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Compliance and effects of biosecurity measures in fish farms in the Adamaoua Region (Cameroon)

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Abstract
The main objective of this study was to evaluate biosafety practices in fish farms in the Adamawa region of Cameroon in order to contribute to the improvement of fish production. A cross-sectional study was carried from 2024 in the Adamawa region. A semi-structured interview and direct observations were used to collect data on biosafety practices and fish production in 32 fish farms. The main results showed a global biosafety measure compliance rate of 20%. No farm recorded a compliance rate between (25-75) or >75. The training received by fish farmers in aquaculture and the constraints related to biosafety practices, the production system, the production phase, the breeding infrastructure, and disease diagnosis significantly affected the compliance rate. For example, a farm applying 23.08% of biosafety measures recorded the best production, followed by those applying 22.12%, although the mortality rate, the average weight of fish at harvest of less than 300 g, and the non-compliance with feeding hours remained at 20%, 68.1%, and 90.6%, respectively. A strong correlation was thus established between the compliance rate of biosafety measures and fish production, while operational constraints persist as a major obstacle. This study highlights in importance of greater stakeholder involment in the implementation of biosecurity practices and provides a basis of the health certification of fish farmers and quality assurance of their products.

Keywords: Biosafety, Adamawa-Cameroon, compliance rate, fish production, mortality

Introduction

Fishing is a vital source of protein and income and contributes significantly to food security (Ndoazen *et al.*, 2024) [18]. Rice-fish farming is an activity that is gradually becoming established as an agricultural activity in countries with a fishing tradition (Niaré *et al.*, 2023) [19]. Fish farming is an alternative to increase the availability of fish (Niaré *et al.*, 2023) [19]. Sustainable fish farming requires the management of multiple pathologies (Fonkwa *et al.*, 2023) [11]. Economic losses from fish diseases have been postponed by more than USD 12 million in Thailand and USD 26 million for Vietnam (Fonkwa *et al.*, 2023) [11]. Inproving fish production yield is one of the best solutions to meet the ever-increasing demand for fish consummation (Kondombo *et al.*, 2025) [16]. In Cameroon, the production of certain species notably *Oreochromis niloticus*, *Clarias gariepinus* and *Cyprinus carpio* is clearly evolving. An epizootic of *Clarias gariepinus* and *Cyprinus carpio* is highly increasing (Wikondi *et al.*, 2023) [23]. An epizootic of Yersinia in *Oreochromis niloticus* and *Cyprinus carpio* generated a lost of approximately USD 420.50 in a breeding farm in the Centre Region of Cameroon (Fonkwa *et al.*, 2022) [10]. In sub- Saharan Africa, *Heterosis niloticus* is the lowest- growing species (Jeanne *et al.*, 2022) [13]. Failure to comply with biosecurity measures against pathogens has often been the origin of the appearance of mass fish mortalities, particularly in the hatcheries (Johnson *et al.*, 2004; Racicot and Vaillancourt, 2009) [14, 20].

Biosecurity in the aquaculture context is an umbrella term that covers the application of appropriate measures (anticipatory risk analysis) aimed at reducing the probability that an organism or biological agent will affect an individual, a population or an ecosystem, and to mitigate the harmful effects that could result from it (Fonkwa *et al.*, 2024) [12]. It refers to considerations related to the management of aquatic animal health, the preservation of aquatic biodiversity and the reduction of risks that production and consumption of aquaculture products presents for public health. This analysis is carried out in the light of the most reliable information and scientific data in the field of breeding and epidemiology. Biosecurity is a strategic and integrated approach that encompasses policy and regulatory frameworks aimed at analyzing and managing risks related human, animal and plant life and health, including environmental risks associated (FAO, 2007) [6]. Better biosecurity can help improve production and reduce the use of antibiotics. Biosecurity can also be defined as the application of measures to reduce the probability of introduction (external biosecurity) and of the spread of pathogens within the farm (internal biosecurity). The main thing is therefore to avoid the transmission of pathologies either between farms or within the farm (Alarcon *et al.*, 2021) [1]. Biosecurity is a tool for managing diseases risk in a fish farm. Thus, sustainable management of risks linked to diseases in fish farms requires in- depth knowledge of the practice of biosecurity. Once the disease has occurred on the farm, its treatment technically becomes and financially more restrictive (Fonkwa *et al.*, 2023) [11]. The hence objective of this study was to evaluate biosecurity measures on fish farms in order to contribute to the improvement of fish production through better practice of biosecurity measures in the Adamawa region of Cameroon.

Materials and methods

1. Study site

The study was carried out between April and October 2024 in fish farms in the Adamawa region of Cameroon whose characteristics are as follows geographical coordinates: 5° - 8° North Latitude and 11° - 14° East Longitude surface), area: 63,701 km², temperature: 22.6 °C and precipitation: 900 to 1500 mm. Fig. 1 shows the study area.

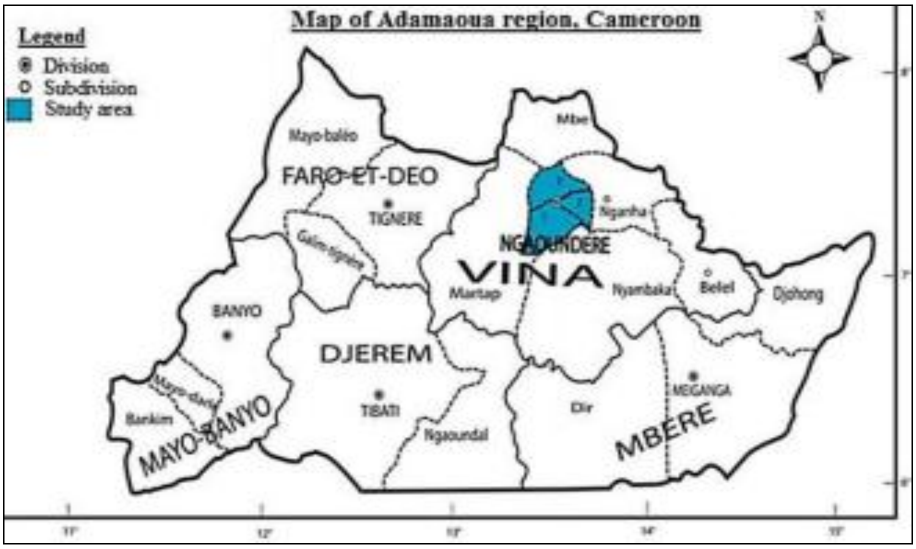
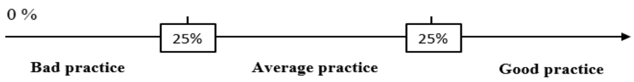


Fig 1: Location of the study site

2. Sampling and data collection

A survey was conducted in fish farms in the Adamawa region-Cameroon. The questionnaire was developed on the basis of the minimum biosecurity measures or prevention measures proposed by Arthur *et al.* (2008) [2]. These measures covered 24 variables on which the questions were directed. The choice of fish farms installed in areas rural and peri- urban was done on the criteria of accessibility, cooperation of fish farmers and their functional state according to Racicot and Vaillancourt (2009) [20]. The sample size was 32 fish farms distributed as follows: Ngaoundere 1st (13), Ngaoundéré 2nd (8), Ngaoundéré 3rd (7), Nyambaka (1), Meiganga (3). The "snowball" method consisted of explaining and briefly presenting the importance of the survey to the managers of the selected farms, then to evaluate the different practices of biosecurity (Thierry, 2009) [22]. All fish farms subject to the investigation were coded with the letter F followed by the corresponding number indicating its location. The variables of interest included on recommendations for biosecurity in aquaculture (Arthur *et al.,* 2008) [2]. Twenty-four biosecurity variables were taken into account to determine the compliance rate of biosecurity measures. The modalities or responses obtained from these variables were analyzed with statistical tests to determine the (practical) characteristics and the typology of fish farms according to preventive measures. The biosecurity level of fish farms is determined through the cases presented. When 0% ≤ Obs. ≤ 25%, this means that the farm has poor biosecurity practices; When 26% ≤ Obs. ≤ 75%, the fish farming is classified as a farm with average preventive practices. When Obs. > 75%, the farm is said to have good biosecurity practices.



The compliance rate (CR) and adoption rate (AR) of biosecurity measures were defined according to Racicot and Vaillancourt (2009) [20].

CR= Nma/Nmr × 100 AR= Nfa/N × 100

Nma: Number of measures applied by a farm or farm score; Nmr: total of measures recommended or prescribed by Arthur *et al*. (2008) [2]; Nfa: Number of farms that apply a given biosecurity measure (total measure score); N: Total number of farms audited.

3. Data analysis

The collected data were entered into Microsoft Excel® 2016 spreadsheet and then were processed and analyzed by SPSS software version 25.0. The cross- tabulations and the diagrams were created using IBM SPSS Statistics 25.0 software.

Results

1. Rate of compliance with biosecurity measures

1.1. Biosecurity features related to the management of people on farms fish farms

Table 1 shows the modality frequencies of the biosecurity measurement variables linked to staff and visitor management practices on the various farms fish farms studied. It also shows that no farm had a visitor park and visitor attire. Furthermore, 59% of fish farmers do not allow these visitors to visitor attire. Finaly, 59% of fish farmers do not allow these visitors to outfit for staff and 15% of fish farmers have footbaths.

Table 1: Biosecurity characteristics related to personnel and visitors in the fish farms

Districts Variables		Ndéré 1st	Ndéré 2nd	Ndéré 3rd	Nyambaka	Meiganga	Adoption rates (%)
Visitor's attire	Yes	0	1	0	0	1	6
	No	13	7	7	1	2	
Visitor park	Yes	0	0	0	0	0	

	No	13	8	7	1	3	0
Footbath/Autoluve	Yes	2	2	0	0	1	15
	No	11	6	7	1	2	
Staff attire	Yes	2	2	0	1	1	19
	No	11	6	7	0	2	
Touching water allowed	Yes	5	3	3	0	2	
	No	8	5	4	1	1	59

1.2. Biosecurity characteristics related to the presence of other animals in the fish farm

Table 2 shows the proportions of fish farms in terms of measures of biosecurity related to fish farm management. It also shows that only 18% fish farmers respect the absence of other animals on their farms, 22% of fish farmers practicing water filtration and 56% of fish farmers have as their source of water supply to the drilling.

Table 2: Biosecurity characteristics related to the presence of other animals in the fish farms

Districts Variables		Ndéré 1st	Ndéré 2nd	Ndéré 3rd	Nyambaka	Meiganga	Adoption rates (%)
Other animals	Yes	11	6	6	1	2	
	No	2	2	1	0	1	18
Water filtration	Yes	1	3	1	0	2	22
	No	12	5	6	1	1	
Water source	Drilling	7	5	3	1	2	56
	River	6	3	4	0	1	

1.3. Biosafety characteristics related to prophylaxis

Health prophylaxis measures

Biosecurity management characteristics related to prophylaxis measures health conditions in fish farms are recorded in Table 3. It also shows that only 22% of fish farmers have knowledge of biosecurity practices, by regarding the fate of dead fish, only 22% of fish farmers take the initiative to recycle, regarding quarantine. It is practiced by 19% of fish farmers, as for the crawl space, 15% of fish farmers respect the recommended 15 days.

Table 3: Biosecurity management characteristics related to prophylaxis measures sanitation in fish farms

Districts Variables		Ndéré 1st	Ndéré 2nd	Ndéré 3rd	Nyambaka	Meiganga	Adoption rates (%)
Biosecurity knowledge	Yes	1	2	2	1	1	22
	No	12	6	5	0	2	
Becoming dead fish	Consumption	5	1	2	0	0	
	Rejection	6	5	4	0	2	
	Recycling	2	2	1	1	1	22
Quarantine	Yes	1	2	2	1	0	19
	No	12	6	5	0	3	
Duration of the crawl space	10 days	12	6	6	1	2	
	15 days	1	2	1	0	1	15

Medical prophylaxis measures

Table 4 shows the biosecurity management characteristics related to the measures of medical prophylaxis in fish farms. It also shows that only 6% fish farmers regularly receive visits from a veterinarian, however it is important to note that 35% of fish farmers are implementing a treatment against fish diseases fish, 10% of fish farmers observe pathologies, 10% of fish farmers have knowledge of common fish pathologies and 0% of fish farmers carry out parasitological analyses on their farms.

Table 4: Biosecurity management characteristics related to prophylaxis measures medical in fish farms

Districts Variables		Ndéré 1st	Ndéré 2nd	Ndéré 3rd	Nyambaka	Meiganga	Adoption rates (%)
Visit of a veterinarian	Yes	0	1	0	1	0	6
	No	13	7	7	0	3	
Observation of the diseases	Yes	0	2	1	0	0	10
	No	13	6	5	1	3	
Knowledge of pathologies	Yes	0	2	1	0	0	10
	No	13	6	6	1	3	
Fish processing	Yes	3	4	2	1	1	35
	No	10	4	5	0	2	
Parasitological analysis	Yes	0	0	0	0	0	0
	No	13	8	7	1	3	0

Table 5 presents the results in relation to the different treatment products. Thus, it shows that 28% of cooking salt asuge, 6.1% of fish farmers use oxytetracycline, 3.1% of fish farmers use medicinal plants, combine oxytetracycline/ table salt and quicklime. It appears very clearly that these are the products most used by fish farmers.

Table 5: Presentation of products used to treat fish

Products used	Frequencies	Percentages (%)
Medicinal plants	1	3.1
Oxytetracycline+Table salt	1	3.1
Table salt	4	12.5
Oxytetracycline	2	6.1
Quicklime	1	3.1
Total	9	28.1

Biosecurity characteristics related to abiotic parameters

Table 6 presents the results of the biosecurity characteristics related to the abiotic parameters of water in fish farms. It also shows that 28% of fish farmers have an idea about the abiotic parameters of the water; only 15% carry out regular temperature readings, 4% of fish farmers assess the rate of oxygen and 4% for pH.

Table 6: Biosecurity characteristics related to abiotic parameters.

Districts Variables		Ndéré 1st	Ndéré 2nd	Ndéré 3rd	Nyambaka	Meiganga	Adoption rates (%)
Idea about abiotic parameters of water	Yes	3	3	2	1	0	28
	No	10	5	5	0	3	
Temperature of measurement	Yes	1	2	1	0	1	15
	No	12	6	6	1	2	
Oxygen level Assessment	Yes	0	1	0	0	0	4
	No	13	7	7	1	3	
Evaluation of the PH	Yes	0	1	0	0	0	4
	No	13	7	7	1	3	

2. Parameters related to fish production

Table 7 presents the frequencies and percentages of characteristics related to the production in the fish farms surveyed. It also shows that 71.9% of fish farmers are involved in the breeding of *Clarias gariepinus* with an Average of dry weight during the stocking which is between 5-10 g, for an average weight harvest at 59.4% of farms between 100-250 g, only 25% of fish farmers had a harvest weight of between 300-350 g. Additionally, it was noted that 81.3% of fish farmers opt for a 6- month production cycle.

Table 7: Frequencies of fish species in fish farms.

Variables	Modalities	Frequencies	Percentage of farms (%)
Raised species	*Cyprinus carpio*	4	12.5
	Clarias gariepinus	23	71.9
	Oreochromis niloticus	5	15.6
	Total	32	100.0
Initial number of fish	300-500	7	21.9
	800-900	3	9.4
	1000-1500	12	37.5
	2000-2500	3	9.4
	3000-3500	3	9.4
	5000-9000	4	12.5
	Total	32	100.0
Initial weight	5-10g	29	90.6
	10-20g	2	6.3
	20-30g	1	3.1
	Total	32	100.0
Production cycle time	1-6months	26	81.3
	6-12months	6	18.7
	Total	32	100.0
Number of fish harvested	150-400	7	21.9
	650-700	5	15.6
	800-1300	10	31.3
	1700-2350	4	12.5
	2700-3250	2	6.3
	4700-8650	4	12.5
	Total	32	100.0
PM at harvest	100-250g	19	59.4
	300-350g	8	25
	600-1000g	5	15.6
	Total	32	100.0

PM: Middle Weight

Table 8 shows the frequencies of fish species and the frequency of distribution of feed in fish farms by district. It also shows that, the *Clarias gariepinus* is the most common species in the districts, for average a period of 6 months, reaches the commercial weight of 300 g and a high survival rate at harvest mainly in the farms of Ngaoundéré 2nd, Meiganga and Nyambaka. Concerning the recommended food distribution frequency of 2 times/day, it was better respected by fish farmers in the Ngaoundéré 2nd and Meiganga districts.

Table 8: Frequencies of production parameters by district.

Districts Variables		Ndéré 1st	Ndéré 2nd	Ndéré 3rd	Nyambaka	Meiganga	Frequencies
Raised species	*Cyprinus carpio*	0	0	1	0	1	2
	Clarias gariepinus	13	6	5	1	2	27
	Oreochromis niloticus	0	2	1	0	0	3
Production of the cycle time	1-6months	10	7	7	1	3	28
	6-12months	1	2	3	0	0	6
PM at harvest	100-200 g	10	3	5	0	1	19
	300-350 g	1	4	0	1	2	8
	600-1000 g	2	1	2	0	0	5
Number of fish harvested	150-400	2	0	2	0	0	4
	650-700	4	2	5	0	0	11
	800-1300	7	1	0	0	0	8
	1700-2350	0	2	0	0	3	5
	2700-3250	0	3	0	0	0	3
	4700-8650	0	0	0	1	0	1
Power supply frequency	1 time/day	6	1	4	0	0	11
	2 times/day	3	6	2	0	3	14
	3 times/day	4	0	1	1	0	6

PM: Middle Weight

2.1 Biosecurity Compliance

Fig. 2 presents the results of general biosecurity compliance by district. This figure also shows that, overall, compliance with the measures of biosecurity is "Poor" between 0% and 25% in all districts investigated. Adoption rates (%) of biosecurity variables in the 32 fish farms were studied. It shows that the average compliance is 20.7% of fish farmers. No farm had a compliance rate between 26 and 75%, nor an adherence rate greater than 75%.

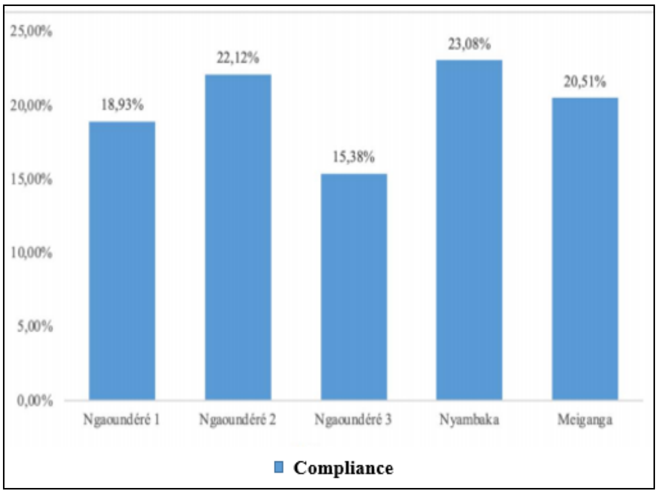


Fig 2: General compliance with biosecurity by district.

2.2 Biosecurity typology of fish farms

The Ascending Hierarchical Classification applied to fish farms depends on the level of practice of biosecurity measures. Four (4) groups (G1, G2, G3 and G4) were recorded. Each group is composed of fish farms from the different districts. Group 1 (G1) consisting of fish farms (F2, F3, F4, F7, F8, F6, F10, F13, F20, F22, F24, F25, F26, F27 and F28,); Group 2 (G2) is made up of fish farms (F1, F5, F9, F11, F12, F14, F23 and F30); Group 3 (G 3) consists of fish farms (F16, F17, F19, F31 and F32); Group 4 (G 4) includes fish farms (F15, F18, F21, and F29). Figure 3 shows the hierarchical classification of fish farms according to the biosecurity measures applied. This figure also shows that 50% of farms fish farms are classified in group 1 (G1) which corresponds to the biosecurity measure(s) are very weakly applied or even non- existent.

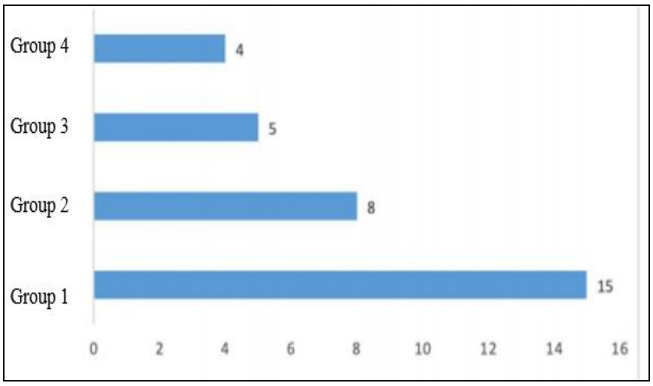


Fig 3: Hierarchical ascending classification of fish farms according to measures biosecurity measures applied.

Table 9 presents the typology of fish farms according to the compliance rate of biosecurity measures. It also shows that, from 0-25% the level implementation is weak, biosecurity practice is poor and the level of risk is major. From 25-75%, the level of implementation is intermediate, the biosecurity practice intermediate and moderate risk level and >75% the implementation level is high, the good biosecurity practice and the risk level is minor. And given that farms fish farms in the Adamawa region of Cameroon recorded an average compliance of 20.7% included between (0-25%), we can thus conclude that these fish farms in the type HAS.

Table 9: Typology of fish farms according to the rate of compliance with biosecurity measures

Percentage (%)	Implementation level	Biosecurity pratice	Risk level	Types of farms
[0-25]	Low	Bad	Major	A
] 25-75]	Intermediate	Intermediate	Moderate	B
] 75-100]	High	Good	Minor	C

CR: Compliance rate

2.3. Impacts of biosecurity measures on fish production

Initial number of fishes in farms

Clarias gariepinus is the most common species in the different farms surveyed by district. Dry of 1 g (raised in hatcheries) or 3 to 6 g (raised in ponds) are poured at a density of 10/m² in monoculture (raising a single species in a tank). The fish are produced by the fish farmer himself or purchased from a colleague fish farmer or in a hatchery center. Stocking fry is relatively simple. You just need to determine the average weight of dry from a sample of a fairly large number. However, the most fish farmers in the different districts did not really have knowledge of the measures to be taken in relation to the stocking density of fish.

Quantity of food to be distributed

The amount of food to distribute in an above- ground tank or in a pond depends on the number of fishes to be fed and their average individual weight. The amount of food to be given to the fish each day varies depending on the quality of this food, between 5-10% of their total weight for juveniles and 1-2% for adults. The closer the fish reach is to an individual weight that is close to that of adults, the greater their daily feed requirements increase despite a decrease in the percentage of feed distribute in relation to the average weight of the fish in the structures. Indeed, a fish of 2 kg which receives only 2%, that is to say 40 g of food per day, receives much more than a 20 g fish which, however, receives 8%, that is to say 1.6 g of food per day. Table 10 shows the percentages (%) of feed distribution according to the average individual weight of fish. It also shows that the bigger or heavier the fish gets the more the percentage (%) of feed distribution decreases until reaching the value standard of 2%.

In a pond of five are with a stocking of 50 subjects per are and the weight average fish of 40 g, the fish biomass is 2 kg/are. According to our table, we start feeding at 6% of the biomass, i.e.: 2 kg x 6/100 = 0.12 kg/are/day. For our five are pond, we must feed: 5 are x 0.12 kg/are/day = 0.6 kg/day. We can also first calculate the biomass of our five are pond (5x2 kg = 10 kg), then 6% of this biomass (10x6/100 = 0.6 kg/day). But it was found that 100% of fish farmers do not take into account these different modalities linked to the quantity of feed to be distributed daily to the fish which depends not only on the number of fishes to feed, but also the average individual weight. This lack of knowledge of these different parameters related to the quantity of food to be distributed per day to the fish explains the quantities abnormal amounts of food distributed daily to fish by fish farmers in the different districts surveyed and their impacts on production.

Frequency of food distribution

The feeding times that were recorded show that only 3 fish farmers out of the 32 surveyed fed their fish at the recommended times, two of the three fed once a day in the afternoon, one fed at 2 p.m and the other at 3 p.m., while the last one fed twice a day at 9 a.m. and 3 p.m. Table 11 presents the frequency and percentage (%) of fish farmers who respect and do not respect the recommended feeding times.

Table 10: Percentage of feed distribution based on average weight individual fish

Average individual weight of fish (g)	Percentage of food to be distributed
1-5	10
6-20	8
21-50	6
51-200	5
201-1000	4
> 1000	2

Table 11: Frequencies and percentages (%) of food distribution by fish farmers

Variables	Frequencies	Percentages (%)
Number of fishes farmars	32	100.0
Fish farmers who respect feeding times	3	9.4
Fish farmers who do not respect feeding times	29	90.6

Fig. 4 presents the results of the frequency and distribution times of feed in fish farms. It also shows that, although most of the fish farmers respect the recommended feed distribution frequency in fish farming which is 2 times a day daily, but unfortunately only 1 fish farmer on 32 respects the recommended distribution times in fish farming which are: in the morning at 9 a.m. and in the evening at 3 p.m. This failure to respect the times of distribution of the food had a significant impact on the survival rate of fish and consequently on production in all farms fish farms surveyed.

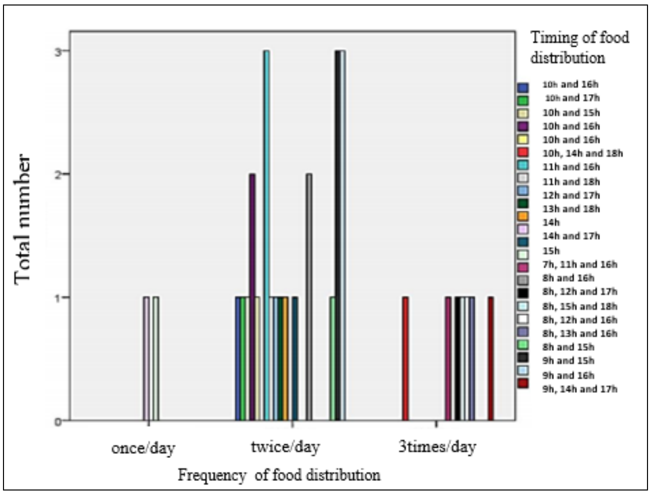


Fig 4: Frequency and timing of food distribution in fish farms

Number of fishes at harvest

Table 12 presents the results of survival and mortality rates according to the number of fishes at harvest in the different farms surveyed. It also shows that, 7 fish farmers out of the 32 stocked between 300 and 500 fish and harvested around 150 to 400 fish, 5 fish farmers stocked between 800 and 900 fish and harvested approximately 650 and 700 fish, 10 fish farmers stocked between 1000 and 1500 and harvested approximately between 800 and 1300 fish, 4 fish farmers stocked between 2000 and 2500 and harvested approximately between 1700 and 2350 fish, 3 fish farmers stocked between 3000 and 3500 fish and harvested approximately between 2700 and 3250, and 2 fish farmers out of the 32 stocked between 5,000 and 9,000 fish and harvested approximately between 4,700 and 8,650 fish.

Table 12: Survival and mortality rates as a function of the number of fishes at the harvest in the different farms surveyed

Number of fishes at harvest	Survival rate (%)	Mortality rate (%)	Compliance rate (%)
150-400	50 and 80	50 and 10	30.0
650-700	85 and 80	15 and 20	17.5
800-1300	80	20	20.0
1700-2350	70 and 85	30 and 15	22.5
2700-3250	70 and 75	30 and 25	27.5
4700-8650	70 and 75	30 and 25	27.5

Average weight of fish at harvest

Table 13 presents the results of survival and mortality rates according to the number of fishes at harvest in the different farms surveyed. It shows that, 32 fish farmers all bred the *Clarias* species at the base, and 28 did so for a period ranging from 1 to 6 months, 22 harvested fish that had an average weight between 100 and 250 g, and 6 harvested fish that had an average weight between 300 and 350 g. The other 4 fish farmers raised fish for a period of 6 to 12 months. They were all producers of broodstock and dry and harvested fish that had an average weight between 500 and 1000 g. From this table, 6 fish farmers out of the 28 who were involved in fattening (during a period of 1 to 6 months) managed to reach the commercial weight which is 300 g at harvest, i.e. a percentage of 21.4% of fish farmers surveyed.

Table 13: Compliance with average fish weights at harvest on farms fish farms

Variables	Modalities	Frequencies	Compliance rates
Species	*Clarias*	28	87.5
Average harvest weight	100-250g	22	68.1
Average harvest weight	300-350g	6	18.1

Discussion

Results of biosecurity measures in fish farms and their effects on fish production in the Adamawa region of Cameroon reveal that the overall compliance rate with the measures remains low. This low level of compliance is corroborated by significant statistical data with an estimated compliance rate of $p > 0.5$ (Haynes *et al.*, 1979) [15]. Identified causes include the non- affiliation of fish farmers to a Joint Initiative Group (JIG), the presence of other animals on farms, ignorance of biosecurity practices, and lack of quarantine fish from other farms. This result similar with to Coulibaly *et al.* (2025) [4] which show that the lack of training on good fish farming pratices contributed to low production rates. In addition, the lack of regular assessment of abiotic water parameters (temperature, dissolved oxygen level and pH) have often been the origin of the appearance of certain diseases such as: gas embolism, acidosis and alkalosis and hole- in- the- wall disease (Tacon, 1995) [21]. The low rate of disinfection of equipment breeding aggravates the situation. These shortcomings compromise the prevention of pathologies aquatic, increasing the risks of environmental and interspecific contamination. The lack of water filtration systems (78%) and the failure to protect farms against animal intrusions (90%) significantly increase the risk of spreading pathogens, as demonstrated by the work of FAO (2010) [8]. The results show also that 84% of farms do not have footbaths or autobaths, and 81% do not do not provide suitable clothing for staff. These figures contradict the recommendations of Craig *et al.* (2006) [5] and Brister and Zimmer (2010) [3], which emphasize the importance of these devices to reduce the transmission of pathogens by visitors and rolling stock.

Furthermore, the non- contribution of veterinarians at 93% and the absence of parasitological or pathological analyses in 100% of the farms studied explain the high rates mortality (25-50%). These data contrast with the expected norms for an efficient fish farming, where mortality should be around 5-15% according to Lacroix (2004) [17] and FAO (2008) [7]. The lack of specialized training for fish farmers and the scarcity of aquatic pathology experts are making the situation worse, limiting the application of measures biosecurity. Fish farmers' ignorance of biosecurity measures (78%) constitutes a major obstacle to the health safety of aquaculture products. This is consistent with the findings of Fonkwa *et al.* (2024) [13] who indicate that fish- borne infections affect million people. The dumping of dead fish into the environment or the consumption of dead fish (53% and 25%, respectively) also contributes to the spread of pathogenic germs. However, in an effort to show fish farmers the positive benefits of the application biosecurity measures on production, it appears that several production parameters were assessed, namely: the species, the duration of the breeding cycle, the watering weight, the average weight at harvest, number of fishes at harvest and frequency distribution of feed. This survey indicated the best production values with the farm of Nyambaka, having received 23.08% as the rate of compliance with biosecurity measures. The values of production parameters were 5-10 g, 1-6 months, 4700-8650, 2 times/day, 300-350 g; respectively for the weight of the watering, the duration of the cycle breeding, the number of fishes at harvest, the frequency of feed distribution and the weight average at harvest. Farms in the 2nd district of Ngaoundéré had a compliance rate of biosecurity measures of 22.12%, come second in terms of production. The values of production parameters were 5-10g, 1-6 months, 2700-3250, 2 times/day, 300-350g; respectively for the weight of the watering, the duration of the breeding cycle, the number of fishes at harvest, frequency of feed distribution and average weight at harvest.

Farms in the Meiganga district had a compliance rate with the measures biosecurity of 20.51%, come third in terms of production. Production parameter values were 5-10 g, 1-6 months, 1700- 2350, 2 times/day, 300-350 g; respectively for the weight of the watering, the duration of the breeding cycle, the number of fishes at harvest, the frequency of feed distribution and the average weight at harvest. The farms in the Ngaoundéré 1st district had a compliance rate of biosecurity measures of 18.93%, come in fourth place in terms of production. The values of production parameters were 5-10 g, 1-6 months, 800-1300, 1 time/day, 100-250 g; respectively for the weight of the watering, the duration of the breeding cycle, the number of fishes at harvest, frequency of feed distribution and average weight at harvest. Farms in the 3rd district of Ngaoundéré had a compliance rate of biosecurity measures of 18.93%, come in fifth place in terms of production.

The values of production parameters were 5-10 g, 1-6 months, 650-700, 1 time/day, 100-250 g; respectively for the weight of the watering, the duration of the cycle breeding, the number of fish at harvest, the frequency of feed distribution and the weight average at harvest. Furthermore, our results showed that farms that had a compliance rate average had a high initial number of fish and achieved fairly good production. Definitely, the application of biosecurity measures is linked to the size of the herd. This corroborates the remarks of Fonkwa *et al.* (2024) [13] that biosecurity was associated with the size of the farms, modern equipment and the health of the herd. Lack of financial resources, small farm sizes and inexperience fish farmers largely explain these gaps. These observations corroborate those from FAO (2011) [9], who point out that biosecurity is better applied in large modern farms with adequate resources.

Conclusion

In the Adamawa region (Cameroon) from 2024, observance and effects of biosecurity measures in fish farms were studied. The compliance rates (CR) with biosecurity measures was 20.7% across all 32 fish farms surveyed. Various factors, such as fish farming training, constraints related to biosecurity practices, the production system, the phase of production, livestock infrastructure and disease diagnosis have a significant impact on the compliance rate. The results show that compliance with the measures of Biosecurity contributes significantly to increasing survival rates and average weight fish at harvest. A strong positive correlation has been established between the application of these measures and production improvement. The effective implementation of production practices biosecurity provides an essential barrier against pathogens, thus reducing the introduction of diseases and promoting optimal management of aquaculture farms. Improving biosecurity practices in the region would therefore be crucial to improving the quality of production and reduce the incidence of certain pathologies. Production fish farming depends mainly on the level of biosecurity and the production system practiced. The fish farms studied are classified into four distinct groups, without any link with their geographical location. Among them, farms applying 23.08% of the measures biosecurity (Nyambaka) show the best production, followed by those applying 22.12% of the measures (Ngaoundéré 2nd). Biosecurity practices in the region of Adamawa are considered insufficient. Full compliance with biosecurity measures improves significantly improve the production performance of farmed fish.

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References

1. Alarcon VL, Allepuz A, Mateu E. Biosecurity in pig farms: a review Por. Health. Man.,2021:7:1-15.
2. Arthur JR, Baldock CF, Bondad-Reantaso MG, Perera R, Ponia B, Rodgers CJ. Pathogen risk analysis for biosecurity and the management of live aquatic animal movements. Diseases in Asian Aquaculture.,2008:6:21-52.
3. Brister D, Zimmer K. Best Management Practices for Aquaculture in Minnesota. University of Minnesota and University of St. Thomas.,2010, 32.
4. Coulibaly PD, Niamien YT, Kouakou NDV. Caractéristiques technico-socio-économiques de la pisciculture dans le Département de Sinfra (Centre-Ouest, Cote d'Ivoire). International Journal of Biological and Chemical Sciences.,2025:19:266-276.
5. Craig SH, Reed B, Keith W, Reagan E, Scott S. Best Management Practices for Finfish Aquaculture in Massachusetts. Western Massachusetts Center for Sustainable Aquaculture. UMass Extension Publication AG-BPFA., 2006, 61.
6. FAO. Biosecurity toolkit. Rome, 2007, 128.
7. FAO. Techniques actuelles de reproduction et d'alevinage, 2008, 95.
8. FAO. La biosécurité aquatique: élément clé pour le développement durable de l'aquaculture. Comité des pêches. 5ème Session., 2010, 14.
9. FAO. World livestock in food security, food and agriculture Organization of the United Nations, Rome, Italy, 2011.
10. Fonkwa G, Nack J, Awah-Ndukum J, Yamssi C, Tomedi EM, Tchoumboue. First report of enteric red plague of Oreochromis niloticus (Cichlidae) and Cyprinus carpo (Cyprinidae) reared in Cameroon: mortality, risk factors and financial loss. Res. Agri. Liv. Fish.,2022:9:323-335.
11. Fonkwa G, Makombu GJ, Kamdem AH, Nack J, Awah-Ndukum J, Tomedi EM, *et al*. Determining factors and zootechnical output of biosecurity practices in fish farms in Wouri Division, Cameroon.Vét. Med. Int., 2023, 12.
12. Fonkwa G, Nsangou KA, Makombu GJ, Ebo'o FBA, Djamou KJF, Eyango TM, *et al*. Gestion des risques de maladies des poisons d'élévages dans le Département de la Mvila, Sud Cameroun. Cameroon Journal of Experimental Biology.,2024:18:64-69.
13. Jeanne W, Tonfack DJ, Meutchieye F, Tomedi TM. Aquaculture of Heterosis niloticus in Sub-saharan African: potentiels and perspectives. Genetics and Biodiversity Journal.,2022:6:37-44.
14. Johnson SC, Treasûrer JW, Bravo S, Nagasawa K, Kabata Z. A Review of the impact of parasitic copepods on marine aquaculture. Zoological Studies,2004:43:229-243.
15. Haynes RB, Taylor DW, Sackett DL. Compliance in health care. Baltimore, John Hopkins University Press., 1979, 516.
16. Kondombo KSC, Silga RP, Coulibaly ND, Bance V, Ouedraogo R, Oueda A. Amélioration des performances de production de *Oreochromis niloticus* (Linnaeus, 1758) par la supplémentation des aliments en teintures médicinales de *Talinum triangulare* (Jacq.) Willd. International Journal of Biological and Chemical Sciences.,2025:19:979-991.
17. Lacroix E. Pisciculture en zone tropicale. Deutsche Gesellschaft für Technische Zusammenarbeit, GTZ, GmbH., 2004, 231.
18. Ndoazen A, Mangar P, Sobdibé PY, Micha JC. Etude socio-économique, environnementale et fonctionnelle

de la chaine de valeur poisson dans le bassin Central du Chari au Tchad. International Journal of Biological and Chemical Sciences.,2024:18:924-937.
19. Niaré T, Timbely D, Kodio H. Performances zootecthniques de *Oreochromis niloticus* (Linnaeus, 1758) et de *Clarias anguillaris* (Linnaeus, 1758) en polyculture dans la rizières (Baguinéda, Mali). International Journal of Biological and Chemical Sciences.,2023:17:2008-2024.
20. Racicot M, Vaillancourt J-P. Evaluation des mesures de biosécurité dans les fermes avicoles au Québec par vidéosurveillance et principales erreurs commises. Bulletin Académique Vétérinaire.,2009:162:265-272.
21. Tacon AGJ. Feeding tomorrow's fish: Keys for sustainability. Options Méditerranéennes,1995:22:11-33.
22. Thierry RL. Les méthodes d’enquête qualitatives et quantitatives et de recueil de données. Fiche repère n°3. Ateliers de l’évaluation villes au carré, 2009, 4.
23. Wikondi J, Ngono EPJ, Nana TA, Meutchieye F, Tomedi TEM. Farming features of African Bonytongue fish Heterosis niloticus in Cameroon, Central Africa. Open Journal of Animal Sciences.,2023:13:232-248.