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DEVELOPMENT AND PERFORMANCE EVALUATION OF PAPAYA SHREDDING AND SQUEEZING MACHINE FOR SMALL-SCALE ATCHARA PRODUCERS

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***Abstract** - The major goal of this research was to design and build a papaya shredding and squeezing equipment for small-scale atchara (pickle) producers in Batangas. The research followed the CDIO methodology, addressing knowledge, technical, and software needs in the conception and design phases, followed by hardware considerations in the implementation phase. The final machine included a shredding chamber, a squeezing component, and a control system, and it outperformed current machines in terms of shredding and squeezing efficiency. The research found the best input loads and operating speeds for the shredder and squeezer, resulting in a significant reduction in processing time. The squeezing time was determined to be more than three times faster than existing equipment, but the shredding efficiency beat standard grating machines significantly. Food safety tests revealed that the finished product was free of E. Coli and Salmonella bacteria that fulfill quality criteria. The successful construction of an efficient, safe, and cost-effective papaya processing machine in this study answers a crucial need for small-scale atchara producers in Batangas, increasing production and product quality, which can assist the local food processing industry greatly.*

Keywords – *Atchara, Machine, Shredding, Squeezing*

INTRODUCTION

The Philippines boasts a rich and diverse culinary landscape influenced by Chinese, Malaysian, Spanish, Indian, and Western traditions, resulting in a complex array of flavors and cooking styles across its 7,000-plus islands. Each region has adopted its own unique approach to cooking, yielding a startling variety of dishes and ingredients.

Various provinces contribute distinct food products to the Filipino culinary tapestry. Examples include Bicol's pili nuts, Davao's Malagos chocolates and banana chips, Amadeo coffee and mango liqueurs, heritage rice, coconut-based products, Cebu's dried mangoes, and Mindoro's banana chips. One standout is the town of Calaca in Batangas, celebrated for its atchara, a beloved Filipino side dish or condiment.

Atchara, inspired by Indian achaar and related to Indonesian acar and Dutch atjar, is a pickled dish with a unique twist. Calaca's atchara is particularly renowned, and it even inspired the Calacatchara Festival, blending the town's name with its signature delicacy.

Atchara primarily features shredded green papayas, along with ingredients like carrot, ginger, bell pepper, raisins, onion, garlic, chilies, and various spices, all preserved in a mixture of vinegar, sugar or syrup, and salt [1]. It is typically stored in glass jars and can be refrigerated or stored at room temperature.

The recipe for atchara has evolved over time, with variations using coconut trunk pith, bamboo shoots, bitter melon, or green papaya. In Batangas, small-scale producers often employ motorized machines for shredding and squeezing the papayas, although these machines can produce non-uniform results and are costly to maintain [2].

The need for more efficient equipment has led researchers to explore better solutions for small-scale atchara producers in Batangas, who face productivity challenges due to the limitations of existing machinery. The goal is to improve efficiency and uniformity in the production process, addressing the pressing issues faced by these producers.

OBJECTIVES OF THE STUDY

The main objective of the study is to design and develop a papaya shredding and squeezing machine for small-scale atchara producers in the province of Batangas. Specifically, this study aims to:

1. Design and develop a machine for shredding and squeezing considering the following parameters:
   1.1 system components;
   1.2 materials specifications; and
   1.3 capacity of the machine
2. Conduct preliminary test to establish the following:
   2.1 shredding speed;
   2.2 shredding time;
   2.3 squeezing speed; and
   2.4 squeezing time
3. Test the performance of the machine in terms of:
   3.1 production rate;
4. Evaluate the properties of shredded papaya in terms of:
   4.1 food safety quality properties

MATERIALS AND METHOD

This study involved the engineering design, planning and analysis so that the parameters used in the study were given considerations according to the objectives set. To obtain the objectives of the study, the whole design and development of papaya shredding and squeezing machine was established in series of stages namely the design and development stage, the preliminary testing stage, the performance testing stage, and the actual gathering of data [3-14].

The design and development of the papaya shredding and squeezing machine considered the proper materials according to their specific function, process and availability. All other components needed in the machine followed the proportions of the initial proposed design with its specifications and dimensions. The concept of technicality and the operation of the machine were also studied in this stage. It also involved necessary drawings, schematic diagrams, and design layout. After accomplishing the design, the researcher proceeded with the development of papaya shredder and squeezer. Important factors were considered in this stage such as the time and financial aspects. This included also the ability of the researcher and the availability of the materials.

In order to assess the performance of the fabricated machine, preliminary testing was conducted after the fabrication of the papaya shredding and squeezing machine. The shredding speed, shredding time, squeezing speed and squeezing time were determined through a series of test.

The machine underwent final testing after all the initial test. Several trials were conducted to evaluate the performance of the machine.
The machine capacity was determined using experimental results from evaluation of the shredding and squeezing efficiency. The right capacity was based on the highest computed efficiency conducted during the preliminary testing.

The shredding speed was determined using a speed control with varying frequency and voltage power supplied to the motor. The right speed was based on the highest computed efficiency conducted during the preliminary testing.

The shredding time for one whole process starting from the feeding of unripe papayas up to the release of the shredded papaya was measured. It was ensured that the shredding time of the papaya shredder production process was better than the existing fruits and vegetables grater.

The squeezing speed was determined using a variable frequency drive which regulates the frequency and voltage of the power supplied to the motor resulting to different speeds. The right speed was based on the highest computed efficiency conducted in the preliminary testing.

The squeezing time was measured in terms of the volume of the moisture content that can be extracted in a given quantity of papaya using the developed squeezing machine. This was compared with the volume of the moisture content that can be extracted using the existing machine. The time it consumed starting from the loading of shredded papayas until the shredded papayas have completely released their liquid was recorded.

The quantity of the processed papayas in a specific span of time was determined and compared with the existing production rate using the existing machine. This was conducted to ensure that the production rate of the developed prototype was higher than the existing. The production rate was computed using the formula: $PR = Q / T$ where PR is the production rate, Q = Output mass and T is the time of operation.

The quantity of shredded papayas using the developed shredding machine was evaluated to determine its efficiency. The shredding efficiency of the machine was computed using the formula [15].

Shredding efficiency (n)

$$n = \frac{Ws - Wd}{Ws} \times 100\%$$

Where:

n = Shredding efficiency (%)

Ws = weight of all shredded material (Kg)

Wd = weight of damage shredded materials (Kg)

The quantity of papaya extract using the developed squeezing machine was evaluated to determine its efficiency. The extraction efficiency of the machine was computed using the formula [16-17].

Extraction Efficiency

$$Ee\% = \frac{100 \times WLE\ \%}{xWFS}$$

Whre:

WLE = Mass of Liquid Extracted in Kg

WFS = Mass of Feed Sample in Kg

x = Juice constant of fruit in decimal

Finally, samples of the shredded papayas from different operations underwent laboratory testing to ensure that they passed the food safety standards as a new raw material in the production of pickled papaya.

RESULTS AND DISCUSSION

The following are the factors considered in the design and development of the papaya shredding and squeezing machine.

As reflected in Figure 1, the planned layout of the design and development of a papaya shredder and squeezer was illustrated. This comprises the isometric view of the project and how the papaya shredder and squeezer will be constructed.

The figure show that the propeller is placed inside the shredding chamber to press the input papaya to the disc blade. This propeller has a size of "40cm x 13.5cm." The motor is placed in the upper part of the propeller in order to easily drive it. The collecting tray is placed below the shredding chamber to collect the shredded papaya. The centrifuge basket is placed inside the cylinder barrel and located beside the shredding chamber. The discharge outlet is placed in the lower part of the cylinder barrel to release the papaya extract. Another motor is placed below the machine to drive the centrifuge basket. The pulley and belt are placed near the motor to transmit the energy from the motor to the centrifuge basket so it could produce a rotary motion. The control box measures "20.5cm x 18cm," and is placed at the top left of the output. The machine has a height of "150cm and width of 81.5cm."

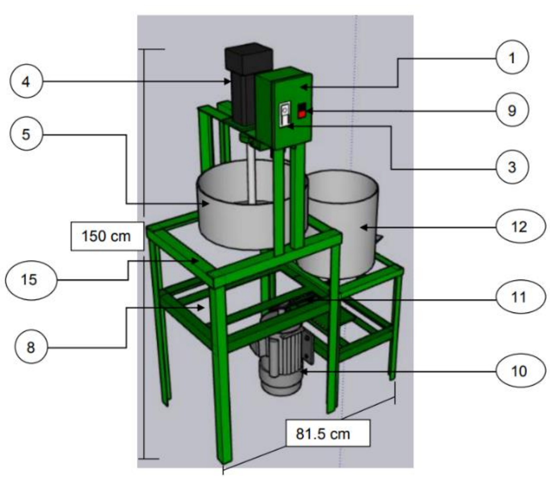

Figure 1. Planned Layout Design of Papaya Shredding and Squeezing Machine

The papaya shredding and squeezing machine in isometric view illustrates the 1) Control box, 3) Speed controller, 4) Speed control motor, 5) Shredding chamber, 8) Collecting tray, 9) Push button station, 10) Induction motor, 11) Belt and Pulley Assembly, 12) Cylinder barrel, and 15) Machine frame.

Figure 2 presents the circuit diagram of the power and control system of the developed papaya shredding and squeezing machine. It can be seen in the figure that a (220V) single-phase power supply is necessary to energize the machine. When the single pole switch is pushed in an ON position, the (220V) supply is activated and at the same time, the speed controller is now ready to set in a specific setting that the motor of the shredding machine is ready for operation. By pressing the single pole switch in an OFF position, the (220V) supply is deactivated and at the same time, the motor of the shredding machine will stop in its operation.

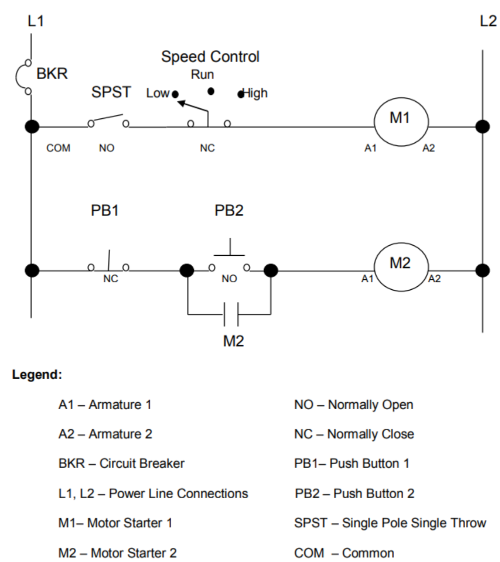

Figure 2. Control Circuit of Papaya Shredding and Squeezing Machine

Pressing the push button 2 will activate the motor starter 2 to hold the contact which will energize the starting capacitor to control the starting current and torque; at the same time, the running capacitor is activated for greater safety of the motor; and then, the motor of the squeezing machine will run in energize state. When the motor reaches 75 percent of the full load speed, the normally closed centrifugal switch will open which will deactivate the starting capacitor. This time, the capacitor is still in operation for the safety and efficiency of the motor operation. The electric motor moves in energize position which serves as the driving force for rotating the belt and pulley which in turn rotates the centrifuge basket connected to them. By pressing the push button 1, the motor starter 2 will be de-energized and will open the normally closed contact connected in start operation. The start and run capacitor will be deactivated in performing its functions. This time, the electric motor will be changed in de-energized position which will stop the rotation of the belt and pulley resulting to the stop rotation of the centrifuge basket.

The papaya shredder and squeezer were developed based on the planned layout design and schematic diagrams previously presented. Figure 3 display the developed project. It can be gleaned from the figures that the machine has a chamber that served as papaya shredders. Inside the cylinder barrel is the component necessary for squeezing operation of the machine. The stainless plate cylinder of the machine served as the feeding unit and barrier of the components of the shredder and squeezer. Inside the control box are the components necessary for controlling the operation of the shredding and squeezing machine. The collecting tray collected the shredded papaya coming from the shredding unit during the shredding operation. The shredded papaya soaked with water and salt were fed in the centrifuge basket which is driven by motor via belt and pulley connections. The papaya extract will come out of the discharged outlet which is connected to the squeezing unit. The speed control varies the speed of revolution of speed control motor of the shredder to get the right speed for the operation, while the push button station controls the induction motor of the squeezer in a start and stop operation.

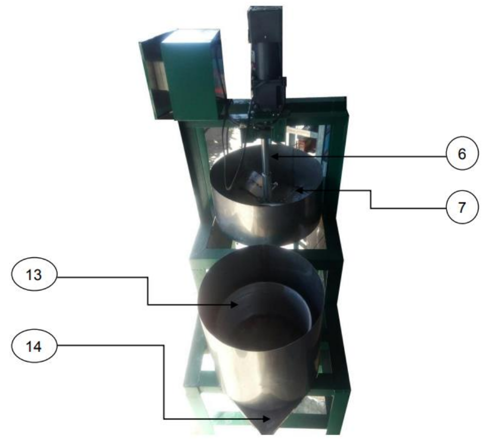

Figure 3. Developed Papaya Shredding and Squeezing Machine

Papaya shredding and squeezing machine in top view illustrates the 6) Propeller, 7) Disc blade, 13) Centrifuge basket, and 14) Discharged outlet.

In determining the capacity of the shredder and squeezer, three trials were conducted using 1.50 kg, 3.0 kg and 4.50 kg of sliced pieces of papaya feed into the machine. *Acceptable* or *Unacceptable* interpretations relative to the operations were classified during the evaluation of different input loads. The input load with the highest efficiency, which is interpreted as *Acceptable* was chosen as the operating capacity of the developed shredder and squeezer. Through analytic calculation considering the input load of the shredder and squeezer with its corresponding efficiency, the input load with highest efficiency was 1.50 kg and 3.0 kg Therefore, all testing was done with a shredding capacity of 1.50 kg and squeezing capacity of 3.0 kg.

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Table 1. *Results of Shredding Capacity*

Trial No.	Weight of Raw Material (kg)	Shredding Time (min)	Operating Condition
1	1.50	5.06	Acceptable
2	1.50	5.21	Acceptable
3	1.50	5.36	Acceptable
Average	1.50	5.21	
Efficiency			94.58%

Table 1 shows the result of shredding capacity of the three trials being conducted. In these trials, 3 batches of raw material were used during the operation. *Acceptable* operations are operations that satisfy the required weight in shredding process in determining shredding efficiency. *Unacceptable* means batches that are not within the range of the desired weight of raw material in the shredding process. The result shows that the average efficiency of the shredder when loading 1.50 kg is *94.58 percent*. According to the data, the result when loading 1.50 kg produced the highest efficiency among all the loads that were used during the preliminary testing. Thus, it was considered as *Acceptable* operation of the machine.

Table 2. *Results of Squeezing Capacity*

Trial No.	Weight of Raw Material (kg)	Shredding Time (min)	Operating Condition
1	3.0	2.49	Acceptable
2	3.0	2.51	Acceptable
3	3.0	2.46	Acceptable
Average	3.0	2.48	
Efficiency			75.77%

Table 2 shows the result of squeezing capacity of the three trials being conducted. In these trials, 3 batches of raw material were used during the operation. *Acceptable* operations are operations that satisfy the required weight in squeezing process in determining squeezing efficiency. *Unacceptable* means batches that are not within the range of the desired weight of raw material in the squeezing process. The result shows that the average efficiency of the squeezer when loading 3.0 kg is *75.77 percent*.
According to the data, the result when loading 3.0 kg produced the highest efficiency among all the loads that were used during the preliminary testing. Thus, it was considered as *Acceptable* operation of the machine.

In determining the speed of the shredder, a speed controller was installed in

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order to manipulate and adjust the speed of rotation of the shredder through its motor and propeller. The speed controller has different speed limits ranging from 26 rpm to 44 rpm. To determine the best speed of the shredder, three trials were conducted using 36 rpm, 43 rpm and 44 rpm speed of motor. *Acceptable* or *Not Acceptable* interpretations relative to the operations were classified during the evaluation of different speeds. The speed with the highest efficiency, which is interpreted as *Acceptable* operation was chosen as the operating speed of the developed shredder. Through analytic calculation considering the speed of the motor with its corresponding efficiency, the speed with highest efficiency was 44 rpm. Therefore, all testing was done with a shredding speed of 44 rpm.

Table 3 *Results of Shredding Speed using 44rpm*

Batch No.	Remarks		
	First Trial	Second Trial	Third Trial
1	Acceptable	Acceptable	Acceptable
2	Acceptable	Acceptable	Acceptable
3	Acceptable	Acceptable	Acceptable
Efficiency			94.58%

Note: Acceptable operations are operations that do not failed or sufficiently shredded the raw materials when the shredder is running while the Not Acceptable operations are operations that failed or insufficiently shredded the raw materials.

Table 3 shows the result of speed of the shredder using 44 rpm. Three operations were used to determine the efficiency of the machine when using 44 rpm. The three operations were categorized as *Acceptable* operations and *Not Acceptable* operations. The result shows that the average efficiency of the shredder when using 44 rpm is *94.58 percent*. According to the data, the result using 44 rpm produced the highest efficiency among all the speeds that were used during the preliminary testing. Thus, it was considered as *Acceptable* operation of the machine.

In determining the centrifuge speed of the squeezer, a variable frequency drive was installed in order to manipulate and adjust the speed of rotation of the basket centrifuge or centrifugal filters or clarifiers through its motor and belt assembly. The variable frequency drive has different speed limits ranging from 580 rpm to 2321 rpm. To determine the best speed of the basket centrifuge, three trials were conducted using 580 rpm, 1160 rpm and 2321 rpm speed of motor. Acceptable or Unacceptable dried papayas were classified during the evaluation of different speeds. The speed with the highest efficiency of dried papayas was chosen as the operating speed of the basket centrifuge. Through analytic calculation considering the speed of the motor with its corresponding efficiency, the speed with highest efficiency was 2321 rpm. Therefore, all the testing was done with a squeezing speed of 2321 rpm.

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Table 4 Results of Squeezing Speed using 2321rpm

Batch No.	Remarks		
	First Trial	Second Trial	Third Trial
1	Acceptable	Acceptable	Acceptable
2	Acceptable	Acceptable	Acceptable
3	Acceptable	Acceptable	Acceptable
Efficiency			75.77%

Note: Acceptable papayas are papayas that turned out completely dried when the squeezer is running while the unacceptable papayas are those papayas that are not dehydrated when the squeezer is running.

Table 4 shows the result of squeezer's speed using 2321 rpm. Three batches were used to determine the efficiency of the machine when using 2321 rpm. The three batches were categorized as *Acceptable* papayas. The result shows that the average efficiency of the squeezer using 2321 rpm is *75.77percent*. According to the data, the result using 2321 rpm produced the highest efficiency among all the speeds that were used during the preliminary testing. Thus, it was considered as *Acceptable* papayas.

The production rate was computed using the formula: $PR = Q / T$ where PR is the production rate, Q = Output mass and T is the time of operation. Table 5: shows the production rate of the developed shredding machine in three trials. The production rate for the first trial was 0.28 kg/min, 0.28 kg/min for the second trial and 0.27 kg/min for the third trial with an average production rate of 0.27 kg/min.

Table *5 Production Rate of the Papaya Shredding Machine*

Trial No.	Weight of Raw Material (kg)	Weight of Shredded Papaya (kg)	Time of Operation (min)	Production Rate (kg/min)
1	1.50	1.45	5.06	0.28
2	1.50	147	5.21	0.28
3	1.50	1.49	5.36	0.27
Average	1.50	1.47	5.21	0.27

Table 6 shows the production rate of the developed squeezing machine in three trials. The production rate for the first trial was 0.76 kg/min, 0.77 kg/min for the second trial and 0.81 kg/min for the third trial with an average production rate of 0.78 kg/min.

Table 6 *Production Rate of the Papaya Squeezing Machine*

Trial No.	Weight of Raw Material (kg)	Weight of Dried Papaya (kg)	Time of Operation (min)	Production Rate (kg/min)
1	3.0	1.90	2.49	0.76
2	3.0	1.95	2.51	0.77
3	3.0	2.0	2.46	0.81
Average	3.0	1.95	2.48	0.78

Table 7 presents the shredding efficiency of the developed papaya shredding machine. Results showed that the shredding efficiencies for three trials were *94.44 percent*, *94.58 percent* and *94.73 percent* respectively.

Table 7 *Shredding Efficiency of the Papaya Shredding Machine*

Trial No.	Weight of all Shredded Material (kg)	Weight of Damaged Shredded Material (kg)	Total Weight of Sliced Papaya (kg)	Shredding Efficiency (%)
1	1.421	0.079	1.50	94.44
2	1.423	0.077	1.50	94.58
3	1.425	0.075	1.50	94.73
Average	1.423	0.077	1.50	94.58

On the other hand, Table 8 indicates the results of the grating efficiency of the existing papaya grating machine being utilized by small and medium-scale atchara producers. The first trial shredded an efficiency of *80.95 percent*; the second trial resulted to an efficiency of *78.04 percent*; and the third trial gained an efficiency of *83.72 percent* with an average efficiency of *80.90 percent*. The results proved that the developed papaya shredding machine was more efficient than the existing papaya grating machine for atchara production in terms of shredding.

Table 8 *Grating Efficiency of the Existing Papaya Grating Machine*

Trial No.	Weight of all Shredded Material (kg)	Weight of Damaged Shredded Material (kg)	Total Weight of Sliced Papaya (kg)	Shredding Efficiency (%)
1	0.42	0.08	0.50	80.95
2	0.41	0.09	0.50	78.04
3	0.43	0.07	0.50	83.72

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Average	0.42	0.08	0.50	80.90

Table 9 presents the squeezing efficiency of the developed squeezer. Results showed that the liquid extraction efficiencies for three trials were *75.58 percent*, *75.77 percent* and *75.96 percent*, respectively.

Table 9 *Squeezing Efficiency of the Developed Papaya Squeezing Machine*

Trial No.	Mass of Liquid Extracted (kg)	Mass of Feed Sample (kg)	Juice constant of fruit in decimal	Squeezing Efficiency (%)
1	1.950	3.0	0.86	75.58
2	1.955	3.0	0.86	75.77
3	1.960	3.0	0.86	75.96
Average	1.955	3.0	0.86	75.77

On the other hand, Table 10 indicates the results of the squeezing efficiency of the existing papaya squeezing machine being utilized by small and medium-scale atchara producers. The first trial squeezed an efficiency of *55 percent*; the second trial resulted to an efficiency of *54.65 percent*; and the third trial gained an efficiency of *54.88 percent* with an average efficiency of *54.84 percent*. The results proved that the developed papaya squeezing machine was more efficient than the existing papaya squeezing machine for atchara production in terms of squeezing.

Table 10 *Squeezing Efficiency of the Existing Papaya Squeezing Machine*

Trial No.	Mass of Liquid Extracted (kg)	Mass of Feed Sample (kg)	Juice constant of fruit in decimal	Squeezing Efficiency (%)
1	0.473	1.0	0.86	55
2	0.470	1.0	0.86	54.65
3	0.472	1.0	0.86	54.88
Average	0.471	1.0	0.86	54.84

The end product was tested through its food safety quality properties. The food safety quality properties of shredded papayas were *E. Coli* and *Salmonella bacteria*. These properties were considered to determine if the final output of the machine is safe enough and free from different kinds of contaminants. Based on the lab test, the result showed that the E. Coli count of the sample shredded papaya using the 1:10 dilution method was less than 10 CFU/ml. It proved that the *E. Coli bacteria* was below the detection limit or was not present in the sample based on the standard detection limit. The analysis affirmed that the submitted sample of 25g shredded papaya was negative for *Salmonella bacteria* using conventional method. It is significant to note that there was no growth of contaminants in the end-product.

CONCLUSION AND RECOMMENDATION

In summary, the study's results indicate that the development and implementation of the papaya shredder and squeezing machine were successful due to appropriate layout design and schematic diagram. This machine has demonstrated functionality with favorable shredding and squeezing speed and efficiency metrics compared to existing machines. Moreover, the project has improved the mechanisms involved in production, shredding, and squeezing operations, rendering it more operational and efficient. Overall, the utilization of this innovative machine is feasible and could be a valuable investment in papaya processing. As a result, it is recommended that end users undergo training to gain the skills and knowledge required for equipment maintenance and operation.

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