# Development Of Chitin Extracting Machine From Crab Shell Wastes For The Production Of Biopesticides

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**Abstract:** This study aimed to develop a chitin extracting machine for the production of biopesticide. The machine is composed of hammer mill, treatment drum, rotating block, plastic strainer sieve screen, heater, and a motor. Hammer mill has the operating capacity of 4kg of crab shells with the operating speed of 1730 rpm. The researchers used two method of extraction process of chitin. The concentration and solute solvent ratio of HCl and NaOH, number of baths, time per bath and temperature was adapted from the study of Islem Younes et al. (2016). The washing time, volume of water for washing and agitating speed was from the study of Ongo et al. (2016). Based on the experimental testing, the obtained number for both baths of water after HCl and NaOH treatment was 2 washes and an operating time of 11 hours and 1.962 minutes. Performance testing of the chitin extracting machine in terms of its extraction rate, percent yield and extraction efficiency was also conducted considering the established operating conditions during the preliminary testing to evaluate the performance of the machine. The results include an extraction rate of 46.834 g/hr, percent yield of 12.9167% with an extraction efficiency of 92.2619%. Also, the pH level of the product after two washes of water was found to be 7.06.

**Keywords:** biopesticide, chitin, crab shell, extracting machine

## 1. Introduction

The increasing number of seafood consumption from households, restaurants and processing plants has generated significant amount of wastes. Each year, six to eight million metric tons of crab and other crustacean wastes are produced worldwide. About 1.5 million metric tons (Mt) of it is disposed in Southeast Asia alone. These wastes have their contributory factors in problems concerning health and environmental hazards because its massive disposal is frequently by burning. Crab shell wastes are composed of 20 percent of calcium carbonate, 60 percent protein and chitin is about 20 percent (Marine Notes, 2007). Chitin is a naturally occurring and the second most abundant linear biopolymer that has significant economic value and great commercial utility. It is widely distributed in nature, being the main structural component of the crustaceans and is non-toxic, biodegradable and biocompatible. Researchers for the past years have focused on different methods of extracting chitin for it has proven its worth in different applications. It has been proven that chitin is suitable for wide range of applications such as in chemistry, medicine, biotechnology, agriculture, environmental protection, food processing, and textile production. Recent investigations confirm that chitin is very important in farming because it is a good inducer of defense mechanisms in plants and has received the attention of researchers because of their anti-insects and anti-fungal biocontrol activities. The Philippines is considered as an agricultural country but despite this, production of food and crops in farming is still insufficient. One major cause is the widespread infestation of insect pests that affects the harvest of farmers. To address this problem, chemical pesticides are widely used in the industry. Unfortunately, these pollute the environment. It alters quality of the soil, depletes the nutritional value of the crops and contaminates it. Likewise, too much exposure to it can lead to serious illnesses and health risks. The increasing sensibility of public and environmental agencies against the application of chemical based pesticides prompted the search for non-hazardous substitute. Biocontrol agents that made up biopesticides are considered as the most reliable alternatives, preventing soil pollution while inhibiting and killing pests through the use of biocontrol agents. Biocontrol agents can be derived from natural materials such as animals, bacteria and plants. Because of this, organic and environmental friendly pesticides are considered as substitute for it. Chitin can also be a non-hazardous alternative for chemical pesticides because several studies have proven its feasibility for this purpose. On the other hand, crab shell wastes generated in the locality has been an alarming problem. They are commonly dumped into the seas and in land that adds to the rapidly growing number of organic wastes that can have further uses. The idea of turning it to something useful would be a great contribution to the society. To provide a solution to this growing concern, this study developed a chitin extracting machine from crab shell wastes for the production of biopesticide. This is seen to play an important role in answering the aforementioned issue. Since crab shells are used as raw material, this will help reduce problem involving improper solid waste management. Once the extracted chitin is turned into pesticide, this will help the agricultural,

specifically farming sector in preventing and inhibiting pests in affecting their harvest. As collecting of crab shells will not be a problem because crabs are available in the market all year round not only the province but also the country therefore, producing crab shell wastes. The output of the study would be of great value for the farming industry within the city and nearby towns that integrates the use of biopesticides from organic sources to reduce and avoid pests. In response to this, the researchers came up with the design and development of chitin extracting machine from crab shell wastes for the production of biopesticide. This machine would be a great help to aid their problem with pests and ensure optimum harvesting production of their crops.

## 2. Objectives of the Study

The main thrust of this study was to develop a chitin extracting machine from crab shells for the production of biopesticide.

Specifically, this aimed to:

2.1 Design a chitin extracting machine taking into considerations the following parameters:
- 2.1.1 system components; and
- 2.1.2 material specifications.

2.2 Fabricate a chitin extracting machine taking into account the design specifications.

2.3 Conduct preliminary testing to establish the following conditions:
- 2.3.1 operating speed of hammer mill;
- 2.3.2 number of baths of water after HCl treatment;
- 2.3.3 number of baths of water after NaOH treatment; and
- 2.3.4 operating time.

2.4 Test the performance of the fabricated chitin extracting machine in terms of:
- 2.4.1extraction rate;
- 2.4.2 percent yield; and
- 2.4.3 extraction efficiency.

2.5 Test the structure and degree of acetylation of the output through Fourier-Transfer Infrared Spectroscopy (FTIR).

2.6 Test the properties of the product output in terms of:
- 2.6.1 pH level

2.7 Test the effectiveness of the chitin biopesticide through actual testing.

## 3. Materials and Methodology

### 3.1 Preparation of Raw Materials

The flower crab shells, were collected from restaurants and households within Batangas City. The shells were washed several times to remove the remaining meat and were sun dried. The washed shells were cut into sizes ranging from 25 to 100 millimeters (mm). The legs and claws were included and they were cut at the joints.

### 3.2 Methods of Testing

The testing of the chitin extracting machine was conducted to evaluate its performance. This was made by considering different testing parameters which included the following considerations:

#### 3.2.1 Method of Determining Operating Speed of the Hammer Mill

The operating speed was determined by conducting several trials. A variable frequency drive (VFD) was used to vary the speed of the motor of the hammer mill. The tests were done using three different speeds of 1600 rpm, 1730 rpm and 1850 rpm. The operating speed range tested was based on the study conducted by Bautista et al., (2015). The operating speed that gave the optimum operation and obtained maximum efficiency of the granulator was chosen.

#### 3.2.2 Method of Determining Operating Time

The operating time was determined from the time of input of the crab shells on the feed hopper up to the end of the extraction process. It included the granulating process, chemical treatment stages, heating, liquid transferring and draining. The time was measured using a timer.

#### 3.2.3 Method of Determining Number of Baths of Water after HCl Treatment

To neutralize the pH level of the treated crab shells after hyrochloric acid treatment, a 1:10 solute-solvent ratio of water was poured by batch while the agitator was still operating to wash the acid (Ongo, et al; 2016). After each bath of water for a certain time, a pH meter was used to monitor its pH level until it was neutralized.

#### 3.2.4 Method of Determining Number of Baths of Water after NaOH Treatment

To neutralize the pH level of the output after sodium hydroxide treatment, a 1:10 solute-solvent ratio of water was poured by batch while the agitator was still operating to wash the alkali (Ongo, et al; 2016). After each bath of water for a certain time, a pH meter was used to monitor its pH level until it was neutralized.

#### 3.2.5 Methods of Determining Extraction Rate

For every trial, the amount of chitin produced and the operating time were recorded. The extraction rate was the function of the weight of the produced chitin over the time of operation.

$$\text{Extraction Rate} = \frac{\text{mass of output (g)}}{\text{operating time (hr)}} \quad (1)$$

#### 3.2.6 Method of Determining Percent Yield

Percent yield was determined by the ratio of the mass of produced chitin to the mass of input crab shells.

$$\text{Percent Yield} = \frac{\text{mass of output (g)}}{\text{mass of input (g)}} \times 100\% \quad (2)$$

#### 3.2.7Method of Determining Extraction Efficiency

Extraction efficiency was determined by the ratio of the obtained percent yield of produced chitin to the percentage of the chitin content that can be extracted from flower crab shells was 14 percent (Tharanathan, 2003).

$$\text{Extraction Efficiency} = \frac{\text{obtained percent yield (\%)}}{\text{chitin content (\%)}} \times 100\% \quad (3)$$

#### 3.2.8 Method of Determining pH Level

The pH level of the final output product was determined by using a pH meter from the Chemical Engineering Laboratory. After two washes during the final bath of chemical treatment stages, the pH meter was submerged in the solution to record the pH level.

**3.2.9 Method of Determining the Effectiveness of Chitin extracted from Crab Shells as Biopesticide Through Actual Testing**

The effectiveness of chitin extracted from crab shells as biopesticide was determined by applying the biopesticide to the plant infested with pests. Pests of the same species were selected. These pests are infesting the same variety of plants grown in the same area under similar conditions by having the same quality of soil, amount of water received and amount of sunlight being exposed. Four set ups were prepared. The first set up had a plant with pests and not treated with any biopesticide. The other one was treated with five grams (g) of chitin biopesticide. The third plant was applied by 10 g of chitin biopesticide. The last plant was treated with 15 g of chitin biopesticide. The test was performed to determine if the biopesticide can effectively induce the plant's defense mechanism against pests. The amount of biopesticide used were 5 grams, 10 grams and 15 grams for each plant according to Environmental Protection Agency (EPA, 2008) for the standard amount of chitin amendment to soil per plant and the study of Trouvelot et al., (2008) and. The time it took to kill the pests was determined. Time was determined in terms of days.

## 4. System Components and their Functions

**4.1 Hammer Mill.**This is used to granulate crab shells by the repeated blows of little hammers. It is driven by a 1 horsepower (hp) motor with a constant speed of 1730 revolutions per minute (rpm). The hammer continuously granulates the crab shells to reduce its size until it reaches the desired particle size one to four millimetres (mm).

**4.2 Treatment Drum.** It is place where the granulated crab shells were treated with chemicals and washed. It also serves as the housing of the rotating block. It is made from blue High Density Polyethylene (HDPE) material which can resist chemical corrosion with a capacity of 200 liters (L).

**4.3 Rotating Block.** It is contained in the treatment drum and its prime purpose is to support the plastic strainer with the granulated crab shells. This is also being driven by the agitator motor. The material used for this white HDPE.

**4.4 Plastic Strainer**. It is used to filter the granulated crab shells. It is placed inside the rotating block and being rotated together with the granulated crab shells to provide agitation. The material used is also HDPE white.

**4.5 Hammer Mill Motor.** It converts the electrical energy to mechanical energy that produces torque needed by the hammer mill to operate. The motor used is a one hp, single phase with a constant speed of 1730 rpm.

**4.6 Sieve Screen.** is installed to ensure that crab shells with acceptable size enters the discharge bin.

**4.7 Agitator Motor.** It serves as the driving element of the rotating block. It is a single-phase motor with a speed of 43.75 rpm and a capacity of 60 Watts (W).

**4.8 Heater.** To extract chitin, certain temperature is needed to be employed in the chemical solution. It helps to raise the temperature of the solution necessary for the extraction process. The installed heater is a quartz immersion type and specified to have a capacity of 3000 W.

**4.9 Feed Hopper.** The feed hopper is used to feed crab shells to the hammer mill chamber. It has a length of 33.5 mm in the opening and 19 mm in the base, and a total height of 36.76 mm.

**4.10 Discharge Hopper**This allows the discharging of the granulated crab shells.

**4.11 Globe Valve.** It is used for the discharge of fluid and effluent after the treatment of crab shells.

**4.12 Control Panel.** It is a chamber where control instruments are displayed and housed. There are two on and off switches for the agitator motor and hammer mill. There is also one toggle switch for the heater. A temperature controller is installed in the panel. It receives sensor signals and controls the quartz immersion heater to maintain a preset temperature.

**4.13 Final Set-up of the Chitin Extracting Machine**

The full and final setup of the chitin extracting machine is shown in Figure 1 after applying the necessary adjustments and modifications to meet the expected improved the operation of the prototype.

***Figure 1.*** *Final Set-up of the Chitin Extracting Machine*

## 5. Results and Discussion

The method used in the extraction process of chitin was from two studies that are widely used from previous literatures. The concentration and solute solvent ratio of HCl and NaOH, number of baths, time per bath and temperature was adapted from the study of Islem Younes et al. (2016). The washing time, volume of water for washing and agitating speed was from the study of Ongo et al. (2016).

**5.1 Operating Speed of Hammer Mill**

Table 1 shows the result of preliminary testing of extracting machine using different speed of Hammer Mill.

***Table 1.*** *Results of Preliminary Testing using Different Speed of the Hammer Mill*

| Operating Speed (rpm) | Time (min) | Mass of Granulated Crab Shells (g) | Losses (g) | Granulating Efficiency (%) |
|---|---|---|---|---|
| 1600 | 9.35 | 3884 | 116 | 97.10 |
| 1730 | 7.72 | 3938 | 62 | 98.45 |
| 1860 | 6.42 | 3909 | 91 | 97.73 |

Operating speed was determined through tests having the different speeds was of 1600 rpm, 1730 rpm and 1860 rpm. The mass of the feed was fixed to 4000 grams to accommodate the solute solvent ratio of the adopted study from Ongo et al. (2016) and produce a pilot scale set up of the machine. Each speed generated its corresponding granulating efficiency. Based on the table above, the speed that gives the highest granulating efficiency was 1730 rpm.

### 5.2 Number of Baths Water after HCl Treatment

The number of baths water after hydrochloric acid treatment was determined by pouring 1:10 solute-solvent ratio of water while the agitator is still operating at 43.75 rpm to wash and neutralize the acid. After each bath of water for five minutes (min), a pH meter was used to monitor the pH level until it is neutralized. This method was adapted from the study of Ongo et al. (2016). The physiologically acceptable neutral pH region of chitin and falls between 6.8 and 7.2 as read by the pH meter.

***Table 2.*** *Number of Baths of Water after HCl Treatment*

| No. of Baths | Amount of Water (L) | Time (min) | pH |
|---|---|---|---|
| 1 | 40 | 5 | 2.13 |
| 2 | 40 | 5 | 7.18 |
| 3 | 40 | 5 | 7.47 |

Table 2 shows that after three washes of the treated crab shells, two baths indicated an acceptable pH level of 7.18.

### 5.3 Number of Baths Water after NaOH Treatment

Number of baths water after sodium hydroxide treatment was determined by pouring 1:10 solute-solvent ratio of water while the agitator is still operating at 43.75 rpm to wash and neutralize the alkali. After each bath of water for five min, a pH meter will be used to monitor its pH level until it is neutralized. This method was from the study of Ongo et al. (2016). Again, the physiologically acceptable neutral pH region of chitin falls between 6.8 and 7.2.

***Table 3*** *Number of Baths of Water after NaOH Treatment*

| | Amount of Water (L) | Time (min) | pH |
|---|---|---|---|
| 1 | 40 | 5 | 9.51 |
| 2 | 40 | 5 | 7.02 |
| 3 | 40 | 5 | 7.23 |

Table 3 shows the results after three washes of NaOH treatment. After 2 washes of water, the output was neutralized and had pH level of 7.02.

### 5.4 Determining the Operating Time

A timer was used in recording the time for the whole operation. Operating time was determined from the time of input of the crab shells on the feeder up to the end of the extraction process which is after the final bath of water after NaOH treatment. The total operating time is presented in Table 4. The time it took for the crab shells to be granulated was 0.1287 hour (hr). For the three baths of the HCl treatment stage, the total filling, bathing, draining and washing time were 0.33 hr, 3 hrs, 0.39 hr and 0.167 hr respectively. During the NaOH treatment stage, the water to be used was heated for 3.03 hours. On the other hand, the total time for total filling, bathing, draining and washing time were 0.38 hour, 3 hours, 0.44 hour and 0.167 hour respectively. Adding up the corresponding time for each process, the total operating time was determined to be 11 hrs and 1.962 min.

***Table 4****. Operating Time of Extracting Machine*

| Extraction Process | Time (hr) |
|---|---|
| Granulating | 0.1287 |
| HCl Treatment | |
| • Filling | 0.33 |
| • Bathing | 3 |
| • Draining | 0.39 |
| • Washing | 0.167 |
| NaOH Treatment | |
| • Heating of NaOH Solution | 3.03 |
| • Filling | 0.38 |
| • Bathing | 3 |
| • Draining | 0.44 |
| • Washing | 0.167 |
| **Total** | **11.0327** |

### 5.5 Production of Chitin from Crab Shell Wastes

***Figure 2.*** *Production of Chitin from Crab Shell Wastes*

Figure 2 illustrates the change underwent by the raw materials up to the final output. 4000 g input of flower crab shells were fed in the hammer mill. After granulating and sieving, there were 62 g of crab shells were splattered and left inside the chamber of granulator. The crushed crab shells then underwent HCl and NaOH treatment after every bath, effluent was observed. After drying the raw chitin, the mass of the final output weighed 516.67 g.

### 5.6 Extraction Rate

Extraction rate is the ratio of the mass of produced chitin after full operation of the prototype to the total operating time. Three trials were conducted to arrive in a reliable result for the assessment of the machine's performance. Table 5 presents the data gathered during the final testing to determine the extraction rate. Each mass of the chitin output was divided by the total operating time. The three trials yielded 46.207 grams per hour (g/hr), 46.927 g/hr and 47.355 g/hr respectively. The mean of the three-extraction rate was computed and came up with an average of 46.834 g/hr.

***Table 5.*** *Extraction Rate*

| Trial | Mass of Product (g) | Operating Time (hr) | Extraction Rate (g/hr) |
|---|---|---|---|
| 1 | 505 | 10.9291 | 46.207 |
| 2 | 518 | 11.0384 | 46.927 |
| 3 | 527 | 11.1286 | 47.355 |
| **Average** | **516.67** | **11.0327** | **46.834** |

### 5.7 Percent Yield

The percent yield was determined by the ratio of the mass of produced chitin to the mass of input crab shells.

***Table 6.*** *Percent Yield*

| Trial | Mass of Chitin (g) | Mass of Input Crab Shells (g) | Percent Yield (%) |
|---|---|---|---|
| 1 | 505 | 4000 | 12.625 |
| 2 | 518 | 4000 | 12.950 |
| 3 | 527 | 4000 | 13.175 |
| | | **Average** | **12.917** |

The percent yield for each trial is shown in Table 6. The mass of the chitin output from the three trials was used to compute for the percent yield. The values were divided by the mass of the input which was 4000 g. For the first trial, the percent yield was 12.625 percent while the second trial had 12.950 percent and the last trial got 13.175 percent. The mean of the percent yield for three trials was 12.917 percent.

### 5.8 Extraction Efficiency

Extraction efficiency was determined by dividing the obtained percent yield to the theoretical percent yield of chitin that can be produced from flower crab shells. It was determined that chitin content from flower crab shells (Portunus pelagicus) was 14percent (Tharanathan, 2003).

***Table 7.*** *Extraction Efficiency*

| Trial | Obtained Percent Yield (%) | Chitin Content (%) | Extraction Efficiency (%) |
|---|---|---|---|
| 1 | 12.625 | 14 | 90.1786 |
| 2 | 12.950 | 14 | 92.5000 |
| 3 | 13.175 | 14 | 94.1071 |
| | | **Average** | **92.2619** |

Table 7 presents the results during the final testing to determine the extraction efficiency. Having the obtained percent yield acquired from the three trials, each was divided by the theoretical amount of the chitin that can be isolated from the flower crab shells. It was found that the first trial had extraction efficiency of 90.1786 percent. The second had 92.5000 percent and as for the last trial, it got 94.1071 percent. The average extraction efficiency was found to be 92.2619 percent.

### 5.9 pH Level of the Product Output

After two washes with water for the final bathing stage, a pH meter from the Chemical Engineering Laboratory was used to determine the pH level of each product output for the three trials. The acceptable pH level of chitin is within the range of 6.8-7.2 as read by the pH meter. The pH meter was calibrated to have an accurate reading of the final output.

***Table 8.*** *pH Level of the Product Output*

| Trial | pH |
|---|---|
| 1 | 7.17 |
| 2 | 6.98 |
| 3 | 7.02 |
| **Average** | **7.06** |

The obtained pH level of the outputs is shown in Table 8. For Trial 1, the pH level was 7.18. For Trial 2, the pH level was 6.98. The output of the third trial had the pH level of 7.02. The average pH level of the chitin output after two washes of water was 7.06.

### 5.10 Laboratory Results

Images from Fourier Transform Infrared Spectroscopy (FTIR) results were analyzed for the verification of the presence of the functional groups that make up chitin. The degree of deacetylation and the spectrum match were determined through laboratory testing. This was done to verify the structure of the samples as compared to the standard set.

***Table 9.*** *Results of Fourier Transform Infrared Spectroscopy*

| Parameter | Unit | Chitin Sample | | | |
|---|---|---|---|---|---|
| | | Standard (LK Biotech Product) | Trial 1 | Tria 2 | Trial 3 |
| OH | $cm^{-1}$ | 3650 | 3750 | 3750 | 3750 |
| N-H Stretching | $cm^{-1}$ | 3350 | 3255 | 3325 | 3350 |
| C-H Stretching | $cm^{-1}$ | 2850 | 2850 | 2850 | 2875 |
| C=O Stretching | $cm^{-1}$ | 1700 | 1700 | 1650 | 1700 |
| N-H Bending | $cm^{-1}$ | 1550 | 1500 | 1600 | 1550 |
| $CH_3$ | $cm^{-1}$ | 1400 | 1350 | 1375 | 1350 |
| C-O-C | $cm^{-1}$ | 1050 | 1055 | 1050 | 1050 |
| N-H | $cm^{-1}$ | 850 | 875 | 855 | 850 |
| Degree of Deacetylation | % | -- | 52.28 | 72.21 | 74.62 |
| Spectrum Match to Standard | % | -- | 94.24 | 95.67 | 95.58 |

Table 13 shows the results of the FTIR based on the spectrum images generated by the output. If the values of the stretch functional groups of the samples are close to that of chitin, the closest is the spectrum's match to standard chitin. Standard chitin structure has FTIR spectrum exhibiting a characteristic band at 3650 $cm^{-1}$ attributing to -NH and -OH

groups stretching vibration and the band 2850 $cm^{-1}$ were an aliphatic C-H stretching bands that converges to OH stretching with N-H. The characteristic carbonyl C=O stretching of chitin at 1700 $cm^{-1}$ are attributed to the vibrations of the amide I band. The sharp band at 1400$cm^{-1}$ corresponds to a symmetrical deformation of the $CH_3$ group and at 1550 $cm^{-1}$ corresponds to the N-H deformation of amide II. The vibrations bands at 1050 $cm^{-1}$ showed C-O-C vibration inside chitin ring and produced many peaks caused by the presence of hydroxide from chitin which contains a single bond C=O. (Puspawati and Dan Simpen, 2010). Moreover, chitin can also be characterized by the degree of deacetylation, that is, it should have a value of less than 75 percent (Brugnerotto J. et al., 2001 and Skoog D. et al., 2007). For Trial 1, the round peak at around 3750 $cm^{-1}$ indicated the presence of the O-H stretch, indicating one or more hydroxyl groups. However, there was indications of the N-H bend at around 3255 $cm^{-1}$ which has a sharper peak, which confirms the presence of the amino group found in chitin. There is a slightly strong peak around 1700 $cm^{-1}$ indicative of the C=O stretch, which suggests incomplete deacetylation which chitin should have. Using the equation derived by Brugneretto et al (2001), the calculated degree of deacetylation is 52.28 percent. The spectrum match of this spectrum to chitin was 94.24 percent. Trial 2 contains similar features to trial 1, but has a more prominent O-H and N-H stretch at around 3750 $cm^{-1}$ and 3325 $cm^{-1}$ respectively. It also had the prominent C=O stretch at 1650 $cm^{-1}$. The calculated degree of deacetylation of this sample was 72.21 percent. The spectrum match of this spectrum to chitin was 95.67 percent. Trial 3 is had a sharper peak of prominent O-H and N-H stretch at around 3750 $cm^{-1}$ and 3350 $cm^{-1}$ respectively. It also had the prominent C=O stretch at 1700 $cm^{-1}$. It got a calculated degree of deacetylation of 74.62 percent. The spectrum match of this sample was 95.58 percent. The spectrum labeled "standard" is the expected spectrum of pure chitin. Many of these features were present in the output yielded in the three trials, and as such it can be reasoned that the synthesized products are very close to pure chitin based on a functional groups perspective. To characterize chitin from chitosan, a sample with degree of deacetylation below 75 percent is chitin, if not, it is chitosan.

### 5.11 Actual Testing of Chitin as Biopesticide

The chitin output was subjected to testing to verify if it can induce the plants' defense mechanism against pests. Four plants infested with an agricultural pests called powdery mildew (Erysiphe orontii) were chosen. Set up A was left untreated with any biopesticide. The other three plants, Set ups B, C and D were treated with chitin biopesticide through soil amendment with amount of 5 grams, 10 grams and 15 grams respectively for each plant in accordance with the standard amount of chitin that can be amended in the soil per plant of Environmental Protection Agency (EPA, 2008) and the study of Trouvelot et al., (2008). At the day of application, 22 downy mildews were present in Set up A upon inspecting the number of pests underneath the leaves of the Banana pepper plant. For Set ups B, C and D; the total number of pests were 23, 27 and 22 respectively. Everyday, the number of pests present and the number of pests killed for each set up were recorded. In Set up A, the number of powdery mildews increased from 22 to 41 after four days. On the other hand, there was no presence of pests upon inspecting the leaves of each plant for Set ups B, C and D. For the last three set ups, it took four days for the chitin to kill the pests

## 6. Conclusions

In line with the objectives of the study and the summary of findings obtained during the testing of the prototype, the conclusions drawn were the following:

1. The chitin extracting machine was designed and fabricated in accordance to the requirements and conformed to the design specifications.
2. The preliminary testing conducted has successfullyestablished the important parameters. In determining the operating capacity, the overall percent yield and the performance of the prototype were considered. It was concluded that 4 000 grams of feed was the best operating capacity since it has allowed the continuous and smooth operation of the prototype with the highest percent yield recorded among the trials made.
3. The actual testing of chitin as biopesticide showed that the mortality of the pests from the plants was evident. After four days from the application of chitin in the soil, it was observed that there was no more presence of Powdery mildew.
4. From the trials made in determining the granulating time and rate, the losses in the raw materials were considered. It was concluded that the losses in the hammer mill were due to the crab granules left inside the hammer mill and the powdering of the crab shells which results on dust particle discharge.
5. To summarize, the results of laboratory tests showed that waste crab shells, when treated can produce chitin that conform with the structure similar to those which are available commercially. More so, the extracted chitin granules can kill pests and therefore can be applied as biopesticide.

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