Mar. Sci. Tech. Bull. 2013 2(1):9-13

MARINE SCIENCE AND TECHNOLOGY BULLETIN

Floating Fish Farm Unit (3FU). Is it an appropriate method fro salmonid production?

Soner Bilen[1]*, Volkan Kizak[2], Asli Muge Bilen[1]

[1]Kastamonu University, Fisheries Faculty, 37200, Kastamonu, Turkey
[2]Tunceli University, Fisheries Faculty, 6200, Tunceli, Turkey

ARTICLE INFO

Article history:

Received: 18.02.2013
Received in revised form: 19.04.2013
Accepted : 25.04.2013
Available online : 23.07.2013

Keywords:

Fish culture
Ship
Rainbow trout
Salmon
Floating fish farm unit

ABSTRACT

Off-shore aquaculture has become an important issue nowadays because of environmental sensitivities and rising conflicts between coastal zone users. From this point of view, a Turkish company has converted a ship into a fish farm in order to gain benefit from the open seas. A 19030 dead weight ton freight ship was transformed into an integrated fish farm to produce salmonids. A 60 m long suction pipe with 1 m diameter, was used for sea water intake from a desirable depth. Sea water was pumped into the fish culture tanks by using 5 pumps each with a capacity of 2500 m^3h^{-1}. Pure oxygen generated from an oxygen generator was added to seawater through diffusers for increasing stocking density by means of raised dissolved oxygen of culture media. In this floating fish farm, the initial average weight of Rainbow trout (*Oncorhynchus mykiss*) was 25±2.7 g. The trout reached 3.7±0.4 kg at the end of 11 months during the production on board. Feed conversion ratio, specific growth rate and stocking density were 1.1±0.1, 1.51±0.3 and 101±2.1 kg m^{-3}, respectively. As a result of the study, trout production on a vessel that enables the use of water from different depth and regulate the water temperature and salinity according to the optimum levels of fish requirements. However, the high costs of crew and energy should be taken into consideration in terms of sustainability of efficient production.

Introduction

Aquaculture is the fastest growing sector in the world, and the reported global production of food fish from aquaculture, including finfishes, crustaceans, mollusks and other aquatic animals for human consumption, reached 63.6 million tonnes in 2011 (FAO, 2012). Hundreds of different species of finfish are farmed globally in a variety of culture environments and production systems (Ayer and Tyedmers, 2009). Atlantic salmon and rainbow trout culture, which currently produces more than 1.5 million tons and 0.7 million tons of fish per year, respectively in the world have a big potential (FAO, 2012).

In Turkey, the culture of salmon has been challenged in the Black Sea in 1992-1995, however due to the high surface water temperatures in the summer period, fish could not survive these conditions. A 3-4 years of trial was conducted in floating traditional fish cages in the Black Sea, however, it has been found that salmon need to stay in the sea for at least one summer in order to catch the fast growing period in the following year to reach a large-economic size. However fish farmers decided to raise trout in the Black Sea instead of salmon. Because, rainbow trout could grow fast during the first year when they were transferred introduced into the sea (Yigit et al., 2006). That's why, rainbow trout has been introduced as a promising species for the cage aquaculture industry in the Black Sea. Today, the production amounts of rainbow trout are more than 100239 tones in inland water and 7967 tones in marine water (TUIK, 2012). Turkey has a big potential on salmonid culture in marine environment in the Black Sea and the Sea of Marmara. Even though the high water temperatures at the surface during the summer period is a limiting factor that inhibit production of salmon in the Black Sea, rainbow trout has been reported to grow 3 to 4

*Corresponding author
E-mail address: sbilen@kastamonu.edu.tr (S. Bilen)
Tel:+90 366 280 23 00 fax: +90 366 215 55 93

times to that of their contemporaries in fresh-water farms (Teskeredžić et al., 1989; Yigit and Aral 1999). Besides the present production of trout in the Turkish seas, innovative culture systems and new applications might be used to successfully introduce salmon in to the aquaculture industry in the Black Sea.

The commercial culturing of fish in cages has expanded significantly in the past 30 years. While most of this development has been with salmonid species, there is still extensive worldwide variety of cage culture species and culture conditions. Trends are toward to larger individual cages and more expanded sites. Many interactive site, species, environmental, engineering, economic and operational factors must be considered during the cage system design process (Huguenin et al., 1997). Submerging salmon cages have been also experienced in some researches (Ablett et al., 1989, Korsøen et al., 2012), however, the cages may result in periods where fish are negatively buoyant, possibly affecting behavior and growth (Ablett et al., 1989). Due to these problems, submerging salmonid cages do not constitute solution in the long summer period.

Negative environmental effects of fish culture in cages are another problem. The environmental impact of marine fish-farming depends on species, culture method, stocking density, feed type, hydrography of the site and husbandry practices, and in general, there happens a waste exposure from fish culture into marine environment around 85% of phosphorus, 80–88% of carbon and 52–95% of nitrogen through feed wastage, fish excretion, faeces production and respiration (Wu, 2000). However, particular concern has been raised about the environmental impacts of farming carnivorous finfish such as salmon. Salmon farming is conducted almost exclusively in marine net-pens, and a number of environmental impacts have been attributed to this form of aquaculture. An important future environment for aquaculture expansion is the sea, particularly offshore waters. Still in many parts of the world, coastal waters, enclosed bays and inlets etc. are utilized but the cost of open water development is currently prohibitive in most instances. However, Turkish aquaculture has already moved offshore based on a new environmental legislation that has been set in year 2006. Despite the difficulties in operating fish farms under offshore conditions, the Turkish aquaculture industry has improved its annual production. We, therefore, need innovative solutions by using technology to improve aquaculture operations in terms of sustainability. Using technology in aquaculture might help us optimizing the culture conditions as well.

The production of salmonids on a ship can be considered as an innovative approach to sustainable and environment friendly aquaculture operation, which also optimize the culture conditions, and potentially improve the economic benefits.

All these conditions have brought the idea to practice salmon culture on a vessel and so was the Floating Fish Farming Unit (3FU) taken off into the Sea. This work also demonstrates the feasibility of rainbow trout and Atlantic salmon culture in Turkey's seas, opening up the possibility for developing a new technology of aquaculture. For this purpose, a 19030 Kt DWT dry cargo ship was converted to a fish farm by Denizsan Shipping Company, and the advantages and disadvantages of the new method in terms of salmonid culture were discussed in the study.

Material and methods

The ship

A 19030 Kt DWT freight ship with a 154.33 m length, 22.80 m breadth and 12.5 m depth was bought in order to transform into an integrated fish farm (Figure 1). The all dry cargos of the ship used in the research were repaired and made a new modification of all members on the slipway, and were transformed into fish tanks in UM shipyard, Izmit-Turkey.

Figure 1. The dry cargo ship (19030 Kt DWT), converted to a fish farm

A fish processing unit was also built on the forepeak (Figure 2).

Figure 2. Fish processing unit.

Oxygen Systems

For the enrichment in dissolved oxygen of the water, OxyMat O-800 oxygen generator was used (Figure 3). High purity oxygen was added to tank water using Akuamaks oxygen diffusers (30 cm). Oxygen levels in the tanks were maintained by PLC (Programmable Logical Control), and Ebro-valves were used to control oxygen levels in the tanks.

Figure 3. Oxygen system of the ship (Oxygen generators, air filters, air compressors, air dryer, Ebro valves)

Water Suction and Discharge

Two different methods were used to pump the water into the fish tanks (Figure 4). First of all, a suction pipe with a length of 60 m and a diameter of 1 m was used to transfer water at optimum temperature from desired depth into the tanks. Secondly, at the periods when the water temperature on the surface was optimum the pumping was done through sea chest (kinistin). The water soaked from suction pipe by three vacuum compressors was transferred to tanks using 5 circulation pumps (2500 L h^{-1}) after transferred to deck head. At the time when water was pumped directly from water chest, there was no extra operation as the entrance of water chest valve is 8 meters below the sea level. All of the circulation pumps were not used at that moment. The number of circulation pumps was determined operationally depending on desired water amount.

Figure 4. Water circulation system (Suction pipe, vacuum compressors, sea chest valves, circulation pumps, brower valves)

Tanks

The tanks were painted with special Hempel epoxy paints, and each of them had own feeding, oxygen, inflow and outflow pipes separately, lighting and probes to detect the temperature, pH level, water level and circulation speed. Tank volumes are given in Table 1, and water inlet and outlet systems are shown in Figure 5.

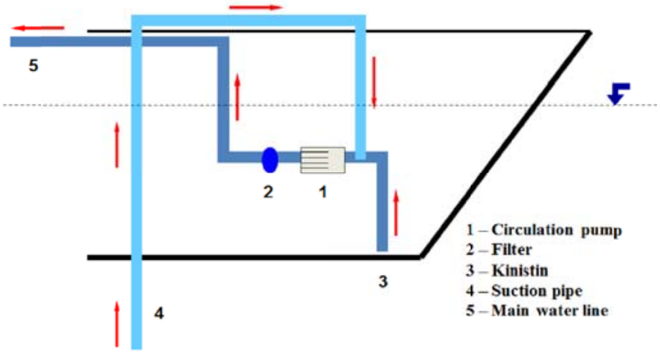

Figure 5. A schematic view of the water circulation system

Energy

Two different types of electrical generator were used on the ship (Figure 6). One of them was YANMAR mark. It was completed from three similar generators to generate electricity for ship and the other generator was CJ700P Perkins with 708 kW. The second generator was used for the circulation pumps and oxygen generators, and also other aquaculture equipments.

Figure 6. Generators.

Table 1. Fish culture tanks and their capacities.

Tank No	1	2	3	4	5	6	7	8	9	10	11	12
Capacity (m^3)	222	298.4	444.73	586.5	1773.44	1773.44	1723.44	2300.15	2898.43	3445.08	1899.52	996.83

Feeding Systems

Feeding was operated automatically using ARENA baiting system and program. Six different silos with 40 tones capacity were produced to stock baits (Figure 7).

Figure 7. Feed silos and automatic feeding systems.

Computer systems

A PLC (Programmable Logical Control) was used on the ship. All water quality parameters, tank water flows, growth factors and feeding were operated by PLC. According to systems, Ebro valves were used for each tank to keep water oxygen level well, and brower valves were used to control water flow into tanks. Oxygen, CO_2 and pH levels were operated by PLC using different probes.

Fish

The fish used in the trial was provided from Filiz Aquaculture Co. (Filiz Su Ürünleri Ltd.), Kırklareli-Turkey, with a batch of Troutlodge Inc. strain rainbow trout. The rainbow trout was reached up to 25±2.7 g in concrete raceways and then transported to the ship.

Food

During the research, a commercial trout feed with a dietary protein level of 42 % and a dietary lipid level of 18 % was used.

Growth Parameters

Feed conversion ratio (FCR) based on the harvest weight (Einen, 1998) was calculated as kg feed delivered divided by the biomass increase for each treatment during the experiment. Specific growth rate (SGR, % day^{-1}) was calculated as SGR= $(\ln(W_2)-\ln(W_1))$ 100 $(t_2-t_1)^{-1}$, where W_2 and W_1 are the wet body weights at day 330 $((t_2-t_1))$.

Operation

A suction pipe with a length of 60 m and a diameter of 1 m was used for water intake. Theoretically, the suction pipe can reach a depth up to 60 m, depending the depth of appropriate sea water. Under normal conditions sea chest was used for water circulation from 8 m depth. Water was transferred to tank by water system as shown in Figure 5. Ebro valves were used for oxygenation and Brower valves were used for water flow.

Results and Conclusion

In this research, we have tried to investigate the feasibility of salmonid culture in a floating fish farm unit. At the beginning of the trial, rainbow trout with an average weight of 25±2.7 g were stocked and reached a final weight of 3.7±0.4 kg after a 11 months feeding period. SGR was found as 1.51±0.3 and FCR was recorded as 1.1. According to results obtained, Floating Fish Farming Unit has been demonstrated as a promising method for fish farming under certain environmental conditions without major loss of growth or compromising the welfare of trout. However, some problems have been experienced during the field work operations. . These problems were especially caused by mechanical breakdown of water suction systems and oxygen generator, and all these problems were related to mechanical applications.

Problems that should be solved can be summarized as follow:

1) huge diesel consumption,
2) lack of well experienced crew,
3) unexpected new system problems.

Energy consumption, crew expenses and heavy weather conditions for sailing caused several problems need to be addressed. The high cost of energy usage, irregular supply and the need of infrastructure and labor for mass production were the main obstacles. Another problem of producing rainbow trout on the ship is the necessity of employing well experienced crew. The crew creates extra costs different from other producing systems. Also, conflicts emerged between the crew and aquaculture engineers at the stage of determining responsibilities and duties during production. According to our knowledge, it was the first salmonid production on a ship in the world. As there is no other previous attempts, some unexpected problems have been faced during fish transfer from inland trout farm to the vessel and also between the tanks, fish processing, and harvest.

In many countries there is an increasing public and planning resistance to placing of cages in inshore locations primarily because of their impact on visual amenity. Additionally it is well known that fish perform much better in offshore sites where the water exchange is invariably greater. Similar to the new environmental legislations started in 2006 in Turkey, cage farming operations in the world may need to be moved to offshore sites. It is essential for Salmonid production to remove limitations at the production period resulting from seasonal reasons in waters of Turkey such as high temperature and provide optimum water conditions to extend the production to whole year. The use of traditional gravity cages limits the production of salmonids to 7-8 month in the year. Submergible cages could be a solution to extend the production to the entire year, however, operational problems are also the case for submersible cage systems. Overall, considering that the cost of crew members and energy supply on the ship can be reduced, fish farming on a vessel seems to be a promising innovative approach for salmonid culture.

Acknowledgements

We would like to thank Mr. Murat MENGENECIOĞLU from Denizsan Denizcilik Co. and workers of the company for their valuable help during the work on the ship.

References

Ayer, N.W. and P.H., Tyedmers. 2009. Assessing alternative aquaculture technologies: life cycle assessment of salmonid culture systems in Canada. Journal of Cleaner Production, **17** (3): 362–373.

Ablett, R.F., C.R. Marr, and J.D., Roberts. 1989. Influence of chronic subsurface retention on swimming activity of Atlantic salmon (*Salmo salar*) in cold temperate conditions. Aquac. Eng., **8**: 1–13.

Einen, O. 1998. Product quality in Atlantic salmon — influence of dietary fat level, feed ration and starvation before slaughter. Doctor Scientiarum Theses, Norges landbrukshøgskole, Ås, Norway.

Food and Agriculture Organization (FAO). 2012. p. 230.The State Of World Fisheries and Aquaculture. FAO, Rome (2010) Fisheries Technical Paper.

Huguenin, J.E. 1997. The design, operations and economics of cageculture systems. Aquacultural Engineering, **16** (3): 167–203.

Korsøen, O.J., T. Dempster, F. Oppedal, and T.S., Kristiansen. 2012. Individual variation in swimming depth and growth in Atlantic salmon (*Salmo salar* L.) subjected to submergence in sea-cages. Aquaculture, **334**: 142-151.

Teskeredžić, E., Z. Teskeredžić, M. Tomec, and Z. Modrušan. 1989. A comparison of the growth performance of rainbow trout (*Salmo gairdneri*) in fresh and brackish water in Yugoslavia. Aquaculture, **77** (1): 1–10.

TUIK. 2012. p. 71. Fishery Statistics. Turkish Statistical Institute.

Wu, R.S.S. 2000. The environmental impact of marine fish culture: Towards a sustainable future. Marine Pollution Bulletin, **31** (4–12): 159–166.

Yiğit, M. ve O. Aral. 1999. Gökkuşağı Alabalığının (*Oncorhynchus mykiss* W.,1792) Tatlısu ve Denizsuyundaki Büyüme Farklılıklarının Karşılaştırılması (A Comparison of the Growth Differences of Rainbow Trout (*Oncorhynchus mykiss* W.,1792) in Freshwater and Seawater-The Black Sea). Turk. J. Vet. Anim. Sci., **23**: 53-59.

Yiğit M., E. Güven and S. Özesen Çolak. 2006. Karadeniz'de Ağ Kafeslerde Balık Yetiştiriciliğinin Gelişimi ve Karşılaşılan Sorunlar (Developments and Problems of Cage Aquaculture in the Black Sea). Su Ürünleri Mühendisleri Derneği Dergisi, **25-26**: 33-39.