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The Success of Freshwater Aquaculture Program: Nile Tilapia or "Nila" Culture In Indonesia

Keberhasilan Program Budidaya Perikanan Air Tawar: Budidaya Ikan Nila di Indonesia

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ABSTRACT

This paper discusses the current status of tilapia aquaculture production, historical development based on the production growth, technological advances in genetic improvement and culture system, trade and product development, strategies, and policies in maintaining and improving national production. All data and information used in this manuscript were collected from available publications relating to the past and present status of tilapia cultivation in the country. Nowadays, Indonesia is the second-largest tilapia producer in the world with the contribution of about 25.89% to tilapia global production. In Indonesia, tilapia is the largest production among other cultured species. The annual growth production of tilapia is inccread 11.61% from 2011 to 2018. West Java Provinceis the largest tilapia producer followed by West Sumatra, South Sumatra, and Central Java. In the last six years, most of tilapia production comes from pond culture followed by floating cages, net cages, paddy fields, and pen culture. The success of tilapia culture is much influenced by technological improve in grow-out and genetic improvement of the local varieties. A side of that, trading and global market oriented are also established with various acceptable products. Tilapia aquaculture in Indonesia shows the succsess story of freshwater aquaculture program from nothing before 1990 to be something at present time. To maintain and increase the future production of tilapia, it needs strategies and policies in production and trade. The tilapia program maybe used as a role model for another economic improrant freshwater species in Indonesia.

Keywords: Tilapia, Aquaculture, Freshwater, Indonesia

ABSTRAK

Makalah ini membahas status produksi perikanan budidaya nila saat ini, perkembangan historis berdasarkan pertumbuhan produksi, kemajuan teknologi perbaikan genetik dan sistem budi daya, perdagangan dan pengembangan produk, strategi dan kebijakan dalam mempertahankan dan meningkatkan produksi nasional. Semua data dan informasi yang digunakan dalam naskah ini dikumpulkan dari publikasi yang tersedia yang berkaitan dengan status budidaya ikan nila di Indonesia di masa lalu dan sekarang. Saat ini,

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Indonesia merupakan produsen ikan nila terbesar kedua di dunia dengan kontribusi sekitar 25,89% terhadap produksi ikan nila dunia. Di Indonesia, ikan nila merupakan produksi terbesar di antara spesies budidaya lainnya. Pertumbuhan produksi ikan nila setiap tahunnya mencapai 11,61% dari tahun 2011 hingga 2018. Provinsi Jawa Barat merupakan penghasil ikan nila terbesar, diikuti oleh Sumatera Barat, Sumatera Selatan, dan Jawa Tengah. Dalam enam tahun terakhir, sebagian besar produksi ikan nila berasal dari budidaya di kolam, diikuti oleh keramba apung, keramba jaring apung, sawah, dan karamba. Keberhasilan budidaya ikan nila banyak dipengaruhi oleh kemajuan teknologi pembesaran dan perbaikan genetik varietas lokal. Selain itu, perdagangan dan orientasi pasar global juga dibangun dengan berbagai produk yang dapat diterima. Budidaya ikan nila di Indonesia menunjukkan kisah sukses program budidaya ikan air tawar dari yang tidak ada sama sekali sebelum tahun 1990 menjadi sesuatu yang besar saat ini. Untuk mempertahankan dan meningkatkan produksi ikan nila di masa depan, diperlukan strategi dan kebijakan dalam produksi dan perdagangan. Program ikan nila dapat digunakan sebagai contoh untuk spesies air tawar lain yang penting secara ekonomi di Indonesia.

Kata kunci: Ikan Nila, Akuakultur, Air Tawar, Indonesia

INTRODUCTION

Indonesia is the second-largest producer of Nile tilapia (*Oreochromis niloticus*) in the world after China, with total production of 1,171,698 tons in 2018 (FAO, 2020) representing an estimate of 25 percent of the country's total national aquaculture production. This species is also the second rank below seaweed in Indonesian aquaculture production and number one among other finfish species. Originally, Nile tilapias is a native species to Africa, but it has been successfully introduced to more than 140 countries both in tropical and subtropical regions (El-Sayed, 2019). It was first introduced to Indonesia in 1969 from Taiwan (Gustiano *et al*., 2008). There after, several strains were also introduced from Thailand (Chitralada and Red NIFI) in 1989, Philippines (GIFT) in 1994, and Japan (JICA) in 2002. In 2016, fourteen new developed local strain have been officially released to support the national production of Nile tilapia. Nile tilapia which is locally known as "Nila" now has been widely cultured in most regions. Nila has became the main freshwater aquaculture commodity in the country due to its ease of maintenance and relatively fast growth. The main production areas for nila are in West Java and West Sumatra (MMAF, 2020). In the last six years, most of nila production comes from pond culture followed by floating cages, net cages, paddy fields, and pen culture. The success of nila culture is much influenced by technological improve in breeding, grow-out and genetic improvement of the local varieties. In the aquaculture development policy for 2020-2024, nila is included in 12 priority commodities, where the planned target for nila culture is to increase from 1.6 million tonnes in 2020 to be 2,245 million tonness in 2024 (DGA, 2020).

The large population of Indonesia and the government's efforts to increase protein per capita, 56.39 kg/capita in 2020, is strongly supported nila culture. Apart from the domestic market, it is also projected to be export-oriented one. Currently, various export products have been developed with almost 70% of its products in 2018 for the USA market. This paper discusses the current status of tilapia aquaculture, historical development based on the production growth, technological advances in genetic improvement and culture system, trade and product development, strategies, and policies in maintaining and improving national production.

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MATHERIAL AND METHODS

Literature study has been carried out in preparing the manuscript. All collected data and information based on available publications regarding to the past and present status of tilapia cultivation in the country were used in analyses. The data and information obtained were then used to explain the obstacles faced, strategies for increasing and maintaining national production, as well as strategies for increasing and maintaining national production. Along with the latest technological advances, analysis to see the feasibility of implementing is also considered to decide or propose strategies related to the challenges, obstacles, and problems faced.

RESULT AND DISCUSSION

The current status of nila or tilapia aquaculture in Indonesia concerning production, history, genetic improvement, cultivation techniques, and trade will be discussed below. Based on this description, the constraints of the challenge will be synthesized to determine a strategy for increasing and maintaining national production.

A. Production

The culture of tilapia provides an excellent model for the success story of a group of fish species cultured outside its natural distribution. The world production of tilapia aquaculture has increased year by year from 2.35 million tonnes in 2010 to 4.52 million tonnes in 2018 (Figure 1) which accounts for nearly 6% of total world aquaculture production. Tilapia currently is the third-largest cultured species produced in the world aquaculture. The main producers of tilapia aquaculture are mostly from Asia regions, and Indonesia contributes about 25.89% to tilapia world's production in 2018 (Table 1). However, it is important to note that tilapia aquaculture in Africa and South America is also increasing.

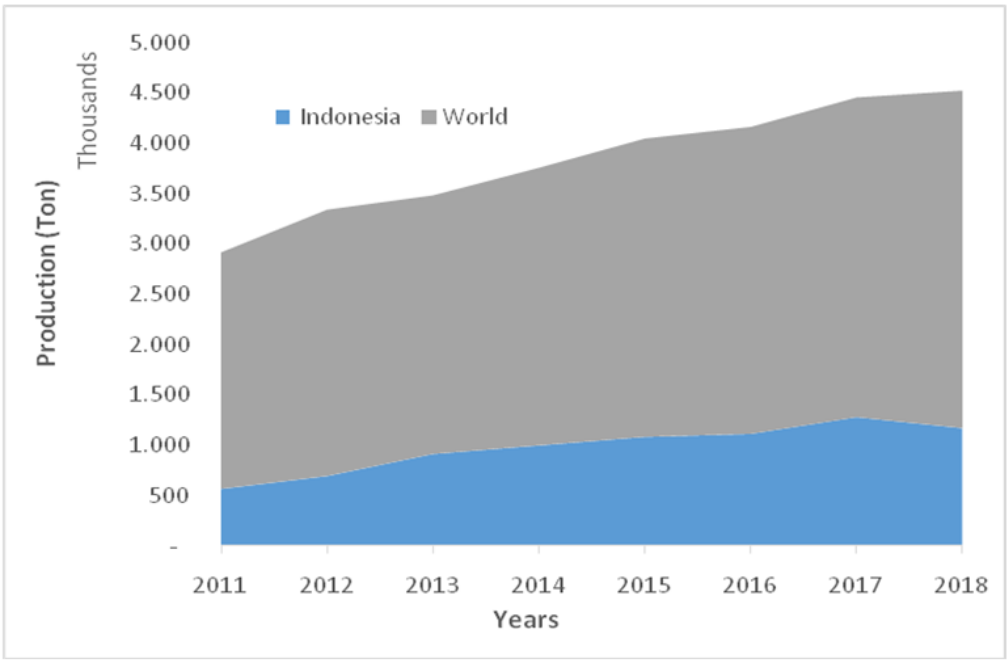

Figure 1. Tilapia production in Indonesia and the world from 2011 to 2018. (Data modified from FAO Fish Stat J)

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Tabel 1. Nilai Ragam Karakter Komponen Hasil dan Hasil Hanjeli

No	Country	Culture Environment	Production	Procentage (%)
1	China	Freshwater	1,218,547	26.93%
2	Indonesia	Freshwater /Brackishwater	1,171,698	25.89%
3	Egypt	Freshwater /Brackishwater	1,051,444	23.23%
4	Brazil	Freshwater	317,000	7.00%
5	Thailand	Freshwater	211,368	4.67%
6	Philippines	Freshwater	167,830	3.71%
7	Ghana	Freshwater	70,628	1.56%
8	Uganda	Freshwater	70,095	1.55%
9	Honduras	Freshwater	33,500	0.74%
10	Lao	Freshwater	31,000	0.69%
	Other countries	Freshwater /Brackishwater	182,321	4.03%
	Global production	Freshwater /Brackishwater	4,525,431	100.00%

Keterangan : Data modified from FAO Fish Stat J

Tilapia culture recorded the highest annual growth rates for decades among all finfish groups. The average growth of tilapia aquaculture in Asia and the Pacific has lagged slightly behind world growth,11.61% during the period 2011 to 2018. Table 2 shows the trend of tilapia production in Indonesia in the same period increased from year to year, but the slope decreased in 2018. Nowadays, tilapia is the biggest contributor to aquaculture production in Indonesia compare to others species.This species is widespread in all provinces in Indonesia, where West Java is the largest producer followed by West Sumatra, South Sumatra, and Central Java. South Sumatra, and Central Java. Tilapia farming was carried out in five different culture systems, mono or mixed with other species, including ponds, net, floating cages, pen, and rice cum fish (Figure 2). In the last six years period, the dominantproduction of tilapia monoculture came from pond followed by floating cages, net cages, rice cum fish fields, and pen net.

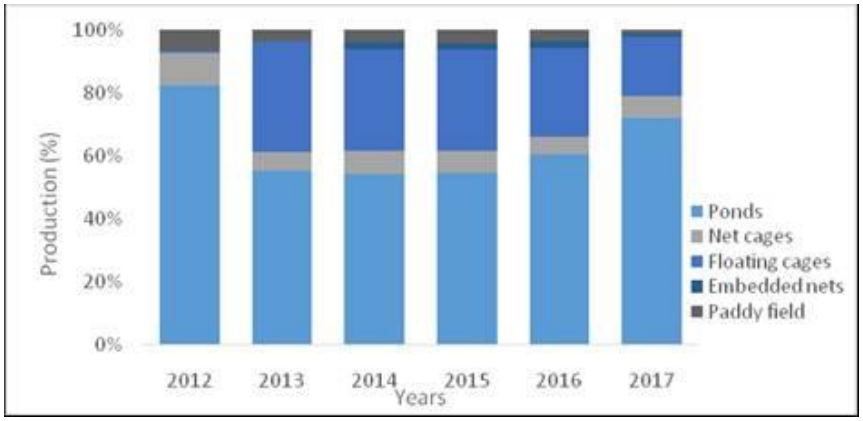

Figure 2. Comparison of Tilapia production in Indonesia based on culture systems from 2012 to 2017. Data were acquired from MMAF Statistic.

B. Historical Status of Tilapia Farming

Nila or Tilapia which refers to *O. niloticus* has been cultured in Indonesia for more than 50 years. At present time, tilapia has become an important fish both for domestic

consumption and export product. The historical phase of the success of tilapia aquaculture is focused on the growth of production and technological advances adopted by tilapia aquaculture development. We divided the historical development of Indonesian tilapia culture into four phases of growth based on production increase and technological development including introduction phase (1970-1990), initial growth phase (1990 to 2000), growth phase (2001 to 2010), and rapid growth phase (2011 to recently) (Figure 3).

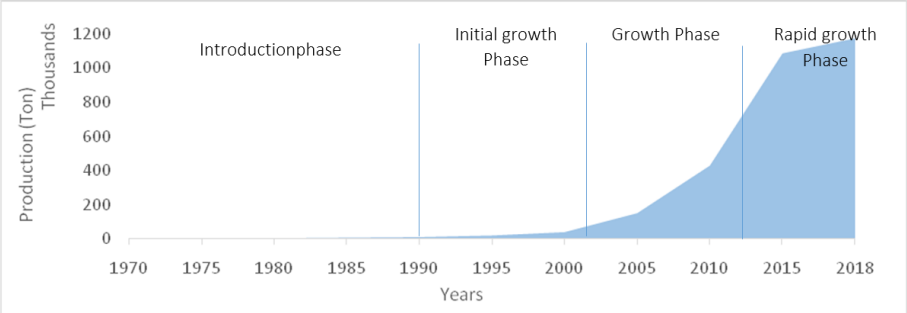

Figure 3. The history of tilapia culture-based production growth in Indonesia (Data modified from FAO Fish Stat J).

C. Introduction Phase (1970 to 1990)

In Indonesia, tilapia is locally known for Nile tilapia (*O. niloticus*) and Mosambique tilapia (*O. mossambicus*). Although it is not a native species to Indonesia, *O. mossambicus* has a local name, "Mujair", which comes from the name of the person who discovered this fish in 1936 in the Serang River, Blitar, East Java. This species of tilapia is thought to be a species introduced by the Dutch from Africa to Indonesia (Schuster, 1950). However, the Mozambique tilapia in Asia including Indonesia shows low production performance due to early maturation, uncontrolled breeding, and slow growth rate.

Nile tilapia or *O. niloticus* which is popularly known as "Nila" is introduced to Indonesia from Taiwan. Hereafter, it was distributed to several provinces in order to increase production and diversify of aquaculture species. The superior selected strain, "Citralada" and "Red NIFI" were also introduced to Indonesia from Thailand in 1988 and 1989, respectively. In 1975 production of tilapia was recorded about 225 tons, it increased significantly to 5772 tons in 1980 and 12.085 tons in 1990. In this period, despite a significant increase in tilapia production, uncontrolled spawning frequently occurs in grow-out ponds resulting in an overload of larvae with slow growth and unacceptable market size. The turning point for tilapia to become a mainstay commodity occurred when there was an outbreak of the koi herves virus (KHV) in common carp. This has led to a shift in the cultivation of common carp to tilapia as an alternative commodity in fish farming in the community.

D. Initial Growth Phase (1990 to 2000)

Initially the national aquaculture program focused on optimizing cultivation techniques and systems as well as seed production. Genetic improvements related to growth rate, food conversion ratio and disease resistance have not been taken into account. Fish quality problems arise when intensification is carried out to pursue high production targets. To solve this problem, efforts were made to import another new strain, GIFT tilapia from Phillipines. The effect of superior tilapia on Indonesia in the early growth phase shows a

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significant increase in production from 13,156 mt in 1991 to 40,836 mt in 2000. In Indonesia, many previous researchers have conducted the genetic research on tilapia (Brzesky and Doyle, 1988; Matricia *et al*., 1989; Jangkaru *et al.*, 1992; Arifin *et al*., 2007). However, these studies were not under national breeding programs. The strategy of improving the genetic quality of tilapia in Indonesia through "selective breeding" was started in 1997 (Gjedrem *et al*., 1997).

E. Growth Phase (2001 to 2010)

The introduction of superior tilapia is a major factor in increasing national tilapia production. This is happening not only in Indonesia, but also in most tilapia producing countries such as China, the Philippines and Thailand. In this case, GIFT tilapia gives a big contribution in increasing production. National tilapia production increased from 50,876 mt in 2001 and increased significantly to 429,053 tonnes in 2010 (Figure 3). Another excellent tilapia, "JICA" was also imported in 2002 from Kagoshima, Japan. Then followed by blue tilapia, *Oreochromis aureus*, from Africa, and GET from the Philippines in 2002. However, the performance of imported superior strains could not be maintained after several years due to lack of knowledge in broodstock management to maintain excellence (Gustiano, 2007). To solve this problem, the national tilapia breeding program was initiated in Indonesia (PPINN, 2002).

F. Rapid growth phase (2011 to present)

The tilapia aquaculture industry entered a rapid growth phase in 2011 following the development of advanced technology through an intensive and super intensive cultivation system supported by local superior seeds. Tilapia production in this period increased from 567,081 mt in 2011 to 1,171,698 mt in 2018 (Figure 3). In this phase, several private export market-oriented companies have made massive investments in Indonesia.

G. Technological advances in tilapia aquaculture

1. Breeding program based genetic improvement.

Improvements in genetic quality to increase tilapia production and productivity can be done in various ways. The introduction of superior strains from outside is a shortcut to improve the performance of local fish (Gustiano, 2007). Crosses or hybridization is another way to improve genetic quality with the aim to get superior characteristics that are better than the original population. Crosses are basically the use of heterotic traits because these traits are dominant and heterozygous at many loci (Tave, 1993) or allele interactions at loci (Kapuscinski and Miller, 2007). Crosses are generally carried out between populations that have certain advantages. In the past, tilapia breeding activities in Indonesia are mostly carried out by farmers to obtain species that have faster growth or certain appearance. Hybrid products are found in many communities. However, if the crossing is carried out uncontrollably, it will result in the loss of certain traits/characters from the original population. To avoid things that are not desirable, it is better if the results of the cross/hybrid are only used as the final product for consumption. There are not many scientific publications on tilapia crossing in Indonesia. It is noted that the results of crosses with better hybrid yields between tilapia (*Oreochromis niloticus*) and tilapia (*Oreochromis mosambicus*) (Sumantadinata and Subardja, 1979; Suseno, 1983) and between tilapia strains (Yunus *et al.*, 1987; Mahardika *et al*., 2011).

The fact shows, there are many hybrids found in communities with local names which are sometimes difficult to trace their origins. We recommend that cross/hybridize should follow the breeding principles and be well programmed. In its development, the crossing method was compiled so that it could produce a superior ”Larasati” strain of red tilapia is in 2009. Crosses were initiated by bringing in various Tilapia strains such as GIFT, NIFI, Singapore, Citralada, and White Tilapia. In 2005, a cross was carried out to get an overview of the performance of the seeds produced. In 2006, it was found that a cross between a female parent of a GIFT line and a male parent of a Singapore line produced the best hybrid.

Next is the “Srikandi” strain, which is a hybridized line that thrives in brackish waters released in 2012. This tilapia is a superior strain resulting from a cross between female Nirwana Tilapia (*Oreochromis niloticus*) and male blue tilapia (*Oreochromis aureus*). Similar to Srikandi, in 2013 a new strain of tilapia was released, namely “Salina” tilapia. This strain has high salinity tolerance up to 20-30 ppt. Apart from crossing/hybridization, selective breeding is another common method for the genetic improvement on tilapia. Selection is a technique for enhancing quantitative traits. The basic principle of selection is to exploit 'additive' alleles in all loci that control measurable traits to increase the population (Tave, 1993). The result of superior genetic improvement of tilapia is the "JICA" strain released in 2004. “Nirwana” strain was released in 2006. This tilapia is a superior strain from the family selection method. The genetic sources of selection activities are Tilapia GIFT and Tilapia GET (Genetically Enhanced Tilapia). Nirwana II was released in 2011 followed by Nirwana III in 2016**.** The “Jati Umbulan” strain was released in 2007. This tilapia strain is the result of genetic improvement through individual selection. The selection of these individuals used 6 basic populations, namely G3 Black Tilapia, G6 Black Tilapia, Punten Black Tilapia, Citralada Red Tilapia, Kedung Ombo Red Tilapia, and Sleman Nila Putih.

Next is the "BEST" strain (Bogor Enhanced Strain Tilapia) which was released in 2008. This family selection program begins with characterization of population types (Arifin *et al*., 2007), population evaluation (Gustiano *et al.*, 2005), followed by selection (Gustiano 2007; Gustiano and Arifin, 2010), performance testing, and multilocation (Gustiano *et al.*, 2005; Kusdiarti *et al*., 2007; Winarlin and Gustiano, 2007) and evaluation of selection results (Gustiano *et al.,* 2013). The “Sultana” strain was released in 2012 in tilapia aquaculture from the individual selection, the following strains were released in 2012: the “Anjani”, “Nilasa” red tilapia, “Pandu” male, and “Kunti” female. Sex manipulation is also carried out on the genetic improvement of tilapia in Indonesia. The "Gesit" (Genetically Supermale Indonesia Tilapia) was released in 2006. This strain is a type of tilapia that has been manipulated by its chromosomes. This tilapia has a YY chromosome type which when mated with female tilapia will produce 95-100% monosex male tilapia. This fish strain was created to control the rapid reproduction of female tilapia and to take advantage of male tilapia which grows faster than female tilapia.

2. Development of Culture Systems.

Research related to cultivation technology, the introduction of tilapia (*O. mossambicus* and *O. niloticus*) was originally spread in public waters such as lakes and reservoirs in Indonesia in 1971-1987 (Hardjamulia and Wardoyo, 1992). *O. mossambicus* is scattered in the Lindu, Limboto, and Tondano lakes as well as the Jatiluhur, Saguling, Cirata, and Selorejo reservoirs. Meanwhile, *O. niloticus* is scattered in Jatiluhur, Saguling, Cirata, and Selorejo reservoirs as well as Tondano Lake. *O. niloticus* which was introduced in 1969 has a larger size, tastier and higher price but stable in population due to the number

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stocked and the unsustainability of the distribution program (Hardjamulia and Wardoyo, 1992).

At the beginning of development, cultivation activities focused a lot on the rice-fish pond, earthen ponds, and running water ponds. The floating net cages (FNC) method was adopted from the Philippines in 1987 (Costa-Pierce and Hadikusumah, 1990). In the further development tilapia farming in the double net cages installed in the lakes and reservoirs was an excellent method for productivity improvement of tilapia (Gustiano and Arifin, 2010). Common carp were commonly stocked at the first layer, while tilapia was cultured in the second layer (Pratiwi *et al*., 2017). This method resulted in double production and improved feed efficiency as tilapia reared in the second layer fed uneaten feed from the first layer. The double net cages system commonly can be found in intensive tilapia farming at Saguling, Cirata, and Jatiluhur reservoirs, West Java. In terms of superior strains for growth, environmental tolerance, and disease resistance, they still consistently showed superiority in different environments even though they were not optimal (Matricia *et al*., 1989; Kusdiarti *et al*., 2008; Winarlin *et al*., 2008) or in the system different cultures (Huwoyon and Gustiano, 2008).

Research on the resistance of tilapia to various environmental conditions has also been carried out such as in salinity environments and low pH/peatlands (Ath-thar and Gustiano, 2010; Huwoyon and Gustiano, 2008). Another alternative is a polyculture of tilapia farming. The increasing interest in polyculture in Indonesia has indirectly boosted the production of tilapia because most see tilapia as an important component in this polyculture system (Fitzsimmons *et al*., 2011). Fitszimons (2013) reported that tilapia polyculture activities in Indonesia were also carried out with a combination of tilapia-tiger prawns, tilapia-milkfish, and tilapia-seaweed-shrimp. Tilapia in the polyculture system with shrimp, apart from providing economic benefits, is also beneficial for shrimp health because it can endanger vibriosis and WSSV infection (Naim and Desyana, 2011).

Nowadays, the use of microbubble technology is a promising technique applied in intensive aquaculture (Jainontee *et al*., 2019). A microbubble generator can be applied for the improvement of water quality in fish culture through the optimum supply of dissolved oxygen in water (Endo *et al*., 2008; Ebina *et al*., 2013). These methods accelerated the growth of tilapia in intensive ponds and provided faster degradation of organic waste in water (Budhijanto *et al*., 2017; Firman *et al*., 2019). The bioflock culture system also has developed rapidly in tilapia super-intensive culture in Indonesia. This technology is an environmentally friendly fish farming method based on manipulation of water resources in the production of heterotroph microorganisms, microalgae, and zooplankton in the ponds used for water quality maintenance and microbial protein as additional fish nutrition (Avnimelech, 2009; Emerenciano *et al*., 2017). Tilapia reared in bioflock system presented more compatible and ideal as compared with other freshwater species. This species has unique capabilities to adapt to bioflock environment system that positively impacts growth and reproduction success (Ekasari *et al*., 2015).

On the other hand, tilapia culture also still has a major problem dealing with disease outbreak occurred both in intensive and super intensive culture systems. The main diseases that lead to tilapia mass mortality are streptococcosis caused by *Streptococcus* spp infection and Motile Aeromonas Septicemia (MAS) caused by infection of *Aeromonas hydrophila* (Supriyadi and Gardenia, 2010). Dealing with this issue, tilapia vaccines were successfully released and registered for commercial production by the Ministry of Marine Affairs and Fisheries such as Caprivac AERO-L (KKP RI. No. D 1206201 BKC) and Streptovac vaccine (KKP RI NO. D 1305224 BKC) (Maskur, 2013). The combination of two vaccines created from *Streptococcus agalactiae* dan *Aeromonas hydrophila* antigens has been developed to improve the efficiency and capability of

product against tilapia diseases (Sugiani *et al*., 2012). Availability of vaccine products for tilapia is an essential factor not only to cope with disease outbreaks but also to improve the quality of tilapia production and replace the use of antibiotics in tilapia culture.

3. Trade and product development

The production of Indonesian tilapia is mostly distributed for the domestic market's needs. The supply chain of aquaculture trade including tilapia for the domestic market involved producers/farmers, collectors, retailers/wholesalers, and consumers. Tilapia products are distributed live and fresh from the producers through collectors as intermediate traders to wholesalers in several big cities. It is reported that the value chain mapping of tilapia for export destinations in Indonesia has four categories of operators including input suppliers, farmers, middlemen/collectors, and processors/exporters. In fact, the supply chain of tilapia for the domestic market was more flexible as the domestic consumers have many options to buy tilapia products from many providers (Figure 4).

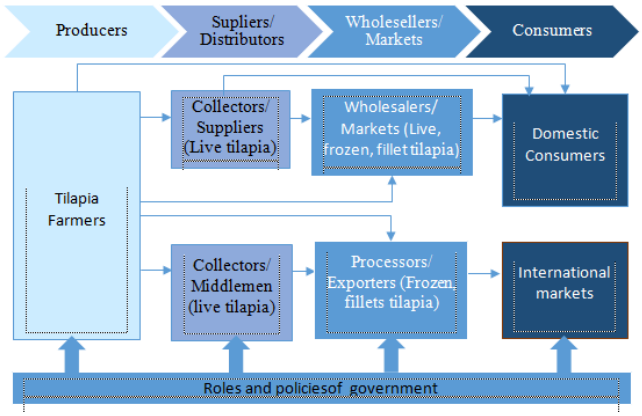

Figure 4. Supply chain mapping of the domestic and international market distribution of tilapia products in Indonesia.

The trend of total tilapia export from 2012 to 2018 shows in figure 5. The highest tilapia export occurred in 2014 (16.972 tonnes) and slightly decreased to 2017 (9179 tonnes) and then increased to 10.938 tonnes in 2018. The production of tilapia in 2018 with the value of USD 60.49 million was recorded that Indonesia was still the second-largest exporter of tilapia in the world after China. Indonesia mainly produced frozen and filleted tilapia for the international market which most tilapia is exportedto the US market.

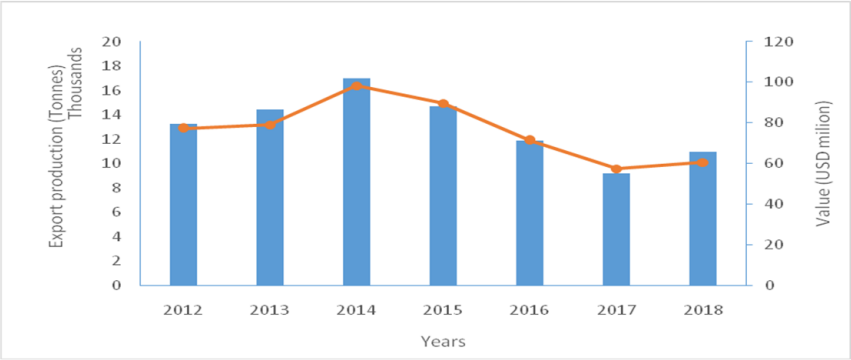

Figure 5. Value and quantity of tilapia products exported by Indonesia from 2012 to 2018.

4. Strategies and policy for development of tilapia farming

The appropriate strategy and policy developments need to consider further development of tilapia production for both short-term and long-term purposes related to farmer's welfare, business, and environmental sustainability. Thus, the spreading of superior tilapia strains and available techonologies to the areas that are potential for tilapia development is essential to achieve targeted production. For the long-term planning, broodstock tilapia center can be considered to be established in potential regions. For the expansion of the tilapia farms, revitalization of "idel" ponds for tilapia farming is an another option. Super intensive culture can also be developed into high-scale and export-oriented products. In this case, the operational standard procedures in super-intensive aquaculture should be standardized and provided. The successful of tilapia industries need suitable areas for development related to techinical and economical aspect equipped with regulation, infrastructure and market.

Further development should also be undertaken in parallel with aquatic biodiversity and genetic resources conservation. Concerning to environmental problems, the government have the implementation of the regulation released by the Minister of Marine Affairs and Fisheries (MMAF) of the Republic of Indonesia (No. Per. 03/Men/2010) regarding the procedures for implementing the protection status of fish species and the MMAF regulation (No. Per. 04/Men/2010) related to the procedures for exploitation of fish species and fish genetics.

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REFERENCES

Arifin, O.Z., Nugroho, E. & Gustiano, R. (2007). Genetic variability of nile tilapia (*Oreochromis niloticus*) population in selection program based on RAPD. *Berita Biologi*, 8 (6), 465-471. https://doi.org/10.14203/beritabiologi.v8i6.826

Ath-thar, M.H.F. & Gustiano, R. (2010). Riset pengembangan pra-budidaya ikan nila Best (*Oreochromis niloticus*) di media salintas. *Media Akuakultur*, 5 (1), 1-9. http://dx.doi.org/10.15578/ma.5.1.2010.1-9

Avnimelech, Y. & Kochba, M. (2009). Evaluation of nitrogen uptake and excretion by tilapia in bio floc tanks, using 15N tracing. *Aquaculture*, 287 (1-2), 163-168. https://doi.org/10.1016/j.aquaculture.2008.10.009

Brzesky, V.J. & Doyle, R.W. (1988). A morphometric criterion for sex discrimination in tilapia. In ICLARM Conference Proceedings (Philippines). ICLARM, Departement of Fisheries, 15, 439-444.

Budhijanto, W., Darlianto, D., Pradana, Y.S. & Hartono, M. (2017). Application of micro bubble generator as low cost and high efficient aerator for sustainable fresh water fish farming. AIP Conference Proceedings 1840, 110008 (2017). https://doi.org/10.1063/1.4982338

Costa-Pierce, B.A. & Hadikusumah, H.Y. (1990). Research on cage aquaculture systems in the Saguling Reservoir, West Java, Indonesia. *Reservoir fisheries and aquaculture development for resettlement in Indonesia*. Philippines: PLN-IOW-ICLARM, 112-217.

Directorate General of Aquaculture (DGA). (2020). Strategic Plan 2020-2024. Indonesia, 95 P.

Ebina, K., Shi, K., Hirao, M., Hashimoto, J., Kawato, Y., Kaneshiro, S., Morimoto, T., Koizumi, K. & Yoshikawa, H. (2013). Oxygen and air nanobubble water solution promote the growth of plants, fishes, and mice. *PLoS One*, 8(6), 1-7. https://doi.org/10.1371/journal.pone.0065339

Ekasari, J., Zairin Jr, M., Putri, D.U., Sari, N.P., Surawidjaja, E.H. & Bossier, P. (2015). Biofloc-based reproductive performance of Nile tilapia Oreochromis niloticus L. broodstock. *Aquaculture Research*, 46 (2), 509-512. https://doi.org/10.1111/are.12185

El-Sayed, A. F. (2019). Tilapia culture. 2nd ed. Academic Press. 346 P.

Emerenciano, M.G.C., Martínez-Córdova, L.R., Martínez-Porchas, M. & Miranda-Baeza, A. (2017). Biofloc technology (BFT): a tool for water quality management in aquaculture. *Water quality*, *5*, 92-109. https://doi.org/10.5772/66416

Endo, A., Srithongouthai, S., Nashiki, H., Teshiba, I., Iwasaki, T., Hama, D. & Tsutsumi, H. (2008). DO-increasing effects of a microscopic bubble generating system in a fish farm. *Marine pollution bulletin*, 57 (1-5), 78-85. https://doi.org/10.1016/j.marpolbul.2007.10.014

FAO. (2020). The state of world fisheries and aquaculture. The United Nation. Food and Agricultural Organization. Rome, Italy, 244 P.

Firman, S.W., Nirmala, K., Supriyono, E. & Rochman, N.T. (2019). Performance evaluation of micro bubble generator on physiological response of Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) farmed at different densities in recirculating aquaculture system. *Jurnal Iktiologi Indonesia*, 19 (3), 425-436. https://doi.org/10.32491/jii.v19i3.504

Fitzsimmons, K., Martinez-Garcia, R. & Gonzalez-Alanis, P. (2011). Why tilapia is becoming the most important food fish on the planet. *Better science, better fish, better life*. Proceedings Of The Ninth International Symposium On Tilapia In Aquaculture. Shanghai, China. 8 P.

Fitszimmons, K. (2013). Latest trends in tilapia production and worldwide. Presentation in Rio de Janeiro, Brazil. 61 P.

Gjedrem, T., Gjoen, H.M., Hardjamulia, A., Widiaty, A., Gustiano, R., Kristanto, A.H., Emmawati, L. & Hadie, W. (1997). Breeding plan for Nile tilapia (Oreochromis niloticus) in Indonesia: individual selection. INGA, ICLARM report. 4, 11 P.

Gustiano, R., Widiyati, A. & Suryanti, Y. (2005). Evaluasi pertumbuhan populasi nila (*Oreochromis niloticus*) di dua lokasi penelitian berbeda. *Aquaculture Indonesiana*, 6, 79-84.

Gustiano, R. (2007). Perbaikan mutu genetik ikan nila. Symposium Badan Riset Kelautan dan Perikanan. 7 P.

Gustiano, R., Arifin, O. Z. & Nugroho, E. (2008). Growth improvement of Nile Tilapia (*Oreochromis niloticus*) based on family selection. *Media Akuakultur*, 3(2), 98-106. http://dx.doi.org/10.15578/ma.3.2.2008.98-106

Gustiano, R. & Arifin, O.Z. (2010). Menjaring laba dari budidaya ikan nila best. Indonesia: IPB Press Bogor. 92 P.

Gustiano, R., Kusmini, I.I., Iskandariah, I., Arifin, O.Z., Huwoyon, G.H. & Ath-thar, M.H.F. (2016). Heritability, response selection and genotype using RAPD on F3 of nile talapine. *Jurnal Riset Akuakultur*, 8 (3), 347-354. http://dx.doi.org/10.15578/jra.8.3.2013.347-354

Hardjamulia, A. & Wardoyo, S.E. (1992). The role of tilapia in capture and culture enhanced fisheries in Indonesia. *FAO Fisheries Report*, (458 Supplement), 162-174.

Huwoyon, G.H. & Gustiano, R. (2008). Uji keragaan ikan nila dan hitam dalam pemeliharaan bersama di kolam. Jakarta: *Pusat Riset Perikanan Budidaya*, 225-228.

Jainontee, K., Norarat, R., Boonchuay, S., Thongdon-a, R., Unsing, A., Booncharoen, P., Janwong, W. & Wesanarat, P. (2019). Preliminary study of the effects of air fine (misro/nano) bubbles (FB) on the growth rate of tilapian in Phan District, Chiang Rai, Thailand. *International Journal of Plasma Environmental Science & Technology*, 1*2* (2), 84-88.

Jangkaru, Z., Sulhi, M. & Asih, S. (1992). Uji banding pertumbuhan ikan nila merah jantan dan hitam jantan dipelihara dalam kolam secara intensif. In *Prosiding Seminar Hasil Penelitian Perikanan Air Tawar*, 1992, 68-72.

Kapuscinski, A.R. & Jacobson, L.D. (1987). Genetic guidelines for fisheries management (No. 17). Duluth, Minnesota: Minnesota Sea Grant, University of Minnesota. 66 P.

Kusdiarti, K., Widiyati, A., Winarlin, W. & Gustiano, R. (2008). Growth of selected and non selected *Oreochromis Niloticus* in floating net cages in Grata Reservoir and Lido Lake. *Jurnal Iktiologi Indonesia*, 8 (1), 21-24. https://doi.org/10.32491/jii.v8i1.283

Matricia, T., Talbot. A.J. & Doyle, R.W. (1989). Instantaneous growth rate of tilapia genotypes in undisturbed aquaculture systems. I. "Red" and "Grey" morphs in Indonesia. *Aquaculture*, 77, 295-302. https://doi.org/10.1016/0044-8486(89)90214-7

Mahardhika, P., Soelistyowati, D.T., Gustiano, R. & Ath-thar, M..H.F. (2011). Performance of four intraspesific hybridization of nile tilapine (*Oreochromis niloticus*) in experimental floating net cages in Lake Lido, Bogor. *Berita Biologi*, 10 (4), 533-540. https://doi.org/10.14203/beritabiologi.v10i4.771

Maskur. (2013). Indonesian Country Report on Emergency Aquatic Animal Diseases Response. OIE Regional workshop on Emergency Aquatic Animal Diseases Response Collaboration with NACA , Bali, Indonesia.

MMAF. (2020). Indonesian marine and fisheries statistic. Jakarta, Indonesia. https://statistik.kkp.go.id/home.php?m=eksim&i=211

Naim, S. & Desyana, C. (2011). Stocking tilapia in shrimp reservoir: Field trial in Aceh, Indonesia. In *Better science, better fish, better life. Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011*. AQUAFISH Collaborative Research Support Program, 383-385.

PPIINN. (2002). Standar prosedur operasional pemuliaan (genetic improvement) ikan nila. Balai Budidaya Air Tawar Sukabumi, DJPB, DKP.

Pratiwi, E., Wardoyo, S.E., Suhenda, N. & Iriana, I. (2017). Utilization of common carp uneaten feed by nile tilapia in environmentaly-sound floating double-net cage culture. *Jurnal Penelitian Perikanan Indonesia*, 4 (2), 41-48. http://dx.doi.org/10.15578/jppi.4.2.1998.41-48

Schuster, WH. (1950). Comment on importation and transplantation of different species of fish into Indonesia. INA: Kantor Pertjetakan Archipel. 31 P.

Sugiani, D., Sukenda, S., Harris, E. & Lusiastuti, A.M. (2012). Haemato responses and histopathology of tilapia (*Oreochromis niloticus*) to co-infection *Streptococcus agalactiae* and *Aeromonas hydrophila*. *Jurnal Riset Akuakultur*, 7 (1), 85-91. http://dx.doi.org/10.15578/jra.7.1.2012.85-91

Sumantadinata, K. & Subardja, D. (1979). Hybridization of nile tilapia (Tilapia nilotica) with Java tilapia (Tilapia mossambica Peters). Indonesian: Lembaga Penelitian Perikanan Darat Pewarta, 2, 31-34.

Supriyadi, H. & Gardenia, L. (2010). Streptococcosis pada ikan nila budidaya di Danau Maninjau. Indonesia: Prosiding FITA. 905-910 P.

Suseno, D. (1983). Pertumbuhan penelitian pertumbuhan ikan mujair (*Tilapia mosambica*) dan nila (*Tilapia nilotica*). Buletin Penelitian Perikanan Darat, 4, 27-34.

Tave, D. (1993). Genetics for fish managers. NY, USA: The AVI Publ. Comp. Inc. 418 P.

Winarlin. & Gustiano, R. (2007). Pertumbuhan nila (*Oreochromis niloticus*) jantan di lingkungan danau dan kolam. *Sainteks*, 14, 210-214.

Winarlin., Gustiani, R. & Kristanto, A.H. (2008). Uji Banding pertumbuhan biomassan ikan nila (*Oreochromis niloticus*) seleksi dan non seleksi di kolam dan danau. Jakarta: *Pusat Riset Perikanan Budidaya*, 21-2.

Yunus, M., Rusmaedi. & Widiyati, A. (1987). Budidaya ikan nila hibrida. Buletin Penelitian Perikanan Darat, 6, 27-31.