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Socioeconomic Characteristics and Biosecurity Measures of Fish Farms in the West Region of Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. Authors DFN, MKK and JAN conceived, designed and coordinated the study. Authors DFN, EM, CTT, AKF and LBFZ coordinated the fieldwork, designed data collections tools and data collection with the guidance of authors JAN and MKK. Authors DFN, AKF, LBFZ, EM and CTT undertook data presentation, quality assessment and statistical analysis and participated in the preparation of initial drafts of the manuscript. Authors JAN, MKK, DFN, CTT and EM critically reviewed the manuscript. All authors read and approved the final version of this manuscript.

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ABSTRACT

Aims: The study aims to evaluate socio-economic and zootechnical characteristics, and biosecurity practices in cultured fish farms in the West Region of Cameroon.
Study Design: A stratified cross-sectional study using random-number generation method of fish farms and their locations to select fish farms without replacing the number.

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Place and Duration of Study: Fish farms in West Region, Cameroon between December 2018 and April 2019.
Methodology: Questionnaire survey and on-farm observations to obtain information on socioeconomic characteristics of farmers, production characteristics of fish farms, biosecurity and preventive measures. Fifty-one fish farms were surveyed.
Results: Most respondents were married (96.1%) Muslims (51%) men (84.3%) with primary school level education (51%) and at least 40 years old (92.2%). Mix fish species farming was widespread with *Oreochromis niloticus* (100%) being predominant followed by *Clarias gariepinus and Cyprinus carpio* (47.1%), *Heterotis niloticus* (9.8%) and *Clarias jaensis* (5.9%). The fishes were fed once daily (35.3%) with farm-made feeds (66.7%) and showed 7 to 12 months breeding cycle (76.5%). Predation, theft, lack of financial and technical support were the main constraints for fish farmers. Extensive (94%) fish farming was predominant and isolation (66.66%), sanitation practices (94.12%) and traffic control (62.75%) were the biosecurity components adopted in farms. Lack of finance was the major cause of abandonment and poor biosecurity compliance rate (<25%) in the study. Husbandry system, culture duration, pond water source, capture method and religion of farmers influenced ($p<0.05$) biosecurity scores.
Conclusion: The study presents the first report on socioeconomic and technical characteristics, and biosecurity measures of fish farming activities in Cameroon. It revealed no socio-cultural and religious taboos in fish farming. Farm biosecurity practices can be improved through education and training of farmers on farm practices and biosecurity measures in collaboration with academic and fishery industry partners for improved productivity of fish farms in Cameroon.

Keywords: Cultured fish farming; socio-economic and Zootechnical characteristics; biosecurity compliance; West region of Cameroon.

1. INTRODUCTION

Aquaculture plays a vital role in food security, livelihood, nutritional and socio-economic well-being in many communities in the world [1,2]. It provides feedstock to the industrial sector, rural development as well as increase export opportunities, enhanced management of natural resources and conservation of biological diversity [3,4]. Fish farming is an efficient means of animal protein production, accounts for more than 50% of supplies of fish in local markets and provides essential nutrition for over one billion people in Africa [5] and poverty alleviation in many communities in developing countries [6-10]. In Cameroon, the total domestic fish production of about 180,000-tonnes per annum is far less than the total expected domestic demand of about 400,000 tonnes annual [11]. Cameroon requires over 220,000 tonnes of fish annually to meet FAO's recommended minimum fish consumption rate of 12.5 kg per head yearly to satisfy basic protein needs [11,12] and relies on overexploitation of fish stocks, development and extension of fish farming [1] and importations of frozen fish.

There is expansion of the fishery sector with potentials for higher production in Cameroon, though the intensification of fish breeding and associated risks of diseases are poorly understood. Spreading of aquatic animal disease is of serious concern to world aquaculture industry, trade and profitability. New diseases are emerging due to growing aquaculture production, production in new locations, new candidate species and new culture methods. Some pathogens frequently encountered in farmed stock cause disease when favorable conditions arise such stressed animals and favourable environmental conditions while others pathogens are highly destructive even under standard and perfect husbandry conditions [2,13-15]. Many factors cause huge losses to production in aquaculture systems but disease is the most serious constraint that causes drop in performance and productivity (due increased morbidities and mortalities) in farms and damage to the livelihood of farmers, loss of job, reduced incomes, and food insecurity [13,15]. Massive production loss of up to 50% due to diseases have been recorded in developing countries causing many farmers to abandon and new farmers to become discouraged in fish husbandry [2,13,15]. Health maintenance in aquaculture through good hygiene and husbandry practices to manage the impact of these pathogens is one of the most important aspects of aquaculture development and management. Biosecurity is the key to reduce the risk of diseases entering in a farm and suitable biosecurity measures can prevent

emerging health issues and reduce impacts of disease with the principle of preventing diseases rather than curative response [2,8,9,13-16]. Improper husbandry practices, inadequate implementation of biosecurity measures, presence of disease-causing agents in fishpond waters and fluctuations in water quality have been associated with the occurrence of fish disease [2,8,13,14,16].

The physical, chemical, and biological factors of water are important in the biology and physiology as well as the feed efficiency, growth rate, health, and survival of fish [7,8,13,14]. Rapid fluctuations of water quality parameters may result in stress, reduce resistance to diseases and possible death of fish. The tolerance levels for water quality parameters vary with different fish species, within which they can survive, grow and reproduce [2,13,16]. Thus, implementation of biosecurity measures will eliminate disease-causing agents from culture environments and hosts as well as limit the spread of pathogens [14]. Reliable sources of stocks, adequate detection and diagnostic tools for avoidable diseases, disinfection and pathogen-eradication, good Manufacturing Practices, Hazard Analysis and Critical Control Points, Traceability and Control of Insects and Rodents and practical accepted legislation are the key elements of biosecurity as these measures protect against transmission of infectious agents and reduce the consequences of infection [9,13,14]. Suitable biosecurity measures are essential to prevent occurrence of health problems and reduce impact of disease and economic losses in fish farms [6,9,10,14]. Therefore, identification, assessment and management of risk factors are important in a standard biosecurity process [9,14]. Proper quarantine of stocks, isolation of affected stocks, maintenance of personal hygiene, control of people, animal and vectors, water supply, feed and farm waste materials are essential biosecurity measures to limit threats of disease outbreak and zoonosis and can significantly influence the socio-economic (and particularly financial) gain from the fish farming [6-10,13,14,17].

Though lack of resources in the fishery sector is a factor in many developing countries including Cameroon, good management systems, implementation of adequate biosecurity measures and favourable culture conditions are essential for healthy fish as well as their optimal performance and productivity. Biosecurity is a core concept for fish farming for purposes of food safety, sustainability and trade worldwide. However, there is dearth of information on evaluation of the level of knowledge of biosecurity and biosecurity practices of producers of the fishery sector in Cameroon. In livestock farms with provisions in place to prevent diseases and disease-causing agents there is reduced financial losses due to diseases [18]. Sporadic and variable reports exist in some countries in Africa on biosecurity scores and factors affecting implementation of biosecurity practices on cattle [19], pig [20], poultry [21,22] and fish [9,17,23] husbandry. There are information on the reproduction, feeding nutrition and production systems of fish [17,23,24] and little or no investigation on the biosecurity measures of fish farms in Cameroon.

In this context, reference information about the characteristics of fish farmers and farming practices that may affect occurrence and transmission of fish diseases, fish survival and suitability of fishpond water for fish farming is important for sustainability and expansion of fishery industry in Cameroon. The objective of this study was to evaluate the socio-economic and technical characteristics, and biosecurity measures in cultured fish farms in the West Region of Cameroon.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in three administrative divisions (Menoua, Noun and Hauts-plateaux) of the West Region of Cameroon (9°50' – 10°20' E and 5°10' – 5°40' N) (Fig 1). The West Region has a typical sudano-guinean climate, characterised by a short dry season (mid-November – mid-March) with a temperature range of 20 – 27ºC, long rainy season (mid-March – Mid-November) with a temperature range of 16 – 23ºC, average annual rainfall of 1600 mm and relative humidity ranging from 49 – 97.9% between the dry and rainy season [25].

2.2 Selection of Fish Farms

A cross-sectional study was carried out during the period of December 2018 to April 2019 using a stratified sampling procedure to select fish farms. Fish farms in eight (8) administrative divisions (Menoua, Noun, Bamboutos, Ndé, Hauts-Nkam, Nkoung-Khi, Mifi and Hauts-Plateaux) of the West Region were sampled for the study. The selection of fish farms was done

by random-number generation method of fish farmers and locations of fish farms from records at the Divisional Delegations of Livestock, Fishery and Animal Industries (DDEPIA) and snowball technique (where the manager of previously known farms helped to identify other farms until all farms in a study division were identified). The selection procedure took into consideration costs, road accessibility (including distance and time to trek to farms), period at which farmers will harvest fish and farmer's willingness to participate in the study. Eligible farms for each study division was numbered and the study farms chosen randomly without replacing the number. Overall, fifty-one (51) fish farms were included in the study.

Fig. 1. Map showing Cameroon in Africa and the administrative divisions of the West Region of Cameroon

(*Source: Map of Cameroon and West Region of Cameroon were adapted from Wikimedia Commons: https://commons.wikimedia.org/wiki/Maps_of_Cameroon)*

2.3 Questionnaire Survey of Farmers and Scoring of Fish Farms

Face-to-face interviews and on-farm observations were used to complete a questionnaire composed of three sections (socioeconomic characteristic of farmers, production characteristics of fish farms, biosecurity or preventive measures). Slight modifications, which took into account local realities, of investigations on scoring and compliance levels of biosecurity measures previously described by Arthur et al. [26], Kone et al. [23], Obosi and Agbeja, [9], Wanja et al. [2] and Kouam and Moussala [20] was used in the study. Briefly, data were collected through semi-structured questionnaire interviews to available and willing respondents who were either the owners of the fishponds or took part in the management of the fishponds. The questionnaire focused on information relating to lifestyle and level consciousness of fish farmers, background information of fishpond (fish species and culture type, water sources, and pond type), management practices (pond fertilization type, farm size, stocking density, feed sources, and seining/harvest practices), disease diagnosis, health management and biosecurity practices. On-farm visits to observe the farming sites and operations as well as the surrounding environment supplemented the interviews. The questionnaire was initially pretested, revised and corrected accordingly before use. The study categorized and analyzed the responses obtained from these variables to determine the characteristics of fish farms according to the biosecurity measures adopted (Biosecurity scoring and compliance levels).

A technical scoring system was developed from the biosecurity indicators (measures), ranging from 0 to 1. A biosecurity measure was coded as 1 if this measure was implemented or present, or 0 if the measure was not implemented or absent [27-29]. The final score for each measure was the sum of all the values recorded on farms (either 0 or 1 per farm) and grouped according the biosecurity components (isolation, traffic control, and sanitation). The biosecurity compliance rates were determined as follows: $R_c = N_{am} / T_m \times 100$ [30]; where R_c = Compliance rate, N_{am} = Number of measures applied by breeder and T_m = Total of recommended measures. The biosecurity compliance level was ranked low when $R_c \leq 25\%$, intermediate if $25\% < R_c < 75\%$ and good $R_c \geq 75\%$ [31].

2.4 Data Analysis

The obtained data were validated, coded (using 1 or 0), entered and stored in Microsoft Excel and then exported onto Statistical Package for the Social Sciences (SPSS) version 22.0 for analysis. Descriptive statistics was performed to summarize socio-economic characteristics, biosecurity scores, and biosecurity compliance levels of cultured fish farmers and zoo-technical characteristics of farms. The significance level was fixed as 5%. The multivariate linear regression model was used to evaluate the relation between biosecurity score of farms and the socio-economic and zootechnical characteristics of farmers and farms [21,32].

3. RESULTS

3.1 Socio-economical Characteristics of Fish Farmers

Overall, 51 fish farms were used in the present study. All the farmers reported that they had been trained in fish farming. Most of the cultured fish farmers were married (96.1%), Muslim (51%), men (84.3%) with primary school level education (51%) and at least 40 years old (92.2%) (Table 1). The average age of the fish farmers was 51.42 ± 10.54 years old (range: 40 – 70 years) and had been involved in fish farming for an average period of 15.50 ± 10.34 years (range: 5 – 40 years). The respondents were involved in fish farming for pleasure and auto-consumption (66.7%) as well as for income generation (33.3%), while (66.7%) are retired civil servants and others practiced crop cultivation and livestock husbandry (31.4%).

3.2 Technical Characteristics of Fish Farms

The study showed that most fish farms (92.2%) in West Region of Cameroon practiced extensive husbandry system (Fig. 2) and the pond size of many fish farmers (54.9%) was less than 300 m^2. Most fish farmers (84.3%) had at most two ponds while some (15.7%) had more ponds on their farms.

The study revealed that many farmers kept *Oreochromis niloticus* (52.9%) and mix farming (47.1%) of *Oreochromis niloticus*, *Clarias gariepinus, Cyprinus carpio*, *Heterotis niloticus* and *Clarias jaensis* in the West region (Table 2).

The fish species were fed once daily (35.3%) with farm made feeds (66.7%) and showed breeding cycle varying from 7 to 12 months (76.5%). Most fish farms in the region used water from rivers (96.1%) and from wells (3.9%). The average weight of harvested fish ranged from at least 300g (37.3%), less than 250g (35.3%) and between 250 and 300g (27.5%).

Table 1. Socio-economic and demographic characteristics of culture fish farmers in West region of Cameroon

Factor	Variables (N= 51)	Percentage (%)
Age group (years)	≤ 40	7.8
	>40	92.2
Sex	Male	84.3
	Female	15.7
Religion	Christian	9.8
	Muslim	51.0
	Animist	39.2
Marital status	Single	0
	Married	96.1
	Widow(er)	1.96
	Divorced	1.96
Level of education (school attended)	Never been to school	13.7
	Primary	51.0
	Secondary	35.3
	Tertiary	0
Received training in fish farming	Yes	100
	No	0
Longevity in fish farming (years)	≤ 10	62.7
	10<x≤ 20	11.8
	>20	25.5
Principal occupation	Fish farmer (Retired civil servants)	66.7
	Farming (Crop and livestock)	31.4
	Business (Trader)	2
Reason for being involved in fish farming	Auto-consumption+ gifts	66.7
	Income generation	33.3

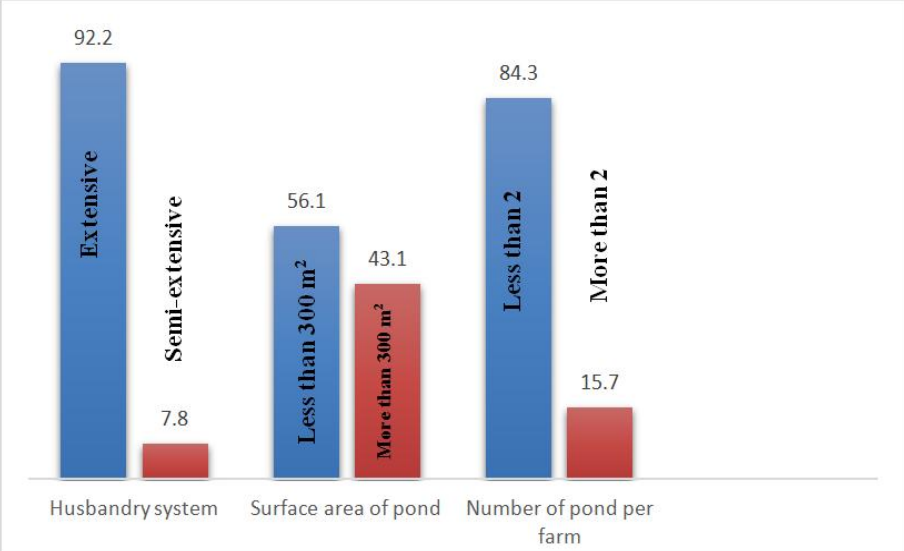

Fig. 2. Model characteristics of fishponds in the West region of Cameroon

Table 2. Zootechnical characteristics of fish farms in the West region Cameroon

Factor	Variables (N= 51)	Percentage (%)
Species of fish cultured(1)	*Oreochromis niloticus*	100
	Clarias gariepinus	47.1
	Cyprinus carpio	47.1
	Heterobranchus longifilis	9.8
	Clarias jaensis	5.9
Combination of fish species cultured	*Oreochromis niloticus*	52.9
	Oreochromis niloticus + Clarias *gariepinus* + *Heterobranchus longifilis* + *Cyprinus carpio*	9.8
	Oreochromis niloticus + *Clarias gariepinus* + *Cyprinus carpio*	31.4
	Oreochromis niloticus + *Clarias gariepinus* + *Cyprinus carpio* + Clarias jaensis	5.9
Type of feeds used(2)	Farm-made foods	66.7
	Agro- industrial by-products	25.5
	Residues (pig slurry+ hen droppings+ cattle manure)	9.8
Feeding frequencies	Everyday	7.8
	Once daily	35.3
	Twice daily	29.4
	After every 2 days	27.5
Source of pond water*	River	96.1
	Wells	3.9
Duration of culture period or Breeding cycle (months)	Months ≤ 6	23.5
	Months >6	76.5
Average weight of harvested fish (gm)	gm ≤ 250	35.3
	250 <gm ≤ 300	27.5
	gm > 300	37.3
Production per production cycle[3] (kg)	kg ≤ 20	7.8
	20 < kg ≤ 120	90.2
	kg > 120	2.0
Annual production (kg)	kg ≤ 20	7.8
	20 < kg ≤ 120	35.3
	kg > 120	56.9
Workforce on the farm	≤ 2	7.8
	>2	92.2
Capture method	Non specialised#	33.3
	Specialised	76.5

(1) Many fish species can be found in the same fish farm

(2) Different feed types can be used by the same fish depending on fish species and maturity status

(3) Harvest frequency per year ranged from 1 to 3 (average = 2)

**: Watering frequencies or Water circulation: Continuous (70.6%); discontinuous (29.4%)*

#: Draining of water (23.5%), landing net (60.8%), net fishing or seine (5.9%), Draining of water + net fishing + landing nets (2%), Draining of water + angling + landing net (7.8%)

#: Others methods rather than using net or synonyms

Many respondents reported lack of financial and technical supports (62.3%) from target structures such as the government, loss of fish (62.8%) due predators, breakage of dam and theft and lack of finance (64.7%) as the main constraints to the development of fish farming in the study region.

3.3 Biosecurity Scoring and Compliance Levels of Fish Farms

The results showed an overall biosecurity compliance rate of 21.57%. Most farms (94.12%) showed low (≤ 25%) biosecurity compliance level, some (5.88%) showed intermediate (26 to 75%) level and there was no farm (0%) that showed high (> 75%) level. Locality had no significant (P>0.05) on biosecurity compliance rates. However, farms in the Hauts - Plateaux division showed an intermediate (moderate) biosecurity compliance rate (27.27%) compared to the other divisions, which showed low (< 25%) rates (Fig. 3).

Though the traffic control biosecurity component showed intermediate or moderate (26% to 75%)

adoption rates for biosecurity measures, low adoption rates for biosecurity measures (< 25%) was high irrespective of biosecurity component (Table 3).

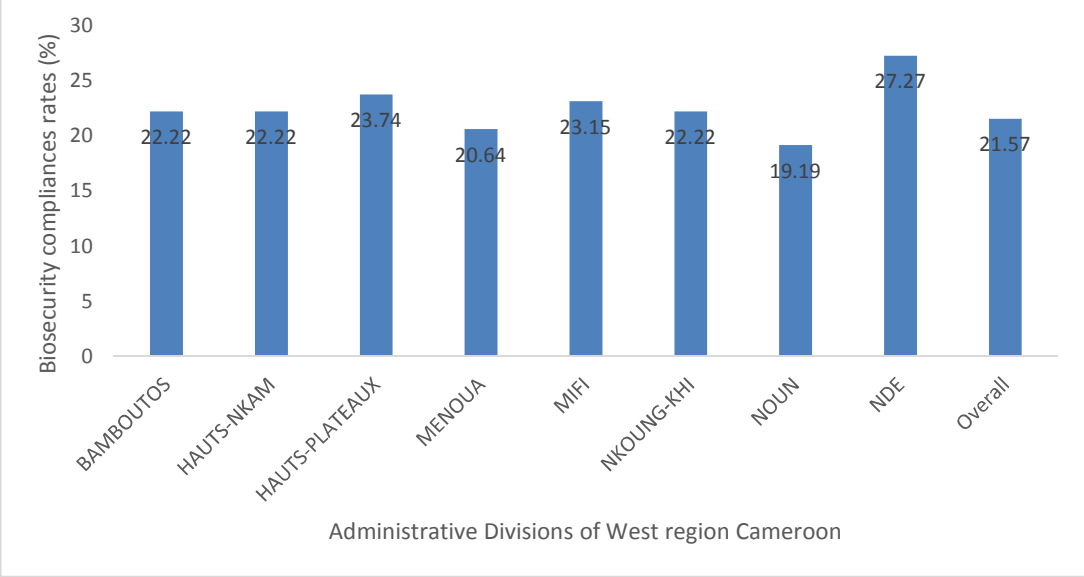

Fig. 3. Distribution of biosecurity compliance rates of in fish farms according to administrative division in the West region of Cameroon

Table 3. Distribution of the adoption and compliance levels of biosecurity measures according to biosecurity components in fish farms of the West region

Biosecurity components	Variable (N= 51)	Biosecurity practices	Total n (%)
Isolation	Farm is fenced	Yes	17 (33.3)
		No	34 (66.7)
	Others animals species are present on the farm	Yes	51 (100)
		No	0 (0)
	New fishes were quarantined before introduction into the pond	Yes	20 (39.2)
		No	31 (60.8)
	Presence of bushes and trees around farms	Yes	0 (0)
		No	51 (100)
	Compliance rates	Low (x≤ 25%)	34 (66.67)
		Moderate [25%<x<75%]	17 (33.33)
		High (x≥ 75%)	0
Traffic control	Visitors allowed around fish ponds	Yes	51 (100)
		No	0 (0)
	Visitors are allowed to have contact with fish in ponds	Yes	47 (92.2)
		No	4 (7.8)
	Materials are exchanged among farms	Yes	51 (100)
		No	0 (100)
	Complete emptying of ponds after each production cycle	Yes	51 (100)
		No	0 (0)
	Water supply tracks protected to trap debris and unwanted aquatic animals	Yes	33 (64.7)
		No	18 (35.3)

Biosecurity components	Variable (N= 51)	Biosecurity practices	Total n (%)
	Compliance rates	Low (x≤ 25%)	19 (34.25)
		Moderate [25%<x<75%]	32 (62.75)
		High (x≥ 75%)	0 (0)
Sanitation	Footbath was functional	Yes	0 (0)
		No	51 (100)
	Veterinary intervention	Yes	0 (0)
		No	51 (100)
	Carcass management	Consumed	19 (37.25)
		Disposed (feed dogs, pits, crop farms)	32 (62.75)
	Workers use personal protective wears (clean coverall and boots) on farm	Yes	3 (5.9)
		No	48(94.1)
	Analysis of water quality	Yes	0 (0)
		No	51 (100)
	Diagnosis of fish diseases#	Yes	4 (7.8)
		No	47 (92.2)
	Awareness of biosecurity measures	Yes	51 (100)
		No	0 (0)
	Awareness of fish diseases	Yes	14 (27.45)
		No	37 (72.55)
	Disinfection of farm tools before use	Yes	3 (5.9)
		No	48 (94.1)
	Treatment of fish diseases*	Yes	4 (7.8)
		No	47 (92.2)
	Compliance rates	Low (x≤ 25%)	49 (96.1)
		Moderate [25%<x<75%]	2 (3.9)
		High (x≥ 75%)	0 (0)

#: Diagnosis of fish diseases by farmer based on skills acquired during fish training program attended
**: Treatment of fish diseases by farmer using plants products*

3.4 Relationship between Fish Farms Characteristics and Implementation of Biosecurity Measures

Multivariate regression analysis of factors affecting the implementation of biosecurity measures showed significant positive relationship ($p< 0.05$) for religion, husbandry system, duration of culture or Breeding cycle, source of pond water, capture method and number of ponds and negative relationship ($p< 0.05$) for size of pond (Table 4). However, the study recorded slight positive relationship ($p>0.05$) for farmer's age group, longevity in fish farming, level of education, principal occupation, feeding frequencies and for protection of water supply tracks to farms to trap debris and unwanted aquatic animals and slight negative relationship ($p>0.05$) for farmer's sex and marital status, reason for being involved in fish farming, production per cycle and workforce in the farm.

4. DISCUSSION

This study presents the first report the evaluation of socio-economic and technical characteristics and biosecurity measures of fish farms in a major fishery production region in Cameroon. It provides information on of the characteristics of fish farmers, husbandry systems, biosecurity scores and factors affecting biosecurity practices in the West region of Cameroon, which is a humid soudano-guinean agro-ecological zone with forest galleries. The predominant involvement of men older than 40 years was associated with low level of interest among the younger age group while the most females in the study communities were engaged in other activities. The finding agrees with Olasunkanmi [33], Obosi and Agbeja [9], Olaoye et al. [10], Ntsama et al. [8] and Adeosun et al. [6] who reported that fishery activities were mostly dominated adult/elderly married men and not by females, younger and unmarried individuals as

Table 4. Regression model of socioeconomic characteristics of fish farmers and technical characteristic of farms influencing biosecurity score of farms

Characteristics	Regression coefficient	p-value
Socioeconomic characteristics of farmers		
Age group (years)	0.049	0.366
Sex	-0.004	0.489
Religion	0.306	0.015*
Marital status	-0.134	0.174
Longevity in fish farming (years)	0.022	0.439
Level of education	0.011	0.469
Principal occupation	0.102	0.237
Reason for being involved in fish farming	-0.065	0.325
Technical characteristics of farms		
Husbandry system	0.416	0.001*
Duration of culture or Breeding cycle (months)	0.566	<0.001*
Workforce on the farm	- 0.044	0.380
Water supply tracks protected to trap debris and unwanted aquatic animals	0.059	0.342
Feeding frequencies	0.016	0.457
Capture method	0.316	0.012*
Production per production cycle (kg)	-0.110	0.221
Source of pond water	0.804	<0.001*
Size of pond	-0.476	<0.001*
Number of ponds per farm	0.340	0.007*

** significant difference (p < 0.05)*

well as farmers being engaged in other occupation apart from fish farming. Also, due to land rights issues and access to water, the fish farms were located in rural communities and most farmers were local inhabitants who owned the fish farming lands and women fish farmers used ancestral lands. The finding agrees with previous reports in other regions of Cameroon [7,8,34] and Nigeria [33,35] that men dominated fish farming. Societal constraints on female inhabitants, with little or no access to land and water, showed low management skill and literacy level who lacked capital and credit opportunities for fishing activities have been reported [36-38]. Women are challenged on the use of assets (e.g. livestock), control over household income and limited entrepreneurial rights to dispose of income and to invest [38]. However, the proportion of women fish farmers in this study was higher than levels reported in Ivory Coast (5.98%) [39], Jamaica (8 – 11%) [40] and lower than proportions in Nigeria (15.8 – 40%), Sri Lanka (30%) and Bangladesh (60%) [6,10,40,41]. The observed variations was due to some regions having well developed fishery sectors and better management abilities of gender-related difficulties in agriculture and animal husbandry. Though women used ancestral land, the study also revealed interest of urban employed and wage earning women in fish farming in agreement with Idumah [42] and Oni et al. [43] who reported that ownership of the farmed plot, education and social status had positive influences on farm productivity. Therefore, proximity of farms to ready markets would positively encourage investments in fish farming.

In the present study, regression analysis revealed strong positive relations (better) between religions (there were more Muslims than the other religious groups among respondents), husbandry system (extensive), duration of culture or breeding cycle (> 6 months) and the implementation of biosecurity measures. Weak positive relationships were shown between age group, longevity in fish farming and level of education of farmers and implementation of biosecurity measures. As a result, the respondents with highest number of years of experience were adult/elderly married men had good skill (technical know-how) and better approaches to fish farming business and poorer biosecurity scores that younger farmers. While young (≤ 40 years) farmers showed fewer years of experience in fish farming, higher level of education and better biosecurity scores than older (>40 years) farmers. Further regression analysis revealed negative relationships between sex and marital status of farmers, workforce size

of farms and implementation of biosecurity measures. The poor biosecurity scores recorded suggest negligence of farm hygiene conditions and practices even with large farm staff sizes. However, the respondents where of mixed religions, different age groups and both sexes and all of them reported having at least primary school educational level, married and trained in fish farming. Workforce especially among farmers with marriage status included family relatives, though there some household members focused more on non-fish farming activities. These findings revealed no socio-cultural and religious taboos in fish husbandries and that proper training of the work force and increasing experience in the domain would have positive influences on biosecurity compliance levels and scores with consequent improvement in the performance and productivity of the fish farms in the region. The positive influences of good education, training and experience on fish farming techniques and the gross economic potential of the fish sector has been described [6,10,14,33-35].

Most farmers in the present study owned less than two ponds whose sizes were less than 300 square meters due to limited to access to land and water. This finding agrees with FAO, [37], Olaoye et al. [10], Adeosun et al. [6] and Shitote et al. [35] who reported that the fish farming in many African countries was at subsistence-level management levels in small size ponds with low levels of production. However, the size of pond has a positive relationship on productivity and net farm income in fishpond production [6,10]. This implies that, with standard fish farming practices when access to land and water are not problematic and given other inputs, increasing pond size in the study region will lead to an increase in productivity and net increase in farm income. However, regression analysis showed that number of ponds was positively while pond size negatively related to implementation of biosecurity measures in fish farms in this study. This implies that, irrespective of number of fishponds, small-sized compared to large-sized pond fish farms recorded better biosecurity scores through implementation of hygiene conditions and standard farm practices.

The study revealed mixed fish farming of *Oreochromis niloticus, Clarias gariepinus, Cyprinus carpio* and *Heterotis niloticus* with *Oreochromis niloticus* being the predominant fish species. The finding is similar to that of Hirigoyen et al. [34], Anoumou et al. [6] and Obosi, and Agbeja, [9] who reported that the *Tilapia spp* including *Oreochromis niloticus* as the dominant species. The *Tilapia spp* was easier to produce, relatively resistant to diseases and available from extension services compared to the other species that are more susceptible and required controlled breeding in more specialised-types ponds. The study is contrary to Olaoye et al. [10] who recorded more farms with *Clarias spp* than *Tilapia spp.* Fish feeds were made on-farm and composed of agricultural by-products with some farmers (particularly farmers with single small ponds) supplementing the ponds with animal solid waste such as pork slurry, chicken manure and cattle manure. In agreement with Olaoye et al. [10] who reported that fish farmers were engaged in other occupations, fish farming was a secondary activity for many respondents were more involved in agriculture. Many respondents applied non-specialised capture or harvest methods (such as complete drainage of ponds and use of unsuitable net or fishing lines) which were laborious, unpredictable and usually demanded extra workforce. The workforce in the present study were mainly composed of family members some of whom lacked experience similar to the observation of Hirigoyen et al. [34].

Lack of financial and technical support from target structures, loss of fish due predators, breakage of dam and theft were the main constraints to the development of fish farming in the study region. Lack of financial and technical support, high cost of feed, lack or poor quality of fry and fingerlings, lack of knowledge of fish farming principles by farmers and lack of technical improvement by extension agents and researchers [7,8,44] have been noted as the main constraints to fishery activity in Cameroon. However, lack of financial and technical support are common challenges among smallholder farmers in many African countries [6,7,10,14,33-37]. Generally, small and marginal farmers in the developing countries do not follow any biosecurity measures in their farm and consider the biosecurity measures as unnecessary financial burden without realizing its potential positive impacts [14]. Implementation of biosecurity measures can have positive impacts on fish farming such as significant socio-economic and financial gains; control of threats of disease outbreak and zoonosis besides enhancing fish farm performance and productivity. Following lack of resources (financial and technical supports) reported by many respondents in the present study reported, government's participation would be vital in

boosting subsistence fish farming [8]. Also, most respondents reported long fish production experience and positive relationship between experience and economic efficiency have been described [6,10] showing that farmers with more experience had better knowledge and technical know-how on how to efficiently manage input resources. Therefore, creating fish farmers associations and cooperatives could strengthen financial capabilities of farmers and attract further finances and necessary technical supports. Nonetheless, lack of scientific knowledge and support as well as unavailability of standard biosecurity protocol, inadequate legal framework and their implementation are important constrains in the fishery sector many developing countries including Cameroon that cannot be overemphasized.

The biosecurity scoring system adopted in this study assumed that all potential biosecurity measures were of equal weight and the system scored each measure equally as either 1 or 0 as previous described [45]. The system provided values to determine the biosecurity implementation levels for farms and biosecurity components, though other systems focus on the prominence of biosecurity measures in reducing the risks associated with the introduction and spread of diseases [20,21,45]. For example, the weighed scoring system for disease transmission pathways do not have the same efficiency since direct contact poses higher risk than indirect contacts with less efficiency to transmit pathogens [45]. The present study used an empirical adaptation of previous described scoring systems [20,21,27,45,46] since farm animal will suffer from poor health due to poor or lack of implementing biosecurity measures. The focus was on the importance of implementing biosecurity measures on the health of farm animals and not the level of risk posed by each biosecurity measure. Therefore, the measures were weighed equally without neglecting any biosecurity measure even when it was thought to be less efficient in the transmission and occurrence of a disease.

Overall, the biosecurity score was rank low (≤ 25%) and the extensive system did not seem to cause the low scores in the study according to FAO/OIE/Work Bank [47] and Haynes et al. [30]. The low (<25%) levels of adoption for biosecurity components (Isolation, sanitation, traffic control) suggest that farmers were negligent of biosecurity practices and did not apply appropriate biosecurity measures. The finding agrees with previous reports that associated poor biosecurity scores to ignorance of farmers (due to lacked training) and inadequate or lack of application (if they knew) of the appropriate measures against disease transmission and occurrence in their farms [9,48,49]. Lack of knowledge and understanding, lack of communication, time, audit programs of biosecurity, potential risks and economic constraint [7-9,14,22] have also been recorded as reasons for low biosecurity compliance levels by farmers. The low biosecurity scores in the present study may suggest implementation of few biosecurity measures due to lack of proper knowledge of the importance of biosecurity in a farm [9,12,14,50]. Similarly, little or no practice of biosecurity measures and low biosecurity compliance rates of fish farming have been reported in Ivory Coast [23], Nigeria [9] and Kenya [2] and intermediate or moderate to high biosecurity practices and compliance levels in other parts of the world [51,52]. Overall, the respondents' awareness of biosecurity in the present study was good but their knowledge, understanding and attitude of Biosecurity measures and practices were evidently limited. All farmers were classified as poor or fair for their compliance with overall farm-level biosecurity measures. The study showed that: farmers' practices were mostly not in compliance with biosecurity principles especially in regards to the adoption of biosecurity components (Isolation, sanitation, traffic control) and the inconsistencies observed indicated that it may be feasible to improve farmer's implementation of biosecurity at farm level.

5. CONCLUSION AND RECOMMENDA-TIONS

The paper presents the first report on socioeconomic and technical characteristics and biosecurity measures and practices of fish farming activities in the West region of Cameroon. Fish farming is a socio-economically profitable activity with no socio-cultural and religious restrictions in the region. However, many factors relating to lack of financial and technical supports, loss of fish due to predators, breakage of dam and theft, and poor biosecurity compliances and scores constrain the development of fish farming. The study showed that, age, religion, experience in fish farming, level of education, husbandry system and breeding cycle (duration of culture) had favourable influences on the implementation of biosecurity measures. The poor biosecurity

scores was due to negligence of standard fish farming practices and poor understanding of biosecurity measures of farmers which can be improved by good educational level and fish farming training in collaboration with academic and fishery industry partners. Also the study revealed that longevity in fish farming, competent workforce (that observe farm hygiene conditions and practices) and good biosecurity compliance levels by farmers are possible and vital for improved productivity of fish farms in the region.

5.1 Compliance with Ethical Standards

The study is not reporting results from an experiment on animals or humans. The researchers performed risk assessment to avoid hazards to persons involved in the project. Permission for the study and Ethical approval were obtained from the required in the West of Cameroon [Regional delegation of Livestock, Fisheries and Animal Industries (RDEPIA) and Faculty of Agronomy and Agricultural Sciences of the University of Dschang, Cameroon] before carrying out the study. The purpose of the study was explained (with the assistance of local veterinary and Fisheries practitioners, community leaders and trusted intermediaries) to fish farmers in the selected administrative divisions.

CONSENT

Fish farmers and their farms were included in the study when verbal informed consent was obtained. Completing the questionnaire further implied consent to participate in the study.

ETHICAL APPROVAL

The researchers performed risk assessment to avoid hazards to persons involved in the project. Permission for the study and Ethical approval were obtained from the required in the West of Cameroon [Regional delegation of Livestock, Fisheries and Animal Industries (RDEPIA) and Faculty of Agronomy and Agricultural Sciences of the University of Dschang, Cameroon] before carrying out the study. The purpose of the study was explained (with the assistance of local veterinary and Fisheries practitioners, community leaders and trusted intermediaries) to fish farmers in the selected administrative divisions. Fish farmers and their farms were included in the study when verbal informed consent was obtained. Completing the questionnaire further implied consent to participate in the study.

DATA AVAILABILITY

The raw data used to support the findings of this study are available from the corresponding author upon reasonable request.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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