Consumer preference, growth and profitability of African catfish (*Clarias gariepinus*) grown in treated and aerated wastewater fed ponds in Kumasi, Ghana

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ABSTRACT
Recycling of wastewater provides a substantial solution to the global issue of water scarcity and high water use in aquaculture. However, this sustainable way of wastewater use has not been given much attention and exploration. This study focused on the consumer preference for fish grown in treated wastewater as well as the effect of aeration on the growth performance and economic benefit of African catfish (*Clarias gariepinus*) grown in treated wastewater. Two hundred (200) respondents from two communities (Chirapatre and Gyinyase) near the wastewater treatment plant in Kumasi were interviewed to determine their willingness to accept and pay for African catfish grown in treated wastewater. For the growth trial, a total of 600 fish (of average initial weight 39.12g) were stocked in two maturation ponds with 4 h (3:00am–7:00am) of aeration daily. The trial lasted for 12 weeks and variables monitored included the survival, growth performance (weight gain, specific growth rate, and yield) and water quality. Fish cultured in non-aerated wastewater ponds (NWFPs) under similar conditions as in aerated wastewater-fed ponds (AWFPs) served as control. The results indicated most important considerations for consumers in their choice of fish to consume were in order of importance; food safety, freshness of fish, taste and packaging. The proximity of consumers to the treatment plant, the price of fish, religion, and age and whether or not they were fish consumers affected their willingness to pay for African catfish grown in the treated wastewater significantly. For the growth trial, dissolved oxygen concentrations in the aerated ponds were significantly higher than in the NWFPs and this led to more than a doubling of the growth rates in the African catfish grown in the AWFPs (189.10g/C6 11.32) as compared to the NWFPs (90.70g/C6 11.59). The pond aeration improved fish growth significantly (p < 0.0098). On economic benefit, the aerated system yielded profits of 618.83 (€103.13) as compared to a loss of 104.99 (€17.50), which was incurred in the non-aerated ponds. Education of the consumers on the process of wastewater treatment and establishment of food safety guidelines will therefore be recommended to increase consumer interest in consuming fish from the treated wastewater.

1. Introduction

Fresh water scarcity with its consequent effect on public health as well as that of the environment cannot be over-emphasized. Water is an essential resource for life, and access to potable water should be a right enjoyed by all according to World Health Organization (WHO), 2003. Water pollution with discharge of raw or untreated sewage into natural water bodies threatens the existing water resources and limits their use.

As indicated by Sato et al. (2013), about 8% of wastewater is treated in low-income nations when contrasted with that of high-pay nations which remains at about 70%, followed by centre-pay nations which is about 66%. Quantities of wastewater generated in Africa far exceed the capacity of existing wastewater treatment facilities. In Ghana, wastewater treatment facilities currently available are meant to serve about 25% of the total urban population, however, a little less than 10% of these treatment plants are functional due to lack of funds (International Water...
Management Institute, 2009). As such, about 85% of wastewater and fecal sludge generated within the country are released directly into the environment without prior treatment (United Nations World Water Development Report, 2017). Once wastewater is treated and safety is assured, it opens up its reuse options.

Among wastewater reuse options for developing countries, wastewater-fed aquaculture appears to be one of the most promising and low-tech sustainable options. Previous studies done by Tenkorang et al. (2012), concluded that it was possible for *Clarias gariepinus* to survive and grow in waste stabilization pond (WSP). The WSPs provided sufficient food to support fish growth with their growth rates comparable to fish grown in traditional fed aquaculture systems. Further studies by Nsiah – Gyambib (2017), also showed that the wastewater quality parameters in the maturation ponds at the Chirapatre WSP were within Ghana EPA and US EPA acceptable limits for effluent discharge, however most of the parameters fell within acceptable limits fish growth except for dissolved oxygen (DO) which could fall as low as 0.0 mg/L for extended periods. In effort to commercialize fish production from treated wastewater as one of the sustainable means in addressing sanitation in Ghana, VIA Water/Aqua-for-All, the Netherlands and International Water Management Institute, Accra supported TriMark Aquaculture Centre, private business entity whose operations are incorporated into the legal framework of Ghana, to pilot a business model where wastewater from community WSP is reuse for fish production and revenue generated from the fish sales is channel back to address the chronic lack of funds for operations and maintenance of the WSP. This model could offer a solution to most fish farmers in the developing countries who face with limited access to nutrient inputs and water (Bunting and Little, 2003).

As a business venture, it is expected that profits are made from the sale of the fish from the optimized WSPs which will then be ploughed back into the operations and maintenance costs of managing the treatment plant. Although, fish grown in well managed and treated wastewater are generally considered safe, there are concerns about the safety of wastewater treatment products for human consumption and in some communities consumers are generally unwilling to patronize fish from waste-fed aquaculture. This research seeks to assess the market available for fish grown in wastewater fed ponds by assessing consumers’ preference for such fish as well as the effect of aeration on growth performance and profitability of African catfish (*Clarias gariepinus*) in waste stabilization ponds.

2. Materials and methods

2.1. The study area

The study was conducted at the Chirapatre wastewater treatment plant within the Chirapatre Estate, a suburb of Kumasi in the Ashanti Region (Figure 1). Kumasi is considered the second largest city in Ghana and has a population of about two million people with an annual growth rate of 5.9 % (Ghana Statistical Service, 2012). Chirapatre Estate has a total population of about 1800 inhabitants (Yeboah-Agyepong et al., 2019).

The Chirapatre wastewater treatment plant is one of the five small-scale wastewater treatment plants within the Ashanti region, and it sources its wastewater from the houses within the estate. The wastewater is channeled through sewer pipes connected through sewer lines and transported directly to the waste treatment site. The treatment plant has three chambers followed by five ponds in sequence for further treatment. The chambers comprise of the grit, influent and one inspection chamber. The ponds have different depths and undergo different biological activities in the treatment process. It comprises one anaerobic pond, two facultative ponds, and two maturation ponds (Figure 2). The anaerobic and facultative ponds have a depth of 5m and 2.5m respectively creating a conducive environment for anaerobic and facultative bacteria to thrive in the ponds respectively hence their names. The maturation ponds have a shallow depth; about 1.5m, that allows sunlight to penetrate the wastewater. The sun rays breakdown pathogens present in the water and make it safe for fish culture. After the wastewater passes through the first three ponds it is expected that waters in the maturation ponds, the final stage of treatment before its discharge into the receiving stream, are of better quality and suitable for the use in fish culture, hence the fish under study in this experiment were cultured in Maturation pond I and Maturation pond II. Each maturation pond has a surface area of about 225m² with a depth of 1m around the inlet and about 0.5m around the outlet. An

![Figure 1. Study Area Map. Source: Adapted from Tenkorang et al. (2012).](image-url)
initial experiment was conducted where the fish were cultured in Maturation ponds I and Maturation pond II under non-aerated conditions, this was immediately followed by the second phase of the experiment where fish were cultured in the same ponds under aerated conditions. These two maturation ponds were fitted with paddle-wheel aerators to aerate the wastewater-fed ponds (AWFPs). The maturation ponds used for the culture of fish will hereafter be referred to as rearing ponds.

2.2. Determination of consumer preference and willingness to pay

In order to determine consumer preference a structured questionnaire was administered to 200 individuals; 100 from Chirapatre and Gyinyase. The respondents were selected from the communities based on their proximity to the wastewater treatment plant, this was done on the basis of their knowledge of the existence of the treatment plant as well as the knowledge of the treatment process and its potential to affect their preference as well as their willingness to buy fish cultured from such a system. Households were selected based on their presence or absence of a respondent at home when the survey was conducted. The survey was conducted between the hours of 10 am -2pm (GMT) and was targeted at least one respondent per household hence each respondent represented a household. The study employed both self-administration and verbal administration of the questionnaire. The period of data collection spanned October, 2018 to December, 2018. Factors such as food safety, freshness, size of fish, price, fish packaging among others were considered in assessing the respondents’ fish consumption behavior. These factors were rated based on their level of importance in purchasing fish using a Likert scale.

2.3. Nursing fingerlings and stocking fish in wastewater (rearing) ponds

*Clarias gariepinus* fingerlings of average weight 5g were acquired from a commercial hatchery (Gala Farms Limited, Kumasi) and nursed for a period of 12 weeks in concrete tanks prior to pond stocking. Water supply to the fish tanks in the hatchery was from a well. Fingerlings were fed to satiation twice a day using a commercial catfish grower feed with 42% protein, 12% fat and 10% ash. Prior to stocking fish into the rearing ponds, the ponds were prepared following procedures adopted by Yeboah-Agyepong et al. (2019). Each pond (225m²) was stocked with 600 fish of average size 39.12g. The fish were not fed but depended solely on natural food sources. This was to prevent further pollution of the water by the waste from the feed. Due to low concentrations of DO recorded in previous studies (Yeboah-Agyepong et al., 2019), a 4-wheeled paddle aerator (Leafy, aSYC-1.0, HT Solar) was installed in both ponds to aerate the ponds for 4 h (03:00–07:00 GMT) each day. The fish were grown for a period of three months (July–September), after which they were harvested and depurated in clean water from a well onsite in concrete tanks for 16 days based on previous work done by Nsiah–Gyambibi (2017), to reduce the microbial load on the fish before smoking and selling.

2.4. Determination of fish growth, water quality and production economics

One hundred fish were randomly sampled from each experimental pond bi-weekly using a dragnet and their bulk weight determined to the nearest 0.01g using analogue kitchen scale. Total fish harvest was done at the end of the three months. Growth rate of fish was then evaluated using weight gain (WG), specific growth rate (SGR) and percentage survival (S) at the end of the study. Water quality parameters were measured bi-weekly during the three months culture period in the two rearing ponds. Physicochemical variables such as temperature, DO, and pH were measured *in situ* with the Hach Multi-parameter probe (Model: 58225800), while chemical oxygen demand (COD) and biological oxygen demand (BOD) were measured using the open reflux method and the 5-Day BOD dilution test method respectively (American Public Health Association-APHA, 1999).

The economic benefit of the wastewater-fed aquaculture was assessed using a simple enterprise budget. The enterprise budget usually provides an overview of the costs and returns as well as the cost benefit ratio of a particular enterprise for one production cycle to ascertain its profitability (Rod and Dennis, 2001).

2.5. Data analysis

Results obtained from the survey was analyzed using the probit regression model using the StataIC 13 software. The probit regression, otherwise known as the probit model is used to perform a regression with a variable with binary outcomes. In the model, the dependent variable takes only two outcomes, it is expected that the inverse standard normal distribution of the probability is modelled in a linear combination of the predictors (Thomas, 2016). It employs the probit link function which is also used to estimate maximum likelihood of one of the variables falling into one of the two possibilities. Probit regression can be mathematically expressed as;
This equation defines the conditional probability of $Y$ occurring given $X$. Where $y_i = \text{the continuous variable (dependent variable)}$, $X_i = \text{dummy or dichotomous variable (independent variable)}$, $e = \text{error term}$.

Fish growth data obtained from aerated ponds were compared to non-aerated ponds using unpaired t-test (GraphPad Prism version 5.01 Software). All differences were considered significant at $p < 0.05$.

3. Results

3.1. Socio-demographic characteristics and consumer preference

The results in Table 1 indicate that out of the total number of respondents, 89 (44.5%) were males and 105 (52.5%) were females. Six respondents did not indicate whether or not they were male or female. With regard to age distribution, the results as shown in Figure 3 indicate that majority (33.5%) of the respondents are within the 40–59 years of age category followed by respondents between the age category of 20–39 years of age (33%). Respondents with tertiary education level and above (Figure 4) were about 34% and those without formal education and below secondary were 29 (14.7%). With respect to income levels as described in Figure 5, 40 (22.6%) of the respondents had an average income level of between €500.00 – €750 (€83.33 – €125.00) per month, this formed the highest percentage of the respondents. The second majority of the respondents (38 respondents - 21.5%) had income levels between €251.00 - €500.00 ($41.83–$83.33) per month.

3.2. Knowledge of wastewater treatment and fish consumption behavior

Consumers were asked if they were aware of the endpoint of the wastewater from their homes, their responses showed that 152 (77.6%) of the respondents had some idea of where their wastewater goes, most of which were treated in a treatment plant. The second majority of the respondents (38 respondents - 21.5%) had income levels between €251.00 - €500.00 ($41.83–$83.33) per month.

Table 1. Descriptive statistics summary of demographics and fish consumption behavior of respondents.

| Variable               | Frequency | %     | Variable            | Frequency | %     | Variable               | Frequency | %     |
|------------------------|-----------|-------|---------------------|-----------|-------|------------------------|-----------|-------|
| Gender                 |           |       | Catfish form        |           |       | Wastewater endpoint*   |           |       |
| Male                   | 89        | 44.5  | Fresh               | 15        | 8.2   | No                     | 43        | 21.9  |
| Female                 | 105       | 52.5  | Smoked              | 129       | 70.1  | Yes                    | 152       | 77.6  |
| Marital status         |           |       |                     |           |       |                        |           |       |
| Single                 | 83        | 41.5  | Combinations        | 27        | 14.7  | No                     | 79        | 39.7  |
| Married                | 115       | 57.5  | Fish purchasing point|         |       | Yes                    | 120       | 60.3  |
| Religion               |           |       |                     |           |       |                        |           |       |
| Christian              | 169       | 84.5  | Market              | 135       | 69.6  | No                     | 172       | 86.9  |
| Muslim                 | 26        | 13    | Farmgate            | 16        | 8.2   | Yes                    | 25        | 12.6  |
| Fish consumption       |           |       |                     |           |       |                        |           |       |
| No                     | 4         | 2     | Fish consumption location |         |       | No                     | 74        | 37.6  |
| Yes                    | 195       | 97.5  | Home                | 97        | 50.3  | Yes                    | 123       | 62.4  |
| Catfish consumption    | 8         | 4.1   |                     |           |       |                        |           |       |
| No                     | 16        | 8     | Restaurants         | 3         | 1.5   | No idea                | 14        | 7.2   |
| Yes                    | 184       | 92    | Home/Chop bars      | 42        | 21.8  | Marine                 | 43        | 22.2  |
|                        |           |       | Home/Restaurants    | 23        | 12.1  | Freshwater             | 37        | 19.1  |
|                        |           |       | Chop                | 6         | 3.1   | Yes                    | 26        | 13.4  |
|                        |           |       | bars/Restaurants    |           |       |                        |           |       |
|                        |           |       | Home/Chop           | 13        | 6.7   | Marine and pond        | 38        | 19.6  |
|                        |           |       | bars/Restaurants    |           |       | Marine and pond        | 7         | 3.6   |
|                        |           |       |                     |           |       | Marine, freshwater and pond | 28       | 14.4  |

Wastewater endpoint*+- respondents were asked if they were aware of where the wastewater generated from their homes ends up.
them citing examples such as gutters, sea, evacuation by cesspit and also the wastewater treatment plant. Again, 120 (60.3%) of the respondents were aware of the existence of a wastewater treatment plant in the area but with respect to wastewater treatment process, 172 (86.9%) of the respondents were unaware of it.

132 (66%) of the respondents were not concerned about the source of their fish as that variable had no bearing on the purchase or consumption of fish as shown in Figure 6. Only 30% of the respondents considered this when buying fish. Considering where respondents buy the fish they consume from, majority of the respondents, 135 (69.6%) bought from the market (including cold stores, table top markets), only 8.2% of the respondents preferred to buy their fish at farm gate. Further probe into consumer knowledge of the sources of fish led to the following outcome; about 43 (22%) of the respondents said the fish they consumed came from marine sources and 37 (19.1%) presumed that the fish came from freshwater, while 38 (19.6%) presumed that the fish came from either marine or fresh water sources. Of the respondents’ surveyed, majority of them (92%) were catfish consumers while few (8%) were non-catfish consumers in the two communities. In terms of frequency of consumption of fish in general, Figure 7 shows that 92 (47.4%) consumed fish more than eight times in a week, 61 (30.5%) of the respondents consumed fish 3–5 times in a week and 32 (16%) consumed fish 6–8 times in a week, and the remaining nine respondents (4.6%) consumed fish less than five times in a week. Most of the respondents consumed fish at home (97 or 50.3%) instead of restaurants and chop-bars. The preferred form in which the fish was consumed was smoked (70.1%, Figure 8). Results presented in this section are all described in Table 1 above.

The factors that influenced the consumers’ preference for fish in general included food safety, price, size, taste, packaging, freshness as well as the specific species of fish with the most important factors being, food safety (63%), freshness of the fish (51%), taste (44%), and packaging (41%), described in Figure 9. Price and the size of the fish did not really affect consumers’ decision to purchase or consume fish.

3.3. Consumers’ willingness to pay for fish

The study proceeded further to examine the willingness of consumers to pay for the fish produced in treated wastewater. In achieving this, the probit regression model was used and the results are reported in Table 2. The results revealed a positive and significant relationship between the proximity to the treatment plant (location), the current price GHe12/kg (€2/kg), fish consumption (whether they consume fish or not) and their willingness to pay for the fish produced in treated wastewater at 5% significance level.

Specifically, the results showed that individuals who were further away from where the wastewater is treated were less likely to purchase the catfish grown in the treated wastewater compared to individuals who are close to the treatment site. Also, individuals who perceived the current price (€2.00) to be affordable were more likely to purchase relative to those who perceived the current price to be expensive. Also, with regards to religion, the study showed that individuals who were Muslims were more likely to purchase fish from the treated wastewater as compared to individuals who were Christians. With respect to age, individuals who were less than 20 years were more likely to purchase the said fish compared to individuals who were older. However, the study reveals that education (secondary and above), source of fish, number of dependents, and age (between 20-39 and 40–59 years) had a positive but insignificant relationship with willingness to pay for fish produced in treated wastewater. This indicates that the source of the fish did not affect consumers’ preference to purchase or consume the catfish from the treated wastewater. Again, the results revealed negative but non-significant relationship between knowledge about the
treatment process, income (between €42 and €125 and above €125), gender, and the willingness to pay for fish produced in treated wastewater. This non-significant outcome means that these factors do not influence individuals’ willingness to pay for fish produced in treated wastewater.

3.4. Growth and water quality

The results obtained from the study showed that the growth rate in the AWFPs was higher than the growth rate in the NWFPs as indicated in Figure 10 and Table 3. Weight gain, specific growth rate, and total yields, and survival rates recorded for AWFPs were also higher compared to the NWFPs.

Aeration resulted in improved DO levels, which was more than double in the aerated pond compared to the non-aerated ponds and also resulted in lower COD and BOD levels, however, temperature remained fairly the same (Table 4).

3.5. Cost benefit analysis of production Clarias gariepinus in treated wastewater per production cycle

The total cost and revenue generated for growing *Clarias gariepinus* in treated wastewater for 12 weeks is summarized in Table 5. Fish grown in the maturation ponds under both aerated and non-aerated conditions were not fed; this eliminated the cost of feeding and reduced the production costs. The difference in weight gain of the fish in the aerated and non-aerated wastewater-fed ponds influenced the total revenue generated from either of the systems. Although, aeration improved the growth rate of the fish grown in the aerated maturation ponds, it did that at an extra cost of €30.00 (€5.00) to the cost of production for its use during the period of culture in the aerated system. The aerated system recorded a higher revenue; €1338.83 (€223.14) as compared to the non-aerated maturation ponds €585.02 (€97.50). However, the production recorded a loss of €104.99 (€17.50) for the fish grown in the non-aerated whereas the aerated ponds generated a profit of €618.83 (€103.14). Benefit cost

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**Table 2. Estimated binary probit results of factors influencing consumer willingness to buy fish from treated wastewater.**

| Variable                          | Coefficient | Robust Std. Error | Marginal Effect | P-value |
|-----------------------------------|-------------|-------------------|-----------------|---------|
| Education: Secondary & above      | 0.0141      | 0.3020            | 0.0466          | 0.9629  |
| Religion                          | 0.5001      | 0.2798            | 1.7876          | 0.0738  |
| Source                            | 0.2039      | 0.2345            | 0.8693          | 0.3847  |
| Treatment process                 | -0.0347     | 0.3038            | -0.1141         | 0.9091  |
| Location                          | 0.4261      | 0.2091            | 2.0383          | 0.0415  |
| Current price                     | 0.9276      | 0.2687            | 3.4522          | 0.0006  |
| Reduced priced                    | 0.5207      | 0.3710            | 1.4037          | 0.1604  |
| Income (GHC251-750)               | -0.2756     | 0.4062            | -0.6785         | 0.4975  |
| Income (above GHC750)             | -0.1849     | 0.4363            | -0.4238         | 0.6717  |
| Fish consumption                  | 1.4206      | 0.4267            | 3.3294          | 0.0009  |
| Dependents                        | 0.0640      | 0.0532            | 1.2036          | 0.2287  |
| Age less than 20 yrs.             | 0.6208      | 0.3728            | 1.6650          | 0.0959  |
| Age:20–39yrs                      | 0.3512      | 0.2908            | 1.2076          | 0.2272  |
| 40–59 yrs.                        | 0.2750      | 0.2990            | 0.9233          | 0.3588  |
| Gender                            | -0.0672     | 0.1984            | -0.3389         | 0.7347  |
| Constant                          | -2.2416     | 0.8144            | -2.7524         | 0.0059  |

The highlighted figures show a significant relationship between the respective variable and the willingness of the respondents to pay for fish produced in the treated wastewater.
That women are mostly responsible for the household shopping. One of the challenges of using treated wastewater for culturing fish is the consumers’ willingness to accept or consume fish coming from such an environment even though the treated wastewater might meet all the health and hygiene guidelines for re-use of wastewater for aquaculture (Gebrezgabber et al., 2015).

In Ghana and in Kumasi to be precise, consumers of fish generally do not bother about the source of the fish they consume. Comparatively in this study, the source of the fish did not significantly affect the preference of the consumer to purchase or consume fish cultured in the treated wastewater. The main factors known to affect fish consumption and preference from several studies are age, gender, marital status, family size, income levels among others (Erickson et al., 2007). From literature additional reasons have been given for high consumption of smoked catfish and this includes the fact that it has good taste, it remains whole when used in soups and stews and also had a longer shelf-life as compared to the other forms of processed fish (Aggrey- Fynn, 2001).

Fish preference and consumption from this study was generally based on the availability and the price at which fish was being offered. General perception of the respondent regarding their preference for the smoked catfish was because they considered the smoked catfish to be a healthier source of meat due to the long hour of smoking which reduces the fat contents of the fish, the price at which the fish was being offered was considered affordable for the consumers at different income levels (Erickson et al., 2007). From literature additional reasons have been given for high consumption of smoked catfish and this includes the fact that it has good taste, it remains whole when used in soups and stews and also had a longer shelf-life as compared to the other forms of processed fish (Aggrey- Fynn, 2001).

Figure 10. Growth performance of African catfish cultured in the non-aerated wastewater fed pond (NWFPs) and aerated wastewater fed pond (AWFPs) for 12 weeks.

Table 3. Survival and growth performance of African catfish cultured in Non-Aerated wastewater-fed pond (NWFPs) and aerated wastewater-fed pond (AWFPs) for 12 weeks.

| Parameters                        | NWFPs          | AWFPs          |
|----------------------------------|----------------|----------------|
| Initial average weight (g)       | 39.13 ± 6.5    | 39.12 ± 4.8    |
| Final average weight (g)         | 90.70 ± 11.59  | 189.10 ± 11.32 |
| Weight gain (g)                  | 51.57 ± 1.6    | 149.98 ± 19.9  |
| Specific growth rate (%/Day)     | 0.92 ± 0.007   | 1.39 ± 0.11    |
| Initial number of fish stocked    | 600            | 600            |
| Final number of fish harvested    | 430 ± 14.14    | 475 ± 15.56    |
| Survival (%)                     | 71.67 ± 2.35   | 78.5 ± 2.12    |
| Yield (g/225m²)                  | 39001.00 ± 1282.69 | 89822.2 ± 2941.71 |
| Yield (Kg/ha)                    | 1733.38 ± 56.59 | 3958.49 ± 106.97 |

Results are presented in means ± SD (n = 2).

Table 4. Water quality parameters measured in the aerated pond (AWFPs) and the non-aerated pond (NWFPs) over 12 weeks culture period.

| Parameter          | NWFPs       | AWFPs       |
|--------------------|-------------|-------------|
| Temperature (°C)   | 23.49 ± 0.19| 25.5 ± 0.1  |
| DO (mg/L)          | 2.04 ± 0.36 | 4.7 ± 1.2   |
| COD (mg/L)         | 136.0 ± 4.0 | 100.0 ± 10.0|
| BOD (mg/L)         | 45.0 ± 10.0 | 40.0 ± 2.5  |

Results are presented in means ± SD, n = 2.

4. Discussion

4.1. Consumer preference for catfish grown in treated wastewater

Majority of the respondents in the survey were women, this was because the women were mostly at home at the time the survey was conducted. The occupations; mostly petty traders, of most of these women restricted them to their house and its environs. Some men also delegated their spouses to fill out the questionnaire on the basis that the women were responsible for the food purchases of the home. This was in line with conclusions drawn by Darko (2019), and Obiero et al. (2014), that women are mostly responsible for the household shopping. One of the challenges of using treated wastewater for culturing fish is the consumers’ willingness to accept or consume fish coming from such an environment even though the treated wastewater might meet all the health and hygiene guidelines for re-use of wastewater for aquaculture (Gebrezgabber et al., 2015).

In Ghana and in Kumasi to be precise, consumers of fish generally do not bother about the source of the fish they consume. Comparatively in this study, the source of the fish did not significantly affect the preference of the consumer to purchase or consume fish cultured in the treated wastewater. The main factors known to affect fish consumption and preference from several studies are age, gender, marital status, family size, income levels among others (Erickson et al., 2007). From literature additional reasons have been given for high consumption of smoked catfish and this includes the fact that it has good taste, it remains whole when used in soups and stews and also had a longer shelf-life as compared to the other forms of processed fish (Aggrey-Fynn, 2001).
than eight times in a week owing to the fact that fish was a cheaper source of protein especially in households where numbers of dependents were high (between 4-6). This concurs with findings by Gebrezgabher et al. (2015), who reported that fish was consumed by consumers of Kumasi more than six times a month. The high fish consumption in the two towns surveyed is quite unusual considering that these are non-fishing towns. For the small number of non-catfish consumers identified in this study, most were not concerned about the culture in wastewater but reasons for not consuming the fish was religion related. They do not consume specific species of catfish from the Clariidae family such as Clarias gariepinus (big head catfish) but rather preferred the other species of catfish.

It is perceived that higher levels of education increases consumers’ appreciation for safe and hygienic food. According to Fernandez-Polanco and Luna, (2010) consumers with higher education tend to be more particular about their health status and are more inclined to purchase fish whilst considering the source of the fish. Contrary to findings by Gebrezgabher et al. (2015) and Fernandez-Polanco and Luna, (2010) education did not significantly affect the respondents choice at Chirapatre and Ginyase to consume or purchase fish from the treated wastewater probably because expenditure patterns of most individuals were influenced by their income levels and not their educational level.

Proximity to the treatment plant and awareness of the wastewater treatment process seemed to affect the choice of the respondents to consume fish from the wastewater. Respondents from Ginyase who were not in close proximity to the treatment plant were less likely to consume fish coming from the treated wastewater due to perceptions that fish cultured in the treated wastewater may not be too safe for human consumption. This could be attributed to the fact that these individuals may not be privy to how the fish is processed to ensure it is of good quality and safe for human consumption and for that matter they may be less likely to purchase the fish. The reverse was true for consumers in Chirapatre who were privy to the wastewater treatment process and hence were more likely to consume fish cultured in the treated wastewater, agreeing with findings by Gebrezgabher et al. (2015) which said that residents in Kumasi did not mind where the fish they consume comes from.

Age distribution saw majority of the respondents falling within the 40–59 age range (33.5%) followed by respondents between the age range 20–39 (33%). Respondents with ages below 20 proved to be more likely to consume fish from the treated wastewater, this may be due to the fact that individuals at such ages do not have much influence on the food they consume since most of the foods they eat are provided by their parents and guardians. Also, individuals at such ages are not conscious of food safety issues, are more conscious of sustainability issues or they do not consider the sources of the food they consume.

Fish cultured in the treated wastewater did not pose any health risk to the consumers according to a study on heavy metal and microbial contamination of fish cultured in the wastewater (Yeboah-Agyepong et al., 2019). Heavy metals concentration in both fish and water were all within acceptable limits for human consumption according to FAO and WHO limits. Microbial concentrations were expectedly high on the skin and gut of the fish, however a protocol for depuration and smoking was developed which further reduced the microbial concentrations significantly making the fish safe for human consumption (Yeboah-Agyepong et al., 2019). This was reassuring according to findings of this study because majority of the consumers preferred their catfish smoked.

4.2. Growth performance of african catfish

This study revealed that the growth performance of fish in the aerated pond was more than twice that of the non-aerated ponds. Improved growth performance was as a result of increased DO concentration falling within the optimum ranges (3.05–4.10 mg/L) required by the catfish as reported by Vivien et al. (1986). The DO is a very important parameter which affects fish growth, feed utilization as well as the survival of fish in a pond. When DO concentrations are too high or too low, the growth parameters listed above are usually negatively affected. This study recorded an average DO concentration of about 2.03 mg/L higher in AWFPs compared to NWFPs, the increase in

Table 5. Cost benefit analysis of growing African catfish in AWFP and NWFP for 12 weeks.

| Item                        | Quantity | NWFPs | Total (¢) | Quantity | AWFPs | Total (¢) |
|-----------------------------|----------|-------|-----------|----------|-------|-----------|
| Final weight                |          | 90.70g| 189.10g   |          |       |           |
| Gross Receipts              |          |       |           |          |       |           |
| Catfish (Yield-cost/kg)     | 39.001   | 15.00 | 585.02    | 89.2552  | 15.00 | 1338.83   |
| Total Gross Receipt (A)     |          | 585.02| 1338.83   |          |       |           |
| Initial weight              |          |       |           |          |       |           |
| Variable Cost               |          | 39.13g| 39.12g    |          |       |           |
| Catfish fingerlings         | 600      | 1.00  | 600.00    | 600      | 1.00  | 600.00    |
| Labor (Field assistant/month) | 3       | 20.00 | 60.00     | 3        | 20.00 | 60.00     |
| Aerator** (cost/pond/month)| 0        | 0.00  | 0.00      | 3        | 10.00 | 30.00     |
| Total Variable cost(B)     |          |       |           |          |       |           |
| Fixed cost – C             |          | 30.00 | 30.00     |          |       |           |
| Pond rent                   | 3        | 10    | 30.00     | 3        | 10    | 30.00     |
| Total cost (B + C)         |          |       | 690.00    |          |       | 720.00    |
| Total Revenue              |          | 585.02| 1338.83   |          |       |           |
| Profit                     | -104.99  |       |           | 618.83   |       |           |
| Profit Margin              | -0.15    |       |           | 0.86     |       |           |
| Profit per fingerling      | -2.69    |       |           | 6.93     |       |           |
| Break even price per fish  |          |       |           |          |       |           |
| Above TVC                  | 16.92    |       |           | 7.73     |       |           |
| Above TC                   | 17.69    |       |           | 8.07     |       |           |
| BCR                        | 0.85     |       | 1.86      |          |       |           |

** Total cost of €10,000 (€1,666.67) spread over 15 years.
the DO concentrations created an optimum environment required for catfish growth. The difference in weight gain indicated that the increase in DO concentrations due to the aeration resulted in better utilization of natural food sources available in the nutrient rich pond for growth. Nutrient rich wastewater ponds are also often characterized by the abundance of phytoplankton and zooplanktons (Vollenweider et al., 1992), the African catfish is also known to be carnivorous and tends to feed more on zooplankton food sources which are available in the pond. These zooplankton species are also dependent on DO and therefore feed more on zooplankton food sources which are available in the pond. These zooplankton species are also dependent on DO and therefore compete with the fish for the limited DO concentrations in the ponds (Sultana et al., 2017).

In terms of fish growth, a similar study conducted by Tenkorang et al. (2012) at the Ahinsan waste stabilization ponds where fish were stocked at the same stocking density of 4 fish/m², recorded weight gain of about 714g over 29 weeks culture period with a specific growth rate of 2.14%/day which was higher than what was recorded in this study. However, survival rates were lower (58%) than what was recorded for this study (79%). It could also be concluded that the high mortality recorded reduced the stocking densities per pond and this increased the weight gain in the sense that there were few fish in the pond consuming abundant natural food resources available in the pond. NWFPs had specific growth rate of fish averagely 0.92%/day for the maturation ponds and this was significantly different from the specific growth rate after the installation of the aerators (1.39%/day). The difference in terms of growth rate was appreciable considering the fact that the fish were not fed during the culture period. This indicates that if the time of aeration is increased to cover the entire period, i.e. between the hours of 8:00pm-7:00am GMT where DO is likely to be low, feed utilization in the pond will be improved thereby impacting the growth rate of the fish positively.

4.3. Cost benefit analysis

Cost of production was slightly lower than in traditional commercial fish ponds due to the fact that the fish were not fed and solely depended on natural productivity resulting from high nutrients in the wastewater. The monetary advantage of not feeding in a wastewater fed aquaculture system is clearly seen in the relatively higher profit margins recorded even in the first 12 weeks. Aquaculture feed forms about 60% of production costs increasing the overall production cost and thereby reducing the profit margins of the regular aquaculture activities as compared to the wastewater fed aquaculture (Hasan, 2007). With fish feed being the most expensive component in traditional fish culture (Amenyogbe et al., 2018) taking that aspect out in wastewater fed aquaculture makes it a more affordable method of fish production. This indicates that wastewater fed aquaculture has the potential to be more economically successful as compared to regular aquaculture assuming high survival rates and good growth rates are achieved.

The aquaculture sector is a very important sector in the country’s development contributing about 3–5% to the country’s GDP. Apart from augmenting the shortage in the quantity of fish demanded relative to the fish supplied, the industry provides a source of livelihood to about 10% of Ghana’s population (Amenyogbe et al., 2018). Wastewater fed aquaculture is becoming an attractive alternative to mainstream aquaculture because of the low capital investment.

The difference in growth rates in the AWFPs as compared to the NWFPs translated to profits in the AWFPs as compared to the loss in the NWFPs. This shows that aside the reduced cost of production due to no supplemental feeding of the fish, increased DO concentrations were significant to cause an increase in fish yield thereby generating profits for the AWFPs. Also, the cost per kilogram of fingerlings used in stocking the ponds were higher than the price at which the matured fish were sold making the venture slightly unprofitable especially in the NWFPs system. This high cost of fingerlings was due to the increase in the size of the fingerlings to about 40g before stocking in the ponds.

Agreeing with the findings of this study, aeration improved growth rate in Channel catfish and also contributed €1,848.70 more income and 2,095kg/acre more fish in the aerated ponds as compared to the non-aerated ponds (Quyyum et al., 2005).

According to Kumar et al. (2014), annual fish production from a municipal wastewater treatment facility rented out to a private contractor for aquaculture stood at about 14,000kg, profits generated from the fish sales also stood at about €10.47. This agrees with findings from this study which shows that wastewater fed aquaculture when well-developed is a profitable venture.

In a work done by Duodu (2015) based on mainstream aquaculture activity where fish were fed full and half rations of the recommended rates of commercial feeds, he noted that although the revenue generated from the full ration was higher, the half rations recorded higher net profits as compared to the full ration, also agreeing with findings that when feeding is reduced and fish made to rely on additional food sources available in the pond, higher profits could be recorded.

5. Conclusion

The most preferred form of the African catfish grown in the treated wastewater was smoked mainly due to health reasons, taste, and the lower prices at which the fish were being offered. According to general comments from the respondents smoked catfish were perceived to be a healthier and an affordable source of protein for consumers of different income levels. In the order of importance, consumers considered food safety, freshness of fish, taste, and packaging as the most important factors that affected their decision to consume fish. The source of the fish and the price did not affect the consumers’ choice to consume fish from the treated wastewater, majority of the respondents were aware of the presence of a treatment plant in the area but with regards to the treatment process majority of the respondents were unaware. The proximity of consumers to the treatment plant, the price, religion, age, and whether or not they consume catfish affected their willingness to pay for African catfish grown in the treated wastewater significantly.

Survival and growth rates of African catfish grown in the aerated ponds with higher DO levels were higher as compared to the non-aerated ponds, implying that the aeration was effective in increasing the productivity levels of the system. The aeration was advantageous in terms of growth performance, and also in terms of economics.

To increase consumers’ interest in consuming African catfish from the treated wastewater, the community should be educated on the process of the wastewater treatment as well as the measures adopted to improve fish quality and safety for human consumption. This will help change the perception of the consumers who were not interested in consuming the fish due to food safety concerns.

For this study, aeration was also done for four hours a day (3:00am to 7:00am), this time should be extended to cover the entire period where the DO concentrations were at 0 mg/L (8:00pm-7:00am). If paddle wheel is to be used, then the ponds should be deepened to avoid high turbidity levels, otherwise other forms of aeration should be considered. The aeration could also improve the growth of zooplankton and also increase utilization of the natural food sources for growth. In the maturation ponds, the fishes were not fed any supplemental feed but they still showed appreciable growth. Therefore, it is recommended that further studies should be conducted to identify the natural food items in the pond that the fish are feeding on and conditions manipulated to increase the productivity levels of those species.

Declarations

Author contribution statement

Sey E. Suzette: Performed the experiments; Wrote the paper.
Agboah W. Nelson and Edziyie Regina: Analyzed and interpreted the data; Wrote the paper.
Amoah Philip: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.
Yeboah-Agyepong Mark: Performed the experiments; Wrote the paper.
Nsiah-Gyambibi Raphael: Performed the experiments.
Abbas Shabana: Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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