KeSEBAE NEWS

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Aquacultural Engineering

By: *Teddy Onyango*

1.0.INTRODUCTION

Aquacultural engineering is a discipline of science that aims to solve technical problems associated with farming aquatic vertebrates and plants in a large or small scale. Aquaculture in Kenya comprises of freshwater and mariculture. The fish species breed in mariculture includes finfish/ milk fish, grey mullets, shellfish, oysters, shrimp and seaweeds. There are two types of fresh water aquaculture; cold and warm water culture. In Kenya, from the fresh water systems, majorly two kinds of fish are produced; nile tilapia and the African cat fish. Nile tilapia contributes 75% of fish production while 25% from the African cat fish and other species. Over 90% of Kenya's fish is produced from Lake Victoria. The main sources of fish in the country are capture fisheries and aquaculture. These two, have earned the country an estimate of 70 million dollars in the export market. With the continuous growth in population in Kenya, aquaculture has become a major contributor as a source of food to the country's population. According to the ***State of Aquaculture in Kenya 2021*** report by Kenya Marine and Fisheries Research Institute, farmed fish production in Kenya would need to reach 150, 000 tonnes in 2030, in order to generate enough fish to maintain the low per capita fish consumption for the growing population.

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A fortnightly Newsletter touching on topical issues affecting our environment.

KeSEBAE NEWS is a Newsletter of the Kenya Society of Environmental, Biological and Agricultural Engineers (KeSEBAE)

Inside this Issue!

The average national per capita consumption rate of fish in Kenya is 4.5 kg per year compared to the global average rate nearing 20 Kg per capita per year; with a 0.8 percent Gross Domestic Product (GDP). The total fisheries production in 2019 in Kenya was 147,000 metric tonnes (MT) valued at $ 237 million. (KNBS, 2020). The fisheries potential of Kenya's inland waters, mainly from commercial fishing is estimated to between 150,000 and 300,000 MT.

The main sources of fish in the country are capture fisheries and aquaculture. These two, have earned the country an estimate of 70 million dollars in the export market. Production from capture fisheries has stagnated and declined over the past decades

Although marine waters hold a great potential, the current production level is only at 25,000 MT per annum. Current production is mainly from inland fresh water sources accounted for 121,000 MT, while aquaculture accounted for 12.8%. In spite of the fact that most rivers and lakes in Kenya have been exceeded and fish output from these sources plateaued in the last 5 years, capture fisheries remain the dominant fish suppliers in Kenya.

Aquaculture has the potential of being the alternative to bridging the increasing gap between fish demand and supply in Kenya. There are three types of aquaculture production systems; extensive, semi-intensive and intensive systems. In Kenya, mainly semi-intensive and extensive systems are present. Under intensive systems, the methods used are; raceways, recirculating aquaculture systems (RAS), cages and ponds. For instance, Kamuthanga fish farm in Machakos county use RAS for fish farming while Jewlet farm project on Lake Victoria located in both Kendu-bay and Homa-bay practise fish farming using floating cages. The recent import of Chinese fish into the country, sold cheaply has brought stiff competition to the locally produced fish. Efforts by the government to limit imports through institution of proper regulatory framework have created an enabling environment for aquacultural farming to thrive in Kenya.

1.1. Overview.

A market report by Technavio in 2019 indicated that the total world's Aquacultural seafood production had surpassed 86 million tons with its value to be at USD 180.2 billion. Projections anticipate a rise to USD 224.2 billion by the year 2022. The Food and Agricultural Organization produced a report on the contribution of aquaculture to global food production sector and it indicated that generally aquaculture continues to grow faster than other major food production sectors. It will grow even further as human population continue to bulge, increase of the middle class resulting to lifestyle change and more consumption of animal protein and increase of urbanization.

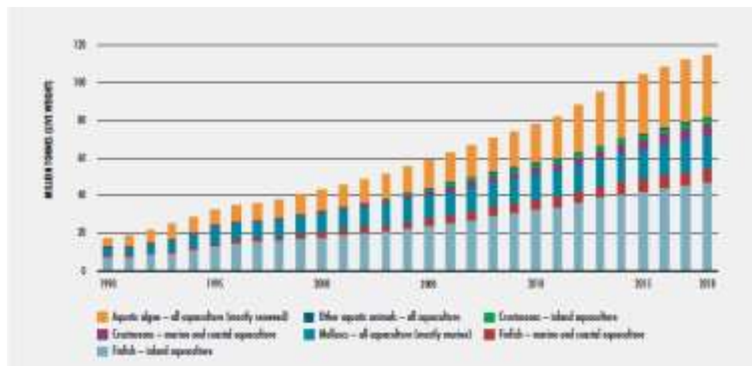

Figure 1.2: World Aquacultural production of aquatic animals and algae, 1990-2018 (FAO, 2020)

Aquacultural engineering is a discipline of science that aims to solve technical problems associated with farming aquatic vertebrates and plants in a large or small scale. It can be practiced in sea cages, ponds or recirculating systems and each of these designs are based on production goals and economics of operation. This field of science requires knowledge of mechanical engineering, biological engineering, environmental systems, material engineering and instrumentation. The discipline borrows a lot of principles from waste water treatment fisheries and traditional agriculture.

Aquacultural engineering has played a significant role in aquaculture industry today which accounts for half of sea food in the world. The global aquaculture consists of variety of seafood farming including fish, aquatic plants, algae, crustaceans, molluscs and other organisms. The rising awareness on the nutrition content of Aquacultural products around the world is one of the key factors fueling the market's growth over the recent years. Through scientific research, it has been proven that consumption of Aquacultural products prevent as well as alleviate a myriad of diseases; contributes to brain development and improved reproduction health. In addition to health benefits, due to effects of climate change aquaculture is seen to be a more efficient way of food production as it requires less inputs compared to the mainstream food production that is farm tillage and also has lower carbon footprint.

Currently, China dominates the global aquaculture market and accounts for nearly 70 % of the market in terms of both volume and value (FAO, 2020). The second largest market share for aquaculture products is India, followed by Indonesia, Chile, Norway, Japan, South Korea, The United States and the United Kingdom.

Another benefit associated with this form of food production is increase in job opportunities. Surprisingly, the rate of growth of exports from developing countries has been significantly faster than that of exports from developed countries creating employment locally. Aquacultural industry has led to creation of employment for more than 41 million people all over the world as suggested by the FAO report.

These and other more reasons support the importance of this field of food production not only for the present but also for the future generations. This paper thus explicates on the different aspects of Aquacultural engineering; from the products that are cultivated in these systems, control parameters, the challenges and negatives in the industry and future projections.

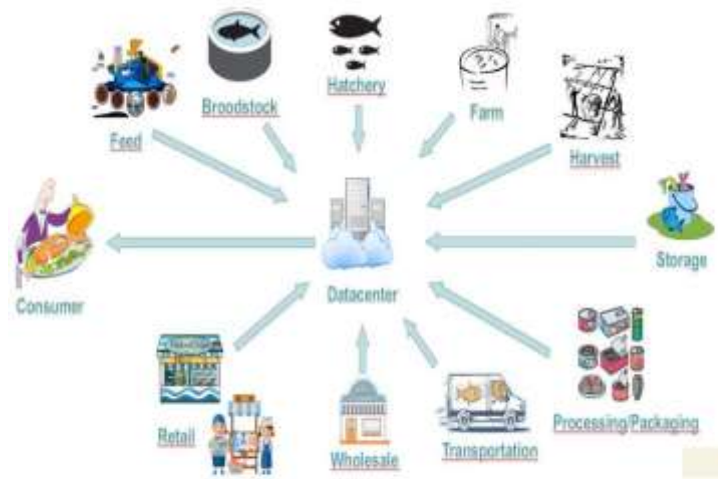

Figure 1.1: Fish production process and systems.

1.2. History of Aquacultural Engineering

Aquaculture was first introduced in Kenya by the colonial government in 1920s. from then, static pond water culture was introduced and embraced in the country. It begun by rearing native tilapiines afterwards common carp and African catfish. In the 1960s, aquaculture was promoted as a means of food production that was sustainable whose main objective was to improve the nutrition of the country men, create employment and others.

After independence, the first Fisheries Department[1] was created by the newly formed government. It was a sub-unit under the Ministry of Agriculture. In 1960s, the country experienced a rapid spread of rural pond fish farming in the country, with Nyanza and western provinces spearheading the trade. In 2007, the aquacultural production was about 4,250 metric tons, with a pond coverage of 217 hectares, 301 dams and 497 Hectares of reservoirs, 248 tanks and raceways.

In 2013, the total area under fish ponds was 2,105 hectares. Fish production since then has fluctuated, but a steady rise has been exhibited all through. Currently, the aquaculture value chain in Kenya is relatively sustainable with good income and providing job opportunities to thousands in the country.

Kenya Marine and Fisheries Institute (2021)- State of Aquaculture in Kenya 2021 report

2.0.Aquacultural Systems.

Aquacultural engineering is practiced in different systems in aquacultural production. Aquaculture which can be land based in ponds or water based in cages have systems categorized as semi-intensive, intensive or extensive depending on the inputs and production systems (Gumbe. L, 2019). The systems are diverse in terms of culture methods, practices, facilities and integration with other agricultural activities. The following are the main systems of aquaculture.

2.1. Earthen Ponds

They the most commonly used type of facility for inland aquaculture production and considered to be least intense. In high production levels where many ponds are required, they are designed to share levies to reduce cost of construction through reduced movement of excavation material and also efficiently utilized land resource. Water for these systems can be from wells, rainwater, watershed runoff, springs, streams or even lakes. Their design takes advantage of topography to have water flowing in and out of the systems by gravity and not pumping. They are lined with high density polythene papers to prevent infiltration of water into the ground and constructed with inlets and outlets for circulation of clean water.

Figure 2.1: Inland fish pond.

2.2. Cages

There are different cage systems used in aquacultural production. The most predominant type is the floating cage system where fish cages are attached to a floating structure on the surface of the water body. This is mostly practices on ponds, lakes and rivers and open sea. It involves having fish confined to nets in either a pond or water bodies such as lakes and rivers. Can be made using soft materials such as net and nylon or hard materials such as extruded plastic- and plastic-coated wire. The disadvantage of using cages is that the fish is vulnerable to predators and in case there is disease outbreak it affects all the fish.

In the open ocean, the cages are submerged more than 200 feet below the water surface and are attached to an underwater grid. The grid is designed to be perpendicular to the ocean currents so as to ensure a constant flow of fresh water without exposure to fish wastes generated from other cages. They can be lowered or raised to allow divers to enter the cages for either maintenance or harvesting of the fish. As the fish is confined to the cages, a feed boat feeds them through a hoarse pipe with spirals for even distribution. Cameras are placed at the bottom of the cages to monitor how the fish respond to the feed thus controlling the amount of feed delivered. This system is intensive and has not yet been adopted in Africa. The cages can be moved around and expansion is relatively straight forward. The disadvantage with these systems is that there is no control over weather, water quality and potential disease outbreak.

In rare case aerators are put in place to circulate oxygen in the water. In normal circumstances natural water circulation in the systems and algae help in oxygen circulation.

Figure 2.2: Sea cages **Source**: Aquatech Indonesia

2.3. Raceways.

These are rectangular structures built above or below ground where water flows in one end and out the other end. They require good quality of water supplied in large volumes. The raceway can be constructed using concrete, fibre glass or even wood. Length to width ratio is mostly above 5:1. Drop structures along the raceways create a splash of water that enables diffusion of oxygen. The fish are fed automatically through installed mechanical feeders with hoppers designed to evenly spread the feed in the water.

Waste generated by the fish is swept downstream by the constantly moving water. Certain raceways have settling ponds for collection of solid waste. In large raceway facilities there are waste treatment plants that clean the water before releasing it back to the environment. These systems need biological engineers for effective and efficient operation

2.4. Recirculating System.

These systems are the most intensive aquacultural systems as they rely on external power mechanical processes and managerial expertise. It has the following components;

i. **Culture tank-** Holds the fish that is being grown. There's also constant inflow and outflow of water from this tank.

ii. **Filters-** Once waste is generated by the fish it is pumped from the tank and either passed through a screen or a drum filter where solid waste is extracted from the water. This can be used as organic manure in crop production. The water that passes through goes to biological filters which can either be rotating bio contractor, fluidized bed filter, sand filter or trickle filter that have large surface area to volume where bacteria can grow. The bacteria help breakdown ammonia through nitrification cycle into nitrates. Carbon dioxides and nitrite is removed though degassing technology.

iii. **Sterilization-** The cleaned water is sterilized from any disease-causing pathogens that might harm the fish

iv. **Oxygenation pump-** Circulates oxygen into the cleaned water before it is pumped back to the fish tanks.

This process goes on for several times and at the same time clean water is added into the recycled water.

3.0. Fish production process

All these systems of production have a similar cycle with regards to fish production. The cycle starts with careful selection of the species of fish needed for breeding so as to have the best output in terms of taste, resistance to diseases and body mass. While the fish are in the breeding tanks, the temperatures are controlled through sensors attached to the tanks to maintain optimum level in order to necessitate breeding and even the survival of the spawn. The eggs are then collected and moved to the hatchery between 24-36 hours where they hatch into fingerlings. After 30 days the fish is moved to the nursery to be fed and monitored for two months. During this period, they are graded, counted and vaccinated from any diseases that might threaten their survival.

These fish throughout their growth period have to live is a conducive environment that is; the water must always be clean, well oxygenated and at the right temperature and pH. The tanks have inlet and outlet pipes that supply clean water to the fish whenever required. Filters are fitted onto these pipes to prevent any form of blockage or trapping of the fish in the systems. In largescale production where monitoring is mostly done automatically, sensors use the waters turbidity and oxygen level as parameters for turning pumps on and off. All this data is collected, stored analyzed and relayed to different machines through internet hence the system is referred to as Internet of Things.

3.1. Fish Processing.

Aquacultural engineering also involves mechanization of harvesting process especially in large scale production where manual harvesting is not efficient. Machines such as trolleys and forklifts are used to transport the fish into processing plants for value addition where the raw product is transformed into other fish products of higher values and longer shelf life which significantly reduces the postharvest losses.

The primary fish processing processes include; Washing, Gutting, Cutting, Drying, Preserving and Packaging

Figure 3.1: Fish processing plant **Source:** Morgan's fish house

Through conveyor belts, automatic guillotines and precision cutting equipment food handling by humans has been minimized therefore guaranteeing food safety in the processing plants. Some of the value-added products from fish are;

- Fish balls.
- Fish nuggets.
- Fish burgers.
- Canned fish.

Figure 3.2: Value added fish product **Source**: Kenya Tropical sealife Limited

From the design of the habitat to the growing stage and finally harvesting and processing of the aquacultural products it is surely needless to say how important engineering is in the field of aquaculture.

4.0.Concerns in the Aquacultural Industry.

We must however not be oblivious to some of the eye-opening issues in the aquacultural sector. Many companies that are practicing aquaculture along the water bodies have led to destruction of precious ecosystems such as the mangrove for the space. Aquaculture engineering has also been associated to water eutrophication and reduction of water quality along the water bodies that supply the organizations with the essential commodity.

Aquatic animal disease is also an emerging issue associated with this huge industry which is mainly caused by poor water quality (toxic) and overcrowding of the fish. For this reason, food safety has been a worry for the consumers of the aquaculture industry.

5.0.The Situation in Kenya.

Kenya has 13,600 km2 of inland lakes and 640 kilometers of coastline (Abuyeka, 2020) which provides a good potential for aquacultural engineering to boost the county's economy. In a speech by the President during the launch of the New Ocean Action Agenda on 3rd December 2020, it was established that the coastal economic bloc; Mombasa, Kwale, Kilifi, Tana River, Lamu and Taita Taveta identified the ocean and blue economy as a priority in their county development plans.

The lake Region Economic bloc that represents socio-economic aspirations of fourteen counties within the Lake Victoria Basin constituting 30 % of Kenya's population also has similarly priorities. The head of state further acknowledged that there is need for sustainable utilization of these resources hence implementation of policies aimed at tackling the challenge of ocean pollution especially through plastic.

In a bid to accelerate blue economy at the coast, Liwatoni Fisheries Complex has been reconstructed aimed at training 1000 fishermen on different fish processing activities.

Bandari Maritime Academy was also established in 2018 to train youths on skills needed in the Blue Economy. The Kenya Coast Guard Service promotes sustainable utilization of Kenya's ocean resources through prevention of illegal fishing.

The Sustainable Blue Economy Conference in 2018 hosted by Kenya in partnership with Canada and Japan established the key objectives of the Blue Economy to be sustainable use of ocean resources for economic growth, livelihoods and jobs and finally ocean ecosystem health.

Aquaculture in Kenya is mainly practiced through pond tanks and cages on different fish farms, right from Mount Kenya to the far west of the country; western Kenya. Among them, Kamuthanga fish farm in Machakos and Jewlet fish farm in Lake Victoria were of note and discussed as our case examples.

5.1. Kamuthanga Fish Farm in Machakos

The Kamuthanga fish farm[2] located in Machakos county, Kenya, is the largest aquaculture operation in Kenya. It was created by Food Tech Africa and it is the first Africa's certified fish farm. It has a production capacity of 100,000 tonnes of fish per year, and it is targeting to reach 300 000 tonnes in the foreseeable future. The facility provides 58 job opportunities to local workers, 25 being women. The aquacultural system in Kamuthanga is an intensive system employing recirculating culture system (RAS) as their primary method. It is made up of complex system of tanks tunnels and pipes which host about one million fingerlings. The system is divided into a hatchery, breeding area, fish growing area and storage water tanks. The water in pond tanks is heater by solar water panels or kuni booster, an African invention, depending on the weather season.

Figure 5.1: Pond tanks in Kamuthanga **Source:** Kamuthanga fish farm

5.2. Jewlet Fish Farm in Lake Victoria

Jewlet enterprise located in Kendu-bay and Homa bay counties, is a fish farm with a vast establishment of a total of 53 ponds and three water reservoirs. They provide quality fingerlings as well as table size fish. Jewlet farm produces both fish and fish products. Some of the fish species produced are cat fish and tilapia. Jewlet also produces catfish and mono-sex tilapia fingerlings in addition to quality fish feeds. Examples of fish feed produced are floating pellets and fry starter powder. It is one of the largest fingerling producers in Kenya, supplying 6 million fingerlings annual or an average 0.5 million monthly.

Figure 6: Jewlet fish farm **Source:** Jewlet

[2]Kamuthanga farm https://kamuthanga-farm.business.site/

Of the three, the first site is a 4-acre farm at Kajiei with 16 ponds, the second Kamwala is a 6-acre piece of land and has 29 ponds and several large hapa nets. The third firm is Mariwa fish farm with over 2 acres of water surface with 10 ponds.

6.1. Fish Feed Production Process s Jewlet

The fish production unit is composed of a number of unit being, the hatchery, feeds production units, the cages where fish grow to table size and the breeding section.

During hatchery, of fingerlings (tilapia and catfish), all tilapia yolk sac fry produced are transported and the sex reversed into all male tilapia fingerlings at Kamwala, 5 km away from Kajiei and Mariwa farms.

Figure 6.1(1): fish hatchery section at Jewlet farm **Source:** Jewlet

Selective breeding is done at Kajiei and Mariwa sites where water supply to the pond is from underground. Kamwala site is endowed with a hatchery with laboratory facilities, and has 29 fish ponds and several large *hapa* nets for mass breeding, sex reversal and selective breeding.

Figure 6.1.(2): Feeds production unit **Source**: Jewlet

In the feeds production unit, Jewlet produces 2 tons daily of floating pellets, one tonne of starter powder and 2 tonnes of grow out marsh, all minimum 28% crude protein for tilapia. It also produces other fish feed products for cat fish and tilapia at different stages of up to 46% crude protein specialised for different stages. The main market for the fish feed are the cage farming projects in Lake Victoria. They are also supplied to Kakamega, Nandi, Homabay counties and in central Kenya: Kirinyaga, Embu and Tharaka Nithi.

6.0. Mariculture in Kenya

Mariculture in Kenya is underdeveloped mainly due to accessibility concerns, conflicts over land ownership and lack of clear policies about undersea fish exploitation.[3] The current mariculture production data indicates that there are over 100 metric tons of sea weeds, milkfish, shrimps and mud crabs produced in small scale. Mariculture in Kenya thereby remains unexploited as its potential for increased fish production lies untapped.

Mary. A. Apiyo (2018). **A review of aquaculture production and health management practices of farmed fish in Kenya** https://www.tandfonline.com/doi/full/10.1016/j.ijvsm.2018.07.001

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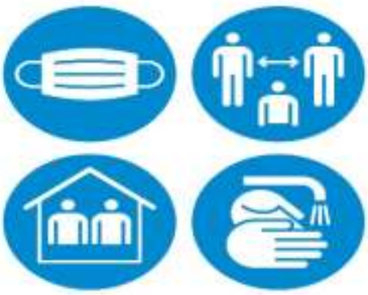

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Contact: **Ezekiel Oranga**
The **Kenya Society of Environmental, Biological and Agricultural Engineers**
P.O Box 10677 - 00100
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