



Full Length Research Paper

Buffering efficiency of plantain plant (*Musa acuminata*) parts and calcium carbonate on acidic borehole water for fish production in Port Harcourt, Nigeria

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Low water pH has been a major problem affecting the growth and profitability of aquaculture in Port Harcourt, Nigeria. In recent times, organic agriculture is being advocated for safe and healthy food thus alternative buffer agent is necessary to combat this challenge in order to boost fish production. Based on this, a preliminary study was conducted to compare buffering efficiency of plantain plant parts and calcium carbonate on pH of acidic borehole water. Eighteen (18) 100-liters shaded plastic tanks of three replicates per treatment were used. The tanks were three-quarter (3/4) filled with acidic borehole water (pH 4.20). There were 5 treatments as follows: Treatment 0 (T0)- only borehole water (BHW, control), Treatment 1 (T1) - BHW + 27g dried stem, Treatment 2 (T2)- BHW + wet stem (27g), Treatment 3 (T3)- BHW + dried leaves (27g), Treatment 4 (T4) -BHW + wet leaves (27g) and Treatment 5 (T5)- BHW + 27g (CaCO₃). Dissolved oxygen, pH and temperature of water were measured twice daily [morning (M) and afternoon (A)] for 16 days. The minimum [5.84±0.01 (A)] and maximum [7.70±0.02 (A)] pH values were recorded in T0 and T1 respectively at the end of the study period (Day 16). However, there was no significant difference between pH of water in T1 [6.60±0.01 (M) and 7.70±0.02 (A)] and T5 [7.04±0.03 (M) and 7.53±0.02 (A)] on Day 16 (P>0.05). On Day 7, pH of water in T1 [6.56±0.01 (M) and 6.60±0.02 (A)] and T5 [6.61±0.01 (M) and 6.66±0.02 (A)] were also similar (P>0.05) and both pH values were within the FEPA acceptable pH limit for fish production. On Day 4, pH of water in T5 [6.10±0.01 (M) and 6.13±0.02 (A)] was significantly (P<0.05) higher than that in T1 [5.55±0.02 (M) and 5.68±0.03 (A)]. The buffering efficiency of dried stem (T1) was significantly higher than that of dried leaves (T3) (P<0.05). Dried stem and leaves of plantain plant competed favourably with the buffering efficiency of CaCO₃. This study therefore suggests the use of dried stem and leaves of plantain plant as organic sources of buffer for fish production. It is free of cost and safe for fish production and human consumption.

Keywords: Organic buffer, potency, plantain plant, acidity, aquaculture.

INTRODUCTION

Water pH is a critical water quality parameter for fish culture. Water quality is one of the most critical factors besides good feed/feeding in fish production (hatchery operation and management, nursery, grow-out and brood stock management). Deterioration in the quality of water increases stress on the captive animals, reduces their growth, makes them vulnerable to disease and cause heavy mortality. Based on this, understanding the physico-

chemical qualities of water is critical to successful aquaculture. To great extent, water determines the success or failure of an aquaculture operation. Managing water quality is important but expensive (Estim, 2009). The quantity of hydrogen ions (H⁺) in water will determine if it is acidic or basic. The acceptable range for fish culture is normally between pH 6.5-9.0 (Swann, 2010). High acidity or alkalinity can cause direct physical damage to skin, gills and eyes. Prolonged exposure to sub-lethal pH level can cause stress, increase mucus production and encourage epithelial hyperplasia with sometimes fatal consequences. Extreme water pH can influence and affect blood pH of fish, resulting in either acidosis or

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Table 1. Application guideline for liming material.

pH of pond bottom	Heavy loamy or clays	Sandy loam	Sand
5.1-5.5	5400	3600	1800
5.6-6.0	3600	1800	900
6.1-6.5	1800	1800	0

Source: Viveen *et al.* (1986)

alkalosis of the blood. Generally, the pH of water in Port Harcourt city, Nigeria is acidic (Davies, 2008). This is a serious constraint to aqua-culturists. Port Harcourt is a highly industrialized city in the Niger Delta area of Nigeria. There are many oil exploration activities going on in this area.

Water quality and quantity vary from place to place and are affected by ecological factors such as soil and air quality. On a whole, ground water is considered more desirable for aquaculture because it has more consistent water quality than surface water, and is less likely to contain pathogens or fish (Estim, 2009). However, the ground water (borehole) in Port Harcourt has low pH. This has been a major problem affecting the growth and profitability of aquaculture in Port Harcourt. The use of agricultural lime [Calcite, CaCO₃ of dolomite CaMg(CO₃)₂] has been the conventional method of buffering water and increasing its pH (Boyd, 1981; Viveen *et al.*, 1986).

In recent times organic aquaculture is being advocated for safe and healthy food. Organic aquaculture is an attempt to mitigate some of the harmful effects of chemicals in a sustainable way. Aquaculture has grown rapidly over the years, from less the one million tones in 1950 to over 50 million tones in 2006. The growing importance of the aquaculture sector at the same time also implies an ever increasing responsibility and accountability to produce safe and healthy products in a sustainable way including in terms of economic feasibility, environmental integrity and social responsibility.

Plants (aquatic and terrestrial) have gained recognition as materials for biotechnology. Water hyacinth has been used for the production of iofuels. Davies and Mohammed (2011) reported the moisture-dependent engineering properties of water hyacinth parts with the view of briquettes (solid iofuels) production. Fakoya *et al.* (2011) presented an exposition on the potential of seaweed resources for exploitation, culture and utilization in West Africa: a case study of Nigeria. Tiger nut (*Cyperus esculentus*) was used for the production of energy and it has known as medicinal plant (Abano and Amoah, 2011). Iranian Pistachio has been utilized for iofuels production (Kouchakzadeh and Tavakoli, 2010). Wood vinegars were utilized as sustainable coagulating and anti-fungal agents in the production of natural rubber sheets (Baimark *et al.*, 2008).

Plantain (*Musa acuminata*) is a perennial herb and it is abundant in Port Harcourt. It contains vitamins A, C and K and high levels of calcium, magnesium, sodium,

phosphorus, zinc, copper and cobalt (Brooker *et al.*, 1987). It has been used basically for its food and medicinal importance (Brooker *et al.*, 1987; Wikipedia, 2012). To the best of my knowledge, it has not been used as organic buffer in aquaculture. The aim of this study is to compare the buffering efficiency/ potency of plantain parts (stem and leaves) and calcium carbonate on acidic borehole water for fish production in Port Harcourt.

MATERIALS AND METHODS

The study was carried out in Roone Fish Farm, Abuloma, Port Harcourt, Nigeria. Eighteen (18) 100-litres shaded plastic tanks of three replicates per treatment were used for this study. Duration of the study was sixteen (16) days. The tanks were placed on outdoor concrete tanks and three-quarter (3/4) filled with acidic borehole water (pH 4.20). They were kept open throughout the study. Initial pH and temperature were taken in-situ using Hanna pHep meter (H19127). The pH meter electrode was inserted into the water up to the marked point (3.5cm) on the meter for two (2) minutes. The meter was agitated slightly at interval so that the probe (electrode) could read the pH. Reading was taken once the displaced value was stable for few seconds. However, initial dissolved oxygen was measured using Freshwater Aquaculture Testing kit Model AQ-2 (Code 3633-03) by using 75 ml of the borehole water.

The plantain plant parts were manually harvested with cutlass and cleaned to devoid of foreign matters (stones, dust and plant materials). Each part of this plant was divided into two groups (dried and wet). The plant parts for drying were sun-dried for 5-7 days following the method adopted by Bamgboye and Boluwafawi (2008) and, Davies and Mohammed (2011). Dried and wet plant parts were weighed using electronic scale TH-500 (500g X 0.1g). The two groups of plant parts were used as one piece (uncrushed form). Calcium carbonate was in powdered form (from the manufactured company). The acidic borehole water in these tanks was treated as follows: Treatment 0 (T0)- borehole water (control), Treatment 1 (T1)- dried stems (27g), Treatment 2 (T2)- wet stems (27g), Treatment 3 (T3)-dried leaves (27g), Treatment 4 (T4)-wet leaves (27g), and Treatment 5 (T5)- CaCO₃ (27g). Viveen *et al.* (1986) guideline (Table 1) for application of liming materials was adopted as a guide for the amount of organic buffer (plantain plant parts) used. That guideline further stated that ‘if the selected rate is adequate, pH will be 6.5 after two (2) to four (4) weeks’.

Table 2. pH of water treated with plantain parts and calcium carbonate.

Day	Time	Borehole (T0)	Dried stem (T1)	Wet stem (T2)	Dried leaf (T3)	Wet leaf (T4)	CaCO ₃ (T5)
1	M	4.20±0.01a	4.20±0.01 a	4.20±0.01a	4.20±0.01 a	4.20±0.01a	4.20±0.01 a
	A	4.20±0.01a	4.20±0.01 a	4.20±0.01a	4.20±0.01 a	4.20±0.01a	4.20±0.01 a
4	M	4.65±0.02 e	5.55±0.02 b	4.68±0.02e	5.35±0.02c	4.73±0.01d	6.10±0.01 a
	A	4.68±0.01 e	5.68±0.03 b	4.73±0.01e	5.52±0.02 c	5.01±0.01d	6.13±0.02 a
7	M	4.97±0.01 e	6.56±0.01 a	5.13±0.03d	5.84±0.03 b	5.30±0.02 c	6.61±0.01a
	A	5.01±0.01e	6.60±0.02 a	5.14±0.01d	6.03±0.02 b	5.51±0.03 c	6.66±0.02 a
10	M	5.21±0.03 e	6.65±0.03 a	5.37±0.02d	6.01±0.01 b	5.62±0.02 c	6.87±0.02 a
	A	5.26±0.01 e	7.53±0.01 a	5.41±0.01d	6.14±0.02 b	5.70±0.01 c	7.62±0.01 a
13	M	5.53±0.02 e	6.42±0.02 a	5.59±0.01d	6.23±0.01 b	5.76±0.03 c	6.91±0.02 a
	A	5.59±0.03 e	7.65±0.01 a	5.67±0.02d	6.34±0.02 b	5.91±0.01 c	6.98±0.01 a
16	M	5.79±0.02d	6.60±0.01a	5.81±0.01d	6.38±0.01b	6.04±0.01c	7.04±0.03a
	A	5.84±0.01e	7.70±0.02a	5.89±0.01e	6.54±0.02c	6.23±0.01 _d	7.53±0.02a

Means of same time with different letters on same row are significantly different (P<0.05)
M=morning, A=afternoon, T=treatment, CaCO₃=calcium carbonate

This study used the suggested amount of liming material for sandy pond as a guide to estimate the quantity of the used organic buffer as shown below.
Calculation for amount of plantain plant parts used
900kg of organic buffer=1X10⁷m³ of water of pH 5.6-6.0
0.009kg (9g) of organic buffer =100L of water of pH 5.6-6.0
Therefore, 9gX3 (factor) was assumed for 100L of water of pH below 5.1

The pH and temperature of the treated borehole water were monitored twice daily (morning and afternoon) in-situ with Hanna pHep meter (H19127) following the above described method for 16 days. The dissolved oxygen of treatments was also measured twice daily (morning and afternoon) using the above described method for the duration of study. The measurement of these water quality parameters were restricted to 16 days in accordance with Viveen *et al.* (1986) recommendation of minimum duration of 14 days to obtain pH 6.5 if selected rate of liming materials is used. Data were subjected to analysis of variance (ANOVA) and Duncan Multiple Range using SAS (2003) statistical package.

RESULTS AND DISCUSSION

The buffering of plantain plant parts and calcium carbonate on acidic borehole water was assessed. The measurement of the acidity or alkalinity of a substance, for example, pond water is known as pH. Changes in either can exert a power influence over both water quality and water chemistry and will have a marked effect on the fish health and filter activity (FishDoc, 2009). The highest pH value [7.70±0.02 (A)] was recorded in T1 and the lowest [5.84±0.01 (A)] in T0 (Table 2). The highest value of pH in T1 could be attributed to calcium constituent of the plantain plant (Brooker *et al.*, 1987). Drying might be responsible for the higher concentration of calcium in the dried plantain stems and leaves as the moisture content

of the plant had been reduced by the drying process. Therefore, the calcium quantity in the treatment material is concentrated. pH values in T1, T3 and T5 were within the acceptable pH value of 6.5 recommended for fish production within sixteen days. This indicated that the amount of organic buffer used was adequate. Viveen *et al.* (1986) stated that ‘if the selected rate of liming materials is adequate, pH will be above 6.5 after 2 to 4 weeks’. Therefore, the selected rate of 900kg of liming materials per 1X10⁷m³ of acidic borehole water in this study was okay to raise pH of 4.2 to 6.5.
The pH of the water increased progressively in all the treatments with time. This could be due to the treatment materials and diffusion of air (containing oxygen) into the water. There were significant differences in the increase in pH between Day 1 and Day 16 in all treatments. In T5, the pH increased from 4.20 (Day 1, morning and afternoon) to 6.10±0.01 morning and 6.13±0.02 afternoon (Day 4) while in T1, pH increased from 4.20 (Day 1, morning and afternoon) to 5.55±0.02 morning and 5.68±0.03 afternoon (Day 4). The buffering effect of T5 [6.10±0.01 (M) and 6.13±0.02 (A)] was significantly higher than T1 [5.55±0.02 (M) and 5.68±0.03 (A)]. The fast increase of pH after Day 1 in T5 indicated that calcium carbonate is very efficient to buffer and increase pH of water. This could be attributed to the small particle size (powdered form) of the calcium carbonate unlike the plantain plant parts that had large particle sizes (one piece or uncrushed form). This is in accordance with Viveen *et al.* (1986) report that the efficiency of liming will decrease with increasing particle size of the liming material. However, T5 water cannot be used for fish production until it is at least 14 days (two weeks) (Viveen *et al.*, 1986). Within two weeks of treatment CaCO₃ is toxic to fish. Based on this, water treated with dried plantain stems (T1) is better than T5 for fish culture on 7th day of treatment as it is not toxic to fish. However, the highest pH in T1 was not significantly different from that of T5 at the end of the study (Day 16). However, in T3,

Table 3. Dissolved oxygen of water treated with plantain parts and calcium carbonate.

Day	Time	Borehole (T0)	Dried stem (T1)	Wet stem (T2)	Dried leaf (T3)	Wet leaf (T4)	CaCO ₃ (T5)
1	M	3.30±0.02a	3.30±0.02a	3.30±0.02a	3.30±0.02a	3.30±0.02a	3.30±0.02a
	A	3.31±0.01a	3.31±0.01a	3.31±0.01a	3.31±0.01a	3.31±0.01a	3.31±0.01a
4	M	3.33±0.03e	3.45±0.02b	3.33±0.02d	3.37±0.02c	3.34±0.02d	4.31±0.02a
	A	3.33±0.03e	3.46±0.01b	3.35±0.01d	3.38±0.02c	3.35±0.01d	4.41±0.02a
7	M	3.34±0.03e	3.46±0.03b	3.35±0.03d	3.40±0.01c	3.36±0.02d	4.34±0.01a
	A	3.35±0.02e	3.47±0.03b	3.36±0.02d	3.41±0.03c	3.36±0.03d	4.36±0.02a
10	M	3.36±0.03e	4.31±0.01b	3.37±0.01d	4.30±0.01c	3.37±0.01d	4.38±0.01a
	A	3.37±0.01e	4.51±0.02b	3.38±0.02d	4.32±0.02c	3.38±0.04d	4.42±0.02a
13	M	3.38±0.02e	4.52±0.02b	3.40±0.03d	4.33±0.02c	3.39±0.02d	4.45±0.01a
	A	3.38±0.03e	4.53±0.01b	3.41±0.01d	4.34±0.01c	3.40±0.04d	4.52±0.02a
16	M	3.40±0.02e	4.54±0.01b	4.41±0.02d	4.37±0.02c	4.30±0.03d	4.60±0.02a
	A	3.41±0.01e	4.56±0.02b	4.42±0.02d	4.38±0.01c	4.31±0.01d	4.62±0.01a

Means of same time with different letters on same row are significantly different (P<0.05)
M=morning, A=afternoon, T=treatment, CaCO₃=calcium carbonate

Table 4. Temperature of water treated with plantain parts and calcium carbonate.

Day	Time	Borehole (T0)	Dried stem (T1)	Wet stem (T2)	Dried leaf (T3)	Wet leaf (T4)	CaCO ₃ (T5)
1	M	25.6±0.32a	25.7±0.32a	25.5±0.33a	25.6±0.32a	25.7±0.32a	25.6±0.32a
	A	26.5±0.33a	26.6±0.33a	26.6±0.33a	26.8±0.32a	26.5±0.31a	26.6±0.33a
4	M	25.8±0.32a	25.7±0.33a	25.6±0.32a	25.7±0.32a	25.8±0.32a	25.7±0.32a
	A	26.6±0.34a	26.2±0.34a	26.4±0.35a	26.5±0.31a	26.0±0.31a	26.1±0.34a
7	M	26.1±0.34a	26.1±0.32a	26.4±0.35a	26.3±0.33a	26.2±0.31a	26.1±0.34a
	A	27.1±0.33a	27.4±0.34a	27.2±0.33a	27.3±0.32a	27.2±0.32a	27.3±0.44a
10	M	26.2±0.32a	26.2±0.34a	26.2±0.34a	26.2±0.32a	26.2±0.31a	26.1±0.34a
	A	27.1±0.33a	27.4±0.35a	27.2±0.33a	27.3±0.32a	27.2±0.32a	27.3±0.44a
13	M	26.3±0.33a	26.4±0.34a	26.1±0.32a	26.3±0.31a	26.2±0.33a	26.3±0.33a
	A	27.2±0.34a	27.5±0.35a	27.3±0.34a	27.2±0.32a	27.3±0.32a	27.4±0.35a
16	M	27.1±0.32a	27.1±0.35a	27.1±0.03a	27.2±0.32a	27.1±0.31a	27.2±0.33a
	A	28.0±0.32a	28.3±0.33a	28.2±0.34a	28.1±0.31a	28.1±0.33a	28.2±0.45a

Means of same time with different letters on same row are significantly different (P<0.05)
M=morning, A=afternoon, T=treatment, CaCO₃=calcium carbonate

pH changed from 4.20 (morning and afternoon) on day 1 to 5.5 (morning) and 5.7 (afternoon) on day 4. There was no significant difference between the buffering effect of dried stems and dried leaf on pH of water throughout the study.

The amount of CaCO₃ (27g) readily dissolved in water compared to 27g of dried stem and 27g of dried leaves. This might due to its large surface area and be responsible for the rapid increased in pH of T5 on Day 4. The buffer agents (dried stem, wet stem, dried leaves, wet leaves and CaCO₃) enhanced the buffering process as evident in the obtained results in this study. The pH of water could be increased by exposure to air (containing oxygen) but it is time dependence as observed in the present study. Buffer agents are therefore required to facilitate the process for increased fish production especially fingerling production.

Dissolved oxygen (DO) increased insignificantly as pH increased from Day 1 to Day 16 in all the treatments

(P>0.05). On Day 16, minimum DO (5.79± 0.02mg/L was recorded in T0 and maximum (4.62±0.01 mg/L) in T5 (Table 3). Diffusion of air (containing oxygen) could possibly contribute to the increases of pH of water in all the treatments. The acceptable DO values might possibly contributed to the increased pH (acceptable pH values). This prevented the process of nitrification. Nitrification tends to have a slight tendency to acidify water as well as removing the buffering capacity or hardness of water (FishDoc, 2009)). It depletes DO concentration in water. The nitrifying bacteria (*Nitrosomonas* and *Nitrobacter*) use DO for nitrification of ammonia to nitrate (The Water Planet Company, 2010). In addition, dissolved oxygen prevents denitrification of nitrate to nitrogen gas by facultative heterotrophic bacteria. Denitrification occurs when oxygen levels are depleted and nitrate becomes the primary oxygen source for microorganisms (anoxic condition, less than 0.5 mg/L or 0.2 mg/L). From Table 4, temperature ranged between 25.5 °C ± 0.32 °C and 28.3

±0.62°C in the five (5) treatments and there were no significant differences (P>0.05). Temperature was within the acceptable range for fish production (Boyd, 1981).

CONCLUSION/RECOMMENDATION

The advocacy for organic aquaculture is gaining ground in the present world, it is therefore reasonable to consider dried stem and leaves of plantain plant as organic buffer. Dried stem and leaves of plantain plant buffer water with low pH as CaCO₃ does. This study therefore suggests dried stem of plantain plant (27g per 100-litre tank, ¾ filled with water) for at least seven days and dried leaves of plantain plant (27g per litre-tank, ¾ filled with water) for at least sixteen days as an alternative buffering agents for acidic water for fish production in Port Harcourt and other parts of the world with low water pH problem. However, the present study recommends higher amount of dried and wet plantain plant parts in powdered, granulated, milled and un-milled (one piece) forms to be tested on acidic water to see if pH of 6.5 can be obtained before seven days of treatment. The use of plantain plant parts (especially dried stem and leaves) as organic buffers for safe and healthy fish production is free of cost and can be used by fish farmers for better profitability.

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