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Aquaculture management practices associated with antimicrobial residues in Southwestern Nigeria

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ABSTRACT

Aquaculture production has grown rapidly in Nigeria but with unbridled use of antibiotics which predisposes fish consumers to the risks of antimicrobial residues and resistance. A cross sectional survey of antimicrobial use in aquaculture and occurrence of their residues in African Catfish (*Clarias gariepinus*) samples from Southwestern states of Nigeria were carried out. The results showed that majority of the farmers lacked knowledge of drug residues in aquatic animals, and the food safety and public health implications on consumers. Frequently administered antibiotics include tetracyclines (27.5%), chloramphenicol (22.0%) and gentamicin (18.4%). About 84.7% of tested fish had residues with variable prevalence which were not statistically significant. Risk factor analysis indicated that fish farmers with tertiary and secondary education were more likely to produce fish that contained antimicrobial residues than those with primary education [odds ratio (OR) = 1.91, confidence interval (CI) = 1.24–5.99 and OR = 1.25, CI = 1.08–5.27, respectively] while fish from farms managed by men were about three times more likely to contain residues (OR = 3.25, 95% CI = 1.95–9.35) than those managed by women. Hence, most of the fish from Southwestern Nigeria were indiscriminately dosed with different antibiotics that predispose consumers to the risks of antimicrobial residues with food safety and antimicrobial resistance consequences. Implementation of good fishery management practices and farmers' education are advocated to reduce dependence on antimicrobials.

1. Introduction

Aquaculture is an important sector of Nigerian economic development, more so with the government diversification of the oil-based economy. It is greatly contributing to the national food security, generating employment for the good proportion of Nigerians and with potentials to generate foreign exchange in international trade in fish and shrimps (FDF, 2008; Kareem et al., 2008). Fish is a regular portion of many Nigerians' diet as a source of animal protein, vitamins and minerals. In addition, fish products are relatively cheaper than beef, pork and other animal protein sources in the country (Dauda and Yakubu, 2013). Fish, especially catfish, are relished as a delicacy among Nigerians for home consumption or at fast food joints and restaurants (Olatoye and Basiru, 2013).

Aquaculture production in Nigeria is increasing with increasing population and demand for protein in food. Intensification of aquaculture practices is accompanied by outbreaks of infectious diseases that require treatment (Bondad-Reantaso et al., 2005). Natural and synthetic chemicals such as antimicrobials, disinfectants, parasiticides, probiotics, and other feed additives have become indispensable inputs to treat and prevent bacterial and parasitic diseases in aquaculture, to improve water quality and as growth promoters (Rico et al., 2012). While the use of these substances has been disapproved, it has contributed to the development and growth of the aquaculture sector in Nigeria.

The use of antibiotics in aquaculture systems can create serious economic and health problems. Antibiotic residues have been found in several aquatic products from Vietnam and other Asian countries (Canada-Canada et al., 2009; Won et al., 2011; He et al., 2012). As a result of stringent regulations from the U.S. and European Union (EU), the issue of antibiotic residues in aquatic products for export has been mostly resolved; however, there are no such well enforced regulations

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for Nigerian domestic markets. Since fish and other aquatic products represent a very large portion of their diet, Nigerian people are potentially being exposed to antibiotic residues, which can even in subtherapeutic concentrations lead to an increase in antibiotic resistance. The main danger of antibiotic use is the development and selection of antibiotic resistant pathogens. Since many of the antibiotics used are non-biodegradable, industrial antibiotics used in aquaculture farms can place intense selective pressure on aquatic microbial populations. The presence of a large number of antibiotic resistance genes in these populations is evidence of this selective pressure (Zhang et al., 2009; Pruden et al., 2013).

Moreover, the continued application of compounds such as antibiotics has been associated with the development of drug-resistant bacteria both inside and outside of aquaculture facilities (Le et al., 2005), and environmental residues of highly toxic substances can exert toxic effects on non-target organisms, contributing to a potential degradation of ecosystems receiving aquaculture effluents (Rico et al., 2012). Results of a global survey on antimicrobial use in aquaculture showed high use of antibiotics in fish and shrimp farming, including prohibited drugs (Tusevljak et al., 2013), and this has raised critical human health concerns. Therefore, understanding the processes through which aquatic animals, such as finfish and shrimp, are raised and eventually brought to the dinner table is of extreme importance. The acquisition of detailed information on the use of antimicrobials and other chemical inputs in Nigerian aquaculture is of crucial importance to evaluate their potential risks for human health and for the environment, as well as to evaluate the prudent use of such compounds, and their effectiveness for preventing and treating disease outbreaks. Due to ineffective regulatory control on the use of drugs in fish in Nigeria, indiscriminate use of antimicrobials and the associated socio-economic consequencies, we investigated aquaculture management practices as well as use of drugs especially antimicrobials and assessed their residue presence in African Catfish from commercial aquaculture farms in Southwestern Nigeria.

2. Materials and methods

2.1. Study area

The study was carried out in commercial aquaculture farms located in Lagos, Ogun and Oyo States of Southwestern geopolitical zone of Nigeria. The zone lies between longitude 2°31'E and 6°00'E and Latitude 6°21'N and 8°37'N with a total land area of 77,818 km^2 and a projected population of 28, 767, 752 in 2002. The zone is bounded in the East by Edo and Delta States, in the North by Kwara and Kogi States, in the West by the Republic of Benin and in the South by the Gulf of Guinea. The zone is endowed with many aquaculturable lands. It is an important region where intensive aquaculture activities form a central pivot. Also, small, medium and large scale catfish productions are practiced with growing numbers of fish farms and hatcheries as well as retail outlets of fresh and ready-to-eat catfish markets and restaurants. The study population comprised all the registered catfish farms in Southwestern Nigeria. Farms in Lagos, Ogun and Oyo States were purposefully selected because these states comprised majority of the fish farms in the region. The list of registered farms obtained from the Catfish Farmers' Association of Nigeria was used as the sampling frame for the random selection of the 137 farms which were selected and participated in the study.

2.2. Assessment of drug administration in aquaculture and residue awareness by farmers

Semi-structured questionnaires were randomly administered to one hundred and thirty seven (137) respondents engaged in catfish farming in Lagos (n = 65), Ogun (n = 46) and Oyo (n = 26) States in Southwestern Nigeria to obtain information on farmers' knowledge of drug use and the management practices in the aquaculture farms. Prior to the administration of the questionnaire, the respondents were assured of the confidentiality of their responses since the survey was solely for research purposes. Thereafter, the copies of the questionnaire were retrieved and the responses collated and analyzed.

2.3. Sampling and sample preparation

Sampling was conducted based on the number of farms that responded to the distributed questionnaires, N = 137, Lagos (n = 65), Ogun (n = 46) and Oyo (n = 26). From each of the 137 farms, ten *Clarias gariepinus* (with an average body weight of 1007.08 ± 47.16 g) were collected in a clean, inert container offering adequate protection from contamination, loss of analytes by adsorption to the internal wall of the container and against damage in transit. All samples were affixed with code numbers to maintain sample integrity and traceability. Samples were transported to the Food and Meat Hygiene Laboratory, Department of Veterinary Public Health and Preventive Medicine, University of Ibadan where sample processing and storage were carried out. Fish muscles from each farm were homogenized using a laboratory blender to obtain a composite sample of 500 g of fish per farm, weighed using a mettler balance (Toledo B3002 Deltarange®), wrapped in an aluminium foil, appropriately labeled and preserved at −20 °C in the freezer to avoid deterioration pending further analysis. Ethical approval of this study was obtained from the Human Ethics Committee (Approval number: UI/EC/18/0306) and Animal Ethics Committee (Approval number: UI-ACUREC/18/0075) at the University of Ibadan.

2.4. Determination of the presence of antimicrobial residues in fish

The fish samples were screened for antimicrobial drug residues using a microbial inhibition based broad spectrum antimicrobial residues screening test kit (Premi®Test kit, R-Biopharm Germany). According to manufacturer's recommendation, following hand washing and drying with either tissue paper or a towel, the required number of ampoules was cut open using a pair of scissors. Approximately 2cm^3 of pooled fish fillets was applied to meat press to extract about 250 μl of meat fluid into a petri dish. 100 μl of the fluid in duplicate was pipetted slowly onto the agar in the ampoule, while it was ensured that the agar was not distorted. After 20 min pre-diffusion at room temperature, the meat juice was flushed away by washing the test ampoule twice with demineralized water and the water was carefully removed from the test. The test ampoule closed with foil was incubated in a preheated heating block incubator at temperature of 64 °C. The ampoules in the heating block incubator were withdrawn after the negative control changed colour at about 3 h.

Positive control samples were antibiotic free cultured catfish from fish disease investigation aquarium whose fillets were spiked with known concentrations of oxytetracycline and amoxicillin based on the detection limits recommended by the manufacturer (oxytetracycline = 100 μg kg^{-1}, amoxicillin = 15 μg kg^{-1}); http://tuoteluettelo.mediq.fi/liitteet/d377796/. The fillet juice samples (n = 6) were spiked with 50, 100 and 200 μg kg^{-1} oxytetracycline as well as 7.5, 15, 30 μg kg^{-1} amoxicillin, while sterile demineralized water (antibiotic free) was used as the negative control.

2.5. Statistical analyses

Data entry and analysis were done using SPSS version 15. Variables in the questionnaire were presented as frequency and percentage. Associations between socio-demographic, economic, and farm management variables and presence of residue or drug usage in fish was determined using chi-square. Variables that were significant at $p < 0.20$ were entered into a binary logistic regression model to determine those that were predictors of residue presence and drug usage in fish. Level of significance was set at $\alpha \leq 0.05$.

3. Results

3.1. Aquaculture ownership, location and production

The Aquaculture Ownership, Location and Production data are presented in Table 1. Eighty of the respondents (58.4%) were fish farm owners while fifty seven (41.6%) were fish farm workers. Most of the respondents were males (89.9%) and were older than 40 years (59.8%). Also, majority of the farmers (65.0%) had tertiary education and about 53.0% had at most 10 years fish farming experience. This survey also showed that most of the farms (82.5%) were not located close to water pollutants. Concrete ponds were commonly used with most farmers having at most 20 ponds. None of the surveyed farms routinely carried out the chemical analysis of soils. The production data recorded from the survey indicated that 78.1% of the farmers engaged in small and medium scale farming with most farmers producing at most 20 tons per year.

Table 1
Aquaculture Ownership, Location and Production in Southwestern Nigeria.

Variable	Frequency	Percentage
Respondent		
Owner	80	58.4
Worker	57	41.6
Sex of owner		
Male	123	89.9
Female	14	10.1
Age of owner (years)		
<40	55	40.1
41–60	57	41.6
>60	25	18.3
Education level of owner		
Primary	13	9.5
Secondary	35	25.5
Tertiary	89	65.0
Farm location		
Lagos	65	47.4
Ogun	46	33.6
Oyo	26	19.0
Years of experience		
≤10	73	53.2
11–20	31	22.6
>20	33	24.1
Access of farm location to water pollutants		
Yes	24	17.5
No	113	82.5
Location of farm in industrial area		
Yes	28	20.2
No	109	79.8
Proneness of location to flooding		
Yes	57	41.6
No	80	58.4
Chemical analysis of farm soil		
Yes	0	0.0
No	137	100.0
Type of fish farming system		
Small scale (< 5000)	53	38.7
Medium scale(5000–10,000)	54	39.4
Large scale(> 10,000)	30	21.9
Type of aquatic animal (β)		
Tilapia	47	25.4
Catfish	137	74.1
Shrimp	1	0.5
Oyster	0	0
Fish Production capacity of farm per year		
<4 tons	56	40.9
4 tons −20 tons	57	41.6
>20 tons	24	17.5
Type of ponds (β)		
Earthen	62	25.8
Plastic/Fibre Tank	45	18.8
Concrete	120	50.0
Tapoline	21	8.8
Number of ponds		
≤10	48	35.0
11–20	56	40.9
>20	33	24.1

(β) = multiple response allowed.

3.2. Fish husbandry system

As shown in Table 2, the sources of water used for fish farming by the respondents include well (18.1%), borehole (27.6%), river (30.7%) and stream (23.6%). Antibiotics and salts were reported as being employed for disease prevention, treatment and control, with 64.2% respondents administering drugs including antibiotics in water. Indications for drug use reported by the respondents were: when aquatic organisms were sick (32.8%), when mortality was recorded (40.2%) and to boost production (27.0%).

Also, the survey showed that most of the respondents (62.0%) obtained their feeds from commercial source while 43.8% of the farmers admitted they administered some drugs through feed with most (66.7%) applying antibiotics in feed. Majority (65.0%) indicated mortality was a reason for administration of drugs in feed. One hundred and twenty (87.6%) of the farmers stored their feed under the required condition

Table 2
Fish Husbandry System in Southwestern Nigeria.

Variable	Frequency	Percentage
Source of water (β)		
Well	36	18.1
Borehole	55	27.6
River	61	30.7
Stream	47	23.6
Use of drugs in water		
Yes	88	64.2
No	49	35.8
Types of drugs		
Antibiotics	77	77.8
Salt	22	22.2
Reasons for use (β)		
When aquatic organisms are sick	52	32.8
When mortality is recorded	64	40.2
To boost production	43	27.0
Water quality is a reason for water analysis		
Yes	50	36.5
No	87	63.5
Water analysis (β)		
Ph	50	42.0
Dissolved O_2	36	30.0
Nitrate	19	16.0
Ammonia	14	12.0
Source of feed (β)		
Self-milled	76	38.0
Commercial feeds	124	62.0
Use of drugs in feed		
Yes	60	43.8
No	77	56.2
Type of drugs (β)		
Antibiotics	59	66.7
Vitamins	22	25.0
Salt	7	8.3
Reason for drug use in feed (β)		
When aquatic organisms are sick	19	21.9
When mortality is recorded	55	65.0
To boost production	11	13.1
Storage of feed under the required condition		
Yes	120	87.6
No	17	12.4
Type of required condition for feed storage (β)		
Room temperature	92	54.2
Proper ventilation	35	20.8
Rodent free	14	8.3
Cool dry place	28	16.7
Chemical analysis of feed		
Yes	42	30.7
No	95	69.3

(β) = multiple response allowed.

with majority (54.2%) storing their feeds under room temperature. Most of the farms (69.3%) indicated chemical analysis of feed was not carried out.

3.3. Management of disease in aquaculture production

Disease management data obtained from the survey are presented in Table 3. Fifty five (40.1%) of the farmers surveyed, had at most an average mortality of 10 per month, 25.6% had between 10 and 21 and 34.3% had more than 20. Most farmers (46.0%) diagnosed disease by clinical signs, (30.7%) by mortality, (7.0%) relied on post mortem finding and (16.5%) by laboratory finding. Eighty eight (29.2%) of the farmers relied on veterinary doctors in diagnosis and treatment of disease while 33.6% on animal health officer and 37.2% on self/experience. Few of the farmers (27.4%) surveyed, performed laboratory test before treatment while all the farmers kept farm record. Most farmers (65.0%) never adhered to manufacturer's instruction on the use of drugs. Only 62.0% of the farmers administered drugs for disease preventive purpose. Oxyteracycline was the most frequently administered drug by fish farmers (27.5%), followed by chloramphenicol (22.0%), gentamicin (18.4%), amoxicillin (17.5%) and enrofloxacin (14.6%). While majority of the farmers (72.6%) did not observe withdrawal period by manufacturer, most of the farmers (65.7%) lacked knowledge of the effect of drug residues in fish and other aquatic animals.

Table 3
Management of disease in aquaculture production.

Variable	Frequency	Percentage
Average mortality per month		
≤10	55	40.1
11 to 20	35	25.6
>20	47	34.3
Disease diagnosis on the farm (β)		
Through clinical signs	106	46.0
Mortality	71	30.7
Post mortem finding	16	7.0
Laboratory finding	38	16.5
Personnel involved in diagnosis and treatment of disease on the farm (β)		
Vet. Doctors	88	29.2
Animal health officer	101	33.6
Self/by experience	112	37.2
Laboratory test before treatment		
Yes	20	27.4
No	117	72.6
Farm record keeping		
Yes	137	100.0
No	0	0.0
Availability of foot dip for disinfection at the farm entrance		
Yes	82	59.9
No	55	40.1
Adherence to manufacturer's instruction on drug use		
Most often	20	14.6
Often	28	20.4
Never	89	65.0
Use of drugs for disease preventive purpose		
Yes	85	62.0
No	52	38.0
Drugs or chemicals most frequently used β		
Tetracycline	85	27.5
Amoxicllin	54	17.5
Gentamicin	57	18.4
Chloramphenicol	68	22.0
Enrofloxacin	45	14.6
Observance of withdrawal period recommended by manufacturer		
Yes	38	27.4
No	99	72.6
Knowledge of effects of drug remains in aquatic tissue		
Yes	47	34.3
No	90	65.7

(β) = multiple response allowed.

3.4. Presence of antimicrobial residues in fish

Antimicrobial residues were detected in 116 of the 137 pooled fish samples tested giving overall prevalence of 84.7% residues in Southwestern Nigeria. Fishes from Lagos, Ogun and Oyo States accounted for 84.6%, 78.3% and 96.2% prevalence of antimicrobial residues respectively as shown in Fig. 1. The prevalence of antimicrobial residue in the samples from different locations were not statistically significant ($\chi 2 =$ 4.10, 0.13).

Positive control samples with 100 and 200 μg kg^{-1} oxytetracycline, and 15 and 30 μg kg^{-1} amoxicillin did not yield colour change, while samples with 50 and 7.5 μg kg^{-1} oxytetracycline and amoxicillin respectively, as well as sterile demineralized water yielded colour change.

3.5. Risk factors and predictors of antimicrobial drug residues in fish

The results of statistical analysis of sociodemographic factors associated with aquaculture management and the presence of residues in fish obtained from different farms indicated that age, type of respondent, sex and years of experience were significantly associated with the presence of residues in fish. Fish from farmers who were between 40 and 61 years of age had the highest residue prevalence (96.5%) followed by those younger than 40 years (87.3%) and those older than 60 years (52.0%). This difference in fish residue prevalence by age of farmers was significant ($\chi 2 = 26.98$, $p \leq 0.0001$). Prevalence of residue in fish was also significantly higher in farms managed by the owner (95.0%) than those by hired workers (70.2%), and in male (90.2%) than female (35.7%) farm managers ($\chi 2 = 15.80$, $p = 0.01$ and $\chi 2 = 28.80$, $p \leq 0.0001$ respectively). Other variables such as farm location and type of fish farming system were not significantly related with the presence of residues in fish (Table 4).

Fish from farms managed by the owners were about 2.1 times more likely to contain antimicrobial residue (odds ratio (OR) = 2.1, 95% confidence interval (CI) = 1.67–7.92) than those controlled by workers while those managed by men were about three times more likely to contain residue (OR = 3.25, 95% CI = 1.95–9.35) than those managed by women. Farm managers who had tertiary and secondary education were more likely to rear fish that contained antibiotic residue than those that had primary education (OR = 1.91, 95% CI = 1.24–5.99 and OR = 1.25, 95% CI = 1.08–5.27 respectively). (Table 5).

Also, sex, years of experience, type of fish farming system, feed source and adherence to manufacturers' instructions were significantly associated with the usage of drugs in fish production. Prevalence of drug use in fish farming was significantly higher ($\chi 2 = 15.81$, $p \leq 0.0001$) in farms managed by men (86.2%) compared to women (42.9%). Farmers with at most 10 years experience used drugs more significantly ($\chi 2 =$ 7.89, $p = 0.02$) on their farm compared to the farmers with more than 10 years experience, while those who engaged in small scale fish farming were found to use drugs more significantly ($\chi 2 = 36.68$, p = 0.02) than those involved in medium and large scale fish farming respectively. Prevalence of drug use by farmers who patronized commercial feeds (65.3%) was significantly higher ($\chi 2 = 11.51$, p = 0.02) than by those who self-milled their feeds (40.8%), while by those who never adhered to manufacturers' instructions (83.3%), it was significantly higher ($\chi 2$ = 21.36, $p \leq 0.0001$) than by those who most often complied (20.8%) and those who often complied (Table 6).

Moreover, farms managed by men were more likely to use drugs in fish production compared to those managed by women (OR = 1.24, 95% CI = 0.83–5.22). Farmers who had between 10 and 21 years of experience and those with more than 20 years were less likely to use drugs compared to those with at most 10 years experience (OR = 0.70, 95% CI = 0.12–0.87 and OR = 0.5, 95% CI = 0.09–0.73 respectively). Farmers involved in small and medium scale fish farming were about five and three times respectively more likely to use drugs (OR = 5.07, 95% CI = 2.03–9.22 and OR = 3.21, 95% CI = 1.60–4.77 respectively) than large

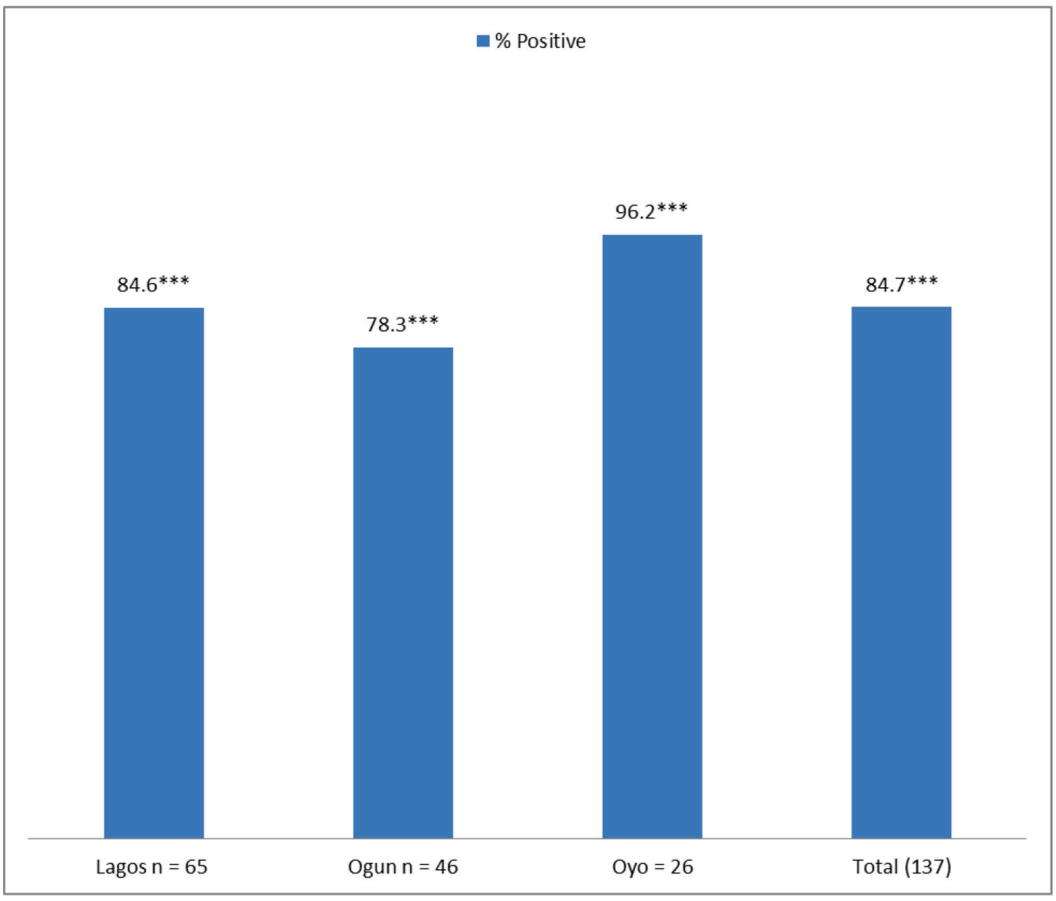

Fig. 1. Association between prevalence of antimicrobials in fish and farm location.
***Prevalence of antimicrobial usage by state location was not statistically significant ($\chi 2 = 4.10, 0.13$).

scale farmers. Farmers that Often and Never adhered to manufacturers' instructions were about two and three times respectively more likely to use drugs than those who Most often complied (OR = 2.15, 95% CI = 1.22–6.31 and OR = 3.07, 95% CI = 1.97–5.27respectively) (Table 7).

4. Discussion

Aquaculture farming is a rapidly growing business in Southwestern Nigeria, attracting the attention of wide range of people with different socio-demographic background. Majority of the respondents in this study owned and manage their farms and this is related to the finding of Aghoghovwia and Ohimain (2015) who observed that those who owned their farms were more than 80%. Also, more of the farm owners were men. This could be because women are mostly involved in processing and marketing of fish as emphasized by Fregene and Digun-Aweto (2008). This observation is similar to the assertion of Brummett et al. (2010), that fishery activities are mostly dominated by men and agrees with the finding of Omasaki et al. (2013), implying that cultural practices including land ownership and decision making within the family limited the participation of women in fish farming. In this study, fish farming were dominated by people that were at most 60 years old while Aliu et al. (2017), observed that it was dominated by farmers who were at most 50 years old. A significant number of the farmers had tertiary education which implies fish farming is dominated by the educated class and mostly by those armed with high level of education. This conforms to the findings of Adebo and Ayelari (2011), Aghoghovwia and Ohimain (2015). Also, Nwabeze et al. (2006), observed that literacy level could have a positive impact on adoption of new innovations. Henri-Ukoha et al. (2011), stated that high farming experience enables the farmers to address production constraints. This study showed that a considerable number of the farmers had a relatively low farming experience.

Farm location is an important factor in aquaculture production as it can affect the quality of pond waters and consequently the productivity and wholesomeness of aquatic animals. This study observed that most of the farms were not located in an industrial area and did not have access to pollutants. While none of the farms carried out chemical analysis of farm soils, a considerable number of the farms were prone to flooding.

Farm production data from Southwestern Nigeria showed that catfish was the most cultured. This may be as a result of the findings of Aromolaran (2000) who reported that *Clarias gariepinus* (catfish) is largely cultured because of its high preference, good marketability, fast growth rate, good feed conversion rate, high resistance to diseases, low mortality rate and can survive in both running and stagnant water. Also, concrete ponds were the most used culture facility. This is similar to findings of Olaoye et al. (2007) and Olaoye (2010) who observed that fish farmers preferred concrete tanks to earthen fish ponds.

Most of the farmers used river and borehole water as their source of water for aquaculture in this study. This is similar to the survey by Adebo and Ayelari (2011) where river was the most used source of water supply for fish farming. Also, commercial feed was more frequently used as source of feed. This may be as a result of the relative acceptability of commercial diet by the catfish family, confirmed by Oresegun et al. (2006). In this study, it was observed that most farmers administered antibiotics more frequently in water and feed especially when mortality was recorded, implying that mortality was a major concern compared to disease and the need to boost production. While routine water and feed analyses are an important factor for a successful aquaculture, it was not reflected in this study as significant number of the farmers did not carry out water and feed analyses.

Sustainable aquaculture production can only occur when fish are

Table 4
Association between variables and prevalence of antibiotic residues in fish from Southwestern Nigeria.

Variables	Presence of Residues		χ2	*p*-value*
	Yes (%)	No (%)		
	116	21		
Age (years)				
<40	48(87.3)	7(12.7)		
41–60	55(96.5)	2(3.5)		
>60	13 (52.0)	12(48.0)	26.98	≤0.0001
Respondent type				
Owner	76(95.0)	4(5.0)		
Worker	40 (70.2)	17(29.8)	15.80	0.01
Sex				
Male	111(90.2)	12(9.8)		
Female	5(35.7)	9(64.3)	28.80	≤0.0001
Education				
Primary	6(46.2)	7(53.8)		
Secondary	28(80.0)	7(20.0)		
Tertiary	82(92.1)	7(7.9)	19.27	≤0.0001
Years of experience				
≤10	73(100.0)	0(0.0)		
11–20	22(71.0)	9(29.0)		
>20	21(63.6)	12(36.4)	28.9	≤0.0001
Farm location				
Oyo	53(81.5)	12(19.5)		
Ogun	40(87.0)	6(13.0)		
Lagos	23(88.5)	3(11.5)	0.96	0.62
Type of fish farming system				
Small scale	48(90.6)	5(9.4)		
Medium scale	46(85.2)	8(14.8)	4.40	0.11
Large scale	22(73.3)	8(26.7)		

* Pearson Chi-square.

Table 5
Predictors of antibiotic residue presence in fish from Southwestern Nigeria.

Variables	Odds ratio	95% CI
Respondent type		
Owner	2.1	1.67–7.92
Worker	1	
Sex		
Male	3.25	1.95–9.35
Female	1	
Education		
Primary	1	1
Secondary	1.25	1.08–5.27
Tertiary	1.91	1.24–5.99

healthy and free from disease. Fish disease management is a combination of preventing the onset of disease and measures to reduce losses from disease when it occurs. In this study, while most farmers administered drugs for disease preventive purpose, the average mortality recorded by most farmers was at most 10 fish per month. Also, economic consideration may be a reason most farmers diagnosed disease on the farm through clinical signs. This could also be the reason most farmers relied on self or experience in diagnosis and treatment of disease and why most farmers did not perform laboratory test before treatment in this study. Most farmers were not aware of the effects of drug residues in aquatic tissue. Apart from economic incentive, this perhaps explained the reason why most of them neither followed the manufacturer's instruction on drug use nor observed the withdrawal period recommended by the manufacturer. Oxytetracycline was the most frequently administered drugs. This is corroborative of the finding of Olatoye and Basiru (2013), who reported oxytetracycline was the most frequently administered antibiotics both to the fish stocks and fish feed by 73% of the respondents in Ibadan. Similarly, Njoga (2012) observed that the drug was the most frequently used among livestock farmers and veterinary practitioners in Enugu.

In this study, the overall prevalence of antimicrobial drug residues in

Table 6
Association between variables and prevalence of drug use in fish from Southwestern Nigeria.

Variables	Drug use	χ2	*p*-value*
Age (years)			
<40	43(78.2)		
41–60	48(84.2)		
>60	21(84.0)	0.79	0.68
Respondent type			
Owner	69(86.3)	.	
Worker	43(75.4)	2.61	0.11
Sex			
Male	106(86.2)		
Female	6(42.9)	15.81	≤0.0001
Education			
Primary	9(69.2)		
Secondary	20(57.1)		
Tertiary	83(93.3)	0.68	0.71
Years of experience			
≤10	66(90.4)		
11–20	22(71.0)		
>20	24(72.7)	7.89	0.02
Farm location			
Oyo	53(81.5)		
Ogun	38(82.6)		
Lagos	21(80.8)	0.04	0.98
Type of fish farming system			
Small scale	53(100.0)		
Medium scale	45(83.3)		
Large scale	14(46.7)	36.68	≤0.0001
Type of aquatic animal raised			
Tilapia	21(44.7)	0.16	0.69
Catfish	63(48.1)		
Water source			
Well	24(66.7)		
Borehole	38(69.1)		
River/Stream	72(66.7)	0.11	0.95
Feed source			
Self-milled	31(40.8)		
Commercial	81(65.3)	11.51	0.001
Adherence to manufacturers instruction			
Most often	5(20.8)		
Often	57(64.1)	21.36	≤0.0001
Never	20(83.3)		

* Pearson Chi-square.

Table 7
Predictors of drug usage in fish from Southwestern Nigeria.

Variables	Odds ratio	95% CI
Sex		
Male	1.24	0.83–5.22
Female	1	
Years of experience		
≤10	1	1
11–20	0.70	0.12–0.87
>20	0.50	0.09–0.73
Type of fish farming system		
Small scale	5.07	2.03–9.22
Medium scale	3.21	1.60–4.77
Large scale	1	
Adherence to manufacturers instruction		
Most often	1	1.22–6.31
Often	2.15	1.97–5.27
Never	3.07	

137 pooled fish muscle samples screened from Southwestern Nigeria was 84.7%, with the prevalence of 84.6%, 78.3% and 96.2% from Lagos, Ogun and Oyo States respectively. The results of this study indicated that farmers freely used antibiotics. The overall prevalence obtained in this study is higher than 52.5% reported by Olatoye and Basiru (2013) in Ibadan. Antibiotic residues are of great concern in food animals in Nigeria as several studies have continued to report high prevalence in several food of animal origin. (Fagbamila et al., 2010; Ezenduka et al.,

2011; Olatoye and Saraye, 2012; Lawal et al., 2015) have also reported antimicrobial residues in food animal produced in Nigeria. The high prevalence of antimicrobial drug residues observed in this study may be due to non-adherence to the manufacturer's instruction on drug use and non observance of the withdrawal period recommended by the manufacturer by most farmers as observed in the questionnaire responses in the present study. Despite the benefit of improved productivity ascribed to the use of drugs, the risk associated with their residues in the tissues of treated animals or their derived products constitutes health hazards to the consumers (Crawford, 1985; Health Canada, 2013). Extensive use of antimicrobials may increase the risk of an adverse effect of residues on the customer including the development of drug resistance, drug hypersensitivity reaction, disruption of normal intestinal flora, carcinogenic, mutagenic and teratogenic effects.

The results obtained from the variables and prevalence of antimicrobial residues in fish and their predictors could be a function of the observance of withdrawal period. In this study, for instance, while the prevalence of residue in fish was significantly higher in farms managed by men than women, the fish from farms managed by men were more likely to contain antimicrobial residue than those of women. However, the results obtained from the variables and prevalence of drug use in fish production and their predictors could be related to any of the reasons for drug use by the farmers as reported from the questionnaire, ranging from prevention, disease, mortality and production boost. In this study, for instance, while newly established farms used drugs more on their farm compared to the older farms, the older farms were less likely to use drugs compared to the newly established farms.

In conclusion majority of the fish produced in Southwestern Nigeria posed antimicrobial risks and food safety consequences as antimicrobial residues were detected with overall prevalence of 84.7%. A lack of knowledge of the effects of antimicrobial residue in fish as well as non adherence to manufacturers' instruction on drug use and non observance of withdrawal period were factors responsible for the high level of residue prevalence. The refusal of fish farmers to follow recommended withdrawal period, would not only lead to the continual detection of these residues in aquaculture products, but also could possibly contribute to the increasing resistant strains of pathogenic bacteria aside causing irritation and hypersensitivity reactions in humans.

However, antibiotics contribute to satisfying the increasing world demand of safe food of animal origin such as fish when used prudently and responsibly under veterinary supervision. Without antibiotics, food animals suffering from bacterial infectious diseases will be denied effective treatment and outbreaks of disease may not be effectively controlled or prevented. With more than 60% of human pathogens today originating from animals, leaving sick food animals untreated poses a risk to both food safety and public health. Implementation of good animal husbandry practices and the use of several alternatives including probiotics, phage therapy and essential oils will help reduce the dependence on antimicrobial agents. Also, risk assessment approaches for preventing diseases, and the development and spread of antimicrobial resistance bacteria in aquatic environments need to be established. Identifying the two-way link between antimicrobial use in aquaculture and antimicrobial resistance in humans is also of critical importance as the aquatic environment often constitutes the final receptacle of both anthropogenic and livestock waste.

5. Recommendation

Based on the findings from this study and the need to ensure compliance with international food safety standards as well as actualizing the potential for export of Nigerian aquaculture products, the following recommendations are to be strictly adhered to.

1. Training and extension services should be conducted for fish farmers to educate them on the significance and benefits of the prudent use of antibiotics. There is a pressing requirement to develop guidelines on prudent use, with multidisciplinary involvement, to reduce misuse of antibiotics in aquaculture, with particular reference to antibiotics classified as critical for human medicine. Veterinarians and farmers should receive training in following these guidelines and, to improve compliance, need to be audited and to receive feedback.
2. There should be appropriate policies and well-designed legislation and regulations on the use of veterinary medicines in aquaculture, including aspects such as procedures for registering medicines for use in aquaculture production; licensing of aquatic animal health professionals; extra-label use; and record keeping by manufacturers, aquaculture production facilities and aquatic animal health professionals. There is also the need for trained workforce and infrastructure necessary to enforce legislation and regulations, with appropriate penalties for violations.
3. Properly select and use veterinary medicines based on available laboratory reports, label (including package insert) information, additional data in the literature and consideration of the pharmacokinetics, spectrum of activity and pharmacodynamics of the drug, with due consideration for the OIE (World Organization for Animal Health) principles for responsible and prudent use of antimicrobial agents in aquatic animals (see OIE, 2018).
4. Cooperation between government, the private sector and academia should be promoted, because dealing with disease should be a shared responsibility among all players in the value chain. The involvement of all stakeholders is critical to efforts to reduce the need for the use of antimicrobial agents.

CRediT authorship contribution statement

Reuben Chukwuka Okocha: Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Visualization; **Isaac Olufemi Olatoye:** Conceptualization, Methodology, Investigation, Formal analysis, Writing - review & editing, Supervision, Project administration; **Peter Ibukun Alabi:** Methodology, Formal analysis, Investigation, Data curation; **Modupe Ganiyat Ogunnoiki:** Conceptualization, Investigation, Resources, Project administration; **Olufemi Bolarinwa Adedeji:** Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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