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Waste from Discarded Oyster Shells: A Promising Raw Material for Lime Industry in The Philippines

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ABSTRACT

The demand for agricultural lime is high, considering its various uses from agricultural production to processing. This study determines the lime potential of three shellfishes, namely: Crassostrea iredalei *(Oyster shell),* Decatopecten radula *(Pecten shell), and* Anodontia edentula *(Mangrove clam shell) as a promising raw material for lime industry in the Philippines and can be used as alternatives for commercially produced agricultural lime. The Hydrogen ion concentration (pH) and the lime concentration using Calcium Carbonate Equivalent (CCE) of each shellfish species were measured and tested for the enhancement of an acidic soil. The experiment was laid out in a Completely Randomized Design (CRD) with four treatments replicated three times. The treatments were as follows: Treatment A- 100g agricultural lime; B- 100g oyster shell lime; C- 100g pecten shell lime; and D- 100g mangrove clam shell lime. Each treatment was combined to the acidic soil sample. The results were statistically analyzed using One-way Analysis of Variance (ANOVA) and Least Square Difference (LSD) at 0.05 level of significance. Results reveal that lime produced from the three selected shellfishes can be a potential source of alternative liming materials for agricultural lime in dealing with soil acidity, entailing lower cost of farm production. Product development and packaging of lime produced from these mollusks is recommended for mass production.*

Keywords**:** Calcium Carbonate Concentration, soil acidity, shell lime, eco-friendly, cost-efficient, circular Econonmy, lime industry

INTRODUCTION

Western Visayas in Region VI holds the largest and the richest contributors of the local aquamarine products in the whole Philippines (Philippine Statistics Authority, 2016). For instance, Capiz, is dubbed as the "Seafood Capital of the Philippines" and the Municipality of Estancia in Northern Iloilo is dubbed as the "Little Alaska of the Philippines, while the Municipality of Carles also in Northern Iloilo, Philippines is well known of its abundant production of Tikab Shells (Pecten). These provinces in Panay Island in the Visayas, is found within the territorial coast of the Visayan Sea. Shell farming is one of the people's sources of livelihood in these provinces because of its abundance of marine life. It forms an essential part of the food among *Ilonggos* and those who live along coastal areas of the Visayan Sea. The variety of shellfishes found in these provinces became an attraction to most visitors. Most fishing communities in the region value these seashells for meat as food. However, empty seashells found no value to people and are commonly disregarded as wastes. Empty shells are thrown anywhere contributing to the bulks of solid wastes in the environment.

The discarded empty shells of Oyster, Pecten and Mangrove clam shells contain potential compound known as Calcium Carbonate ($CaCO_3$). The high content of calcium carbonate in oyster shells, pecten and mangrove clam shells is technically possible for lime production to replace the commercial $CaCO_3$ (Hamester, *et al*. 2012). Shells are a calcium-rich resource that produce Calcium Oxide (CaO) or lime, which is a major panacea in the problem of high soil acidity. They can supplant limestone as source of commercial agricultural lime. Unlike stone lime which has a long-term impact on the deterioration of physical surroundings due to quarrying, shell lime is renewable and eco-friendly. It has proven uses in the environment such as increasing soil pH, improved soil nutritional status metrics including available phosphate and organic matter mass. Powdered shells are effective liming materials for crop cultivation and in eradication of giant earthworms infecting rice farms.

Recognizing the bulk of solid wastes generated in the region due to shellfish consumption, and the current state of agriculture and fishery sectors in the Philippines at the present, the production of lime from these shellfishes is the ultimate solution. The demand for agricultural lime is high, considering its various uses in fish pond and agricultural production (LABMATE, 2013; Gonzales, 2008).

On the other hand, the 2018 Bureau of Agricultural Statistics (BAS) reported that Palay and Corn production decreased by 1.44% and 3.42%, respectively. In the first six (6) months of 2018, crop production decreased by 0.44%. One of the major reasons is attributed to the farmers' continued reliance on chemical-based fertilizers and pesticides that have destroyed soil productivity over time (Asia-and-the-Pacific/Philippines-AGRICULTURER). If this will not be addressed properly, the entire country and the whole world will suffer malnutrition and hunger considering that rice is the most expended staple food in the world and over 90% of the rice consumed worldwide are eaten by people within Asia (IRRI for Asia, 2018).

This research study aimed to produce an eco-friendly and cost-efficient shell lime as alternative for commercial lime for the treatment of acidic soil. This was anchored on the platform of The Philippine Development Plan (PDP) 2017-2022 for Agriculture, Forestry and Fishery Sector. The development agenda was crafted in line with the President's 10-point Socio-Economic Agenda pursuant to Executive Order No. 5, s. 2016, including: 1) a prosperous, predominantly middle-class society where no one is poor; 2) a healthy and resilient society; 3) a smart and innovative society; and 4) a high trust society.

PREPARATION OF LIMING MATERIALS

Empty shells of oyster, pecten and mangrove clam were collected from households, local seafood restaurants (*talabahan)* and food courts. Per species, the empty shells were thoroughly washed with tap water to remove impurities, drained, and then left for two hours or more for air drying. Mechanical crusher was used to reduce the size of the shells for easy calcination.

The crushed shells were then calcinated using a furnace for 2 to 3 hours. Calcinated shells were set aside to cool down. Using a mortar and pestle, they were pulverized and then screened through a fine strainer to form powder-like lime samples.

The finished materials were segregated and placed in storage containers; labeled as: Oyster Powdered Shell; Pecten Powdered Shell; and Mangrove Clam Powdered Shell; correspondingly, for identification purposes. For agricultural lime, samples were obtained from commercially available supply. The standardized procedures are as follows:

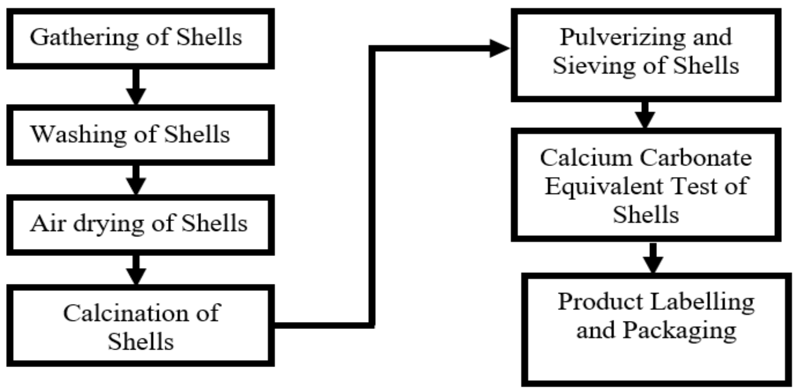

Figure 1. Standardized procedure for production of lime from shellfishes.

Preparation of soil media

Acidic soil sample was gathered at the researcher's backyard. The area was cleared by removing some pieces of stones, weeds, and other rubbish or trash to expose the soil before sampling. With a shovel, 2 kg of soil was obtained at a specific depth of 15 cm (Tenedero and Surtida, 1986) to get a representative mass of sample media. It was pulverized into smaller pieces and spread thinly on top of a table to remove impurities like stones, wood, roots, etc., then air-dried indoor at room temperature for 3 days. The initial pH was tested using standard pH paper to provide benchmark information on soil acidity level.

Experimental treatment

Using a standard weighing scale, 100 g of acidic soil samples were set aside and placed in a reagent bottle. Four applications were prepared, consisting of 100g each of the oyster, pecten, or mangrove clam powders. Each application was added and thoroughly mixed with the acidic soil sample. Completely Randomized Design (CRD) was used for 4 treatments replicated 3 times: Treatment A- 100 g of soil mixed with 100g of agricultural lime; Treatment B- 100 g of soil mixed with 100g of powdered oyster shell; Treatment C- 100 g of soil mixed with 100g of powdered pecten shell; Treatment D- 100 g of soil mixed with 100g of powdered mangrove clam shell. The 12 mixtures were clinically subjected to pH test.

Data gathering procedure

Information on ecological habitat of the selected mollusks were obtained through secondary literature review via websites, online articles and recommendations provided by SEAFDEC Aquaculture Department Library, printed articles and journals, reported studies of both foreign and local researchers available online, and other relevant information and resources from unpublished theses. Data on Calcium Carbonate Equivalent (CCE) as well as the final pH of each powdered shell sample were clinically analyzed in a standard laboratory. The pH of the soil samples and that of the prepared treatments were likewise analyzed by a licensed chemist. The data were then gathered and recorded.

Data analysis procedure

The data gathered were analyzed statistically using the following: Spearman's rho correlation, to test the significant relationship between habitat and pH of the mollusks; One-Way Analysis of Variance (ANOVA), to test the effects on the pH of different treatments; and Least Square Difference (LSD), to test the significant difference of these treatments on soil acidity; at 0.05 level of significance.

STATUS, HYDROGEN ION AND CALCIUM CARBONATE ($CaCO_3$) CONCENTRATIONS OF THE SHELLFISHES

Results in Table 1 show that oyster shell had a pH level of 12.13, with $CaCO_3$ concentration of 103.91; pecten shell had a pH of 12.55, with $CaCO_3$ of 116.65; and mangrove clam shell had a pH of 8.87, with $CaCO_3$ of 95.94. Data revealed that all of the shellfishes have the potential to be used as raw materials in the production of lime and can be utilized to replace the commercial lime in treating acidic soil but when it comes to sustainability, Oyster shells is the most abundant.

Table 1. Status, pH and calcium carbonate concentration of shellfishes

Shellfish	Status[a]	pH[b]	$CaCO_3$ Conetnt (%) [b]
Oyster	Abundant	12.13	103.91
Pecten	Vulnerable	12.55	116.65
Mangrove Clam	Vulnerable	8.87	95.94

[a]SEAFDEC Aqualculture Library. [b]Department of Agriculture (RO-6): Regional Soils Laboratory, Iloilo City, Philippines

Correlations of $CaCO_3$ in terms of pH

Table 2 reveals that correlations are significant at 0.05 level (2-tailed) and further illustrates strong, positive, highly significant correlation between pH and potential lime concentration. As illustrated further in Figure 2, the species having a higher pH tends to have a higher $CaCO_3$ concentration, like in the case of pecten shell; whereas, oyster and mangrove clam, which had lower pH tend to have lower $CaCO_3$ concentrations. This means that increase in pH would correspond to increase in $CaCO_3$ concentration. Adequate management conservation is therefore needed in order to protect and preserve these shellfishes (Arganoza and Geduspan, 2013).

Table 2. Correlation of the pH and the $CaCO_3$ concentration of different shellfishes

Paired Variables	Type of Test	Correlation	SIG
$CaCO_3$ and pH	Spearman's rho	0.0896**	0.001

***Highly Significant at 0.05 alpha level of significant.*

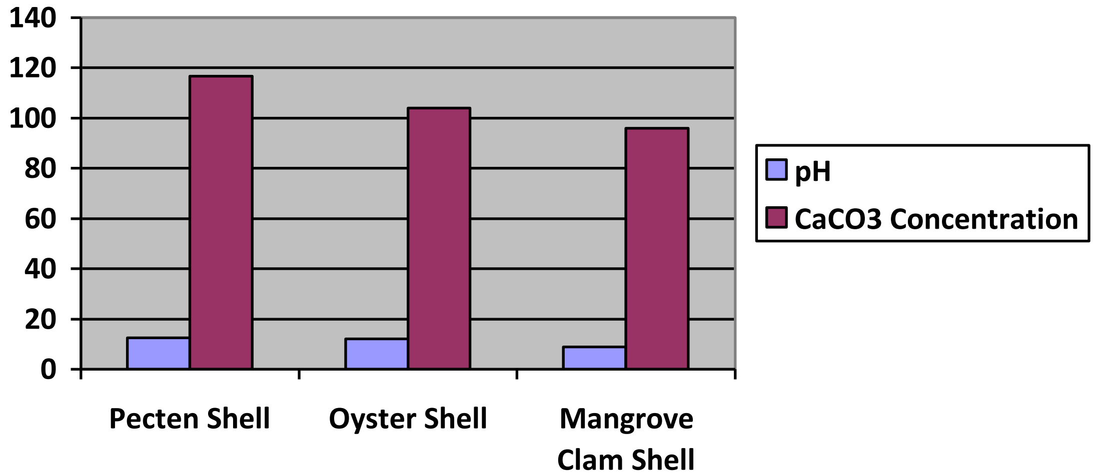

Figure 2. Correlations of $CaCO_3$ concentration of the different mollusks and their pH

Mean pH of soil samples incorporated with lime produced from different mollusks

As shown in Table 3, the acidic soil samples unveil an initial mean pH of 4.26. Data reveal further that from the initial soil pH of 4.26, the soil pH increased after pecten lime was added and the same was raised to 7.12; the oyster increased it to pH 7.00; and mangrove clam to pH 6.43.

Table 3. Mean values of soil pH after treatment of limes from different shellfishes.

Treatment	Initial soil pH	Replication			Soil pH after treatment [a]
		R1	R2	R3	
Oyster lime	4.26	7.13	6.91	6.97	7.00
Pecten lime	4.26	7.15	7.17	7.04	7.12
Mangrove clam lime	4.26	6.51	6.30	6.47	6.43

[a] Department of Agriculture (RO-6): Regional Soils Laboratory, Iloilo City, Philippines

Data further reveal (Table 4) that there was a highly significant difference among different treatments in terms of pH. Thus, the acidic soil treated with powdered shells from oyster, pecten or mangrove clam could positively affect soil acidity, in comparison to the average neutralizing value (ANV) for agricultural lime, which is reported to be as high as 77.0% (Schwab *et al*., 2007).

Table 4. ANOVA of soil samples incorporated with lime produced from different shellfishes.

Sum of squares		df	Mean square	F	Sig.
Between	44.80	3	14.95	1795.799	.000**
Within	0.067	8	.008		
Total	44.917	11			

***highly significant at 0.05 alpha level of significanct*

Results of Post Hoc Tests suggested multiple comparisons of acidity, for the different treatments applied. Using LSD, the Post Hoc Test on pH shows that commercially available agricultural lime (control) had the remarkably highest pH among other treatments (Table 5). It was followed by the treatment with pecten lime. These two treatments had significantly higher pH compared to the treatment using mangrove clam. The mean difference is significant at 0.05.

Table 5. Mean pH of soil samples incorporated with lime produced from different shellfishes with LSD result on the degree of differences

Treatment	N	Mean
Agri-Lime	3	11.2733[a]
Oyster Lime	3	7.0033[b]
Pecten Lime	3	7.1200[b]
Mangrove Clam Lime	3	6.4267[c]
Total	12	7.9558

[a, b,c] *Means having the same superscripts are not significantly different.*

Paired-samples statistics and tests for the differences on the pH of samples after the incorporation of different treatments

There is a highly significant difference on the soil pH before and after incorporation of treatments (Table 6). From acidic pH of 4.26 before treatment application, the soil pH rose and surged to 7.96 (now alkaline) after application of treatments; thus, there is positive significant effect of the different lime concentrations from the selected mollusks in treating acidic soil. This suggests that lime produced from oyster, pecten and mangrove clam shells could be used as raw materials in the production of lime and as alternative to agricultural lime in offsetting soil acidic soil.

Table 6. The paired-sample tests for the difference on the pH showing the different sample after the incorporation of different treatments

pH	Mean	Std. dvn.	Std error mean	T	f	Sig

After	-3.70	2.02	0.58	-6.34**	11	0.00

***Highly significant at 0.05 alpha level of significant.*

Such finding was supported by a study of Fitzgerald (2007) on Shell Waste in Aggregates Project Report for Sea Fish Industry Authority, which revealed that shellfishes from which the flesh has been completely removed can be used in gardens as a substitute for lime. The findings of the present study were also supported by a case study on lime production in Sri Lanka which revealed that: coral and shells can be used as raw materials for lime production. Shells cover 95% of $CaCO_3$ and occur in the size range which can be calcinated directly in kilns (NLA, 2004).

The study of Jakobson (2009) also revealed that seashells also lie closer to the ecological chain. The powder obtained could replace traditional lime, which is millions of years old and must be blasted loose in limestone quarries and then crushed and ground down to powder form. Powdered seashells can also be used within ecological agriculture. For the proper management of the lime industry, data on lime production and consumption, which is presently not available in the country, must be collected and analyzed. Unlike stone lime, shell lime is renewable and sustainable, therefore proper care should be taken for its production. Moreover, this ecofriendly traditional technology should be conserved and maintained (Panda and Mirsa, 2006).

CONCLUSION AND RECOMMENDATIONS

Oyster Shell Lime contained higher pH (12.13), and lime potential concentration ($CaCO_3$) which is equivalent to 103.91%. The utilization of empty oyster shells, which are thrown in the environment as wastes can be used as raw material in producing lime. The government should find the potential of these indigenous materials as substitute for agri-lime that is produce from quarrying of limestone and is proven unsustainable, ecologically harmful, and detrimental to human, plant, and animal life.

Lime produced from Oyster shells is highly effective alternative for agri-lime in treating acidic soil. Mass production of Oyster is necessary to produce greater volume of lime obtained from their shells, as they are renewable and sustainable. Conservation measures and marine protection activities should be strictly implemented and sustained, including seasonal regulatory banning of shell collections, to avoid exploitations and to ensure continuous supply of the commodity.

Lime produced from Oyster Shells is ECO-FRIENDLY and COST-EFFICIENT. The utilization of the bulk of solid wastes generated from discarded shells into lime as treatment for acidic soil is one of the alternative solutions on solid waste problem of the region (Republic Act 9003). It entails lower-cost and readily available compared to agri-lime. It can provide livelihood opportunity and help alleviate the income of farmers, local gleaners and fisherfolks. This technology help in addressing the agenda and Sustainable Development Goals of the government and the Philippine Development Plan (PDP) 2017-2022 for Agri-fisheries Sector in response to the economic challenges that our country is facing today.

In Korea, one of the most productive oyster-farming waters in the world, and shellfish farming constitutes a large portion of the regional economy. However, disposal of oyster shell waste is a serious problem for the industry. Enormous amounts of oyster-shell waste have been illegally disposed of along the southern coast of Korea. The Korean government has supported programs to build calcium and fertilizer factories to increase the recycling of oyster shell waste into reusable commodities (Lee, *et al;* 2010).

Therefore, the production of lime from Oyster Shells could reap huge ecological benefits in the Philippines because of its abundance and sustainability. Recycling discarded oyster shells is a perfect example of circular economy, for they are valuable raw material for lime. Not only does it improve the sustainability of our aquaculture industry but it can also provide secondary economic benefit to Oyster growers, pond operators and processers, Fisherfolks/ local gleaners and farmers in the Philippines. It is a potential source of alternative for agricultural lime in dealing with soil acidity, entailing lower cost of farm production.

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