symbolic attributes including sustainability (e.g., eco-labelling) were not influential in fish purchase choice in the UAE irrespective of nationality unlike consumers from other countries (Fernandez-Polanco et al., 2013; Carlucci et al., 2015; Cantillo et al., 2020; Risius et al., 2019; Asche et al., 2021). However, as shown here, other studies show that production methods are less important to consumers than other attributes (particularly sensory factors) (Lawley et al., 2012).

Among non-nationals, it was difficult to isolate differences in consumer preference either at the point of sale (retail outlets) or when eating out (e.g., restaurants). East Asian preference for crustacea is noted above but this reflects a general preference for specific cuisines at specialist restaurants (particularly in Dubai). Sensory evaluation trials showed little if any difference in the preference of fish among nationalities. This is not surprising as the interaction of factors influencing preference (e.g., availability, familiarity, income, willingness to pay, eating at home vs eating out) are likely to mask national or ethnic preference for fish.

Purchasers of fish in the UAE overwhelmingly prefer fresh whole fish over other forms of fish (particularly frozen, dried or canned). This finding is in contrast to those studies from other countries where frozen fish is popular because of convenience and generally lower price (Claret et al., 2016, Carlucci et al., 2015, Ministry for Primary Industries (New Zealand), 2019). However, in a study of seafood consumers in Canada more than 70 % of respondents preferred fresh over frozen seafood (Witter et al., 2021).

In the UAE, whole fish are preferred because fish can be identified at the point of sale (by preferred species), freshness can be assessed in situ (e.g., by eye/gill colour and appearance) (Mazrooei et al., 2003; Yousuf et al., 2019). Furthermore, whole fish is perceived to be more economical than processed fish particularly as many retail outlets offer free processing (e.g., whole fish to fillets). The prospect of readily available (i.e., year-round), locally-produced, preferred fish including live specimens at restaurants presents a substantial economic opportunity for the UAE.

Consumer preferences reflect sensory (e.g., size, taste, texture, appearance) and non-sensory attributes (e.g., ethnicity, culture, price) (Honkanen et al., 2005). Of all potential candidates for intensive fish aquaculture in the UAE, hamour and barramundi were clearly preferred by UAE seafood consumers. Although, surveys revealed that consumers were less familiar with barramundi, this species was the most preferred in sensory trials with superior taste, texture and overall liking compared with the other species evaluated. Thus, there is a clear difference in stated versus revealed preference (Adamovicz et al., 1994) for fish species among UAE consumers. Shaeri was also preferred by consumers and was well liked in sensory trials. Similarly, safi is preferred but was

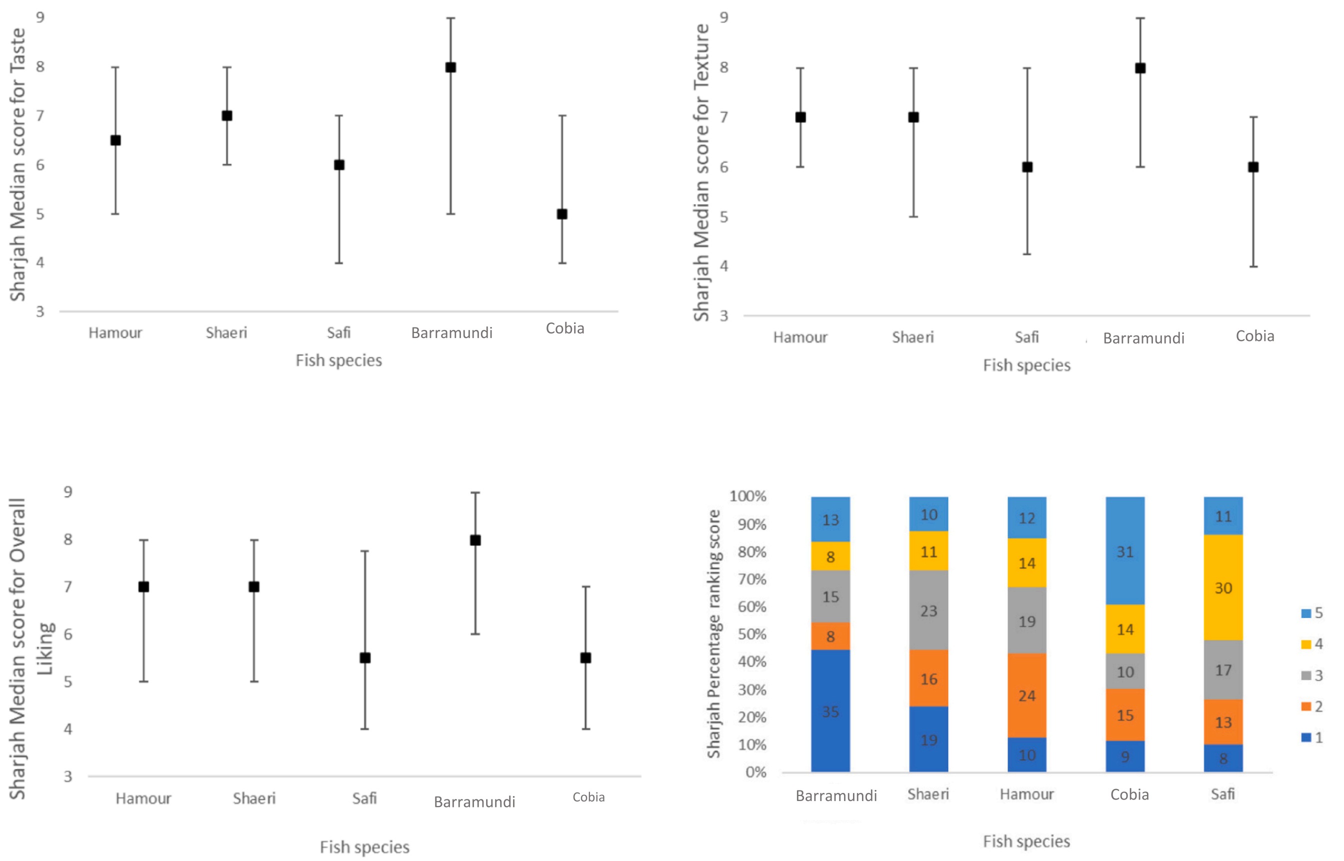

Fig. 8. Sensory evaluation of candidate species Sharjah. Data for taste (top left), texture (top right) and overall liking (bottom left) are median and interquartile range plots. The bottom right figure presents percentage ranking scores (1 = most preferred, 5 = least preferred).

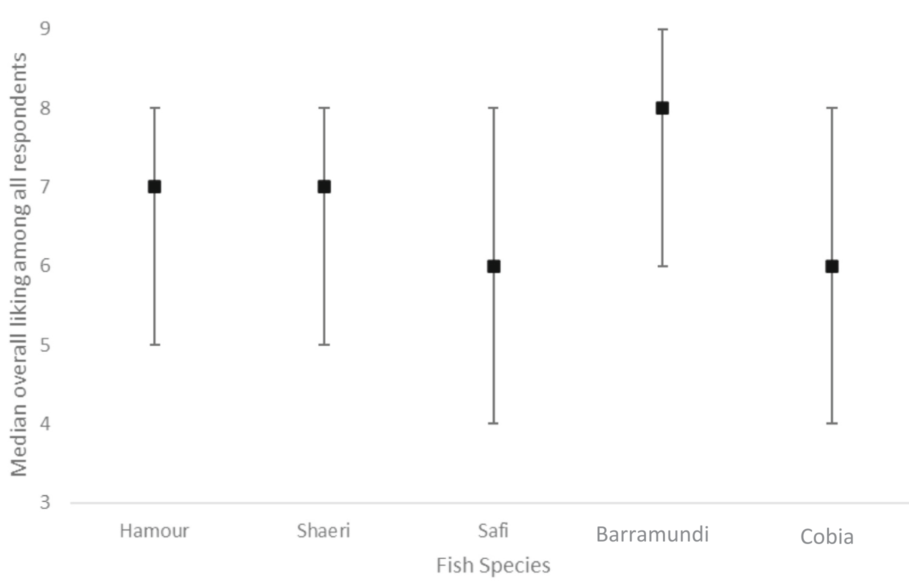

Fig. 9. Combined hedonic scores (taste, texture and overall liking) across Emirates. Data are medians with interquartile range for individual species evaluated by panellists (9 = most preferred, 1 = least preferred).

ranked as the least liked of the fish evaluated in sensory trials. Cobia was also liked (taste, texture and overall liking) in sensory trials.

Although not evaluated in this study, muscle fat content is considered to be the most important attribute of fish flesh quality as it is associated with texture, taste and juiciness (Johansson et al., 2000). When questioned on preferences, panellists in the present study noted that barramundi was preferred because of its juicy texture and pleasant taste. Consumers surveyed, also noted the health benefits of fish but this

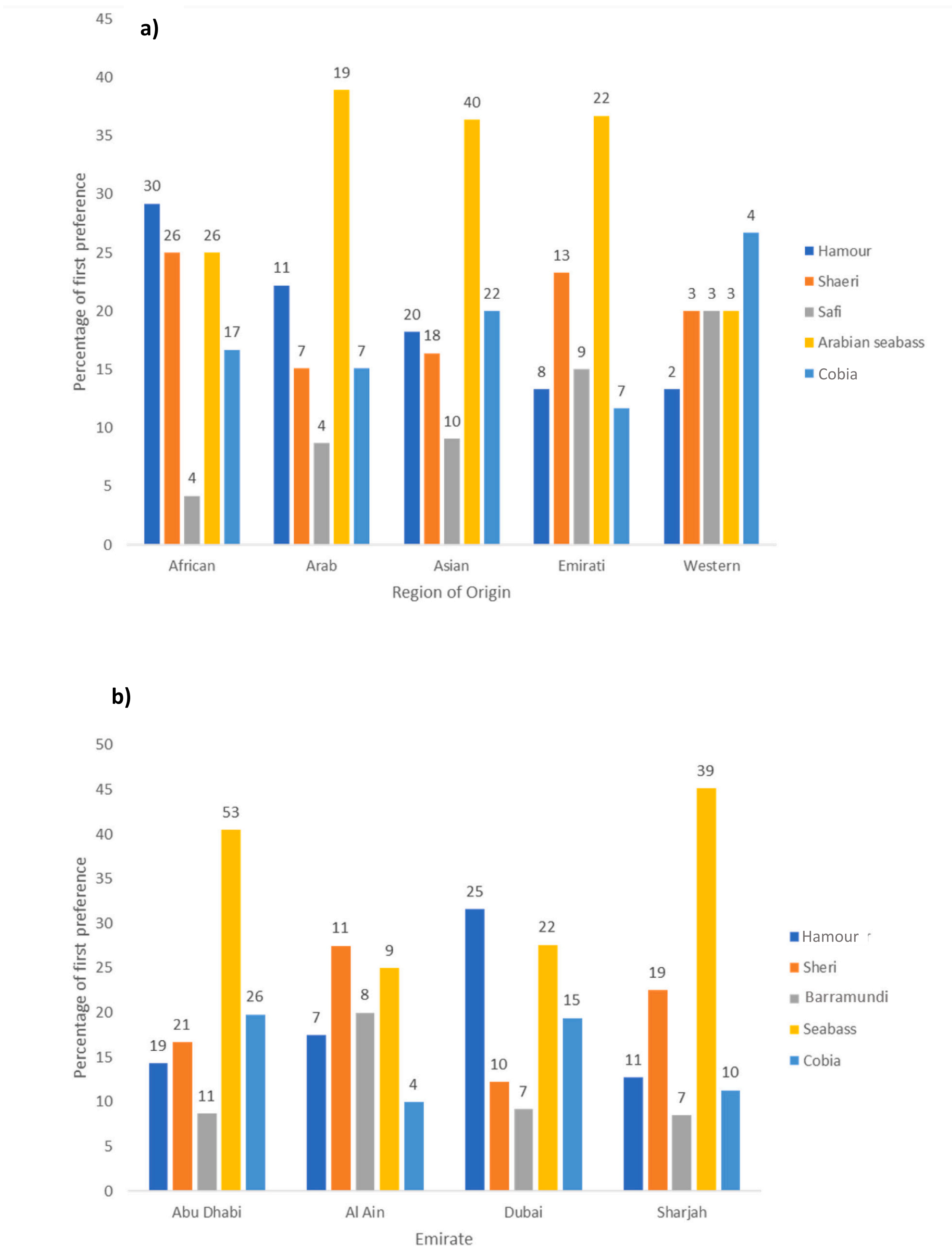

Fig. 10. Comparison of fish preference by consumers of different regions (a) and Emirates (cities) (b). Data are percentage preferred among panellists from each city/ Emirate. Labels show number of panellists in each case.

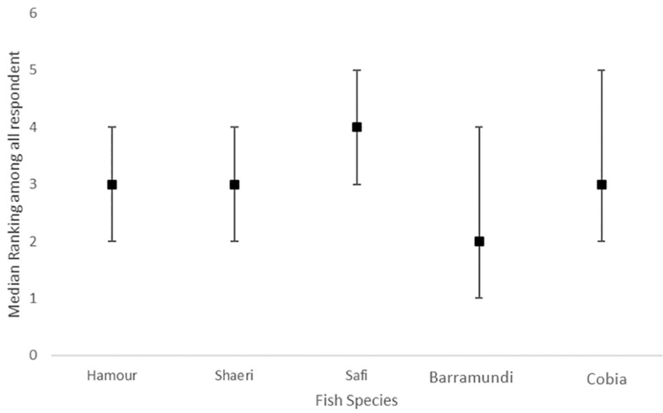

Fig. 11. Ranking of preferred species (1 most liked to 5 least liked) all data combined. Data are medians with interquartile range indicated.

did not influence choice of species. Rather, consumers chose fish over other protein sources because of perceptions of health benefits (Menozzi et al., 2020; Naylor et al., 2021) rather than the nutritional benefits of individual species (Carlucci et al., 2015).

Dietary studies have shown that taste of fish depends on lipid type and source (Johansson et al., 2000; Jobling, 2001; Quillet et al., 2004; Grigorakis, 2007). Compared with wild fish, farmed fish show less variability in quality as they are generally fed regularly usually on high fat diets (Johansson et al., 2000; Glencross, 2006; Lin and Yeh, 2022). However, accumulating excessive lipid in the muscle makes fillet processing more difficult and reduces firmness (Sodeland et al., 2013; Ali et al., 2020). High levels of polyunsaturated fatty acids (PUFAs) can lead to lipid oxidation and the development of unpleasant flavours in fish (Johansson et al., 2000; Sodeland et al., 2013). Fat content in fish is correlated with water content (Sodeland et al., 2013). Thus, fish with a relatively low fat content generally have firm succulent flesh with a mild flavour (Johansson et al., 2000; Lawley et al., 2012; Szűcs et al., 2018) evidently preferred by UAE consumers who commented favourably on the taste and texture of hamour and, particularly, barramundi in sensory trials.

Although only five species were evaluated in sensory trials there may be other species that are equally suited for culture in the UAE. For example, silver pomfret (*Pampus argenteus*) (an established high-value species) was shown to be highly preferred by UAE consumers and commands high retail prices at UAE outlets. This species is successfully cultured elsewhere (e.g., India). Similarly, sobaity (*Sparidentex hasta*), a seabream farmed in Kuwait was highly preferred by UAE consumers and is a rich source of omega-3 fatty acids (Hossain et al., 2018).

Technological advances in aquaculture have refined grow out systems for the efficient production of fish (Asche et al., 2021; Bregnballe, 2015; Kumar and Engle, 2016; Naylor et al., 2021; FAO, 2022). In the UAE, RAS has evolved to provide energy-efficient production of fish, particularly hamour with individual farms producing more than 100 t annually. Yet this current level of production is miniscule compared with large-scale pond or cage culture outside the UAE. Automation of RAS (including water quality monitoring and fish feeding) reduces labour costs and, with the potential application of artificial intelligence (AI) and machine learning, autonomous systems can be established (Bregnballe, 2015). Such systems offer opportunities for expanded production of hamour which is already profitably cultured in the UAE, but also other preferred species including barramundi, safi, and cobia. Hamour is already well accepted by UAE consumers who are willing to pay a price premium for fresh locally-produced fish.

Sea-cage aquaculture is an option for the UAE because fresh water is scarce, pond-farming is not practical given the harsh environmental conditions, and RAS systems are capital and energy intensive (and therefore potentially more costly). However, southern Emirates are subject to periodic harmful algal blooms that present a substantial commercial risk to sea cage culture operations (Villacorte et al., 2015). Northern Emirates such as Ras Al Khaima and Fujairah being closer to, or directly on, the Indian Ocean present opportunities for sea cage culture. However, these Emirate are vulnerable to summer storms (Shamals) which preclude sea-cage culture. This risk may be managed by utilizing RAS for grow-out during summer and sea-cage culture thereafter. Risk mitigation could also include submersible cages which offer protection from storms. Submersible cages are particularly suited to cobia culture, which, as a bentho-pelagic fish are less suited to surface sea cages (Benetti et al., 2010; Sievers et al., 2021). However, such systems are untried in the UAE and, more generally, high water temperature and salinity may detrimentally affect production.

Barramundi and cobia offer excellent prospects for intensive culture in the UAE. Both are high-yielding fish, with barramundi, in particular, showing high specific growth rates (SGRs). Cobia occurs naturally in UAE waters and is targeted by the local fishing fleet. Early studies of sea-cage culture of cobia in the UAE yielded promising results (average body weight of 2.87 kg after 12 months with a Feed Conversion Ratio (FCR) of 2.0) (Yousif et al., 2005) but, since then, trials of cobia culture have discontinued. Studies of the aquaculture of barramundi show that high stocking density can be beneficial as cannibalism is reduced under crowding conditions (Khan et al., 2021). However, high stocking densities can also reduce growth rate and FCRs (Ezhilmathi et al., 2022).

Compared with other countries with economies of scale favouring massive aquaculture production (e.g., China, India, Vietnam, Indonesia) (FAO, 2022), climate and economics suggest that the UAE can only become a niche producer focusing on favoured local species such as hamour. Such local production can offer consumers access to fresh local species, reducing but not eliminating dependence on imported seafood. The results of this study confirm the preference for fresh whole fish. However, sensory evaluation trials reveal that even species unfamiliar to local consumers, such as barramundi and cobia offer prospects for local production.

Author statement

All authors have approved the final manuscript.

CRediT authorship contribution statement

Paul E. McShane: Writing – original draft, Project administration, Investigation, Funding acquisition, Conceptualization. **Marcus Sheaves:** Writing – review & editing, Project administration, Investigation. **Eihab Fathelrahman:** Writing – review & editing, Supervision, Project administration. **Berhanu Degefa:** Writing – review & editing, Investigation. **Nuha N.M.K. Yousif:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Sajid Maqsood:** Formal analysis, Writing – review & editing. **Ebrahim Abdulla Jamali:** Writing – review & editing. **Rumaitha Abdulaziz Alshehhi:** Writing – review & editing. **Nahla Mezhoud:** Writing – review & editing. **Mustafa Abdu Qader Al-Shaer:** Writing – review & editing.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aquaculture.2024.742105.

Data availability

Data will be made available on request.

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