Effervescent Water Coagulant from *Citrofortunella Microcarpa* Scraps for Water Treatment

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Abstract: As the Philippines experiences increasing alerts in water pollution, this study aims to create a Calamansi-based effervescent water coagulant to increase the accessibility of purified water to Filipinos. The study makes use of Citrofortunella microcarpa (Calamansi), a small citrus fruit abundant in the Philippines. Calamansi has a big contribution in the production of agricultural waste as the fruit is mainly utilized for its pulp; therefore, the researchers focused on the usage of Calamansi's peels and seeds, given their ability to absorb minute particles and to kill bacteria. Disposed Calamansi scraps were powderized and mixed with other components to form an eco-friendly effervescent water coagulant. The researchers assessed the efficacy of the Calamansi coagulant by comparing it to Ferric chloride ($FeCl_3$), an existing chemical water coagulant, and testing ten trials of each sample in a contaminated soil-water mixture. The group's findings suggest that the effervescent Calamansi coagulant presented a higher efficacy in water treatment than $FeCl_3$, with its pH, electrical conductivity (EC), total dissolved solids (TDS), and salinity readings all within the standard range. The Calamansi coagulant accumulated more residue than the $FeCl_3$ sample. The study demonstrates that Calamansi seed and peel waste offer a great alternative to chemical-based coagulants in water treatment.

Key Words: water treatment; bath bomb; calamansi; coagulation; adsorption

1. INTRODUCTION

The Philippines is surrounded by numerous bodies of water; however, water shortage has been a prominent issue in the country due to pollution, climate change, and the El Niño phenomenon (World Health Organization, 2019). This water crisis forces Filipinos to consume contaminated water at higher rates, with almost seven million drinking from unsafe water and 24 million having no access to improved sanitation (water.org, n.d.). Further, the severity of water pollution in the Philippines contributes to the rapid increase of agricultural waste.

Citrofortunella microcarpa, commonly known as Calamansi, is a small citrus fruit predominantly cultivated in the Philippines and used as a condiment in Filipino cuisine. Calamansi is one of the main contributors to Philippine agricultural waste, as consumers focus on the fruit's affordability and versatility rather than the adsorbent quality of its scraps. Adsorption is a vital process in water treatment which adheres layers of molecules to the surface of a liquid or solid in contact ("What is adsorption?", 2016).

To address the influx of water contamination and agricultural wastes in the Philippines, the group aims to design an eco-friendly, portable, and accessible Calamansi-based water coagulant with a bath bomb's effervescent formula. Coagulation is a common water treatment technique, involving the adsorption of large amounts of organic compounds and suspended particles (Safe Drinking Water Foundation, n.d.). This coagulant intends to purify polluted water along the marginalized communities in Manila (near polluted riverbanks) and allow them access to clean water supply.

In this study, the group was able to further comprehend water purification through the process of coagulation. The researchers collected Calamansi scraps and created an effervescent Calamansi coagulant as a cheaper substitute for other coagulants in the market. Moreover, they were able to determine the amount of Calamansi peels needed to create an impurity coagulant in the form of a bath bomb, to which they compared Ferric chloride ($FeCl_3$), an existing chemical-based water coagulant, by testing the efficacy of both coagulants in contaminated water. Four tests namely, pH, electrical conductivity (EC), total dissolved solids (TDS), and salinity, were conducted to determine the quality of the water tested. The researchers used comparative analysis, correlation analysis, and regression analysis to analyze the retrieved data.

The study includes several limitations in accordance with the quarantine protocols. The final product is not applicable for large bodies of water and is only tested on controlled basins. With this, the final product is only currently capable of coagulation, as further directives must be approached to achieve total purification.

2. METHODOLOGY

2.1. Literature review

The researchers reviewed past studies and approaches as experimental guides. The group examined a similar study conducted by Dollah et al. (2019) involving the investigation of *Citrus aurantiifolia* (key lime) and *Citrus microcarpa* (kasturi lime) waste as natural coagulants for water treatment, and modified the previous study's setup by incorporating bath bomb technology. Data gathered were corroborated through experimental trials; after which, the group integrated the coagulation process in water treatment.

2.2. Calamansi scraps collection

Disposed Calamansi scraps were gathered and accumulated for two weeks. After two weeks, the Calamansi peels and seeds were sun-dried for one week to eliminate the moisture content. Once the peels turned brittle and observed a light brown color and the seeds hardened with no apparent color change, the scraps were then ground using a mortar and pestle until a powdery finish was achieved.

2.3. Coagulant formulation

The powdered Calamansi scraps were transferred to another container with baking soda and citric acid, following the 2:1 ratio, and were mixed before transferring into the mold which is 4 cm in diameter. The mixture sat in the mold for 15 hours until the coagulant hardened. This procedure was then repeated 9 more times to create ten coagulants with varied compositions (Table 1).

Table 1. *Amount of Calamansi scraps, citric acid, and baking soda added per trial*

Trials	Calamansi Scraps (g)	Citric Acid (g)	Baking Soda (g)
1	0.5	14.8	29.7
2	1.0	14.7	29.3
3	1.5	14.5	29.0
4	2.0	14.3	28.7
5	2.5	14.2	28.3
6	3.0	14.0	28.0
7	3.5	13.8	27.7
8	4.0	13.7	27.3
9	4.5	13.5	27.0
10	5.0	13.3	26.7

2.4. Experimentation

The researchers assessed the efficacy of the coagulants by comparing the Calamansi and the Ferric chloride ($FeCl_3$) samples. For the first experimental setup, the coagulants were tested in contaminated water. Quarantine protocols have restricted the researchers from collecting contaminated water from rivers; therefore, a soil-water mixture, composed of 1 L of tap water and 50 g of soil, was used as a substitute. Electrical conductivity (EC), pH, total dissolved solids (TDS), and salinity tests were first conducted on the soil-water mixture before starting the overall experiment. Then, the Calamansi coagulants were dropped into the soil-water mixture and were left untouched for one hour to allow the residues to settle. The water was then filtered, and the residue was separated from the water. The residues were then sun dried to eliminate the moisture content present in them and were weighed afterward. The four water tests were then again conducted to the water. The same procedure was applied to the second experimental setup. The only difference was that Ferric chloride ($FeCl_3$) was used instead of the Calamansi coagulant (Table 2).

Table 2. *Amount of Ferric chloride ($FeCl_3$) per trial*

Trials	Ferric chloride (g)
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5
10	5.0

2.5. Data Analysis

For a successful trial, the result of the readings should be within standard ranges (Table 3). The results were analyzed via correlation and regression to determine and predict the relationship between the amount of fruit peels and the rate of absorption. Furthermore, a comparative analysis was applied to compare the Calamansi coagulant and the Ferric chloride ($FeCl_3$) samples.

Table 3. *Ranges to be considered*

Water Quality Tester	Range of Required Reading
Water pH Tester	6.5 pH – 8.5 pH
	7 pH at 25°C
Electrical Conductivity Test	200 to 800 µS/cm
Total Dissolved Solids Test	50 – 250 ppm
Salinity Test	Less than or equal to 500 ppm

3. RESULTS AND DISCUSSION

3.1. Comparative Analysis

Based on the ranges of required reading, the Calamansi coagulants were more successful than the Ferric chloride ($FeCl_3$) in impurity removal. Since none of the temperatures were at 25°C, the researchers disregarded this criterion (Table 4 & Table 5).

For the pH levels, the group opted to target the value range of 6.5 and 8.5. Only the Calamansi coagulant with 0.5 g scraps is an outlier, having a pH of 6.4. Otherwise, all of them exceeded 6.5. On the other hand, the Ferric chloride trials were all acidic, ranging from 2.4 to 3.15 (Table 4 & Table 5).

The Calamansi coagulant trials also concurred the needed criteria in the electrical conductivity test. All Calamansi coagulant trials exceeded 200 µS/cm, having 210 µS/cm and 238 µS/cm as the highest and lowest values respectively. All Ferric chloride ($FeCl_3$) trials surpassed the highest standard value of 800 µS/cm; only Trial 1 had the lowest value of 634 µS/cm (Table 4 & Table 5).

Prior to the experimentation, the TDS test for both the Ferric chloride ($FeCl_3$) and Calamansi coagulant have already reached the target ppm, obtaining levels ranging from 82-124 ppm. The results showed little to no change after the Calamansi coagulant trials were conducted, but have grown significantly with the use of Ferric chloride ($FeCl_3$), with values increasing to 317-2040 ppm. All but Trials 1 and 2 greatly exceeded the targeted values (Table 4 & Table 5).

Salinity levels of the Ferric chloride ($FeCl_3$) and Calamansi coagulant before the experiment exhibit the same values as the TDS test, obtaining a target level of less than 500 ppm. For the Calamansi coagulant trials, their salinity levels increased to 121-135 ppm, except for Trial 2 whose salinity decreased to 107. All levels were within the acceptable range. On the other hand, Ferric chloride ($FeCl_3$) trials spiked identically to their TDS results, far surpassing the targeted value, except for Trials 1 and 2 whose values were still within range (Table 4 & Table 5).

While there was no standard for the amount of residue removed, the Calamansi coagulant was shown to have removed greater amounts of residue, with a minimum of 0.65 g removed to a maximum of 4.58 g. The Ferric chloride ($FeCl_3$) managed to remove, at the least, only 0.03 g and at the most, 1.43 g (Table 4 & Table 5).

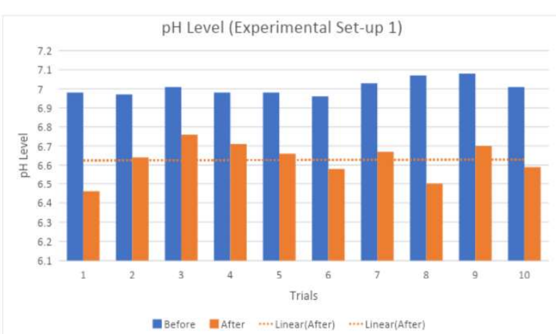

Figure 1. *pH Level (Experimental Set-up 1)*

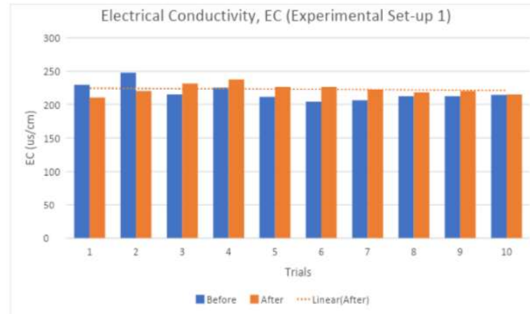

Figure 2. *Electrical Conductivity (Experimental Set-up 1)*

Figure 3. *Total Dissolved Solids (experimental Set-up 1)*

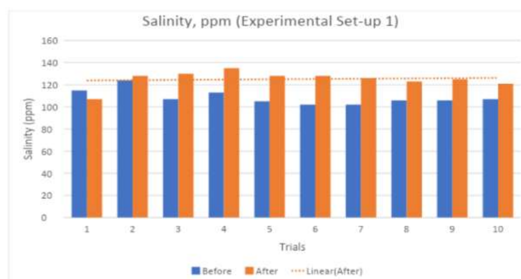

Figure 4. *Salinity (Experimental Set-up 1)*

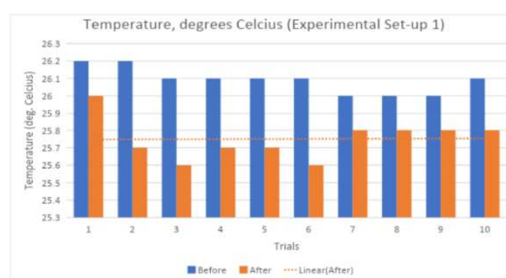

Figure 5. *Temperature (Experimental Set-up 1)*

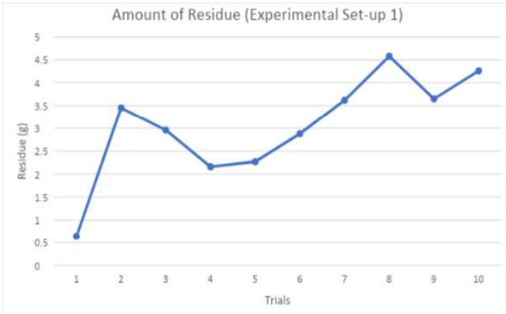

Figure 6. *Amount of Residue (Experimental Set-up 1)*

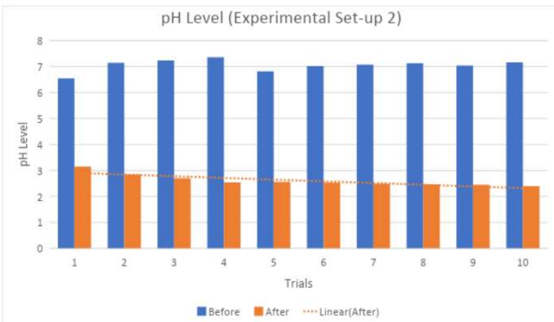

Figure 7. *pH Level (Experimental Set-up 2)*

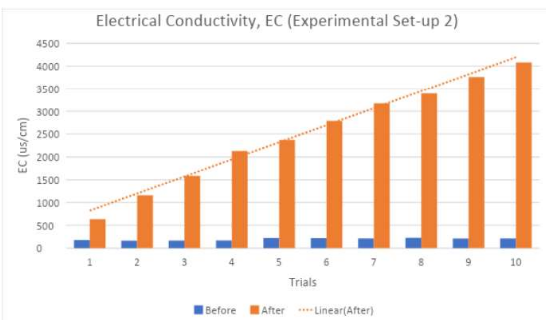

Figure 8. *Electrical Conductivity (Experimental Set-up 2)*

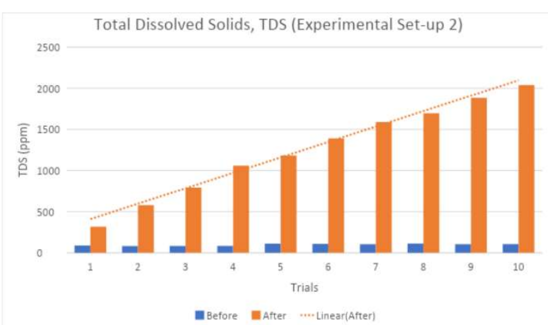

Figure 9. *Total Dissolved Solids (Experimental Set-up 2)*

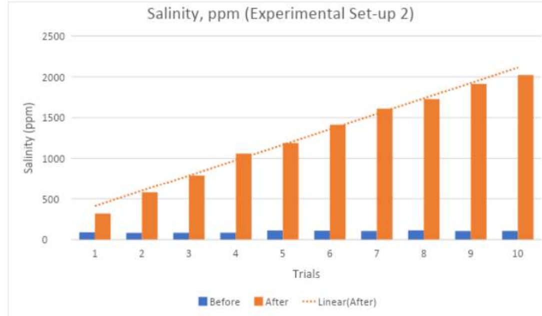

Figure 10. *Salinity (Experimental Set-up 2)*

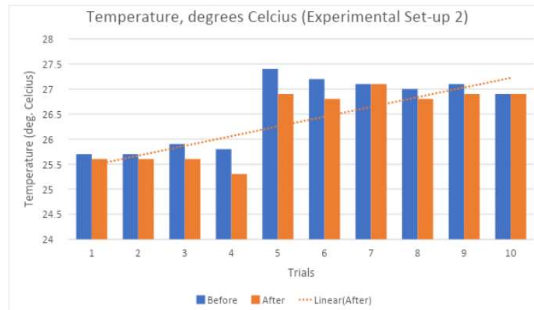

Figure 11. *Temperature (Experimental Set-up 2)*

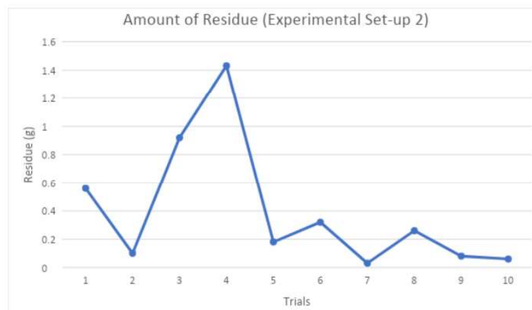

Figure 12. *Amount of Residue (Experimental Set-up 2)*

3.2. Correlation and Regression Analysis

The grams of Calamansi peels have weak correlations with the pH levels, electrical conductivity, total dissolved solids, and salinity. Each of these correlations garnered coefficients of 0.017, -0.16, -0.23, and 0.11, respectively. Since these values are closer to 0 than 1, they have small correlations with the grams of Calamansi peels used. In line with this, the regression coefficients are very low. They garnered values of 0, 0.24, 0.053, and 0.011, respectively.

The relationship between the grams of residue and the grams of Calamansi peels has a high degree of positive correlation, having a coefficient of 0.75. However, the regression coefficient is weak, having a value of 0.56.

On the other hand, the correlation between the grams of Ferric chloride ($FeCl_3$) and the pH levels is a strong negative one, garnering a value of -0.87. The regression coefficient garnered is 0.75.

The relationships of the grams of Ferric chloride ($FeCl_3$) with electrical conductivity, total dissolved solids, and salinity are strong positive correlations. The correlation coefficients and regression coefficients of these three relationships are 0.99.

A moderate correlation is formed between the grams of residue accumulated and the grams of Ferric chloride ($FeCl_3$) used. The correlation coefficient of this relationship is -0.48, while the regression coefficient is 0.23.

Discussion

The formulation of the Calamansi coagulant with the highest efficacy utilized 4.0 g of powderized Calamansi waste which, when mass produced, can greatly benefit our environmental impact. Its compact size of 4 cm in diameter and weight of approximately 45 g makes it easy to bring anywhere. Since Calamansi fruit is an important fruit crop in the Philippines, having produced 14.86 thousand metric tons in the first quarter of 2019 (Araneta, 2020), it can be easily grown and utilized for various purposes.

Comparing both results with the standard range for purified water, the Calamansi coagulant formulated was shown to be more effective. The amount of residue accumulated by the Calamansi coagulants were also greater than the Ferric chloride ($FeCl_3$) coagulants. Its pH levels, EC, TDS, and salinity showed little to no changes after experimentation and were all within the standard. Each of their correlations with the Calamansi garnered coefficients close to 0, resulting in a weak correlation and regression. It, however, showed strong positive correlation and moderate to high regression with the amount of residue. Meanwhile, the results of the Ferric chloride ($FeCl_3$) were either too low or too high for the standard. Each of the readings showed strong positive correlations with Ferric chloride ($FeCl_3$), except for the pH levels which showed strong negative correlation, however, its correlation with the amount of residue was only moderate.

4. CONCLUSIONS

The efficacy of the Calamansi coagulants formulated by the researchers as coagulants for water treatment were investigated and compared with Ferric chloride ($FeCl_3$), an existing chemical water purifier. The coagulant was composed of crushed and powderized seeds and peels of Calamansi mixed with baking soda and citric acid. Ten trials each were conducted for the coagulant and Ferric chloride ($FeCl_3$).

The researchers were able to successfully conduct the experiment. Results showed that the Calamansi coagulant was able to eliminate more residue than the Ferric chloride ($FeCl_3$) coagulant, despite the former having little effect on the water quality. Given that the contaminated water was already within the standard range, the Calamansi coagulant removed the contaminant (soil) successfully, and is thus more effective. Out of the ten trials of the coagulant, Trial 8 which used 4.0 g of Calamansi waste accumulated the most residue while still within the standard range. All trials from the Calamansi and Ferric chloride samples resulted in brown tinted water rich in Iron. The experiment only executed water coagulation and required flocculation, clarification, and filtration to achieve total water purification.

The researchers were able to produce an eco-friendly, portable, and accessible water coagulant through Calamansi waste utilization. Succeeding studies may explore further modifications on the current design to produce a highly-effective, organic effervescent water purifier from Calamansi scraps.

5. ACKNOWLEDGMENTS

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