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Mini Review

SUSTAINABILITY OF SHELLFISH AQUACULTURE IN MONTENEGRO-PERSPECTIVES

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Abstract

Shellfish for human consumption is produced in excess of 15 million tons per year, accounting for roughly 14% of global marine aquaculture, with China being the largest producer (89% of world production). However, in the previous two decades, shellfish output in the European Union has been dropping. This review provides information about shellfish aquaculture in Montenegro, in Boka Kotorska Bay, where most farms belong to the group of small farms. Shellfish production in this bay is constantly increasing. Thus, with minor deviations, the production of shellfish increased from 156 tonnes, as was produced in 2012, to 246 tonnes produced in 2020. However, despite the constant growth of production, statistical data indicate that every year a large amount of shellfish is imported, and there is a need for greater production in the country. The shellfish production capacity in Montenegro is still lower than expected, despite the great potential for development. Aquaculture's development potential is in the areas of increasing production, modernising existing farms, automating production, strengthening the competitiveness and efficiency of the sector, introducing new

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species, better linking aquaculture with tourism and processing, marine spatial planning, promoting aquaculture products and branding products.

Key Words: aquaculture, Montenegro, shellfish, production, sustainability

INTRODUCTION

The global growth of the human population has led to an increase in food production in order to meet the need for protein. This trend has been accompanied by increased production of seafood, which is recognised as an important solution for meeting the growing needs for high-quality protein in the future (Naylor et al. 2000). The Code of Conduct for Responsible Fisheries is a foundation document that establishes globally agreed principles and criteria for the use of fisheries and aquaculture resources. Global fish production reached around 179 million tonnes in 2018, according to FAO data (FAO, 2020), with 156 million tonnes used for human consumption (Delgrado et al., 2021). Aquaculture's average yearly growth rate is predicted to decline from 4.6% between 2007 and 2018 to 2.3% between 2019 and 2030. Shellfish for human consumption is produced in excess of 15 million tons per year, accounting for roughly 14% of global marine aquaculture, with China being the largest producer (89% of world production) (Wijsman et al., 2019). In contrast to global mussel aquaculture production, mussel production in the European Union (EU) has been declining for the past two decades. In 2016, aquaculture production of mussels in the EU fell by 20%, with illnesses, a lack of mussel seed (spat), and low profitability cited as the main factors (Avdelas et al., 2021). The Adriatic Sea's natural resources are used by several countries, among which is Montenegro.

PRODUCTION OF MARINE BIVALVES IN MONTENEGRO

Conditions of habitat

Montenegro is a Mediterranean country with a coastline of 294 km. Mariculture is executed in Boka Kotorska Bay at locations in three municipalities: Herceg Novi, Kotor and Tivat. From the geographical and oceanographic points of view, this bay is an enclosed pool, which differs significantly from the open part of the coast in terms of climatological, geomorphological, and physicochemical characteristics of the waters. The bay can be divided into Kotor-Risan, Tivat and Herceg Novi parts, and has a total surface area of 87.3 km^2 (0.06% of the Adriatic Sea), while the coastline within the bay is 105.7 km long and is located between 18°25' - 18°42' E longitude and 42°24' - 42°32' N latitude. The total volume of the bay is 2.4×10^6 m^3, and the average depth of the bay is 27.6 m (Bartoluzzi et al., 2016; Mandić et al., 2016). It is surrounded by mountain massifs, to the southeast by Lovćen Mountain (1749m), and to the northwest by the branches of the Orjen mountain range (1895m). The Adriatic Sea as a whole, including Boka Kotorska Bay, has moderately warm temperatures ranging from 12 to 25.2 °C (Mandić et al., 2016). A dynamic temperature regime is highly prominent in the bay, because it is a relatively narrow and shallow basin with a large inflow of freshwater. The months of November to April are a rainy part of the year, with enormous amounts of freshwater flowing into the bay. During this time, and in the tidal flows year round, the water flows at speeds of up to 45-50 cm/s. In the annual period of smaller inflow of freshwater, the water has an exit direction, and speeds range from 12-17 cm/s. In addition, it is estimated that 5×10^6 m^3 of wastewater per year is introduced into the bay, which has a huge impact on the ecology of the sea and its inhabitants. Freshwater inflows into the bay vary, and they also carry considerable amounts of suspended particles that alter marine environmental conditions (Grković et al. 2017).

Unfortunately, mostly due to anthropogenic influence, water resources worldwide are disturbed and degraded and today are often limited. Chemical pollution is now a problem for many aquatic ecosystems. In order to determine the quality of saltwater for mussel *(Mytilus galloprovincialis*) farming, the concentrations of heavy and trace metals, and their accumulation levels in mussels, are verified. There have not been many investigations on water pollution along the Montenegrin coastline areas. Jović et al. (2011) used metal and non-metal concentrations in *M. galloprovincialis* as indicators of pollution levels in Boka Kotorska Bay, and when compared to the data from other sources, the mussels from the bay contained a moderate level of pollution. In another study, mussel soft tissue was analysed for zinc, copper, lead, cadmium, arsenic and total mercury (Stanković et al., 2011). The metals were discovered in the mussels at various concentrations, but not at levels above the maximum residue levels set by EU and US Food and Drug Administration (US FDA) seafood rules (Stanković et al., 2011). A group of Italian scientists indicated that microplastics, including microfibers, can be accumulated by marine biota and could pose a risk to food safety and human health (Santonicola et al., 2021). The preliminary findings of an investigation into potential plastic microfiber contamination in mussels and anchovies (*Engraulis encrasicolus*) from part of the Mediterranean Sea off the western coast of Italy revealed that potential plastic and natural microfibers were present in 73% of the samples. To properly assess the risk that microplastics, especially microfibers, pose to food safety and human health, more research is needed. It would be interesting to examine this type of contamination in the Adriatic Sea in Montenegro. De Silva et al. (2021) applied and proposed a combined approach for marine environment pollution monitoring, which provides insight into the trace metals and nylon filaments in mussels and other seafood from the Montenegrin coast.

Production

Production of marine bivalves in Montenegro takes place in Boka Kotorska Bay, where most farms belong to the group of small farms. There are 23 registered shellfish farms, of which 14 grow only mussels *(M. galloprovincialis*), while the other 9 grow mussels and oysters (*Ostrea edulis)* (MONSTAT, 2020). Shellfish farming is carried out according to the system of floating parks. The buoys are placed at a distance of 3.5 m from each other and connected with a double line of ropes, and the ends are connected. The number of anchorages depends on the length of the line, the strength of the winds, the flow of seawater and the wave action in the micro-locality, and at least three are placed (two of 1000 kg at the ends and one of 500 kg in the middle of the line). Mussel seed is collected directly on the farm, using collectors that are placed on the breeding lines. There are no imports of mussel seed to Montenegro in the whole process of shellfish farming. Oysters are grown on the same breeding structures, but with slightly different technology. The breeding process, from the reception of the seed to mussel consumption, is on average 18 months, while in oysters this period is somewhat longer (average of 24-30 months).

The biggest investments in shellfish production are the installation (setting up) of the farm, and the purchase of equipment. Based on the scientific assessment of the Institute of Marine Biology (2020), a farm with an area of one hectare could produce 12 to a maximum of 20 tons of mussels per year. However, by statistical processing of data for 2019, the average production from Montenegrin farms was 10 tons per farm (MONSTAT, 2019). Of the total amount of farmed shellfish, the largest part is mussels, and the smallest share is oysters. In the period 2014-2020, mussels constituted the largest share of mariculture (60.6%), while oysters made up the smallest share (3.2%). In 2020, 229 tonnes of mussels and 17 tonnes of oysters were produced. Shellfish production is constantly rising in Montenegro (MONSTAT, 2020). Thus, with minor deviations, shellfish production increased from 156 tonnes, as was produced in 2012, to 246 tonnes produced in 2020. However, despite the constant growth of production, statistical data show that every year a large amount of shellfish is imported, and there is a need for greater production in the country. Shellfish production is greatly affected by each system's production capacity and by market demand. Although market demand has increased, production in Montenegro can be limited by insufficient production system capacity.

The mussels produced in Montenegro were found to be of satisfactory quality, but there were significant differences in the biochemical composition of mussels from different farming locations (Grković et al., 2020). Qualitative sensory evaluation revealed that all mussels scored 3 or higher out of 5, indicating that they were satisfactory. Fatty acid profiles show high contents of n-3 PUFA and high n-3/n-6 ratios (Grković et al., 2020).

Food safety risks and legislation

The food safety risks associated with farmed shellfish in Montenegro have also been insufficiently researched. In terms of food safety and public health, norovirus (NoV) is one of the most common causes of gastroenteritis epidemics and sporadic cases around the world, linked to the consumption of shellfish contaminated with faecal pollution (Campos and Lees, 2014, Koopmans and Duizer, 2004). The main danger is associated with the consumption of raw or undercooked shellfish. Ilic et al. (2017)

examined the presence of norovirus in mussels aquacultured in Boka Kotorska Bay, and molecular genetic techniques were used to investigate the relationship between the presence of the virus and the number of *E. coli* in mussels, as well as the influence of physico-chemical variables on virus presence. Norovirus was detected in 31 (43%) of the samples, with genotype GII positive samples (54.8%) being substantially more common than genotype GI positive samples (12.9%). In ten (32.3%) of the samples, norovirus of both genogroups (GI + GII) was detected. All GI positive samples were assigned to genotype GI.2, 12 GII positive samples were assigned to genotype GII.4, and 1 GII sample was assigned to genotype GII.2. Phylogenetic analysis revealed a genetic relationship between the norovirus isolates examined and those previously identified in other investigations. Hu/GII.4/sydney/NSW05, the most widely circulating pandemic strain, was found in two shellfish samples assigned to genotype GII.4. There was no link discovered between the virus's presence in shellfish and the microbiological characteristics of saltwater. The norovirus level showed seasonal fluctuation, with the maximum number of positive samples detected during the winter months (December, January and February). The presence of the virus in mussels grew dramatically as the sea temperature dropped, whereas other physico-chemical parameters of the sea water (pH, salinity, oxygen saturation) and variation of phytoplankton and chlorophyll *a* concentrations had no effect on the occurrence of norovirus in the mussels. The findings of this study highlighted the possible risk of foodborne viral illnesses and the need to establish a monitoring plan for the presence of norovirus in mussels; veterinary pubic health measures should be improved. Sewer overflows, which gather sewerage water and discharge crude, untreated sewage into the environment, provide the greatest risk of contamination for all pathogens that could potentially be present in seawater. Control strategies for contamination in mussels, according to Grković et al. (2017), should focus on limiting sewage contamination. The first step in controlling virus contamination is to prevent and control sewage discharges and wastewater from spilling into shellfish farms (Koo et al., 2010).

According to Fonti et al. (2021) the Mediterranean Sea continues to absorb untreated urban effluent. The problem with wastewater treatment plants that conduct only primary sewage treatment is that they are inefficient in removing microorganisms (pathogens, faecal indicator bacteria) and mobile genetic elements. Maravić et al. (2013) showed a significant percentage of *Aeromonas* isolates in wild mussels from the Croatian Adriatic coast were multi-drug resistant and that *Aeromonas* can be considered a reservoir for the dissemination of different resistance genes.

The genus *Vibrio* is one of the most common bacteria found in the ocean and vibriosis is regularly linked to oyster mortality and has the potential to cause severe epizootics in hatcheries. Many *Vibrio* species are known human pathogens and have been linked to gastrointestinal infection epidemics from seafood (Kapetanović et al., 2013). *Vibrio crassostreae* is notably common in diseased animals but almost absent in the surrounding water, according to Bruto et al. (2017), and its pathogenicity is linked to the presence of a large mobilisable plasmid.

Aside from biological hazards, research on various chemical hazards in shellfish can provide information on amounts of metal in marine creatures consumed by humans. Grkovic et al. (2021) studied the concentration of toxic elements in mussels aquacultured in Montenegro and revealed that moderate quantities of mussels from the examined area should be safe for consumption. Perošević-Bajčeta et al. (2021) corroborated that for Boka Kotorska Bay, average concentrations of most elements have decreased over time, but the results of De Simone et al. (2021) showed that mussels from the location nearest to a dense urban settlement were characterised by the highest content of pollutants (microplastics, textile fibres, titanium dioxide microparticles) originating from anthropogenic sources. On the contrary, in farmed mussels from the locations with probably higher phytoplankton abundance, higher carotenoid content was found. According to Drakulović et al. (2012, 2017), Boka Kotorska Bay is home to roughly ten poisonous and potentially harmful phytoplankton species. In order increase the reliability of shellfish species as healthy foods and to stimulate consumer demand, attention should be paid through appropriate monitoring programs to environmental pollutants and biotoxins, which are also very important for food safety and achieving sustainable shellfish production (Kvrgić et al., 2021, Wijsman et al., 2019).

In Montenegro, marine shellfish production legislation is fully harmonised with the relevant EU legislation, and is based on using levels of faecal indicator organisms to determine the classification of a production area, and to determine the appropriate treatment required in a growing area throughout the production cycle and for the end product (European Union, 2004). The European Food Safety Authority's Panel on Biological Hazards has also decided to ban shellfish (mollusc) growth and harvesting in locations contaminated by faeces. The occurrence of *E. coli* was determined in mussel samples collected from Boka Kotorska Bay, and the results classified 68,3% of samples in Class A areas, 31.3% in Class B areas, and 0.4% of samples in Class C areas (Grkovic et al., 2021). In Montenegro, four establishments are registered as dispatch centres for shellfish and among them, two are also registered as shellfish purification centres.

Perspectives

In order for production to be sustainable, it is necessary that there is a market for the appropriate product, that resources are not wasted and become unavailable, and that the product does not accumulate to the extent that it slows down production (Broom, 2021).

The National Fisheries Strategy of Montenegro aims to establish a sustainable aquaculture sector by modernising current farms in order to boost production and improve the sector's competitiveness and efficiency while adhering to high environmental and animal health and welfare standards (MARD, 2015). In order to achieve the goal of increasing production in aquaculture, Montenegro plans to co-finance projects for equipping and modernising existing farms and accompanying infrastructure, as well as for providing additional capacity for seed production. In addition to species that are already bred (mussels, oysters), the production of other species that have not been recorded in Montenegrin farms so far, especially indigenous species, will be favoured. Positive trends in mariculture in the country include an increase in the interest of potential breeders in breeding in open seas, as well as an increase in the production of shellfish (primarily mussels). Negative trends in Montenegrin mariculture are considered to be: small quantities of farmed fish in relation to the estimated capacity of the farms, the small number of farmed fish species and other aquatic organisms, insufficient fish processing capacity, and the finite, now filled, capacity for fish farming in Boka Kotorska Bay. As an expected result of this strategy, the growth of shellfish farming and stagnation of fish farming is expected. Also, shellfish monitoring programs should be introduced in Montenegro, as well as measures to control oyster diseases caused by Ostreid herpesvirus OsHV-1 μvar, based on the Commission Regulation adopted in 2010. This EU law recognises the risk from this virus, which is associated with enormous mortality in oysters, and aims to prevent the virus from spreading to uninfected areas.

CONCLUSION

Mariculture production capacities in Montenegro remain at a lower level than expected, despite the great potential for development. Development potential for aquaculture includes increasing production, modernising existing farms, automating production, strengthening the competitiveness and efficiency of the sector, introducing new species, better linking of aquaculture with tourism and processing, spatial planning of offshore marine sites, promoting aquaculture products and branding products.

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Authors' contributions

MD, IZB, NG and KA: Conceptualization, writing. ZP and DL: review and editing. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare that they have no competing interests.

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ODRŽIVA PROIZVODNJA ŠKOLJKI U CRNOJ GORI – PERSPEKTIVE

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Kratak sadržaj

Globalna proizvodnja školjki za ishranu ljudi iznosi više od 15 miliona tona godišnje, što je oko 14% ukupne morske akvakulture u svetu, pri čemu je Kina najveći proivođač (89% svetske proizvodnje). Međutim, proizvodnja školjki u Evropskoj Uniji (EU) pokazuje opadajući trend u poslednje dve decenije. Ovaj rad daje informaciju o uzgoju školjki u Crnoj Gori, koji se obavlja u Bokokotorskom zalivu, gde sva uzgajališta pripadaju grupi malih uzgajališta. Može se zaključiti da je obim proizvodnje školjki u stalnom porastu. Tako je, uz manja odstupanja, proizvodnja školjki rasla od 156 t, koliko je bilo proizvedeno 2012, do 246 t proizvedenih 2020. godine. Ipak, i pored stalnog rasta proizvodnje, statistički podaci ukazuju da se svake godine ipak uveze velika količina školjki, te da postoji prostor, kao i potreba za unapređenjem proizvodnje. Kapacitet proizvodnje školjki u Crnoj Gori i dalje je na nivou nižem od očekivanog uprkos velikom potencijalu za razvoj. Razvojni potencijali akvakulture moraju uključivati povećanje proizvodnje, modernizaciju postojećih farmi i automatizaciju proizvodnje, jačanje konkurentnosti i efikasnosti sektora, uvođenje novih vrsta u uzgoj, bolje povezivanje akvakulture sa turizmom i preradom, prostorno planiranje morskih lokacija na moru, promociju proizvoda akvakulture i brendiranje proizvoda.

Ključne reči: akvakultura, Crna Gora, školjke, proizvodnja, održivost