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Review

Characterization of Nile tilapia (*Oreochromis niloticus*) Farming Intensities in Liberia

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Abstract: Fish farming is a rapidly growing food sector in developing nations. Liberia is an example of least developed country with a large population facing high poverty levels. This has led to adoption of aquaculture as one of the most important strategies for solving malnutrition and food security problems. However, since the introduction of fish farming, fish yields have been persistently low. To address the shortcomings in fish yields in Liberia, a study was conducted to provide information on fish farming intensities, types, and quality of feeds used by farmers in the culture of *O. niloticus* in Bong, Lofa, Nimba, and Grande Gedeh counties. Using stratified purposive sampling, 120 farmers were interviewed, and their fish feeds were sampled for proximate nutrient analyses. The results demonstrated that fish farming of *O. niloticus* in Liberia is mostly semi-extensive (81.6%), mainly practiced in paddy, barrage, and earthen ponds. On average, farmers produce 165.7 kgha^{-1}of O.niloticus annually, translating to USD 414.25. Farmers use mixed feeding regimes, comprising farmer-made, kitchen waste, and blended commercial feeds. Farmers, on average, spend 43% of their operation cost on feeds, which makes it unsustainable to maintain semi-intensive systems. The main feed ingredients used by Liberian fish farmers are rice bran, wheat bran, corn, palm kernel, and fishmeal. Crude protein levels in feed ingredients are as follows: rice bran (3.7±1.3%), wheat bran (16.4±1.5%), corn (6.3±1.1%), palm kernel cake (14.8±1.4%) and fish meal (63.8±1.3%). Crude proteins were low in formulated feeds, ranging from 8%-15% CP. From this study, poor yields and the slow growth of the O.niloticus can be attributed to low protein diets, rendering farming ventures unprofitable and unsustainable for poor resource farmers in Liberia.

Keywords: Aquaculture feeds; Nile Tilapia; Malnutrition; Semi-intensive; Crude protein

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1. Introduction

The depletion of marine fish stocks and increasing global food insecurity have fueled the rapid growth of aquaculture systems across the world (Matthias, 2020, Yue & Shen, 2022, Dauda *et al.*, 2019). Aquaculture, which encompasses the rearing of fish and other aquatic organisms (Gui *et al.*, 2018), is currently the fastest-growing food sector in the world (Atalah & Sanchez-Jerez, 2020, Barman, 2020), such that in a span of 15 years from the year 2000 to 2015, production rose from 41,724,569.75 to 106,004,183.75 metric tons, with a whopping 154% growth (FAO, 2018). Despite the impressive growth record, Africa only contributed 2.5% to global production, while the least developed sub-Saharan Africa (SSA) nations contributed less than 1.0% (FAO, 2020). The latter has a large percentage of the human population, estimated at 960 million, considered malnourished (FAO, 2011, SCN, 2006). Thus, embracing fish farming in these countries is critical in alleviating hunger and widening the income and, therefore, economic empowerment (Wuyep & Rampedi, 2018, Kassam & Dorward, 2017). Generally, there has been slow adoption of aquaculture in some parts of the African continent (FAO, 2014). The poor aquaculture

productivity, particularly in the poverty-stricken region, is underscored by several factors, including; a lack of policy framework (Ragasa *et al.*, 2022), weak supportive structures and infrastructure (Wuyep & Rampedi, 2018), inadequate aquaculture management skills and most importantly poor quality feeds(Kaleem & Sabi, 2021)).

Aquaculture enterprises have high input demands, with feeds making more than 50% of the total expenses in fish farming (Adéyèmi et al., 2020). For a farmer to strike a significant profit in a shorter time, high-quality and nutritionally balanced feeds are paramount (Anetekhai *et al.*, 2004). However, the high cost of quality feeds impedes its accessibility by the low resource-based fish farmers (Honfoga *et al.*, 2017). Furthermore, the low quality and high cost of feeds make the sector less sustainable for large-scale productions, particularly in rural areas. According to (Singini *et al.*, 2014), most rural farmers settle for low-quality fish feeds sourced from kitchen waste and agro-industry residues. Such feeds not only retards fish growth, lengthens the time to reach market size, and reduces the resilience of fish to bio-physical stress but also degrades the quality of pond water (Hossain *et al.*, 2016).

O. niloticus is ranked as the primary culture fish species and is preferred by tropical sub-Saharan Africa (SSA) farmers because of its versatility in feeding and fast attainment of market size, particularly with all-male populations (Mjoun *et al.*, 2010). However, it requires feeds of adequate nutritional balance to achieve the target size within a farming season (Mjoun *et al.*, 2010). According to Davis (2015), if the pond is sufficiently fertilized, it can sustain the juveniles up to 80 days of grow-out, after which formulated feeds are needed to promote rapid growth (Diana et al. 1994). The low-quality feeds used by farmers have also been shown to contain high Antinutritional factors (ANFs), thus reducing the feed conversion rates and inhibiting growth (Prabu *et al.*, 2017).

The problems of slow up-scaling and out-scaling of fish farming are constrained by feeds and inadequate management skills among farmers, which frustrate SSA farmers (Adeleke *et al.*, 2020). The situation is worsened by political and socioeconomic factors, which compound to disadvantage the aquaculture sector, as in the case of Liberia (Okai, 2018). The country has access to marine fisheries in the Atlantic Ocean. However, several counties are landlocked and rely on fishery products from those with access to the ocean. For decades Liberia's population has relied on wild fisheries for their fish protein requirements; however, disruption in supply caused by several factors, among others civil war, Ebola epidemics, and decline in wild catches, motivated the adoption of fish farming in landlocked counties to bridge the demand gap and offer high-quality fresh fish to the consumers. Despite the multi-sectoral approach to promoting fish farming, no significant contribution from the sector has been recorded (Kpadeh, 2011). Among the challenges Liberian fish farmers face, fish feed-related constraints emerge as the main hindrance to optimizing farming activities. Although fish feeds challenges are widely acknowledged, information on the types and quality of feeds utilized by Liberian fish farmers is lacking. Thus, this study was conducted to provide information on the status of *O.niloticus* farming intensities and the various types and quality of feeds used by farmers in Liberia.

2. Material and Methods

2.1. Description of the study area

The survey and collection of commonly used fish feed samples were conducted in the four Liberian counties of Bong, Lofa, Nimba, and Grande Gedeh. The counties were selected due to their landlocked status and have historically been inaccessible to an adequate supply of fresh and quality fish from the coastal regions. Additionally, they also have significant aquaculture activities compared to other inland counties. Other landlocked counties were excluded from this study on the following basis: A small number of farmers from which no adequate comparative sample could be selected and a lack of experienced farmers in *O. niloticus* farming of more than five years.

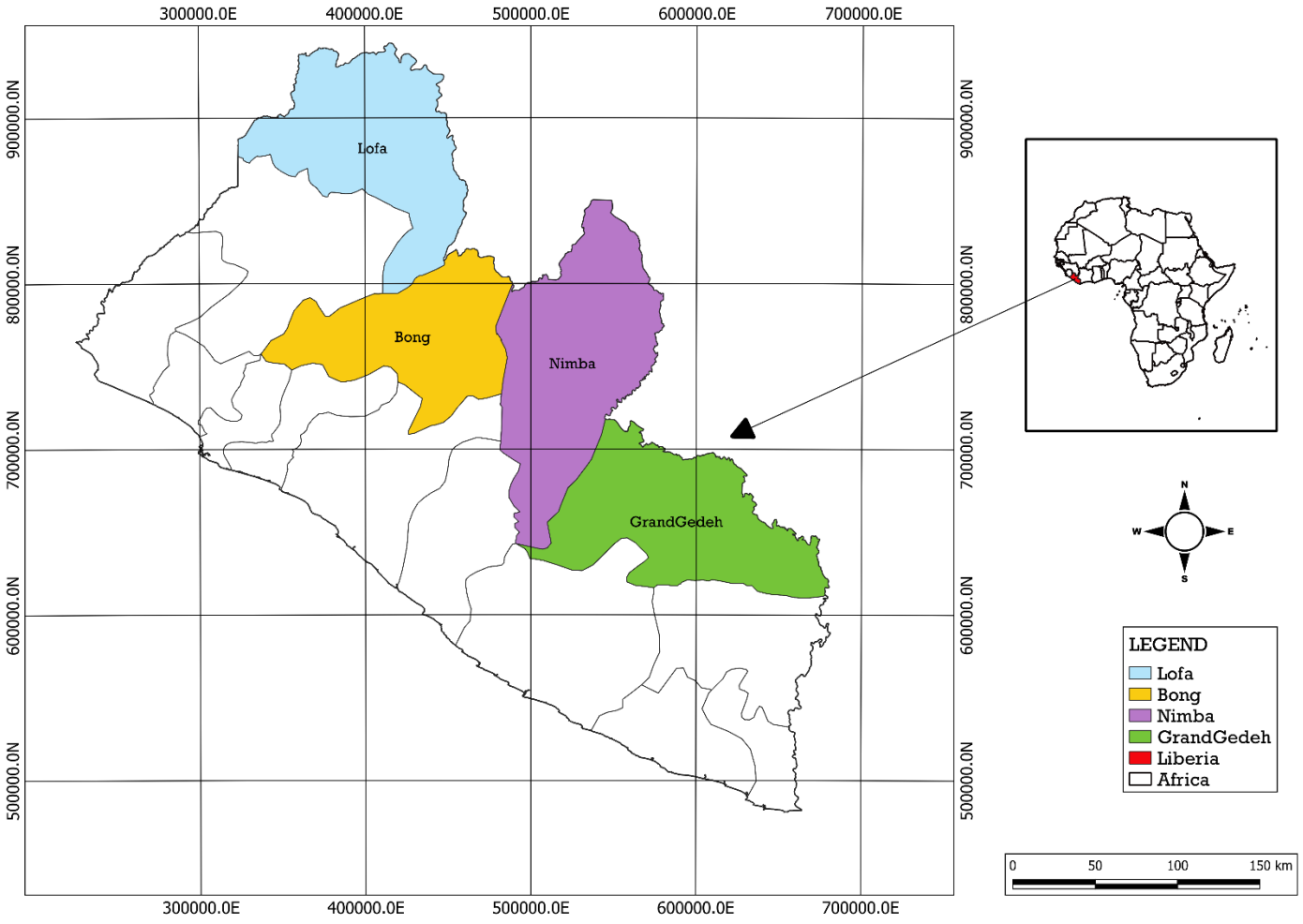


Figure 1. Map of Liberia indicating the Bong, Lofa, Nimba, and Grande Gedeh counties of study.

The survey of aquaculture activities in the four counties was conducted using a mixed structured questionnaire with the cardinal objective of establishing the levels of aquaculture intensity, the types of fish feed commonly used by farmers in Liberia, and the levels of education of households fish farmers. Samples of fish feeds were also collected to determine the proximate composition of the feeds. A clustered purposeful sampling methodology was applied to identify fish farmers who participated in the survey. In each county, participants from youth (18-35 years), women, and adult men engaged in the farming of the *O. niloticus* were identified. Using the sample size formula by (Bartlett *et al.*, 2001, Taherdoost, 2017), $\eta = \frac{p(100-p)Z^2}{E^2}$, a total sample size of 120 farmers were determined.

Where,

η Is the required sample size

P is the percentage occurrence of a state or condition (50)

E is the maximum percentage error required (0.05)

Z is the value corresponding to the level of confidence (1.96)

2.2. Feed sample collection and Crude Protein Analysis

Fish feed samples of 100 grams were collected from each fish farmer in the target counties. The collected samples were mainly obtained from locally made feeds, either containing a single ingredient or compounded using more than one ingredient. Feed samples

were dried at 60º C for 24hour and gr24 hours to pass through a 1mm sieve. The total nitrogen content of the samples was determined using the Kjeldahl method (AOAC, 1997), and the results were multiplied by 6.25 to get the crude protein content, which was expressed as a percentage. Proximate analysis of the feeds was done at the Kenya Marine and Fisheries Research Institute (KEMFRI) and the University of Eldoret laboratories. Data collected were cleaned, arranged, and subjected to descriptive and non-parametric analysis. Significance comparisons were determined at p=0.05 using Kruskal Wallis (KW) and Chi square tests. All analysis were done using IBM Statistical Package for social science version 23.0, and Microsoft Excel 2016.

3. Results

3.1. Fish farmers' characteristics and demographics

The study demonstrated that fish farming in Liberia was mainly dominated by farmers of more than 35 years of age, representing 81.6% of the farmers in all the four counties studied. The level of aquaculture was mostly subsistence, which was practiced comprising 79.2% occupation level. However, a relatively smaller percentage, 21.8%, practiced semi-commercial fish farming. Pond aquaculture constituted 98%, while cage and tank culture contributed 1.2% and 0.8%, respectively. Gender parity was found to be marked, whereby 75.7% of fish farmers were men; however, skewed gender disparities were found dominant among counties, especially in Nimba and Lofa counties, where less than 20% of women actively participated in fish farming, as shown in **Fig. 1**.

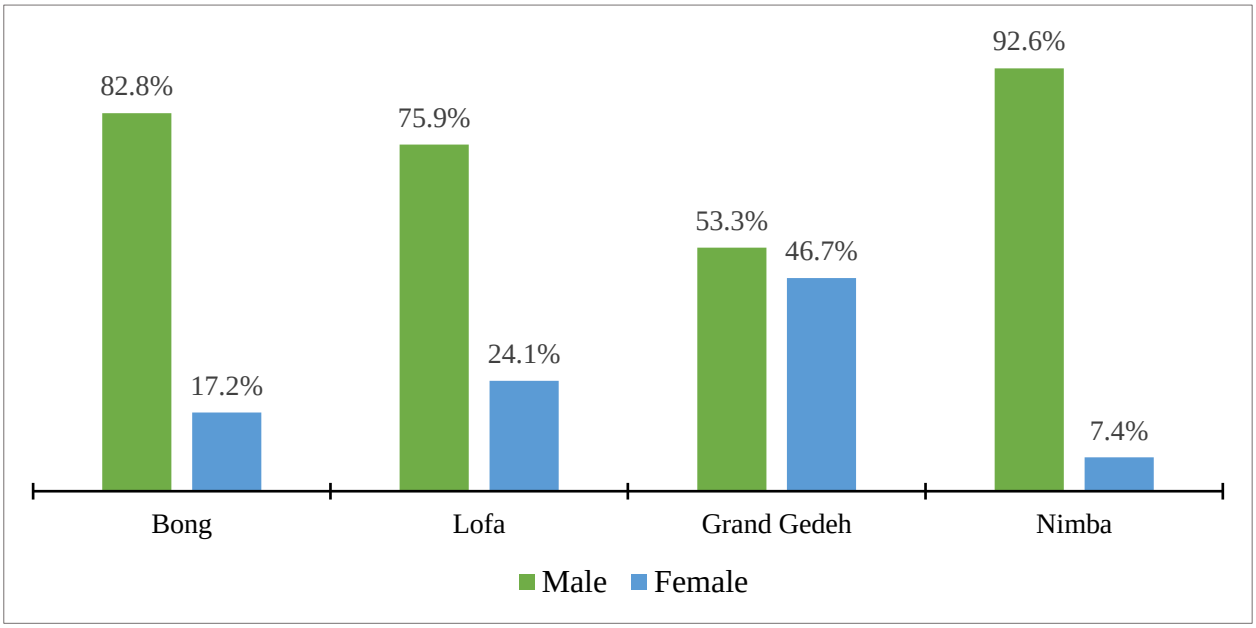


Figure 2. Gender composition of fish farmers in Bong, Lofa Grand Gedeh and Nimba counties, Liberia.

3.2. Education level of fish farmers

Less skilled farmers were found to dominate the aquaculture sector with low basic education and little training in fish farming. The study indicated that 93% of fish farmers had acquired education up to secondary school and below. The literacy level significantly varied among Counties, $\chi 2\ (12) = 27.48$, $p < 0.05$. Fish farmers residing in Bong and Nimba had acquired a higher level of education and training in aquaculture compared to their counterparts in Lofa and Grand Gedeh, as shown in Table 1.

Table 1. Percentage of education level of fish farmers in major farming Counties of Liberia.

County	No formal education	Primary	Secondary	vocational training	University
Bong	31.0	37.9	27.6	3.4	0.0
Lofa	13.8	41.4	44.8	0.0	0.0
Grand Gedeh	16.7	46.7	36.7	0.0	0.0
Nimba	3.7	44.4	25.9	22.2	3.7

3.3. Type of pond systems adopted and fish species reared.

Pond type and size are key factors reckoned in evaluating the progress and production of aquaculture systems. The study found that barrage and paddy ponds were extensively adopted in Bong, Lofa, and Nimba, with more than 60% of farmers adopting the two as their preferred pond systems, while in Grand Gedeh, 65.5% preferred pit ponds. Few farmers used concrete ponds, as indicated in *Table 2*. The pond sizes also varied significantly Kruskal Wallis (KW); $\chi 2\ (3) = 42.812$, $p < 0.001$.

Table 2. Adoption (%) of pond types the Bong, Lofa, Nimba, and Grande Gedeh. Counties of Liberia.

	Paddy pond	Barrage pond	Concrete pond	Pit pond
Bong	31.10	35.00	23.80	10.30
Lofa	33.30	25.00	14.30	20.70
Grand Gedeh	2.20	0.00	47.60	65.50
Nimba	33.30	40.00	14.30	3.40
Average size (m^2)	1531.1	1503.7	478.6	710.3
Mean ranks	71.89	81.08	25.5	44.07

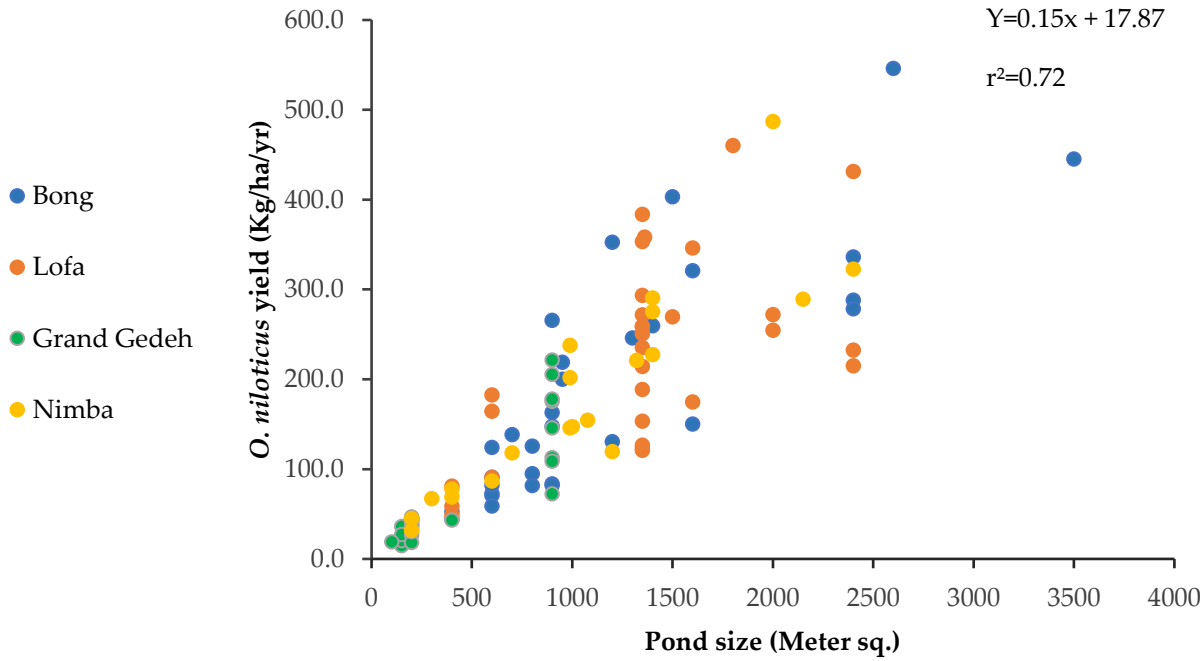
Besides rearing *O.niloticus*, farmers also farmed; *Tilapia mossambicus, Tilapia Zilli*, *Heterotis niloticus*, and Catfish (*Clarias gariepinus*), as reported by 21.1%, 26.7%, 45.6% and 6.7% of farmers, respectively. The species were reared under polyculture systems, rice co-culture, or monoculture in semi-intensive systems. Other species include; silverfish (*Oreochromis niloticus* L.), which was integrated into many aquaculture systems in Grand Gedeh County. Table 3. Shows different fish types reared by Liberian *O.niloticus* farmers.

Table 3. Fish species contribution (%) to fish farming in Bong, Lofa, Nimba, and Grande Gedeh counties.

Counties	*Clarias gariepinus*	***Tilapia Mossambicus***	*Oreochromis niloticus* L	***Tilapia Zilli***	***Heterotis niloticus***
Bong	11.5	11.5	0.0	23.1	61.5
Lofa	0.0	26.1	0.0	13.0	60.9
Grand Gedeh	0.0	9.1	31.8	22.7	36.4
Nimba	15.8	42.1	0.0	52.6	15.8

3.4. Influence of Fish pond size on yield of O. niloticus

The relationship between pond size and *O. niloticus* yield is shown in Fig 2. Pond size positively and significantly correlated (R squared= 0.72, p=0.001) to the production of *O. niloticus*farmer. Big-sized ponds tended to have higher fish yields compared to small ponds.



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3.5. Types of fish feeds on used by farmers in production of the O. niloticus 173

Liberian fish farming can be categorized as semi-intensive, where fish farmers use on-farm made feeds, including kitchen wastes and locally made feeds. Imported feeds are mainly sourced from Ghana and Sierra Leon. The locally-made fish feed is the main type utilized by 67.2% of farmers, while only 32.8% of farmers use blends of imported feeds in their fish feeds. 174 175 176 177 178

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	Type of feeds used		
County	**Local made**	**Household left overs**	**Imported**
Bong	80	44	60
Lofa	48	56	36
Grand Gedeh	56.7	63.3	70
Nimba	61.9	52.4	57.1

Table 4. Percent types of feeds used in *O. niloticus* farming in Bong, Lofa, Nimba, and Grande Gedeh counties. 180 181

The study also demonstrated that farmers use agro-industry sourced by-products as their main feeds. The feeds either are fed to fish as a single ingredient or blended (Formulated). The commonly used feeds included; rice bran, palm kernel, wheat bran, corn, fish-meal, and associated blends. Both single and blended feeds had significantly varying crude protein levels in each county of counties investigated. For instance, rice bran, an extensively utilized fish feed ingredient in all the counties under investigation, was found to have an average crude protein content of 3.7%, 4.0%, 2.9%, and 2.3%in Nimba, Bong, Grand Gedeh, and Lofa, respectively. Other feeds collected from the farmers and their respective %CP were as indicated in *Table 3*. 182 183 184 185 186 187 188 189 190

Table 4. Levels of Crude protein (%) in fish feeds. 191

Feed type	Feed ingredient	Mean %Crude protein (Mean±Standard deviation)	Range
Single-ingredient feeds	Rice bran	3.7±1.3	2.3-5.7
	Wheat bran	16.4±1.5	14.0-18.1
	Corn	6.3±1.1	5.0-6.8
	Palm kernel cake	14.8±1.4	12.9-16.4
	Fish meal	63.85±1.3	62.5-65.4
Blended feeds	Ricebran + soybean	8.264±5.4	3.4-16.4
	Ricebran + Cowpea	9.45±3.9	4.6-14.2
	Ricebran + Corn	6.99±2.6	4.4-11.3
	Ricebran + Fishmeal	15.27±10.6	5.1-32.2
	Ricebran + Palm kernel cake + Fishmeal	19.34±7.8	10.2-28.3

3.6. Fish feeding challenges

The study identified high cost as the major constraint to the use of high-quality commercial fish feeds. Despite farmers adopting extensive and semi-intensive systems, feeds still accounted for 42.98% of total input costs. Besides the high cost of quality feeds, the spread of disease and pollution of fish environments were ranked by 18.3% and 31.3%, respectively, by farmers.

4. Discussion

4.1. Fish farmer characteristics

Results presented herein demonstrate low education levels among farmers in the fish farming sector in Liberia.These findings are expected as the country has the lowest literacy levels in Africa, attributed to the long period of war that disrupted and decimated the education system for more than 14 years from 1989 to 2003. According to (UNESCO, 2020), the average literacy in Liberia as of 2020 was 48.3%, and the value dropped down to an average of 4% for the rural population with upper secondary school level. These results indicate that the fish farming sector is dominated by farmers who have attained primary or secondary education. *O niloticus* farming is also dominated by mature people of more than 35 years of age, which is explainable by the high resource and time demands required by the venture. Young Liberians' have not accumulated enough resources to invest in businesses, including fish farming. Similar observations were made by Akuffo and Quagrainie (2019). They demonstrated that fish farming is an expensive undertaking requiring surmountable resources and high-level management skills to operate, which many youths in developing countries lack. On the other hand, mature or older farmers adopt fish farming as their old age investment, as reported by (Ifeonu *et al.*, 2019). Besides, older farmers are in a position to access bank financing compared to the youth.

4.2. Pond characteristics and influence on O. niloticusproduction

The pond fish culture is the main *O. niloticus* mode of farming in Liberia, and this type of aquaculture is common in other sub-Saharan countries (Kassam & Dorward, 2017, Abowei *et al.*, 2011). The current study established that the adoption of ponds varied by Counties. Nimba, Bong, and Lofa counties use large-sized semi-intensive earthen pond types, including barrage and paddy ponds. In contrast, Grand Gedeh *O niloticus* farmers have embraced small pond farming majoring in concrete and pit ponds. The variation in types of ponds adopted across the counties could be explained by the fact that fish farming in Liberia originated in the former three counties. Hence, farmers settled for multipurpose big-sized ponds and affordable to construct, as in the case of paddy ponds as found by Nhan (2007). One interesting finding revealed by the current study is that *O. niloticus*

yields increased proportionally to the size of the ponds. A possible explanation for this finding is that the size of the pond is essential in regulating water quality, in that small ponds, water deteriorates faster and has a low recovery rate.

Similarly, small ponds have lower oxygen available to the fish, hence compromising growth. Big ponds like; Barrage and Paddy ponds offer stable water quality (Juliette *et al.*, 2016); therefore, quality characteristics such as; ammonia, dissolved oxygen, and pH are constantly regulated (Rahaman *et al.*, 2011). When well-fertilized, the barrage and paddy ponds will have high plankton levels, the primary fish food (Abowei *et al.*, 2011).

4.3. Feed types, quality, and challenges

O. niloticus farming in Liberia is mainly semi-intensive, utilizing locally available agro-industry waste products like rice bran. More than 60% of farmers in each county depend on the by-products of milling as the primary feed for their fish in which dependency is cost influenced. For instance, brans of different cereals are cheap and easily accessible to farmers, increasing their usage. Mmanda *et al.* (2020), (Chenyambuga, 2014) reported that more than 80% of fish farmers rely on locally sourced feeds dominated by cereal brans. *O. niloticus* farmers also use imported feeds to complement the locally sourced feeds. More than 40% of farmers in each county use imported feed to blend the locally sourced, surpassing locally sourced feeds in some counties. The findings are supported by findings by Adéyèmi *et al.* (2020), who found that fish farmers in Benin highly depended on imported feeds because of the insufficient supply of feeds by the local system. Results indicated that, on average, all agro-industry cereal brans and other plant-based by-products utilized by farmers are significantly low in crude protein as compared to findings by Mmanda *et al.* (2020), who reported 9.3%, 13.1%, and 15.5% of crude protein in rice bran, maize bran, and palm kernel, respectively. These values are three times what was found in the present study. The low quality of feeds in Liberia can be attributed to adulterations, which include the addition of sand and other low nutritional materials (Nalwanga *et al.*, 2009). The fish feed industry in Liberia is poorly developed. Currently, no industry is engaged in manufacturing commercial fish feeds in the country. Imported feeds are very expensive, which hinders their use in Liberia; as Limbu *et al.* (2016) explained, imported feeds are highly taxed, hence transferring the cost to the resource-constrained farmers with low purchase capacity.

5. Conclusion

The present study demonstrates that *O. niloticus* farming in Liberia is constrained by farmers' inadequacies and the poor quality of feeds. The bulk (79%) of the Liberian fish farmers are in semi-intensive subsistence farming.

6. Recommendations

The aquaculture government and non-governmental organizations in Liberia should strive to improve the quality of fish feeds and introduce best management practices in fish farming through capacity building.

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Matolla G: Research concept, Manuscript writing, and proofreading

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Written informed consent for publication must be obtained from participating patients who can be identified (including by the patients themselves). Please state "Written informed consent has been obtained from the patient(s) to publish this paper" if applicable.

Data Availability Statement: The data collected under this research is available from the corresponding author upon request.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix. Annex 1: Questionnaire form used in data collection

Evaluation of Nile Tilapia farming intensities and document the impact of different types of feed on Nile Tilapia farming in Liberia

Consent statement

Greetings,

My name is…… {Name of the enumerator}, and I am grateful for your warm welcoming. Am here to collect data on your fish farming activities, particularly on feeding, feed types and challenges on production of Nile Tilapia. The data is meant to provide a highlight into research on "Nile Tilapia production intensities in Liberia" by a PhD student who is undertaking his studies at the University of Eldoret, Kenya. Your participation (fully or partially) is voluntarily. The collected data will be treated with utmost confidentiality and will only be used for stated purpose and creation of awareness that might help in developing supportive policies towards more efficient fish farming in Liberia. Upon consent to participate, the survey also assumes that (1) You (herein denoted as respondent) are not under

influence of any substance, person/s or mental related illness that can interfere with the authenticity of the information you are expected to provide. (2) The responses that you will provide will be consciously made and accurate. Where you find difficult answering a question kindly request for further explanations. I hereby request you to participate in the survey. The interview might take 1 hour. **WELCOME**

Consent given Yes ☐ No ☐ (Tick according to respondents answer)

{If the respondent declines on consent, record the questionnaire number, thank them and move to another farmer as per the provided list}

Section 1: Farmers information

1. Farmer code…… (to be provided by enumerator).
2. GPS
   (a) Northing…….
   (b) Easting……
3. County of the respondent (Select where applicable)
   i. Bong ○
   ii. Lofa ○
   iii. Nimba ○
   iv. Grande Gedeh ○

3.1 Sub-county of the respondent…….

4. Sex of the respondent (Owner of the fish farm) (Select where applicable)
   i. Male ○

ii. Female ◯ 333

iii. Prefer not to say ◯ 334

5. Age of the respondent (Owner of the fish farmer) (Select where applicable) 335

(a) Below 35 years ◯ (b) Above 35 years ◯ 336

6. Highest level of education attained (Select where applicable) 337

i. No education ◯ 338

ii. Primary ◯ 339

iii. Secondary ◯ 340

iv. Vocational ◯ 341

v. University/College ◯ 342

Section 2: General fish farming information 343

1. How long have you been practicing fish farming?…… (indicate the answer in years) 344

2. What motivated your ambition to start fish farming? (Tick all that applies) 345

i. Source of income ☐ 346

ii. Create employment ☐ 347

iii. Market availability ☐ 348

iv. Diversify investment ☐ 349

v. Availability of government/NGO support ☐ 350

vi. Past experience ☐ 351

vii. Any other ☐ 352

State any other factor that motivated you to join fish farming …… 353

3. Total pond size owned……. (meter squares) 354

4. Name fish species you actively farm (Tick all that applies) 355

   i. Nile Tilapia ☐ 356

   ii. Silver Tilapia ☐ 357

   iii. Tilapia Zilli ☐ 358

   iv. Tilapia Mossambicus ☐ 359

   v. Heterotis niloticus ☐ 360

   vi. Catfish ☐ 361

State any other species farmed……. 362

(b) What are the advantage of farming Nile Tilapia over other species? 363

   i. Short maturation period ☐ 364

   ii. Efficient feed conversion ☐ 365

   iii. Can feed on any type of feed ☐ 366

   iv. Can survive under diverse range of environmental conditions ☐ 367

   v. Has ready market ☐ 368

   vi. Any other ☐ 369

State any other Nile Tilapia advantages……. 370

(c) What are the disadvantages of farming Nile tilapia over other species? 371

   i. Feed requirement ☐ 372

   ii. Over population ☐ 373

   iii. Lack of market ☐ 374

iv. High competition from other species ☐ 375

v. Poor adaptation to Liberian climate ☐ 376

(d) What was your total harvest of Nile Tilapia in 2020……(convert to kgs) 377

(e) Rate the productivity of Nile Tilapia over other farmed species 378

i. Very poor ○ 379

ii. Poor ○ 380

iii. Average ○ 381

iv. Good ○ 382

v. Excellent ○ 383

Section 4: Fish feeding 384

1.0 What type of feed do you use to feed your fish? 385

i. Local commercial feeds ☐ 386

ii. Imported commercial feeds ☐ 387

iii. Kitchen remains ☐ 388

2.0 Are feeds used in {Section 4, (1)} continuously available for production period? 389

Yes ☐ No ☐ 390

3.0 (a) If you use local formulated fish feeds, do you prepare the feeds yourself? 391

Yes ☐ No ☐ 392

(b) If Yes, which ingredient do you use and their combination ratio?..... 393

(C) Where do you source your feed ingredients? 394

i. On farm ingredients (crops, grains etc) ☐ 395

ii. From food processors (millers, etc) ☐ 396

iii. Any other? ☐ 397

Specify other sources for your feed ingredient 398

(d) If you don't produce your own feeds, where do you source farmer formulated feeds? 399

i. Other fish farmers ☐ 400

ii. Local feed vendor ☐ 401

iii. Local market ☐ 402

iv. Any other ☐ 403

Specify any other……. 404

(e) How much do you pay per Kilograms of locally formulated feeds…….(state amount in USD) 405

(g) If you use commercial feeds, where do you source them? (Tick all that apply) 406

i. Local Agro-dealers ☐ 407

ii. Local markets ☐ 408

iii. Government ☐ 409

iv. Non-governmental organizations' ☐ 410

v. Import ☐ 411

vi. Other ☐ 412

(h) What challenges do you face in accessing commercial feeds? 413

i. Expensive ☐ 414

ii. Not available locally ☐ 415

iii. Poor quality ☐ 416

iv. Others ☐ 417

Specify other challenges ……. 418

4.0 How do you administer the feed to the fish? 419

i. Manual broadcasting ○ 420

ii. Automated feeding ○ 421

iii. Other ○ 422

Specify any other feeding mechanism used…… 423

5.0 (a) Do you keep records on the impact of feed to the growth of the fish? 424

Yes ☐ No ☐ 425

(b) If yes, what are the growth aspects monitored? (Tick all that apply) 426

i. Fish weight ☐ 427

ii. Fish length ☐ 428

iii. Fish yield ☐ 429

iv. Survival rate ☐ 430

6.0 (a) Have you received training on how to formulate feed for the farmed fish species? 431

Yes ☐ No ☐ 432

(b) If **YES,** what aspect of feed formulation were you trained in? (Tick all that apply) 433

i. Feed rationing ☐ 434

ii. Feed ingredients ☐ 435

iii. Feed types ☐ 436

iv. Feeding different fish species ☐ 437

(c) Who provided the training? (Tick al that apply) 438

i. Government extension officers ○ 439

ii. Non-Governmental organizations ○ 440

iii. Research institutions (Universities, agriculture organizations etc) ○ 441

iv. Fellow farmers ○ 442

v. Any Other ○ 443

Specify any other place/organization you received training 444

7.0 What are some of challenges you face in feeding your fish? 445

8.0 What management practice do you adopt to ensure that the fish are in the best of condition? 446

9.0 What are your recommendation on improving aquaculture in the country? 447

i. Increased government support in terms of inputs ☐ 448

ii. Improved extension services ☐ 449

iii. Improved access to quality feed ☐ 450

iv. Other ☐ 451

Specify any other suggestion; ……. 452

Finally, you are requested to provide samples of your fish feeds to the enumerator for laboratory testing. (Provide at 453

least 500g of each fish feed type) 454

Thank you for your participation 455

456

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