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POTENTIAL OF USING RICE-STRAW ASH AS LIMING MATERIAL IN AQUACULTURE

T K Paul[1] and M M M Alam*[2]

[1]*District Fisheries Officer, Department of Fisheries, Dhaka, Bangladesh*
[2]*Department of Fish Health Management, Sylhet Agricultural University, Sylhet-3100, Bangladesh*

Abstract

The study was conducted to assess the feasibility of rice-straw ash (RSA) as liming material in aquaculture through four experiments for a period of 6 month from February to July 2003. The first experiment was carried out using quick lime (CaO) as control. The second was conducted to determine the effects of RSA on mud turbidity and water quality. The third was conducted to determine the effects of RSA on water quality and growth of Nile tilapia (*Oreochromis niloticus*). The fourth was conducted to determine the effects of RSA on water quality. The neutralizing value and efficiency rating of RSA were about 11.02% and 30.17%, respectively, which were much lower than CaO. RSA brought total alkalinity to $227 mgL^{-1}$ as $CaCO_3$, which was much lower than CaO (1,775 mg/L as $CaCO_3$). Total hardness increased by RSA was significantly higher than CaO ($P < 0.05$). Increase of pH by RSA was significantly lower than CaO ($P < 0.05$). RSA was not effective in removing mud turbidity. Total alkalinity was positively correlated with RSA doses. RSA raised pH value significantly at all doses compared to control. All treatments indicated that RSA released significant amount of phosphorus. RSA has potentials to be used as low-cost alternative liming material and phosphorus source for aquaculture. It is therefore recommended that RSA may be applied at the rate of 7.5 - 20 g/L^{-1} to maintain favourable pH, total alkalinity and total hardness in aquaculture pond. The study will contribute to increase aquaculture production through utilizing low-cost alternative liming material i.e. RSA, especially for resource-poor farmers.

Keywords: Rice-straw ash, alternative liming material, pH, aquaculture, *Oreochromis niloticus*

Introduction

Pond soils play an important role in the dynamics of ponds through interactions with the water. Soil acidity affects soil pH, nutrient availability, elemental deficiencies and toxicities, soil biological activity and water quality parameters, and ultimately the overall productivity of the pond. Therefore, control of soil acidity is one of the most important aspects of pond management. In aquaculture lime is applied to raise total alkalinity in water to ensure that carbon is not a limiting factor (Bowman, 1998). Liming is a remedial procedure necessary in acidic ponds to improve conditions for growth and survival of aquatic animals and to enhance the response of plankton for fertilization (Boyd, 1990; Paul and Alam, 2011). Low alkalinity and soil pH reduce fish production because pond waters for fish production should have optimal alkalinity (Swingle, 1961). In acidic environments fish growth is slowed and phosphorus becomes insoluble and, thereby, unavailable (Boyd, 1982). Lime increases benthic production in fertilized ponds apparently through increasing nutrient availability (Bowling, 1962). Liming increases microbial activity diminishes the accumulation of organic matter in pond bottom and favours the recycling of nutrients (Pamatmat, 1960).

The liming materials, most frequently used, are agricultural limestone ($CaCO_3$) and dolomite $CaMg(CO_3)_2$ (Paul and Alam, 2011). Other common liming materials are slaked or hydrated lime $Ca(OH)_2$ and quick lime or burned lime (CaO). In Bangladesh fish ponds are usually limed with agricultural lime ($CaCO_3$) and quick lime (CaO). As Bangladesh using arable land (70.1% of the total land in 2012) in agriculture (The World Bank, 2014), has an abundant quantity of rice-straw, the by-products from the rice fields. Virtually, there is no practical use for this by-product. Rice-straw ash, by-product of rice-straw following burning as cooking material, has no practical use at the

***Corresponding author: M M Alam,** *Department of Fish Health Management, Sylhet Agricultural University, Sylhet, Bangladesh, E-mail: mhbb_alam@yahoo.com*

moment. A research was carried out by CARE-Bangladesh to control Epizootic ulcerative syndrome (EUS) of fish in ponds using ash indicated that there had been a general increase in fish production (Nandeesha *et al*. 2001). Another participatory study carried out by the CARE-Bangladesh 'Farmers Field School' (FFS) reflected the efficiency of ash both in terms of increase in fish production and disease control (Islam, 2003). Small-scale rural aquaculture is becoming increasingly important in Bangladesh. Poor farmers can use rice-straw ash to treat their ponds. Thus, they can reduce production costs, which will in turn improve their livelihoods. However, little information on the roles of rice-straw ash in aquaculture is currently available. The objectives of the study were: i) to determine the physico-chemical properties of rice-straw ash; ii) to identify the effects of using rice straw ash on water quality; and iii) to find out the appropriate dose of rice-straw ash as liming material to improve water quality in aquaculture ponds.

Materials and Methods

The study, composed of four experiments, was conducted at the Asian Institute of Technology (AIT), Thailand during February 2003 to July 2003.

Experimental materials: Rice-straw was collected from AIT Agriculture Experimental Farm, and burnt to rice-straw ash (RSA). Quick lime (CaO), urea and triple superphosphate (TSP) were purchased from a local market. Nile tilapia fingerlings were collected from AIT Aquaculture Farm.

Determination of Physico-chemical properties of rice-straw ash (RSA): This experiment was conducted at the AIT Aquaculture Lab to determine the following physical and chemical properties of RSA and CaO. Five samples of RSA and CaO were taken to determine neutralizing values and three samples for efficiency ratings using sieve analysis method (Boyd, 1990)). Solubility of RSA and CaO was determined by dissolving them in distilled water in 1L beakers and determining total dissolved solids (TDS) concentration under the saturation condition (Boyd and Tucker, 1992). Total alkalinity, total hardness and pH values were also determined in the saturated solutions (Boyd and Tucker, 1992).
Neutralizing value is calculated using the following formula

$$\text{Neutralizing value (\%)} = \frac{(V\text{-}T)(N)(5000)}{S}$$

Where, V = Volume hydrochloric acid (ml); T = Volume sodium hydroxide (ml); N = Normality (should be same for acid and base); and S = Sample weight (mg)

Calculation of efficiency rating, (%)

Particle size range		
Screen scale	mm	Efficiency
Retained on 10 mesh	> 1.70	0.036
Retained on 20 mesh	1.69-0.85	0.127
Retained on 60 mesh	0.84-0.25	0.522
Passed 60 mesh	<0.24	1.000

Identification of the Effects of RSA on mud turbidity and water quality

***Experimental design*:** There were nine treatments with three replicates. RSA was applied at 0, 2,500, 5,000, 7,500, 10,000, 12,500, 15,000, 17,500 and 20,000 mgL^{-1} into the prepared turbid water in 25L plastic buckets. The experiment was conducted in a completely randomized design.

***Experimental setup*:** Turbid water was prepared by mixing soil with tap water at a dose of $30gL^{-1}$, stirring vigorously and standing for 2 days. All 27 buckets were filled with 14 L prepared turbid water. RSA was added into the turbid water at the above doses, respectively. Turbidity and pH were measured at 0, 0.5, 6, 12, 24, 72 and 168 hours after the addition of RSA. Total alkalinity and total hardness concentrations were determined at 0, 24, 72 and 168 hours after the addition of RSA.

***Analytical methods*:** Turbidity was measured in Nephelometric Turbidity Unit (NTU) by a turbidity meter LTP4 (The Nephelometric system). pH was measured with a digital pH meter (DIGICON model-205). Total alkalinity and Total hardness were analyzed by the titration and by EDTA titration method, respectively (Boyd and Tucker, 1992).

Identification of the Effects of RSA on water quality in fertilized cement tanks with Nile tilapia

***Experimental design*:** The experiment possessed four treatments: (T_1) no liming (control); (T_2) liming soil by CaO; (T_3) liming soil by rice-straw ash (RSA); and (T_4) liming water by rice-straw ash (RSA-water). The control had four replicates, while other treatments had three replicates each. Liming rates for soil were calculated based on soil acidity, while liming rates for water were determined based on the weekly measured total alkalinity concentration to maintain total alkalinity at 75 mgL^{-1} as $CaCO_3$. This experiment was conducted in a completely randomized design for two months.

***Experimental setup*:** Thirteen outdoor concrete tanks of 2×2.5×1 m^3 were used for this experiment. The tanks were filled with a layer of 10 cm soil collected from AIT Aquaculture Farm. Soil samples were taken from all tanks for determining soil acidity using a PVC tube soil sampler. Due to highly acidic soil, all tanks were limed by quick lime based on soil acidity as pre-treatment to reduce soil acidity. One week later, soil samples were taken again from all tanks for determining soil acidity and liming rates for treatments T_2 and T_3. One week after liming, all tanks were filled with tap water up to 80 cm, and fertilized with urea and TSP at rates of 28 kg N and 7 kg P/ha/week, which were used for weekly fertilization throughout the experimental period. One week after the initial fertilization, sex-reversed Nile tilapia fingerlings of 10-15 g in size were stocked at the rate of 2 $fishesm^{-2}$ in all tanks. Water depth in all tanks was maintained at the initial level by weekly adding tap water to compensate water losses due to evaporation.

***Determination of lime application rate*:** The requirements of liming materials for acidic soil were determined using the following methods described by Pillai and Boyd (1985).

Liming rate (kg $CaCO_3ha^{-1}$) = (8 – pH of mud buffer mixture) × 6,000

The application rates of RSA and CaO as liming materials were determined (Boyd, 1990).

$$\text{Lime application rate (kg/ha)} = \frac{\text{Liming rate as } CaCO_3 \text{ (kg/ha)}}{NV/100 \times ER/100}$$

Where, NV = neutralizing value (%); ER = efficiency rating (%)

***Analytical methods*:** Individual weight of the stocked and harvested fish was measured using an electronic balance, and the number of fish at stocking and harvest was counted. Water samples were taken weekly or bi-weekly from all tanks at 09:00 h using a column water sampler for the analysis of the following parameter. DO, temperature and pH were measured in situ. Dissolved Oxygen (DO) was measured weekly at 10 to 15 cm below the water surface at 06:00 h and 16:00 h using a DO meter (YSI model 57). Water temperature was measured weekly at 10 to 15 cm below the water surface at 06:00 h and 16:00 h using a DO meter (YSI model 57). pH was measured weekly at 10 to 15 cm below the water surface at 06:00 h and 16:00 h using a digital pH meter (Digicon pH –205). Total alkalinity and Total hardness were analyzed weekly and biweekly by acid titration and EDTA titration method, respectively (Boyd and Tucker, 1992). Total ammonia nitrogen (TAN) and Total Kjeldahl nitrogen (TKN) were analyzed by phenate-hypochlorite and Micro Kjeldahl method, respectively (American Public Health Association, 1981). Nitrite-nitrogen (NO_2-N) and nitrate-nitrogen (NO_3-N) were analyzed by Cadmium reduction method (American Public Health Association, 1981). Total phosphorus (TP) and Soluble reactive phosphorus (SRP) were analyzed by sulfuric acid digestion plus Ascorbic acid reduction and ascorbic acid reduction method, respectively (American Public Health Association, 1981). Chlorophyll *a* was analyzed by flurometric method.

***Identification of the Effects of RSA on water quality in fertilized plastic buckets Experimental design*:** The experiments were four treatments: (T_1) no liming (control); (T_2) liming soil by CaO; (T_3) liming soil by RSA; and (T_4) liming water by RSA. Treatment one (T_1) was four replicates and the others with three replicates each. Liming rates for soil were calculated based on soil acidity, while lime rates for water were determined based on the weekly measured total alkalinity concentration to maintain total alkalinity at 75 mg L^{-1} as $CaCO_3$. This experiment was conducted in completely randomized design for one month.

***Experimental setup*:** Thirteen plastic buckets of 47 cm in diameter and 64 cm in depth were used for this experiment. The buckets were filled with a layer of 10 cm soil collected from AIT Aquaculture Farm. Soil samples were taken before filling the buckets for determining soil acidity, and the soil in buckets for treatments T_2 and T_3 were limed using CaO and RSA, respectively. One week after liming, all buckets were filled with tap water up to 44 cm, and fertilized with urea and TSP at the rate of 28 kg N and 7 kg $Pha^{-1}week^{-1}$, which were used for weekly fertilization throughout the experimental period. Water depth in all buckets was maintained at the initial level by weekly adding tap water to compensate water losses due to evaporation. The methods for determining lime application rates and water quality were the same as those described in Experiment 3.

***Statistical analysis*:** The data were analyzed statistically by one-way analysis of variance (ANOVA) and regression analysis using SPSS (version 11.0) statistical software package (SPSS, Chicago, USA). Differences were considered significant. All means were given with ± standard error (SE).

Results and Discussion

Physico-chemical properties of rice-straw ash (RSA): All measured physical and chemical properties of RSA and quick lime were significantly different from each other ($P < 0.05$) (Table 1). Both neutralizing values and efficiency rating for RSA were lower than quick lime. Neutralizing value of RSA was only about 11.02%, while efficiency rating was approximately 30.17%. RSA brought total alkalinity concentrations to 227 mgL^{-1} as $CaCO_3$, which were much lower than the increased concentration by quick lime (1,775 mgL^{-1} as $CaCO_3$). Total hardness concentration increased by quick lime was significantly lower than that by RSA ($P < 0.05$). Increase of pH caused by quick lime was significantly higher than that caused by RSA ($P < 0.05$).

Table 1. Physico-chemical properties of RSA in comparison with quick lime (CaO)

Liming materials	Neutralizing value (%)	Efficiency rating (%)	Total Alkalinity (mgL^{-1} as $CaCO_3$)	Total Hardness (mgL^{-1} as $CaCO_3$)	pH	TDS (mgL^{-1})
Rice-straw ash	11.02±0.19	30.17±0.04	227±8.19	85.0±1.7	9.82±0.01	3433.3±43.7
CaO	91.11±0.16	75.1±0.12	1775±1.73	14.3±0.3	10.39±0.01	1856.7±11.3

The neutralizing values of RSA and quick lime determined in the present study were 11.02% and 91.11%, respectively. In a similar study, Paul and Alam (2011) reported much smaller neutralizing value for Rice-husk ash (RHA), which was 2.55%, but similar value for quick lime. The relative neutralizing value of RSA was 22%, which was above 4 times higher than that of RHA (Paul and Alam, 2011) and much lower than that of commonly used liming materials such as calcium oxide or quick lime (179%), calcium hydroxide or hydrate lime (136%), calcium magnesium carbonate or dolomite (109%), calcium carbonate or agricultural lime (100%), and calcium silicate (86%) (Boyd, 1990). Thus, RSA is much less effective in liming than these common liming materials, and also than other liming materials such as fly ash (78%) and wood ash (79.8%), but more effective than RHA (5%) (Paul and Alam, 2011).

Table 2. Mean values of water quality parameters during the study period

Dosages (mgL^{-1})	Turbidity (FNU)	pH	Total Alkalinity (mgL^{-1})	Total Hardness (mgL^{-1})
T1 (0)	$287±1.16^{a}$	$4.62±0.03^{a}$	$13.58±0.48^{a}$	$204.00±9.88^{d}$
T2 (2500)	$288±1.49^{ab}$	$5.99±0.30^{b}$	$30.08±5.69^{b}$	$204.00±8.16^{d}$
T3 (5000)	$289±1.47^{bcd}$	$6.33±0.35^{c}$	$54.00±13.64^{c}$	$203.83±10.60^{d}$
T4 (7500)	$289±1.72^{bcd}$	$6.59±0.39^{cd}$	$75.33±21.13^{d}$	$191.67±7.25^{c}$
T5 (10000)	$290±1.75^{cd}$	$6.80±0.45^{de}$	$88.25±25.10^{e}$	$190.83±7.48^{c}$
T6 (12500)	$288±2.47^{abc}$	$6.92±0.44^{de}$	$106.08±31.61^{f}$	$179.83±4.48^{b}$
T7 (15000)	$288±2.75^{ab}$	$7.02±0.46^{efg}$	$108.42±32.08^{f}$	$171.17±3.85^{a}$
T8 (17500)	$290±2.34^{de}$	$7.14±0.48^{fg}$	$119.83±35.69^{g}$	$172.50±4.94^{a}$
T9 (20000)	$291±2.23^{e}$	$7.31±0.51^{g}$	$152.42±46.64^{h}$	$169.83±6.23^{a}$

Mean values with different superscript letters in the same column for RSA were significantly different (P<0.05)

Effects of RSA on mud turbidity and water quality: The turbidity values in the treatments with high doses of RSA (12,500 – 20,000 mgL^{-1}) were significantly lower than those in the control ($P < 0.05$). The overall mean turbidity values in the treatments with RSA were significantly higher than those in the control ($P< 0.05$) (Table 2).

Total alkalinity concentrations increased dramatically upon the addition of RSA at all doses, and maintained at the levels during the entire experimental period. Final concentrations of total alkalinity were positively linearly correlated with RSA doses ($Y = 0.0094X + 18.852$, $r^2 = 0.9643$, $n = 27$, $P < 0.05$; Fig. 1). Total hardness concentrations increased steadily in the control and in RSA treatments at doses upto 10,000 mg/L throughout the experimental period, while total hardness concentrations decreased in RSA treatments at higher doses at beginning then increased towards the end of the experiment. Total hardness concentrations had negatively linear relationship with doses of RSA ($Y = 233.16-0.003X$, $r^2 = 0.7804$, $n = 27$, $P < 0.05$; Fig. 2). RSA raised pH values significantly at all doses, compared to the control. Values of pH increased steadily over time at all doses of RSA. Values of pH increased linearly with increasing doses of RSA ($Y = 0.0001X + 6.0233$, $r^2 = 0.6274$, $n = 27$, $P < 0.05$; Fig. 3). The results from the study showed that RSA was not effective in mud turbidity removal and similar result was also reported for RHA (Paul and Alam, 2011). It might be due to the darker color and suspended particles caused by RSA, and it tended to raise turbidity with increasing doses just after application.

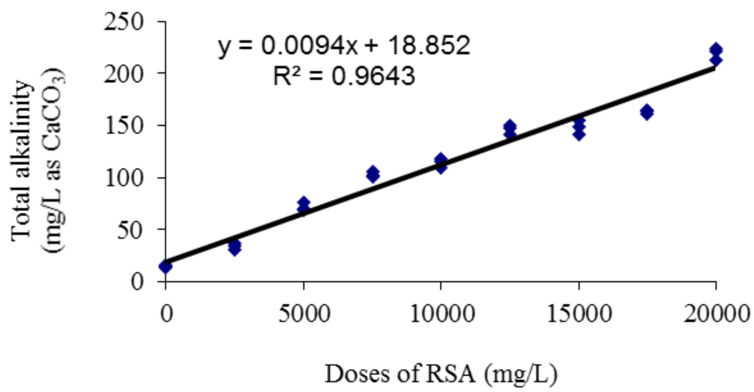

Fig. 1. Relationship between RSA doses and final values of total alkalinity

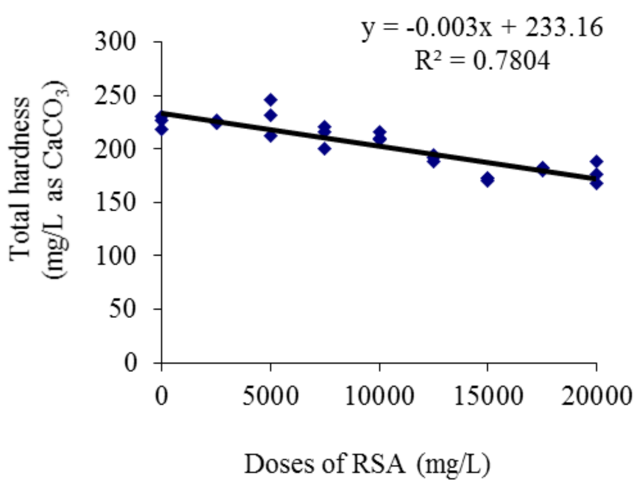

Fig. 2. Relationship between RSA doses and final values of total hardness

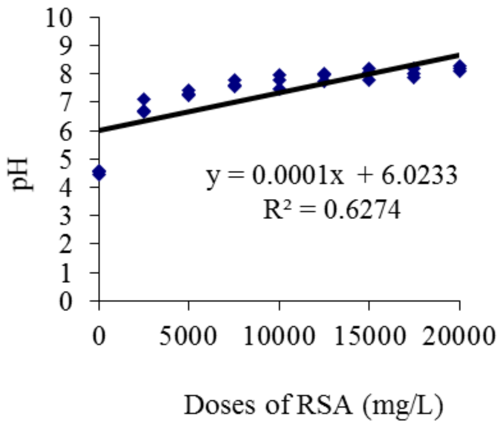

Fig. 3. Relationship between RSA doses and final values of pH

The most effective technique to remove mud turbidity from water is the introduction of electrolytes of opposite charge (Boyd, 1990). In the present study, the turbidity value of the end of the experiment two was significantly different ($P < 0.05$) in RSA-treated water. The highest turbidity reduction was recorded at the RSA dose of 15000 mgL^{-1}. The present study showed that total alkalinity concentrations and pH values increased linearly with increasing doses of RSA. Similar trend was also reported for RHA (Paul and Alam, 2011). However, there were negatively linear relationships between RSA doses and total hardness concentrations. The similar relationships between RHA doses and total hardness concentrations were also reported (Paul and Alam, 2011). Probably, cations released from RSA flocculated with colloid particles.

Effects of RSA on water quality in fertilized cement tanks with Nile tilapia: There were no significant differences for all water quality parameters except for TP measured at the end of the experiment and overall mean values of total alkalinity, nitrite-N, TP and SRP ($P > 0.05$; Table 3). Overall mean values of total alkalinity in the control and quick lime treatments were significantly lower than those in the RSA and RSA-water treatments ($P < 0.05$). TAN concentrations decreased steadily throughout the entire experimental period, while the concentrations of nitrite-nitrogen, nitrate-nitrogen, TKN, TP, SRP fluctuated during the experiment. Nitrite-N concentrations were lowest in RSA treatment, intermediate in the control and RSA-water treatments, and highest in the quick lime treatments ($P < 0.05$). Concentrations of TP and SRP were significantly higher in the RSA treatments than those in the other treatments ($P<0.05$). Mean weights of Nile tilapia at harvest ranged from 40 to 67 g/fish in the 48-day culture period giving mean daily weight gains of 0.57-1.11 $gfish^{-1}day^{-1}$. There were no significant differences in all growth and yield performance parameters among all treatments (Table 4). There were no significant differences in pH values between the control and liming treatments. This was probably caused by the pre-treatment using quick lime to neutralize soil acidity, because the soil was heavily acidic. However, in experiment 4 without the pre-treatment, pH values were significantly higher in the liming treatments than in the control, and RSA raised pH values in water to the similar levels raised by quick lime.

Furthermore, RSA was able to raise total alkalinity in water to significantly higher levels than quick lime. Similar to RSA, RHA was also reported to raise pH and total alkalinity values in respect to quick lime (Paul and Alam, 2011). Thus, the present study demonstrated that RSA is a good source of carbon in aquaculture.

Effects of RSA on water quality in fertilized plastic containers: The final values of pH were significantly lower in the non-limed treatment (control) than in the limed treatments (CaO, RSA and RSA-water treatments) ($P < 0.05$), while the overall mean pH values were lowest in the control and RSA-water treatments, and highest in the CaO and RSA treatments ($P < 0.05$; Table 5).

Table 3. Mean values (± SE) of water quality parameters measured weekly

Parameter	Treatments			
	Control	CaO	RSA	RSA-water
DO at 06:00 h (mgL^{-1})	7.70 ± 1.28	7.94 ± 1.62	7.47 ± 0.89	6.97 ± 0.92
DO at 16:00 h (mgL^{-1})	12.83 ± 1.98	12.78 ± 1.95	12.10 ± 1.61	12.22 ± 1.58
Temp at 06:00 h (º C)	29.9 ± 0.4	29.7 ± 0.4	29.6 ± 0.4	29.8 ± 0.4
Temp at 16:00 h (º C)	32.4 ± 0.7	32.4 ± 0.7	32.2 ± 0.6	32.5 ± 0.7
pH	9.21 ± 0.40	9.11 ± 0.42	9.45 ± 0.26	9.02 ± 0.39
Alkalinity (mgL^{-1} as $CaCO_3$)	50 ± 5.2^a	52 ± 3.9^a	80 ± 7.4^b	76 ± 5.7^b
Hardness (mgL^{-1} as $CaCO_3$)	407 ± 76.2	508 ± 91.5	299 ± 50.6	526 ± 105.0
TAN (mgL^{-1})	0.60 ± 0.21	0.69 ± 0.33	0.35 ± 0.21	0.39 ± 0.25
NO_2-N (mgL^{-1})	0.15 ± 0.08^{ab}	0.22 ± 0.09^b	0.06 ± 0.02^a	0.15 ± 0.06^{ab}
NO_3-N (mgL^{-1})	0.40 ± 0.07	0.41 ± 0.08	0.39 ± 0.08	0.33 ± 0.06
TP (mgL^{-1})	0.20 ± 0.02^a	0.18 ± 0.02^a	0.79 ± 0.08^b	0.35 ± 0.03^a
SRP (mgL^{-1})	0.01 ± 0.00^a	0.01 ± 0.00^a	0.37 ± 0.03^b	0.10 ± 0.03^a
TKN (mgL^{-1})	3.20 ± 0.30	3.38 ± 0.28	2.82 ± 0.12	2.91 ± 0.26
Chlorophyll a (mgm^{-3})	144 ± 8.13	146 ± 28.1	131 ± 46.4	155 ± 29.7

Mean values with different superscript letters in the same row were significantly different (P <0.05)

Table 4. Growth and yield (mean ± SE) of sex-reverse Nile tilapia during the 48-day period

Parameters	T_1 (Control)	T_2 (CaO)	T_3 (RSA)	T_4 (RSA-water)
Stocking				
Density ($fishm^{-2}$)	2	2	2	2
Mean weight $gfish^{-1}$)	13±0.59	12±0.28	12±0.48	13±0.41
Total weight ($gtank^{-1}$)	135±5.87	128±2.79	129±4.76	132±4.10
Harvest				
Mean weight ($gfish^{-1}$)	67±2.87	54±10.52	55±7.15	67±0.52
Mean wt gain ($gfish^{-1}$)	53±2.88	41±10.30	42±6.67	53±0.26
DWG ($gfish^{-1}$)	1.11±0.06	0.86±0.07	0.87±0.08	1.10±0.16
Total weight ($gtank^{-1}$)	555±56.31	541±105.21	513±83.44	618±29.82
Total wt gain ($gtank^{-1}$)	420±52.55	413±102.98	385±78.84	486±27.57
Survival (%)	82.50±6.29	100.00	93.33±3.33	93.33±3.33

Table 5. Mean values (± SE) of water quality parameters

Parameter	Treatments			
	Control	CaO	RSA	RSA-water
DO at 06:00 h (mgL^{-1})	5.9±0.15^c	5.9±0.20^c	5.23±0.14^{ab}	5.37±0.12^b
DO at 16:00 h (mgL^{-1})	7.23±0.18^c	5.67±0.33^{ab}	5.8±0.40^{ab}	6.3±0.20^{ab}
Temperature 06:00 h (^{0}C)	26.9±0.06^b	26.67±0.03^a	26.63±0.03^a	26.7±0.06^a
Temperature 16:00 h (^{0}C)	34.63±0.07^d	34.33±0.07^{bcd}	34.1±0.17^{abc}	33.97±0.03^{ab}
pH	6.73±0.23^a	9.17±0.03^d	8.97±0.03^{cd}	8.83±0.09^{bcd}
Total alkalinity (mgL^{-1}as $CaCO_3$)	27±4.02^a	95±3.31^b	287±5.53^d	132±3.63^c
Total hardness (mgL^{-1} $CaCO_3$)	199±10.46^b	260±9.15^c	131±6.0^a	198±3.60^b
TAN (mgL^{-1})	2.23±0.15^b	0.5±0.00^a	0.27±0.03^a	0.63±0.09^a
NO_2-N (mgL^{-1})	0.07±0.03	0.03±0.03	0.17±0.07	.013±0.03
NO_3-N (mgL^{-1})	0.4±0.00	0.27±0.09	0.33±0.03	0.3±0.00
TP ($mg L^{-1}$)	0.6±0.06^a	0.4±0.06^a	1.37±0.03^c	1.0±0.06^b
SRP (mgL^{-1})	0.2±0.00^a	0.2±0.00^a	1.47±0.07^c	0.93±0.07^b
TKN (mgL^{-1})	6.97±0.33^b	5.1±0.15^a	3.9±0.26^a	3.73±0.27^a
Chlorophyll a (mgm^{-3})	332±61.4^c	340±38.2^c	51±1.76^a	80±6.74^{ab}

Mean values with different superscript letters in the same row were significantly different (P< 0.05)

The pH values in the limed treatments were quite stable. The highest concentration of total alkalinity was achieved in the RSA treatment ($P < 0.05$). Concentrations of nitrite-N and nitrate-N fluctuated throughout the experimental period. There were no significant differences in both final and overall mean nitrite-N concentrations among all treatments ($P > 0.05$). Both overall mean and final concentrations of SRP and TP were significantly higher in the ash treatments (RSA and RSA-water) than in the control and CaO treatment ($P < 0.05$). Both overall mean and final concentrations of chlorophyll *a* were significantly higher in the control and CaO treatment than in the ash treatments ($P < 0.05$) but lowest in RSA treatment in the final and overall mean concentration respectively. Chlorophyll *a* concentrations in the CaO treatment increased dramatically until the mid-way of experiments, and then decreased rapidly towards the end of the experimental period, while chlorophyll *a* concentrations in other treatment were lower but more stable throughout the experimental period.

Phosphorus concentrations (TP and SRP) in the RSA treatment were significantly higher than in the control and the quick lime treatment. RSA contained 4.13% P_2O_5, which was lower than that in chicken manure, but higher than that in other manure (Staniforth, 1982). However, both TP and SRP concentrations in the RSA treatment were much higher than fertilized and manured fish ponds. This might imply that phosphorus contained in RSA is easily dissolved in water and well available, thus RSA may be a good and cheap resource of phosphorus for aquaculture, especially for rural aquaculture. The growth performance of Nile tilapia in the RSA treatments was not significantly different from the control and the quick lime treatment implying that there were no adverse effect of RSA on the growth and survival of Nile tilapia. Similar results were also found for RHA in relation to growth performance of Nile tilapia (Paul and Alam, 2011).

RSA is feasible to be used in aquaculture at the rate of 7.5 – 20 g L^{-1} to raise water pH and provide low-cost carbon and phosphorus. It has been proven in the present study that there are great potential to use RSA in aquaculture as an alternative liming material and phosphorus source. However, more research should be conducted to develop the strategy to utilize RSA in aquaculture.

To conclude, Bangladesh is a major rice producing country. In rural areas, people use rice-straw as cooking materials producing huge amount of RSA. The present study was conducted to identify the potentials of RSA as liming materials in aquaculture. As it is found, RSA has much lower neutralizing values and efficiency rating compared to those of quick lime and other commonly used liming materials in aquaculture. Therefore, greater amount of RSA would be required to achieve the similar effects. RSA has less effectiveness in removing mud turbidity. The application of RSA could increase total alkalinity, pH and total hardness in tank water, and maintain acceptable levels of water quality for fish culture. Growth of Nile tilapia was not affected by the addition of RSA. RSA released significant amount of phosphorus in the form of TP (0.79-1.37 mgL^{-1}) and SRP (0.37-1.47 mgL^{-1}) to the water and could be a cheap source of phosphorus for fish culture. RSA is widely available at much lower costs than other liming materials and has potentials to be used as low cost an alternative liming material and phosphorus source for aquaculture, especially in rural aquaculture for resource-poor farmers.

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References

American Public Health Association. 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. American Public Health Association, American Water Works Association, and water Pollution Control Federation. Washington DC, USA. 1134p.

Bowling M L. 1962. The effects of lime treatment on benthos production in Georgia farm ponds. In Proc. Annual Conf. Southeast Assoc. Game & Fish Counc. 16:418–425.

Bowman J R. 1998. A review of lime requirement determination methods for aquaculture ponds. FISA/PARADI: Grahamstown, South Africa. 195p.

Boyd C E. 1982. Water Quality for Pond Fish Culture. Developments in Aquaculture and Fisheries Science, Vol. 9. Elsevier Science Publishers B. V., Amsterdam, Netherlands. 359p.

Boyd C E and Tucker C S. 1992. Water Quality and Pond Soil Analyses for Aquaculture. Alabama Agricultural Experimental Station, Auburn University, USA. 183p.

Boyd C E. 1990. Water Quality in Ponds for Aquaculture. Auburn University. Alabama, USA. 482p.

The World Bank. 2014. Agricultural land (% of land area). Retrieved October 01, 2015, from http://data.worldbank.org/indicator/AG.LND.AGRI.ZS

Islam S, Karim M, Nandeesha M C, Khan M C, Chinabut S and Lilley J H. 2003. Farmer-based investigation of treatments for ulcerative disease in polyculture ponds in Bangladesh. Asian Fisheries Science. Asian Fish. Sci. 16:327-338.

Nandeesha M C, Haque S, Karim M, Saha S K and Mohan C V. 2001. Making health management relevant in the context of rural aquaculture development: Lessons from the CARE LIFE project. In: Primary Aquatic Animal Health Care in Rural, Small-scale, Aquaculture Development. Technical Proceedings of an Asia Regional Scoping Workshop. Dhaka, Bangladesh. 27th –30th September 1999.

Pamatmat M M. 1960. The effects of basic slag and agricultural limestone on the chemistry and productivity of fertilized ponds. M.S. Thesis, Stickney, R.R. (1979). Principles of warm water aquaculture. John Wiley & Sons. New York. 375p.

Paul T K and Alam M M. 2011. Potential of using rice-husk ash as liming material in aquaculture. Bangladesh J. Fish. Res. 15-16:1-14.

Pillai V K and Boyd C E. 1985. A Simple Method for Calculating Liming Rates for Fish ponds. Aquaculture. 46:157-162.

Staniforth A R. 1982. Straw for Fuel, Feed and Fertilizer. Farming Press Limited. 153p.

Swingle H S. 1961. Relationships of pH of pond water to their suitability for fish culture. Proc. Pacific Sci. Cong. 10:72-75.