



## Aquaculture State, Challenges and Technologies in the Middle East

Shaima Ibrahim Alameri<sup>1,a</sup>, Maitha Ahmed Almakhmari<sup>1,b</sup>, Sathiya Maran<sup>1,c</sup>, Reem Yousef Almansoori<sup>1,d</sup>,  
Sabra Ahmed Alqubaisi<sup>1,e</sup>, Aisha Abushelaibi<sup>1,f</sup>, Kok-Song Lai<sup>1,g</sup>, Swee-Hua Erin Lim<sup>1,h,\*</sup>

Health Sciences Division, Abu Dhabi Women's College, Higher Colleges of Technology, 41012 UAE

\*Corresponding author

### ARTICLE INFO

### ABSTRACT

Review Article

Received : 11/05/2021  
Accepted : 01/12/2021

**Keywords:**  
Aquaculture  
Middle east  
Challenges  
Technologies  
Fish diseases

The aquaculture industry in the Middle East (ME) is still relatively new compared to other parts of the world, making this region highly dependent on other countries for the production of food and feed needs. Aquaculture activities in the world at current is mainly focused in China; this may be propelled by its own internal demand for seafood as determined by the United Nations Food and Agriculture Organization (FAO). Challenges faced in the ME has not been elucidated so far and the issues arising might be unique only to this region due to aquaculture being in the initial stages coupled with water access and limitations, climate and geography, in addition to pollution. This review paper will present and discuss global needs for seafood focusing later on the needs in the ME, followed by a discourse into the importance, types and challenges of aquaculture in the ME. Baseline knowledge and infrastructure to enhance knowledge is a pressing need at this stage of infancy. It is hope this sector will continue to develop, and with the support of stakeholders, aquaculture in the ME will achieve a state of independence.

<sup>a</sup> [shaimaalameri97@hotmail.com](mailto:shaimaalameri97@hotmail.com)  
<sup>c</sup> [sathiya.maran@monash.edu](mailto:sathiya.maran@monash.edu)  
<sup>e</sup> [abudhabi448@gmail.com](mailto:abudhabi448@gmail.com)  
<sup>g</sup> [lkoksong@hct.ac.ae](mailto:lkoksong@hct.ac.ae)

<sup>b</sup> <http://orcid.org/0000-0001-5589-5946>  
<sup>d</sup> <https://orcid.org/0000-0001-5617-901X>  
<sup>f</sup> <https://orcid.org/0000-0003-0150-8976>  
<sup>h</sup> <http://orcid.org/0000-0002-1887-2232>

<sup>b</sup> [maitha\\_Almakhmari@hotmail.com](mailto:maitha_Almakhmari@hotmail.com) <http://orcid.org/0000-0002-0044-6024>  
<sup>d</sup> [sabralqubaisi@hotmail.com](mailto:sabralqubaisi@hotmail.com) <https://orcid.org/0000-0002-0693-4192>  
<sup>f</sup> [aabushelaibi@hct.ac.ae](mailto:aabushelaibi@hct.ac.ae) <http://orcid.org/0000-0002-2372-893X>  
<sup>h</sup> [terin@hct.ac.ae](mailto:terin@hct.ac.ae) <http://orcid.org/0000-0001-5177-0257>



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## Introduction

Aquaculture is the process of rearing, breeding and harvesting of aquatic species in a controlled aquatic environment and is defined by The United Nations Food and Agriculture Organization (FAO) as "The farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants". Farming indicates some sort of intervention in the rearing process to increase production, such as regular stocking, feeding and protection from predators. Farming also signifies individual or corporate ownership of the stock being cultivated. Therefore, although aquaculture is a mechanism to produce food and the benefits far outweigh the adverse effects, in addition to positively improving economy, the possible consequences of the process affecting the environment and increasing concerns regarding the health of consumers remain (Ruiz-Chico et al., 2020).

Aquaculture has been reported as a component of a complex global food system that is progressively changing

and growing (Fiorella et al., 2021). The increase in demand for seafood yearly is largely due to an increase in with the worldwide population. A recent report cited that between 2000 and 2012, aquaculture has doubled its global fish production rate to meet the world's current demand. Nonetheless, the present production of aquaculture needs to be increased to more than double to adequately meet the rapidly growing demand (Waite et al., 2014). Global demand for seafood is predicted to increase over the years and FAO has reported that an excess value of 40 million extra tons of seafood, which is a rise of almost 30%, will be needed to meet the growing demand by 2030. The United States is considered to be one of the largest importers of seafood by value. In 2018, the total import value of eatable and uneatable seafood products was USD 40.3 billion, however this has increased to USD 1.9 billion or 5% USD compared with 2017 (Mordor Intelligence, 2020).

To date, most aquaculture activity takes place in Asia, particularly in China. The dramatic expansion of China's aquaculture for the past decade has contributed for most of the fish consumed by the people around the world. This has created a good source of income, leading towards food security and economic growth (FAO, 2014).

The Middle East (ME) is surrounded by seven seas; The Persian Gulf, mediterranean, the Gulf of Aden, the red Sea, the Black Sea, the Caspian Sea and the Arabian sea; this makes the region a good source for fresh seafood (Towers, 2014). However, at current, there is limited information pertaining the importance, significance and challenges of aquaculture in the ME.

This review aims to provide an overview of aquaculture scene in the ME, focusing on its challenges, technologies and future prospect. This will not only help to enhance knowledge in aquaculture development, types, and fish production in Asia and the Middle East but also provide insight into understanding the challenges among fish farmers for future innovations and expectations in the aquaculture sector in this region.

### Importance of Aquaculture

Aquaculture or "aquatic animal and plant farming" is an integral part of human culture, health and economies; it has significantly filled the gap of seafood demand (Tidwell & Allan, 2001, Love et al., 2017). Recent reports described that seafood supports about 10–12% of the world population and is considered a part of a healthy nutrition, providing almost 3 billion people with 20% of dietary protein needs and micronutrients (Love et al., 2017).

In terms of health and nutritional benefits of fish and aquatic foods, seafood offers a healthier food source than terrestrial meat products because seafood has a higher protein content, lower caloric density, high content of omega-3 polyunsaturated fatty acids, higher mineral and vitamin; vitamin D, vitamin A, folic acid, vitamin B<sub>12</sub>, vitamin E, coenzyme Q<sub>10</sub>, choline, calcium, minerals, copper, magnesium, zinc, iron, iodine and selenium (Tacon, Lemos and Metian 2020). Consumption of seafood is widely promoted as an excellent source of easily digestible protein and essential fatty acids that are essential for metabolic functions (Norman et al., 2019).

Scientific reports have described the health benefits of consuming fishery and fish products especially towards reduced risk of death from heart disease such as coronary heart disease and stroke (Trivedi et al., 2021, Tani et al., 2021, Forouhi et al., 2018, WHO & FAO, 2011), reduction in the risks of diabetes (Chen et al., 2021), improved visual and cognitive development as well as increased duration of gestation (Hellberg et al., 2012), improved neurodevelopment in infants and children when fish is consumed before and during pregnancy (Hamazaki et al., 2020), and finally, reduction the risks of thyroid cancer (Cléro et al., 2012).

The prominent role of aquaculture towards food security is synonymous. The term "food security" is defined as the need to have access at all times to adequate provision and absorption of nutrients in food to garner a healthy and active life (FAO, 1996). In 2016, an increase of more than 20 kg per year of global per capita fish consumption was observed, this made up 6.7% of all

protein consumed by humans (FAO, 2018). FAO reported that China has the highest overall consumption for fish followed by India and the rest of Asia, and the consumption is predicted to increase globally over the next few years (FAO, 2018).

### Importance of Aquaculture in the ME

In the ME, aquaculture is one of the fastest growing sectors, largely due to the highest product traceability standards and safety, rigorous biosecurity, and state-of-the-art technology. The aquaculture production of ME has increased speedily from 837,247 tonnes in 2005 to 1,768,917 tonnes in 2014, with an approximate of 111% increment, and has been predicted to increase to 2.4 million tonnes in near future (Tolon, 2017).

The significant demand for seafood from aquaculture over the last few decades is mainly due to the increase of seafood consumption per capita in the region. For instance, the United Arab Emirates (UAE) recorded a total of 51.1 kg per capital consumption of seafood, which is one of the highest in the world and four times the world average. This is followed by Oman (36.7 kg/per year), Bahrain (16.9 kg/per year) and Qatar (16.5 kg/per year) (Chibber, 2013). The upsurge of seafood consumption in these gulf countries is due to the increase in population growth, tourism numbers, and the rise in incomes per capita (Napier, 2014). Despite its huge demand and consumption, total seafood production in the ME is only about 2.17% of the total international production (*Middle East Fish and Seafood Market (2020-2026)*, 2020).

Highest fish consumption in ME is reported by United Arab Emirates (UAE), Oman, Qatar, Bahrain and part of South Yemen (Towers, 2014). As maintained by The Environment Agency Abu Dhabi (EAD), aquaculture amounted to about 810 tonnes the production in Abu Dhabi alone of aquatic specieses with a value of approximately USD 5.06 million representing a 20% growing in production in 2018. The Food and Agriculture Organisation (FAO) also reported that over the past three years, tuna fish production was recorded to be 19,700 tonnes, whereas in 2016 the pelagic fish's production was 10,480 tonnes that in 2018 increased to 10,550 tons. A recent report by Chalil and colleagues described that about 44% of the total seafood production in the ME is sourced mostly from Egypt, Iran and Turkey (Chalil, 2019).

### Types of Aquacultures in the ME

Aquaculture can be sub-grouped to mariculture, algaculture and multi-trophic aquaculture (Bert, 2007). Mariculture is the aquaculture outlet that grows aquatic animals in the exposed marine or an enclosed part of the ocean or tanks or ponds filled with seawater (Nash, 2011). Mariculture is denoted as a subgroup of the bigger aquaculture sector, involving the cultivation of both freshwater and marine organisms (Phillips, 2009). Algaculture is the form of aquaculture that produces algae in a controlled temperature, source of light and dietary properties (Lucas et al., 2019). The integrated multi-trophic aquaculture (IMTA) is an evolved aquaculture system which combines different species with distinct nutritional needs into one framework (Grosso et al., 2021). An example of this method is growing seaweed which

utilises ammonia and phosphorus excreted by fish and shrimp while oyster fish feed on the solids produced by fish and shrimps.

In ME especially in the UAE, fishing is primarily conducted from the open fibreglass dories and traditional wooden dhows. Dome shaped wire traps are the most commonly used fishing gear although a variety of other methods exist including; gillnets, fixed inter-tidal fence nets, trolling lines and hand lines (Shallard et al., 2010).

In UAE, the types of aquaculture are divided into land-based and sea-based aquaculture. Land-based aquaculture includes the ponds, fence, closed system aquaculture RAS (Recirculation aquaculture system) and integrated aquaculture (McLean, 2003) whereas, sea-based aquaculture uses cages, coastal fences and suspended aquaculture systems. Another common aquaculture type is the sea-based aquaculture, whereby floating cages or nets composed of a wooden frame, netting or fabric is used. Besides the mentioned, UAE also employs multiple systems, ranging from comparatively easy systems such as basins, lakes, integrated aquaponics and aquaculture to compound systems based on technology, including the RAS.

### Challenges and limitations of Aquaculture

Aquaculture is still a developing economic sector in ME. The governments have been promoting this sector in Oman, UAE and KSA by supplying fingerlings of regional species, developing a framework for aquaculture, reducing investment constraints and relaxing institutional policies, in addition to mapping out suitable sites (Lavieren et al., 2011). The main challenges and limitation faced in the ME is limited availability to freshwater and suitable soil, insufficient tidal amplitude of land-based culture and restrictions in the availability of suitable marine sites (Jan-Dec, 2016). Another main issue in the region is the high-water evaporation and highly fluctuating air temperature rates which can make water temperature and salinities rise above acceptable level for many farmed species.

#### **Fishmeal**

Fishmeal is the main protein source for farmed species in their diet. Growing aquaculture industry increased the need for fishmeal which proportionately leads to increased demand and price (Olsen & Hasan, 2012). In the early nineties the average cost of fishmeal was approximately 400–500 USD/tonne, and a steady increase was observed with the price reaching to 1200 USD/tonne from 2002 till 2017. One of the factors that contributed to this issue is because feed fish may have been directly used for population consumption in addition to decrease in feed fish catch due to unregulated fishing and stricter quota settings (Tacón et al., 2011). Furthermore, fishmeal is being widely used as an important component in feed for meat producing animals and poultry, due to its high nutritional quality. Studies have been carried out in addressing this issue and one of the solutions was to use plant proteins with improved nutritional benefits replacing fishmeal in aquaculture diets (Olsen & Hasan, 2012). Apart from plant proteins, terrestrial animal by-product meals such as bone and meat meal, poultry by-product and blood meals are also considered feed ingredients of good nutritional quality

(Tacon et al., 2006). Furthermore, bacterial protein meal has also being produced as a source of fishmeal and it has shown to benefit salmon as feeds in the Atlantic

(Bendiksen et al., 2011, Aas et al., 2006, Berge et al., 2005).

#### **Pollution**

Pollution is another main challenge faced in aquaculture. With the increasing demand of aquaculture production, an increased pollution and impact on the environment is also observed. Pollution in aquaculture is attributed to nutritional, genetic, chemical as well as disease affliction and invasive species. Nutrient pollutions are uneaten feed pellets, feed fines and faecal material which accumulates below culture cages. And finally, diseases infecting fishes would affect the local marine ecosystem. Antibiotics, antiparasitic, fungicides, biologics, hormones, chemical solutions and compounds used for therapeutic control of diseases uncontrolled used leads to aquatic biodiversity toxicity, residue accumulation, microbial community selection for emergence of multi-antibacterial resistant strains and antibiotic resistance (Lulijwa et al., 2020).

#### **Aquatic Environment Additives**

Water additives are added to fish farms for several reasons including enhancing the growth of aqua organisms, providing nutrients as well as protection, prevention from diseases and finally, to provide a more natural environment to the animals (Flegel, 1998). Uncontrolled use of water additives affects the production capacity and water quality (Dauda et al., 2019). This may cause issues such as over-growth of algae and accumulation of inorganic elements that are toxic to aquatic animals and the environment. For instance, oxidation reaction between ammonium (derived from fish waste) and bacteria (derived from probiotics) will lead to accumulation of toxic substances such as nitrite ( $\text{NO}_2^-$ ) and nitrate ( $\text{NO}_3^-$ ) (Avnimelech, 1999). In addition, in 2014, an environmental pollution happened in Vietnam due to the overusing of inorganic chemicals in aquaculture (Bui et al., 2016).

#### **Climate Change**

Climate change is another challenge faced in the aquaculture sector, it causes significant mortalities among aquatic creatures such as fish, plants, corals, and mammals (Barange et al., 2018). High temperatures cause negative effects on the physiology of fish due to lowered ability to transport oxygen to tissues. In addition, growth of harmful algal due to infrastructure arising from extreme events such as floods could occur and an increased susceptibility to bacterial infections due to climate change is also a challenge (Cochrane et al., 2017).

#### **Bacterial Infection and Antimicrobial Resistance**

Bacterial infections in aquaculture causes billions of dollars lost per year due to pathogens; these include viral and parasitic infections. A common infection is the *Aeromonas hydrophila* which causes motile aeromonad septicaemia (MAS), a disease in fish that can spread with environmental contamination or direct contact with sick fish (Zmysłowska et al., 2009); the MAS disease leads to high rate in mortality and high economic losses.

Chryseobacteriosis, a skin syndrome affecting salmon, caused by *Chryseobacterium* species, is a fish spoilage agent and it is classified mainly as a freshwater disease (Pridgeon & Klesius, 2012). Infectious diseases are the major cause of the increased mortality rate in fish stock (Sudheesh et al., 2012). Disease outbreaks are also responsible for the loss of supplements during the farming process which increases economic losses (Bui et al., 2016). Major bacteria that can cause contamination to aquatic products are *Vibrio* species, *Nocardia*, *Aeromonas*, *Streptococcus*, *Flavobacterium*, *Yersinia*, *Edwardsiella*, *Lactococcus*, *Renibacterium*, and *Mycobacterium* (Granada et al., 2015, Sudheesh et al., 2012).

Antimicrobial resistance is one of the global public health issues for both humans or animals. The overuse of antimicrobial drugs in aquaculture will lead to the development of resistant microorganisms. For example, *Vibrio* isolated from a shrimp pond indicated its resistance to oxytetracycline (4.3% of the whole number of isolation) and furazolidone in (1.6% of the whole number of isolation) (Tendencia & de la Peña, 2001). In addition, *Salmonella* spp. showed resistance to several antibiotics such as oxalonic acid and oxytetracycline (Alcaide et al., 2005). Furthermore, in Iran, *E. coli* showed 100% resistance to gentamycin, ciprofloxacin, chloramphenicol, ampicillin and tetracycline (Tajbakhsh et al., 2015).

### Genetic Pollution

Aquaculture species that escape from farms have the potential to create major environmental problems; this is known as "Genetic pollution" (Grewe et al., 2007). These include establishment of potentially destructive feral populations and intro-aggression of foreign genes into natural populations from both genetically modified fish and hatchery-reared fish and invertebrates. The interbreeding of feral cultured fish and wild fish can have drastic genetic effects on local wild species. It may create new species with lower immunity against disease and parasites in the wilderness or create dominant fishes that will overrun the existing ones. This could pose a threatening condition to countries like ME which is surrounded by seven seas that could foresee a quick spreading of genetic pollution. These scenarios can be avoided by employing molecular engineering solutions that enables fish to be fertile under hatchery conditions and functionally sterile outside of captivity (Grewe et al., 2007).

### Aquaculture Technologies, Trainings and Education

Technologies in aquaculture have been reported to play an important function in delivering enhanced food security with a holistic approach that encompasses the complete value chain (Little & Bunting, 2016).

Surface-enhanced Raman scattering (SERS) is widely used for pathogen detection and has also been proven to be sensitive for trace chemical detection; a broad range of target including bio- and nonbiomaterials (DNA, metabolites, pesticides, and proteins) can be detected (Lu & Serajuddin, 2020). Another important aspect of aquaculture is disease prevention. Probiotics, for instance, have been used to improve immunity and enhance shrimp health. RNA interference (RNAi) is being tested by multiple emerging and established companies. Another promising innovation in tackling disease prevention is the

oral delivery of vaccines which is a boon in terms of efficiency and ease of use, and is suitable for all ages and sizes of fish. It reduces handling and damage to fish, can be used repetitively as fish mature and could prove to be less costly while yielding lower mortality rates.

The Marine environment Research Centre (MREC) with Ministry of Environment and Water, UAE have been focussing in aquaculture developments in ME. One of the main initiatives is re-stocking the waters with local species by producing fingerlings, such as white spotted spinefoot, orange spotted grouper, large scale mullet and sobaity sea bream (Jan-Dec, 2016). Besides this, in the UAE other developments such as 360,000m<sup>2</sup> fish reserve was allocated in the coast of Fujairah to encourage fishermen to adopt sustainable fishing methods (*Region's Largest Fish Reserve Launched*, 2013), a 56,000 m<sup>2</sup> Siberian caviar farm in Abu Dhabi which produces 700 tons of sturgeon meat and 35 tons of caviar per year (Towers, 2013), and a land based 500,000 m<sup>2</sup> salmon, grouper and sea bream RSA farm in Abu Dhabi (Churchill, 2014).

In terms of aquaculture development in Saudi Arabia 66.7 million Saudi riyals have been allocated to benefit small scale agriculture producers and fishermen in providing technical assistance and expertise in 17 initiatives and covers transfer of technology, sustainable management of natural resources, sustainable crop production, management of fisheries resources and strengthening of rural institutions (Towers, 2012).

In terms of aquaculture education and trainings in the ME, a shortage of experienced management and skilled aquaculture technicians have been reported. To date only the King Abdul Aziz University in Jeddah and King Faisal University in Al-Ahsa offers undergraduate aquaculture courses. Training and guidance have also been given by the Ministry of Agriculture and Water, and King Abdul Aziz City for Science and Technology in encouraging aquaculture development (Mubarak & Eide, 2009).

### Conclusion

ME countries rely largely on other countries to meet local feed and food requirements. The rising demands due to increasing population, combined with the need to reduce dependency on imports, have been adding to the potential for aquaculture these developing markets. However, there are main challenges such as pollutions, inadequate off-shore sites and limited expertise that need to be addressed. Moreover, technology can be used to overcome the challenges by reducing disease outbreaks or to enhance fish immunity. Aquaculture's future directions require refinement of present methods; technological developments are needed to increase in recirculating systems and aquaponic systems. These systems can then promote aquaculture to be practiced nearly everywhere, including marine species cultivation in places far from the coast.

### Acknowledgement

The authors are grateful to the Ministry of Climate Change & Environment UAE and to the Higher Colleges of Technology

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