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Effects of stocking density on growth, production and farming protability of African catfish *Clarias gariepinus* (Burchell, 1822) fed chicken viscera-diet in earthen ponds

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Abstract

The effects of stocking density on growth, production and farming profitability of *Clarias gariepinus* fed practical chicken viscera-diets was studied in earthen ponds for 90 days. Fish (initial weight: 13.1 ± 0.2 g) were hand-fed to apparent satiation twice daily with diet (43 % crude protein, 20 kJ g^{-1}) formulated by mixing 30 % of chicken viscera with locally available ingredients (diet CVM30), and distributed to three triplicates group of fish, each group assigning one of the three densities: 5, 7 and 10 fish m^{-2}. Survival rate was not affected by stocking density ($p>0.05$). Final weight, specific growth rate and weight gain increased until density of 7 fish m^{-2}, and decreased at 10 fish m^{-2} ($p<0.05$), the optimal values attaining 260.7 g, 3.32 % day^{-1}, 1890.3 %, respectively. The AFCR is as lower in all stocking density, values ranging from 0.96 to 1.20. Yield and annual production are density-dependent, values ranging from 100.5 to 209.9 kg are^{-1} and from 407.7 to 851.1 kg $are^{-1}year^{-1}$. The profitability index was high, amounting 2.08 to 2.25 in all stocking density ($p<0.05$). The highest profitability index was obtained at density of 7 fish m^{-2}, whereas identical value was obtained with 5 and 10 fish m^{-2}densities. Based on the growth performances and taking into account the lack of capital to invest in rural areas, the study suggests rearing *C. gariepinus* at the density of 7 fish m^{-2} with diets containing chicken viscera meal at up 30%, for optimal fish production and profit in Benin rural areas.

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Introduction

The African catfish *Clarias gariepinus* is a globally popular aquaculture species largely distributed throughout Africa and Asia (Goda *et al.,* 2007; Nyina-wamwiza *et al.,* 2007; Osman *et al.,* 2007; Abdelhamid 2009; Khan and Abidi 2011). It is widely cultured in freshwater ponds because of their easiness in reproduction, high growth rate, tolerance to high densitiy culture conditions, and resistance to diseases, excellent flesh quality and ability to accept a wide variety of feed (Huisman and Richter 1987, Nyina-wamwiza *et al.,* 2007; Khan and Abidi, 2011; Chor *et al.,* 2013). The technics culture for the full life cycle of African catfish has been well-established and their global production has been increased from 11.787 tons in 2000 to 517.357 tons in 2010 (FAO, 2010). However, intensive African catfish culture have failed due to the high protein commercial diets with increased feed cost (Cho *et al.,* 2013; Taufek *et al.,* 2016). Indeed, fish diet is mainly based on FM as the dietary protein source. The limited FM supply, coupled with its increasing demand has greatly inflated the cost of this commodity (Tacon & Metian 2008). Therefore, it is a priority to design growth-promoting diets that combine cost-effectiveness with low dependence on fish meal as the primary protein source (Rossi & Davis 2012).

In that way, unconventional dietary animal protein sources have been experimented as substitutes for FM in diets for many fish species (Goda *et al.,* 2007; Mondal *et al.,* 2008; Cho *et al.,* 2013; Mohanta *et al.,* 2013; Bhaskar *et al.,* 2014; Taufek *et al.,* 2016). Ovissipour *et al.* (2012) and Ju *et al.* (2013) recently investigated the use of marine fish viscera meal as partial or total replacement for fishmeal in diets for *Acipenser persicus* and *Polydactylus sexfilis*, respectively. Our previous results showed that up to 30% chicken and marine fish viscera could be incorporated in diet for *Clarias gariepinus* without any adverse effect on growth, feed utilization, production and body composition (Oke & Abou, 2016; Alofa *et al.*, in press). In developing countries, the growth in human population continues to increase, outpacing animal protein production.

Farmers resort to increase stocking density to meet the subsequently needs for fish production. Stocking density is a significant factor that determines the fish production in earthen ponds where dissolved oxygen level is generally lower. It is well established that inappropriate stocking densities can impair the survival, growth performance, behaviour, health, water quality, feeding and fish production, as well as welfare parameters in fish (Islam *et al.,* 2005; Rahman *et al.,* 2006; Abou *et al.,* 2007; Ashley 2007; EFSA 2008; Gibtan *et al.,* 2008).

According Leatherland and Cho (1985) and Siddiqui *et al.* (1989), overstocking causes stress, which leads to enhanced energy requirements causing reduced growth and feed utilization ratio, but understocking results in failure to maximize net yield. Many studies have reported the effects of stocking density on the health of farmed fish (Wedemeyer 1997). For example, *Salvelinus alpinus* suffer less physical damage and grow more rapidly at high density (Jorgensen *et al.,* 1993), while *Dicentrarchus labrax* (Vazzana *et al.,* 2002) and *Sparus aurata* (Montero *et al.,* 1999) show evidence of reduced health at high density.

Indeed, *C. gariepinus* shows some interesting deviation at high stocking density. Understocking density, juvenile of *C. gariepinus* are naturally highly aggressive. Furthermore, its aggressiveness, territorial defense and development of hierarchies and individual dominance are often reduced at overstocking density (Kaiser *et al.,* 1995b; Hecht and Uys 1997). However, growth and survival rate of fish decrease once certain threshold densities are attained (Hecht and Uys 1997). Thus, the optimal stocking density for African catfish culture must be studied in order to know the density from which both growth and production decreased significantly. Identification of optimum stocking density in earthen ponds may sustain growth and improve returns for population prosperity.

The main purpose of this study was to investigate the effects of stocking density on growth, production and farming profitability of C. *gariepinus* fed low-cost viscera-based-diets.

Materials and methods

Experimental site

The study was conducted in earthen ponds for 90 days at the experimental station at Louho village, in Porto-Novo suburb.

Fish and experimental design

African catfish fingerlings (initial average weight 13.1 ± 0.2 g) were obtained from the Tonon fish farming foundation located at Calavi and were transported to the experimental station. Fish were stocked into 9 earthen ponds (10 × 3 × 1 m, each) assigned to three treatments in triplicate, each treatment corresponding to one of stocking density 5, 7 or 10 fish m^{-2}. These densities were chosen taking into account the water quality parameters. The ponds were filled naturally from water table.

Diet and feeding

The proximate composition of feed ingredients is giving in Table 1. The experimental diet (43% crude protein and 20% crude lipid) was formulated using local available ingredients to meet the nutritional requirements of the juvenile catfish (Table 2). Blood and chicken viscera meals were obtained following the procedures described by Oké & Abou (2016).

The feed ingredients were ground in grinding mill to desired particle size, weighed and mixed thoroughly in a food mixer for 30 min. The hot water (about 30 % of dry weight ingredients) was progressively added to one kilogram of diet formulated and blended. The resulting dough was cut into paste and sun-dried for about three days at 32-35°C. After drying, the diets were manually broken into small particles of about 5 mm (passage through a 5 mm sieve) and preserved in refrigerator (+4°C) until used. The proximate composition of feed ingredients and diet were analyzed according to standard methods (AOAC, 2012). Fish were hand-fed to apparent satiation twice daily at 09:00 and 17:00 hours. Care was taken to stop feeding as soon as the fish stopped eating. At each fortnight, forty percent (40%) of the stocked fish in each pond were sampled out with a seine net (12.7 mm mesh size) and weighed.

Water quality parameters

Temperature, dissolved oxygen, hydrogen ion concentration (pH), conductivity and total dissolved solid (TDS) were measured at a deep of 10 cm using multiparameter HANNA HI-9828. The water transparency was measured using Secchi disk.

Growth and production evaluation

Growth performance and feed utilization of fish were calculated based on the following equations: Survival (S, %) = 100 × (final count) (initial count)$^{-1}$; Daily weight gain (DWG, g day^{-1}) = $(W_f - W_i)/\Delta t$; Weight gain (WG, %) = 100 × $(W_f - W_i) / W_i$; Specific growth ratio (SGR, % day^{-1}) = 100 × $[\ln (W_f) - \ln (W_i)]\ \Delta t^{-1}$; Apparent Feed conversion ratio (AFCR) = FI (FB – IB)$^{-1}$; Protein efficiency ratio (PER) = (FB – IB) DPI^{-1}; Condition factor (CF) = 100 × $W_f L^{-3}$; Yield (Y, kg/are) = (FB – IB) S^{-1}; Production (P, kg are^{-1}year^{-1}) = ([FB – IB)/S] × 365) Δt^{-1}. Where W_i and W_f = initial and final mean body mass (g); Δt is the duration of experiment (days); FB the final biomass per pond (g); IB the initial biomass per pond (g); FI the total feed intake (g); DPI the dietary protein intake; L fish longer in cm; S pond superficies.

Table 1. Proximate composition (as % dry matter) of diet ingredients.

Ingredients	Dry matter	Crude protein	Crude lipid	Ash
Fish meal	92.0	66.0	7.9	15.8
Bood meal	90.9	71.9	1.7	6.4
Maize bran	91.4	6.2	3.1	1.4
Soybean oilcake	94.8	30.0	13.2	3.7
Chicken viscera	90.9	35.0	22.0	6.3

Table 2. Ingredients and proximate composition of experimental diet for *C. gariepinus* juveniles.

Ingredients	Incorporation level (%)	Price (US$ kg^{-1})
Fish meal	15	0.58
Blood meal	23	0.18
Maize meal	20	0.26
Soybean oilcake	10	0.67
Chicken viscera meal	30	0.30
Palm oil	2	1.36
Proximate composition (%MS)		
Dry matter	88.3	
Crude protein	42.8	

Ingredients	Incorporation level (%)	Price (US$ kg^{-1})
Lipid	12.0	
Carbohydrate	32.4	
Gross energy (KJ g^{-1})	20.0	
Cost of feed¥(US$ kg^{-1})	0.49	

¥Including handling and process (for comparison, 1US$= 586.69 FCFA at present).

Profitability evaluation

The results of the experiments were extrapolated to one-year for economic evaluation of each triplicate. A simple economic analysis was developed to compare the relative profitability of *C. gariepinus* in each triplicate. Values of total costs of production (TC) consisted of variable costs (expensive that vary with stocking density) and fixed costs (costs not vary with stocking density). Variable costs included costs of inputs such as fingerlings, feeds, routine labor, and transport costs, whereas fixed costs included the depreciation of ponds. The entire production was sold at market price (US$ 2.56 per kg). Thus, the gross return (GR) was evaluated by multiplying the gross production of fish by the kilogram market price. The Net return (NR) and profitability index were evaluated as follows:

Net income (NI) = GR – TC

Profitability index= NR / TC

Statistical analysis

The normality and homogeneity of the data was explored using Hartley's test (Hartley, 1959). Differences and interactions in mean values for survival, growth performance and feed utilization between stocking density were analyzed using one-way ANOVA and significant differences were identified using Student-Newman-Keul*spost hoc* tests for *post hoc* multiple comparisons. Data were analysed using SPSS version 22.0 for windows (SPSS, Chicago, Illinois, USA). The level of significance for all analyses was determined at $P < 0.05$.

Results

Water quality parameters

The mean values (± SD) of the water quality parameters measured in the stagnant earthen pond during the experimental period are presented in Table 3.

There were no significant differences between temperature, pH, conductivity and total dissolved solid in all treatments ($p>0.05$). However, water transparency and dissolved oxygen significantly decreased with increasing stocking density ($p<0.05$).

Growth, feed utilization and production

The growth performance, feed utilization and production of *C. gariepinus* reared under different density are presented in Table 4.As shown in Table 4 and Fig.1, growth rate of *Clarias gariepinus* was significantly affected by stocking density. FW, SGR, DWG and WG were significantly higher in fish stocked at density of 7 fish m^{-2} ($p<0.05$).

Fish survival rates were not significantly affected by stocking density ($p>0.05$). Fish yield and annual production significantly increased with increasing stocking density ($p<0.05$).

The highest yield (209.9 ± 3.5kg are^{-1}) and annual production (851.1 ± 13.0kg^{-1}are $year^{-1}$) were obtained in fish stocked at higher stocking density, and the lowest yield (100.5 ± 2.0kg are^{-1}) and annual production (407.7 ± 6.2kg^{-1}are $year^{-1}$) in those stocked at low stocking density.

The Apparent feed conversion ratio in this study was significantly affected by stocking density. AFCR increased significantly ($p<0.05$) with increasing stocking density (Table 4). The best AFCR was obtained with the stocking density of 5 and 7 fish m^{-2}, which values were significantly lower than that for fish reared at density of 10 fish m^{-2}.

Economic analysis and profitability

As showed in table 5, total variable cost significantly increased with increasing stocking density, from 344.2 to 722.7 $USare^{-1}year^{-1} ($p<0.05$).

Total cost of production follow the same trends in variable costs and ranged from354.2 ± 9.6to 732.6 ± 21.3$USare^{-1}year^{-1} ($p<0.05$). Gross return and net return significantly increased with increasing production, values being significantly influenced by stocking density.

The highest density required the highest total cost of production but also provided the highest net return per pond. The cost of production of one kilogram ranged from 0.79 ± 0.01 to 0.83 ± 0.01, with significant differences between stocking density ($p<0.05$).

The profitability index was high, amounting 2.08 to 2.25 in all stocking density ($p<0.05$). The highest profitability index was obtained at density of 7 fish m^{-2}. However, identical values were obtained with fish stocked at densities 5 and 10 fish m^{-2}.

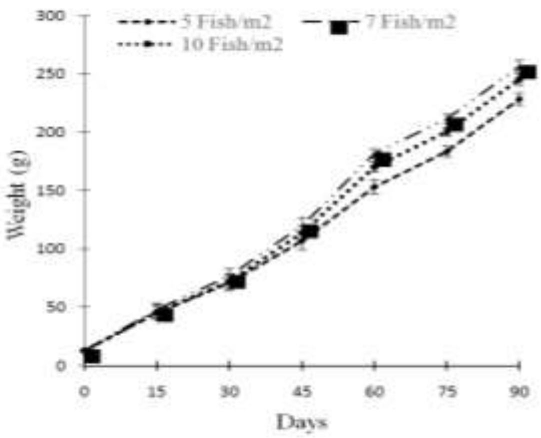

Fig. 1. Mean weight gain every 15 days of juvenile *Clarias gariepinus* reared under different densities.

Table 3. Mean values (± SD) of water quality parameters in the stagnant earthen pond during 90 days experiment.

Parameters	Stocking densities (Fish m^{-2})		
	5	7	10
Transparency (cm)	20.1 ± 0.34^a	17.90 ± 1.47^b	15.14 ± 2.04^c
Temperature (°C)	30.59 ± 1.48	30.67 ± 1.49	30.35 ± 1.48
pH	6.06 ± 0.29	6.24 ± 0.62	6.02 ± 0.13
Dissolved oxygen (mg/l)	4.21 ± 0.10^a	3.20 ± 0.08^b	2.51 ± 0.10^c
Conductivity (µS/cm)	107.52 ± 12.49	109.24 ± 12.86	112.93 ± 13.96
TDS (ppm)	53.76 ± 6.11	54.71 ± 6.29	56.64 ± 6.82

Table 4. Growth performance and feed utilization of *Clarias gariepinus* stocked under different density in earthen ponds during 90 days experiment.

Parameters	Stocking densities (Fish m^{-2})		
	5	7	10
Initial weight (g)	13.1 ± 0.2	13.1 ± 0.2	13.1 ± 0.3
Survival (%)	93.5 ± 2.8	91.5 ± 1.6	90.3 ± 0.5
Final weight (g)	228.2 ± 3.3^c	260.7 ± 3.1^a	245.4 ± 3.6^b
Condition factor	0.96 ± 0.07^a	0.95 ± 0.05^a	0.92 ± 0.05^b
Specific growth rate (%.day^{-1})	3.18 ± 0.01^c	3.32 ± 0.01^a	3.26 ± 0.01^b
Daily weight Gain (g.day^{-1})	2.39 ± 0.03^c	2.75 ± 0.03^a	2.58 ± 0.04^b
Weight Gain (%)	1642.2 ± 19.9^c	1890.3 ± 18.9^a	1773.3 ± 22.1^b
Yield (kg are^{-1})	100.5 ± 2.0^c	158.6 ± 2.5^b	209.9 ± 3.5^a
Production (kg $are^{-1}year^{-1}$)	407.7 ± 6.2^c	643.3 ± 8.1^b	851.1 ± 13.0^a
Apparent food conversion ratio	1.10 ± 0.03^b	1.11 ± 0.02^b	1.20 ± 0.03^a

In each line, means with no letters or with the same letters as superscripts are not significantly different (*P*> 0.05). Data are means of three replicates.
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Table 5. Costs and financial indicators for the production of *Clarias gariepinus* reared at stocking densities of 5, 7 and 10 fish m^{-2}

Diets	CVM30		
Number of fingerlings (No are $^{-1}$year^{-1})	500	700	1000
Amount of feed supplied (kg are $^{-1}$year^{-1})	118.4 ± 4.9^c	192.4 ± 5.8^b	278.8 ± 10.9^a
Feed cost (US$ kg^{-1})	0.49	0.49	0.49
Fixed costs (FC, US$ are $^{-1}$year^{-1})			
Depreciation of ponds (20 years)	9.94	9.94	9.94
Total fixed costs (US$ are $^{-1}$year^{-1})	9.94	9.94	9.94
Variable costs (VC, US$ are $^{-1}$year^{-1})			

Diets		CVM30	
Total feedcost (US$)	232.0 ± 9.6^{c}	377.2 ± 11.3^{b}	546.5 ± 21.3^{a}
Feeding cost (US$)	28.80	28.80	28.80
Fingerling cost (US$)	63.92	89.49	127.84
Pond managment cost (US$)	15.20	15.20	15.20
Harvestprocedurescost (US$)	4.34	4.34	4.34
Total variable costs (US$ are^{-1}year^{-1})	344.2 ± 9.6^{c}	515.0 ± 11.3^{b}	722.7 ± 21.3^{a}
Total cost of production¶ (TC, US$ are $^{-1}$year^{-1})	354.2 ± 9.6^{c}	524.9 ± 11.3^{b}	732.6 ± 21.3^{a}
Gross fish production (GP, kg are $^{-1}$year^{-1})	426.7 ± 18.8^{c}	668.1 ± 19.4^{b}	886.8 ± 17.4^{a}
Cost of production of one kg of fish$^{\lambda}$ (CFP, US$/kg)	0.83 ± 0.01^{a}	0.79 ± 0.01^{b}	0.83 ± 0.01^{a}
Profitability indicators			
Gross return£ (GR, US$ are $^{-1}$year^{-1})	1090.9 ± 48.0^{c}	1708.2 ± 49.5^{b}	2267.4 ± 44.6^{a}
Return above variable cost¥ (RAVC, US$ are^{-1}year^{-1})	746.7 ± 38.4^{c}	1193.2 ± 38.2^{b}	1544.7 ± 23.3^{a}
Net return§ (NR, US$ are $^{-1}$year^{-1})	736.7 ± 38.4^{c}	1183.3 ± 38.2^{b}	1534.7 ± 23.3^{a}
Profitability index¢ (PI)	2.08 ± 0.05^{b}	2.25 ± 0.02^{a}	2.10 ± 0.03^{b}

US$ 1 = CFA 586.69. In each line, means with no letters or with the same letters as superscripts are not significantly different ($P > 0.05$). Values are mean ± SE for three replicates.

Discussion

Water transparency was significantly higher at high density and consistently lower at low density, which might be due to the reduction of the plankton production by higher density of fish (Rahman & Monir 2013). Dissolved oxygen concentration showed significant decrease with increasing stocking density. This could probably be attributed to the higher consumption rate of oxygen at higher density of fish and other aquatic organisms (Boyd 1982). However, water quality parameters measured from ponds were not significantly different between treatments and were within the acceptable ranges for *C. gariepinus* culture (Viveen *et al.*, 1985).

The results from this study clearly demonstrate that stocking density significantly affected growth rate, feed utilization and production of *C. gariepinus* fingerlings reared at different density in earthen ponds. Growth parameters, such as final mean weight, specific growth rate and daily mean gain of *C. gariepinus* fingerlings were significantly higher at density of 7 fish m^{-2} than those stocked at densities of 5 and 10 fish m^{-2}, although fish were hand-fed at satiation with the same feed. Similar findings were reported with catfish, *C. gariepinus* by Toko *et al.* (2007), Shoko *et al.* (2016) and Monir & Rahman (2015), and with other species by Diana *et al.* (1996), Abou *et al.* (2007) and Shoko *et al.* (2014), who reported significant differences between growth performances of fish reared at different densities.

Stocking density also affected the growth of *Clarias macrocephalus* × *C. gariepinus* hybrids grown in concrete ponds at three different densities (Jarimopas *et al.*, 1992). Stocking density is already cited as an inhibitory factor for fish growth (Jarimopas *et al.*, 1992; Irwin *et al.*, 1999). As reported by Wuertz *et al.* (2006), high stocking density produces stress with consistent elevation of cortisol levels, which induces a wide variety of secondary physiological responses (Barton and Iwama 1991; Wendelaar Bonga, 1997) that resulted in growth decrease (Jodun *et al.*, 2002). Diana *et al.* (1996) and Pankhurst & Van der Kraak (1997) reported that poor growth performances at high density could be due to the low water quality parameters, especially dissolved oxygen. But, according to Monir & Rahman (2015), increasing stocking density may also result in a competition for food and habitat for higher number of fingerlings. Therefore, the lower growth performances obtained at density of 10 fish m^{-2} in both diets might be due to lower dissolved oxygen values recorded in these treatments and competition for food. This is confirmed by Diana *et al.*, (1996) who reported that lower growth rate obtained at high density could be associated to the low water quality parameters especially dissolved oxygen.

The survival rates of *C. gariepinus* were not significantly affected by stocking density, consistency with other reports on catfish (Haylor, 1992; Islam *et al.*, 2005; Toko *et al.*, 2007).

The survival rate of *C. gariepinus* in ponds was not clearly influenced by stocking density, as reported by Hogendoom and Koops (1983), and the high value generally obtained, as in this study, is probably attributed to air breathing and relatively high tolerance of *C. gariepinus* to poor water quality conditions (Hecht *et al.*, 1996 cited in Toko *et al.*, 2007).

The interpretation of the effects of stocking density on fish growth is very complex as the results are affected by many interdependent factors. In the present study, the growth of African catfish *Clarias gariepinus* was influenced by stocking density. This was in agreement with previous findings reported by Bok and Jongbloed (1984), and Hossain *et al.* (1998), who reported an inverse relationship between individual growth rates and fish density in *C. gariepinu* sstocked at different densities in earthen ponds. Similarly, other study reported decreasing growth rate with increasing stocking density of *C. gariepinus* reared in earthen ponds at densities of 2.0, 10.0, 20.0 and 60.0 fish m^{-2}Micha (1975), as cited in De Graaf and Janssen 1996).

In this study, the highest AFCR was achieved at the highest stocking density. This relationship between stocking density and AFCR obtained here agree closely with reports in *Pangaciussutchi* cultured in ponds (Almazán-Rueda, 2004), as well as in *C. gariepinus* and other species (Watanabe *et al.,* 1990; Almazán-Rueda, 2004; Abou *et al.,* 2007; Minor and Rahman, 2015). In contrary, our results are not in agreement with Shoko *et al.* (2016), who reported no effects of stocking density on feed conversion ratio in African sharp tooth *C. gariepinus* cultured in earthen ponds. Despite the increasing values at high density, AFCR obtained in this study were lower, indicating better feed utilization efficiency.

The yield and annual production were density-dependent. This suggests that higher densities may be used to increase production and to improve net income of farmers as well as farming profitability.

These results are similar with those previously reported on increase in production with increasing stocking density of *C. gariepinus* reared in cages (Hengsawat *et al.,* 1997), and in earthen ponds (Islam *et al.,* 2005; Shoko *et al.,* 2014b). Similar net yield and annual production trends were also obtained with many other species such as Tilapia (Watanabe *et al.,* 1990; Abou*et al.,* 2007) and *Astacus leptodactylus* (Farhadi & Jensen 2015). The increase in annual production as stocking density increases in this study could be attributed to a combination of high survival and increasing stocking density (Hengsawat *et al.,* 1997).

A simple economic analysis showed that the total cost of production increased with stocking density as a result of the increase of variable costs, due mainly to the fingerlings costs. A positive net income was realized with different stocking densities studied. Furthermore, the results indicated that return above variable cost and net return were density-dependent. These findings were in agreement with those reported by Hengsawat *et al.* (1997), Abou *et al.* (2007), Van De Nieuwegiessen *et al.* (2009) and Shoko *et al.* (2014a). The good net returns achieved in all stocking density in the present study suggest that farmers can make profit by feeding *C. gariepinus* with CVM 30 at density of 5, 7 or 10 fish m^{-2}. High profitability was achieved at 7 fish m^{-2} and same values were obtained at 5 and 10 fish m^{-2}. Based on the growth performances which were significantly lower at 10 fish m^{-2}, probably sufficient to reduce growth overtime, and taking into account the lack of capital to invest in rural areas, the densities of 7 fish m^{-2} appeared sustainable for optimal production and profit in farming *C. gariepinus* in Benin rural areas.

Conclusion

The present study demonstrates that high stocking density negatively affected the growth and feed utilization efficiency of catfish *C. gariepinus* fingerlings reared in stagnant earthen ponds. However, water quality deteriorate is also an important environmental factor that influence significantly the fish welfare. Stocking density of 7 fish m^{-2} provides the better production of large-size individual fish and higher farm profitability.

Therefore, it could be recommended that farmers use chicken viscera-based-diets and an initial density of 7 fish m^{-2} to minimize the cost of fish production and improve farm profitability.

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