FABRICATION AND PERFORMANCE EVALUATION OF AN IMPROVED MECHANICAL COCONUT MILK EXTRACTOR

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The study aimed to evaluate the performance of an improved mechanical coconut milk extractor to determine its capacity and efficiency in extracting coconut milk from grated coconut meat. The improved extractor is geared towards the sustainable production of coconut milk, maximizing extraction and utilization to reduce waste compared to the screw press currently used in the locality. The coconut milk extractor with IPOPhil Utility Model registration no. 2-2016000363 was fabricated using stainless-steel materials on parts with direct contact with the food, and the rest were painted mild-steel materials using 3- ton hydraulic jack. Mature coconut fruits were selected, cut, grated, and packed using a nylon net. Capacity and efficiency were evaluated based on 2 kg of grated coconut meat load per press. The findings revealed that the design had a capacity of 50.78 kg/h with 2.30 minutes average pressing time, producing 1.08 kg of coconut milk, which is 54% extraction efficiency. The screw press produced 21.65 kg/h capacity in 5.5 minutes of pressing time, producing 1.09 kg coconut milk with 54.50% extraction efficiency. There was a significant difference in extraction capacity and no significant difference in extraction efficiency at a 1% level of significance. The improved extractor production cost amounted to Php14, 599.00 for one unit, which can be recovered in 72 days, operating at four (4) hours per day, charging Php 1.00/kg pressing load. It is recommended to conduct further improvements on the design to suit the needs of the coconut milk producers, food manufacturers, and VCO processors.

Keywords: capacity, coconut milk, coconut milk extractor, efficiency, sustainable production

INTRODUCTION

The coconut tree, also known as the "tree of life," is one of the major crops in the Philippines. In 2013, it marked its significance to the country's economy with export sales gross of PhP77.4 billion behind rice, banana, and corn as top earners. It is estimated to grow in 3.56 million hectares of agricultural land, where 3 million farmers are primarily engaged in coconut production as a primary livelihood and source of income (PSA, 2019).

President Rodrigo Duterte vetoed Senate Bill 1233 and House Bill 5745 which are the consolidated bills creating the Coconut Farmers and Industry Trust Fund and strengthening the Philippine Coconut Authority (PCA). These bills were created to address the stagnant growth of the coconut industry, anchored to provide assistance and programs for the purpose improving the farm production and farmers' economic return. Given the coconut industry's current situation and the twin bills' veto, the government must address other emerging needs affecting coconut farmers (Castillo & Ani, 2019).

Coconut's main products such as "copra" and coconut oil have been greatly affected by world price fluctuations primarily due to competitors like palm oil, soybean, and corn oil. Coconut farms affected by typhoon require at least a year to recover fully. Production quality even comes to a lower end due to poor nutrition. More problems are evident in diminishing coconut plant farm density due to the demand for coco-lumber products used as scaffoldings and forms in building construction which also results in declining production. Limited funds for research endeavors, postharvest technologies adaptation, and poor farm road conditions also contribute to the existing problems. (Ani & Aquino, 2016; Lapina & Andal, 2017).

Presently, coconut farmers in the Philippines have been crying out for copra prices, which continued to plunge early this year, affecting their livelihood. The current market price of copra dropped to almost 30% in three years, from Php36.44 in 2017, to Php31.94 in 2018, and a sharp decline to Php12.17 per kilogram in February 2019 (PNA, 2019). Clearly, the government has no control over the fluctuating copra price as it is dictated by the global oil market dominated by palm oil and soybean oil, with a share of 35 percent and 26 percent, respectively. The copra price drop has affected 367,234 coconut farmers in the Eastern Visayas region alone. It is estimated that 1.83 million people, or nearly half of the region's 4.4 million population, dependent on coconut production, are affected.

Coconut milk is now used as a coffee creamer in other countries. It is best as a milk substitute in food for persons who are lactose-intolerant and have a prevalence of hypercholesterolemia (Tulashie et al., 2022). Axelum, a local company, is now packing and selling coconut milk products in the United States (PNA, 2019). Locally, the production of coconut milk is also gaining ground in public market business. Many food vendors adopt buying ready-to-use extracted coconut milk rather than buying coconut or grated coconut meat, considering the time of preparation from breaking, grating, and hand and cloth disinfection for manual extraction of coconut milk.

Current extraction of coconut milk from grated coconut is currently done by a screw press in the locality. Farmers turn the screw clockwise with this lever, pushing the materials downward and creating a force against the lower press plate. With the present setup, the foundation of the mechanical press is bolted onto the flooring of the establishment to counter the screw turning up to a pressure the operator can sustain by force. The setup requires the machine and bucket containing the material below the operator, which could be a factor in milk contamination.

The Coconut milk extractor, with utility model registration no. 2-2016000363, have been developed and adopted/utilized by ten (10) coconut farmers' association from Region VI. The innovation address problems on mobility, making it transferrable to any location anytime, to make it more convenient for the operator since the machine can just be placed on top of the table. Barangay market day "tabo" is still observed in Negros Island, hence transportation and utilization are projected to increase. Improvements have been made in the second prototype to address the bending of angle bars as frame support by incorporating upper support with ring plate and solid shafting underneath the lower press frame. VCO is a new, highly value-added version of coconut oil in health food markets (Agarwal, Ravindra 2017), of which the producers are the silent beneficiaries of the utility model.

The angle bar frame was replaced with solid shafting to address the bending of base support as observed and based on the feedback from coconut processors' collaborators of the original design. Further improvement for the extractor includes utilizing stainless-steel materials for all parts in direct contact with coconut meat. To ensure the hygiene of the milk extracted and to scrupulously clean it after every extraction (Olanrewaju, Taopiq. 2015). With the innovation, the performance of the design will be evaluated based on its capacity and efficiency in extracting coconut milk from grated coconut meat.

Objectives

The study aimed to design, fabricate, and evaluate the performance of mechanical coconut milk extractors. Specifically, the study aimed to determine the following:The specifications of the improved coconut milk extractor; the design yield efficiency of the improved coconut milk extractor, the yield efficiency of the existing screw press coconut milk extractor used, to determine if there is a significant difference in extraction capacity and efficiency between the improved and screw press coconut milk extractor presently utilized in the market, and the cost of production for one unit improved coconut milk extractor.

METHODOLOGY

Improved Coconut Milk Extractor

The improved coconut milk extractor using stainless steel materials with direct contact with coconut meat, which include the screw, upper press plate, and bucket, was used for the performance evaluation of the improved coconut milk extractor on its performance, based on capacity and efficiency using 2 kg/load grated coconut meat.

Coconut Milk Extraction Evaluation Flowchart

Figure 1 shows the schematic diagram of the coconut milk extraction using input, process, and output.

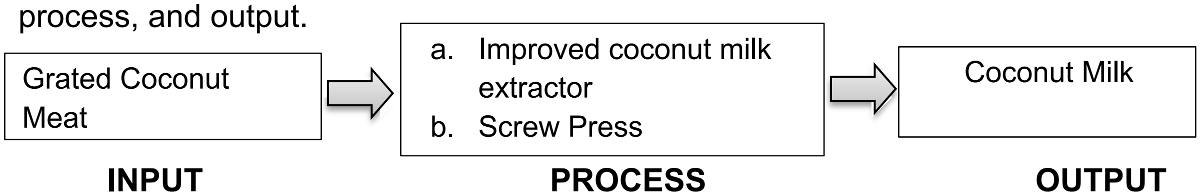

Figure 1. Schematic Diagram of the Coconut Milk Extraction

Figure 2 shows the flowchart in the fabrication and performance evaluation of the improved coconut milk extractor.

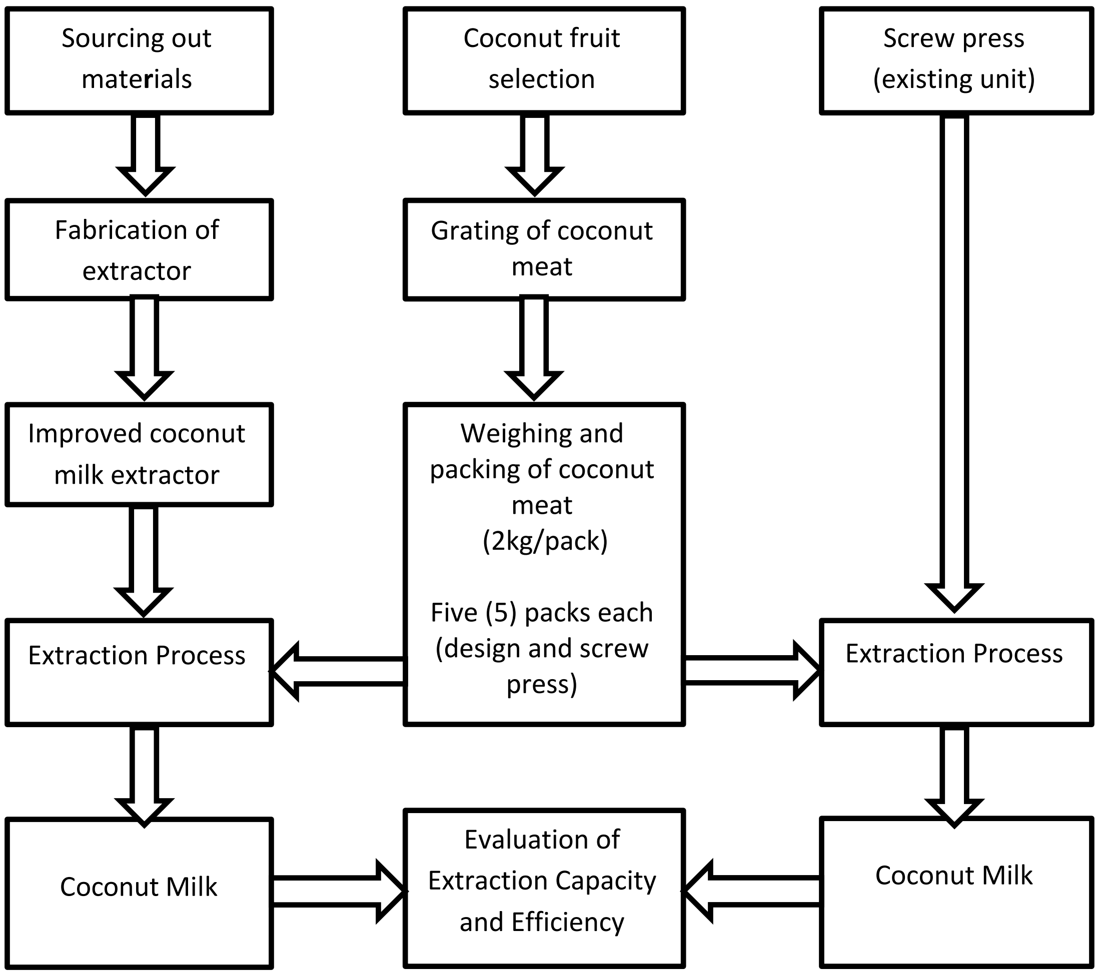

Figure 2. Coconut Milk Extraction Evaluation Flowchart

The coconut milk extractor utilized in the study with stainless-steel materials used on parts with direct contact with the food, and other parts such as the frame, were painted with mild-steel materials using three (3) tones hydraulic jack. Figure 3 shows the isometric view of the UM on coconut milk extraction.

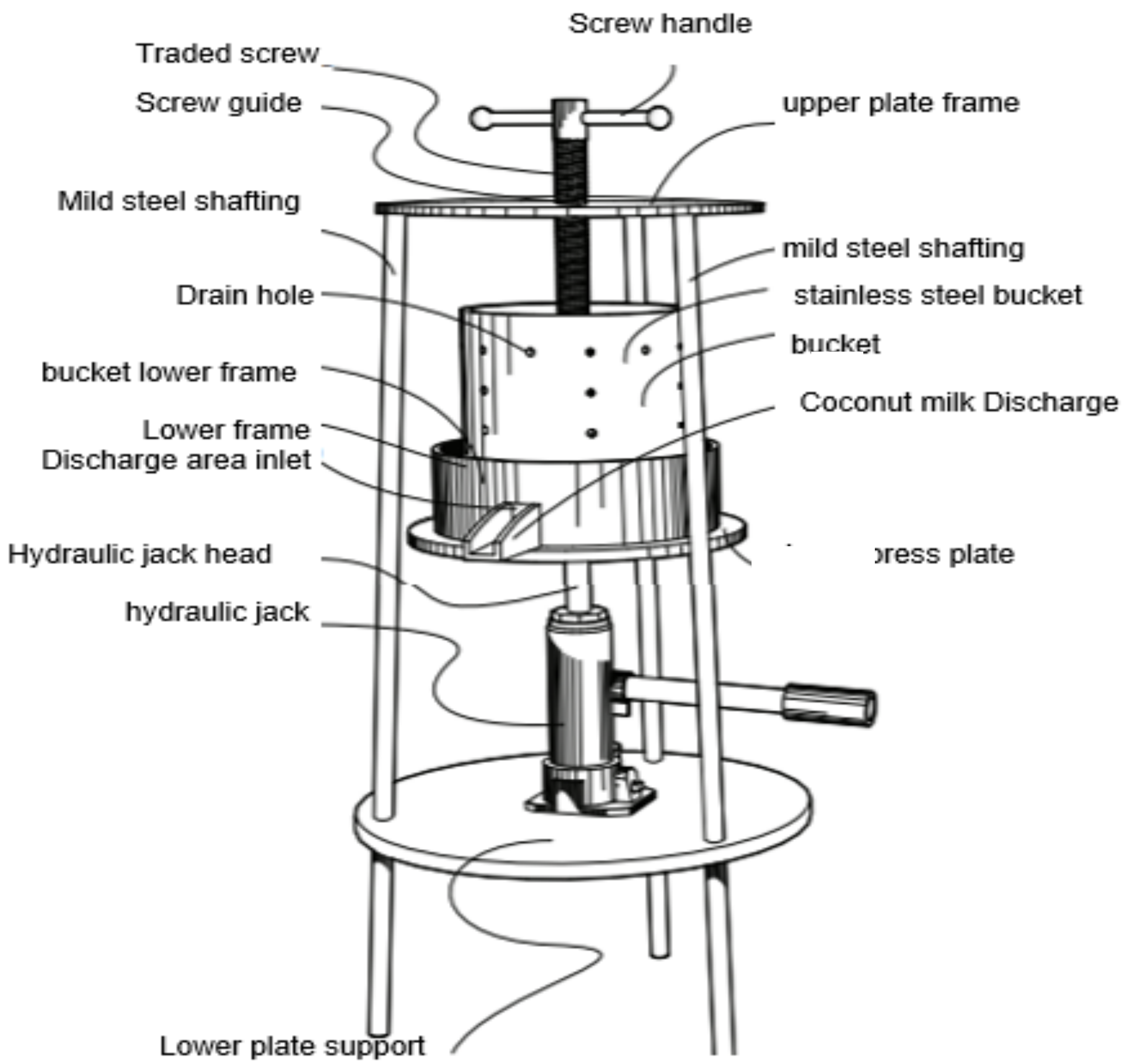

Figure 3. Isometric view of the improved coconut milk extractor

Materials for Fabrication of One Unit Coconut Milk Extractor

The materials used to fabricate a one-unit mechanical coconut milk extractor are shown in Table 1. Some of these materials formed the frame and were welded, while the stainless bucket was fabricated based on specifications. The hydraulic jack formed part of the system.

Table 1. *Materials for the Fabrication of Mechanical Coconut Milk Extractor*

Quantity	Unit	Specifications
1	pc.	Stainless steel shafting 0.04m diameter x 0.3 m length full tread at .005 spacing
1	pc.	Stainless steel shafting .05 m diameter x .05 length full inner tread as bolt
3	pcs.	Steel shafting .03 m diameter x 0.70 m length
1	pc	Steel plate 0.33 m diameter x .01 m thickness with three (3) holes at the corner for 0.03 shafting
1	pc	Steel ring plate 0.33 diameter x .03 thickness with three (3) holes at the corner for 0.03 m shafting, with .05 m diameter ring at the center, upper plate frame
1	pc	Steel plate, 0.22 m diameter x .03 m, bottom press with hydraulic jack guide at the bottom, bottom plate frame
1	pc	Stainless steel plate, 0.17 m diameter x .03m upper press plate with handle.
1	pc	Stainless steel bucket, 0.20 m outer diameter 0.03 m height, 0.18 m inner diameter at 0.21 m height as the pressing chamber with 0.006 m diameter drain holes spaced 0.03 m apart around the chamber, with spout 0.05m x 0.05m x0.03m as milk outlet
1	set	Hydraulic jack, 3-ton capacity
½	kg	Welding electrode,
1	pc	Grinding wheel
1	can	Paint spray, silver

Fabrication of Improved Coconut Milk Extractor

The fabrication of the frame, bucket, and screw of the mechanical coconut milk extractor was done using the materials seen in Table 1. From the given design, the height of the hydraulic jack, bucket, and screw was the determining factor of the frame height. After welding the 3 shafting's to the steel plates to form the frame, all welding points and edges were ground to smoothen the surface, and the design project was finally painted.

The stainless bucket was pre-ordered from stainless steel shop fabricator with the given specifications considering their workforce expertise. The stainless-steel screw and nut were treaded in a machine shop following the square thread requirements at five threads per inch at ¼ deep for higher compression strength. The screw nut has been welded on the central part of the upper plate frame, and three (3") diameter stainless steel plate was welded at the bottom end of the screw. One-inch stainless steel nut has also been welded at the upper end of the screw that was used as a turning mechanism.

Coconut Fruit Selection, Grating, and Weighing

Fifty pieces of mature coconut fruits were selected, de-husked, and cut in half; inspection was done as to the meat's color, smell, and firmness in texture without any discoloration as a sign of damage. The fruits were grated using a mechanical grater, and the meat was mixed thoroughly to have an even mixture. Out of the grated meat, 10 packs were prepared, each weighing 2 kg that was used in the milk extraction, five (5) packs were used for the design of mechanical coconut milk extraction, and another five (5) packs for the screw press currently used in the public market.

Coconut Milk Extraction Procedure

The extraction of coconut milk from grated coconut was done in the public market in Kabankalan City. The procedure for the extraction was outlined below using the design of a mechanical coconut milk extractor and the existing screw press extractor currently used in the market.

Improved Coconut Milk Extractor Operation

The performance evaluation of the improved coconut milk extractor for coconut milk extraction used 2kg /load of grated coconut meat using 5 samples. Data were gathered to determine its capacity and efficiency.

The 2kg grated coconut meat was placed inside a net bag and the stainless-steel bucket, and on top of it, the stainless steel upper pressing plate was placed. The hydraulic jack was inserted on the bottom of the frame using the guide to secure that it was positioned at the central part of the pressing frame. On top of the jack, the bottom press plate was placed, and the bucket was positioned on top of it. The pressing screw was adjusted, turning it clockwise until its bottom reached the bucket's upper press plate, providing the initial pressure to firm the assembly.

The hydraulic jack was secured by turning the lock clockwise, and the lever was operated by pushing it up and down to move the piston upward, pressing the coconut meat inside the bucket cylinder, extracting the coconut milk going to the downspout of the bucket until no more milk came out. The coconut milk was collected using a plastic bucket and weighed.

The materials were removed by unlocking the hydraulic jack, pushing the bucket downward, and turning the screw counterclockwise until its lower end was free from the top of the bucket. The bucket was removed from the assembly, as the upper press plate and the nylon net containing the grated coconut meat.

For maximum extraction of milk, a second pressing was done, placing the extracted meat upside down in the bucket, and the operation of the design was repeated for loading and unloading.

Screw Press Extractor Operation

The screw press extractor in the market used five (5) samples to gather data on coconut milk extracted per 2kg grated coconut meat to determine its capacity and efficiency.

The 2 kg grated coconut meat was placed inside a net bag and the stainless-steel bucket, and on top of it, the stainless steel upper pressing plate was placed. The pressing screw was turned clockwise, moving the screw downward, pushing the upper press plate downward against the bottom plate, extracting the coconut milk. The milk was collected using a plastic bucket, weighted, and recorded for the first pressing.

Pressing was unlocked by turning the screw counterclockwise, moving the screw upward until its lower end was above the top of the bucket, and the bucket was removed from the assembly. The net containing the grated coconut meat was removed from the bucket, placed upside down for the second pressing, and positioned again at the bottom plate. The screw was turned clockwise, and the milk for the second pressing was collected.

Performance Evaluation

The improved coconut milk extractor and the existing screw press were evaluated using the extraction capacity and efficiency of the machine to extract coconut milk as output in the process. Two-kilogram grated coconut meat was utilized as input, and time elapsed in the extraction process was recorded. The extracted coconut milk for the first and second pressing was used as output. For the calculation of Extraction Capacity and Efficiency, the formula below was used.

Extraction Capacity

The capacity(kg/h) of the improved coconut milk extractor and the existing screw press was done in an actual setting in the public market. The capacity was computed using the amount of grated coconut meat (2 kg) as input per load and the elapsed time (h) in the first and second extraction.

$$\text{Extraction Capacity (kg/h)} = \frac{\text{amount of grated coconut meat as input (kg)}}{\text{time used in extracting milk (h)}}$$

Efficiency

The extraction efficiency (%) was computed using the formula below, with the total amount of coconut milk extracted (kg) in the first and second pressing as output and the amount of grated coconut meat used (2 kg /load) as input.

$$\text{Efficiency (\%)} = \frac{\text{output (kg)}}{\text{input (kg)}} \times 100\%$$

Statistical Tools

For problem 2, on the coconut milk extraction efficiency of the design, the mean was utilized, considering it was the most stable among measures of central tendency.

For problem 3, the mean was utilized on the coconut milk extraction efficiency of the existing screw press utilized in the market.

For problem 4, on the analysis of variance, a t-test in two independent samples was utilized to determine if there was a significant difference in the design capacity and efficiency compared to the screw press on coconut milk extraction.

RESULTS AND DISCUSSION

This section presents the coconut milk extraction as the output of this study; it includes the capacity and efficiency of the improved coconut milk extractor and the existing screw press presently used in the market, the significant difference in extraction capacity and efficiency between the design and screw press, and the cost of production for one-unit coconut milk extractor.

Specifications of the Improved Coconut Milk Extractor

The actual picture of the improved coconut milk extractor is shown in Figure 4. All materials with direct contact with the grated coconut meat and milk, including the screw, were made of stainless steel, and other materials were coated with paint as a requirement for food grade products. The height of the machine was 0.71 m, the frame diameter at 0.33 m, and a gross weight of 35 kg with a 3-ton hydraulic jack.

The major components of the improved coconut milk extractor included the bucket, frame, screw press, upper and lower press plates, and hydraulic jack.

The **bucket** was made of stainless steel with a maximum grated coconut meat capacity of 3 kg, provided with drain holes spaced 1 inch apart to facilitate drainage for milk extracted from the meat. It comprised an outer collection layer to hold the milk and drain it to the spout.

The **frame** comprised one ring plate and one round plate connected at the top and bottom with 1-inch diameter mild steel shafting. The upper plate supported the nut of the screw press located at the central part of the plate, and the lower plate served as a platform for the hydraulic jack.

The **screw press**, 12 inches long, was made of stainless steel 1 ½ inch shafting, full square trade at five (5) grooves per inch. One- inch stainless steel nut was attached at the upper end and used as a turning mechanism and adjustment where the other end was welded to 3-inch diameter stainless round plate, which was in contact with the upper press plate in the bucket.

The **upper press plate,** made of stainless steel, was smaller than the inner diameter of the bucket. The plate held the grated coconut meat inside the bucket and was supported by the round plate at the end of the screw.

The **lower press plate** was made of ordinary steel; its diameter was equal to the outer diameter of the bucket. It was located directly above the hydraulic jack; it pushed the bucket upward as the hydraulic jack was operated to press the coconut meat inside the bucket.

The **hydraulic jack,** 3-ton capacity, was positioned at the bottom plate of the frame, centrally located to push the lower press plate upward from its center. The pressing capacity and efficiency of the design were dependent on the power of this mechanism.

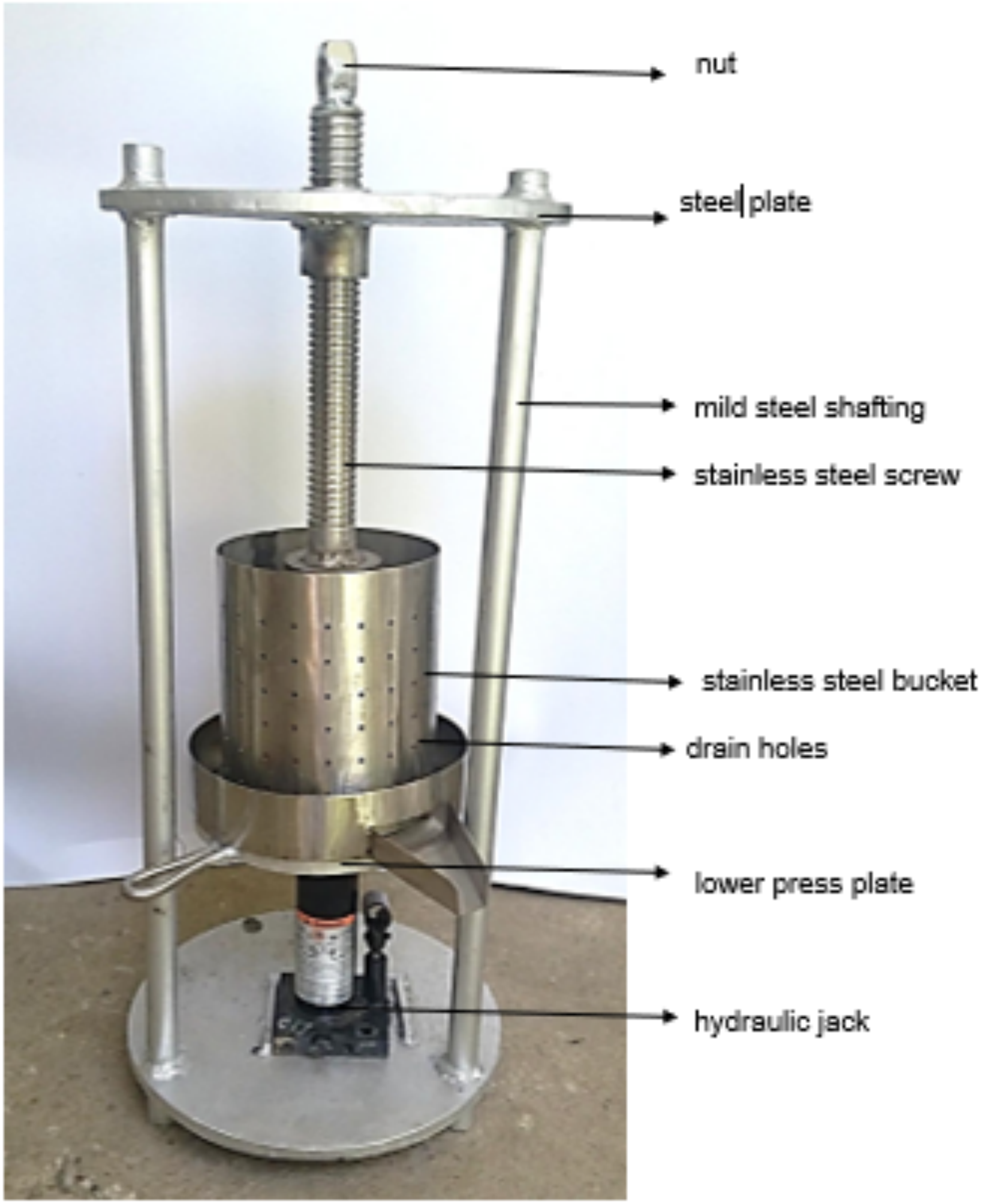

Figure 4. Improved Coconut Milk Extractor

Improved Coconut Milk Extractor Capacity and Efficiency

Table 2 shows the extraction capacity and efficiency of the improved coconut milk extractor.

Table 2. *Improved Coconut Milk Extractor Capacity and Efficiency*

Trial	Input	Improved coconut milk extractor			
		Milk extracted	Time of extraction	Capacity	Efficiency
	(kg)	(kg)	(s)	(Kg/h)	(%)
1	2.00	1.05	112.00	64.29	52.50
2	2.00	1.05	140.00	51.42	52.50
3	2.00	1.08	151.00	47.68	53.75
4	2.00	1.10	160.00	45.00	55.00
5	2.00	1.12	146.00	49.32	56.25
total	10.00	5.40	709.00	50.78	54.00
Ave	2.00	1.08	141.80	50.78	54.00

The improved coconut milk extractor had a capacity of 50.78 kg of grated coconut meat per hour, equivalent to 406.20 kg per day for 8 hours of operation. If a medium size mature coconut fruit yield 0.50 kg, the extractor would have a capacity of 812 nuts for 8 hours of operation.

The extraction efficiency was 54% by weight. On average, 2 kg grated coconut meat used as input load yielded 1.08 kg of pure coconut milk. This extraction efficiency was 4.97%, higher than the extraction efficiency of a machine designed and developed for coconut milk extraction with nozzle clearance of 2 mm with a rotational speed of 40 rpm, which yielded about 49.03% coconut milk (Mohan et al., 2019).

Maximizing milk extraction from grated coconut meat increases yield and productivity. Based on manual extraction as practiced by one VCO producer in Negros Occidental, extracted coconut meat, when subjected to further extraction using the design, resulted in 110 ml additional coconut milk. This extracted milk contributes at least

10% more coconut milk. According to the stall owner of coconut milk during regular days, on average, his coconut milk stall in the public market utilized 200 coconut fruit equivalent to 100 kg of coconut meat, about 50 loads at 2kg /load in the extractor. Using the improved coconut milk extractor may generate 5,500 ml more milk and additional possible income amounting to Php 440.00, using the prevailing market price of Php 20.00/250ml coconut milk.

Extraction Efficiency of the Existing Screw Press

Table 3 shows the extraction capacity and efficiency of the existing screw press.

Table 3. *Screw Press Extraction Capacity and Efficiency*

Trial	Input (kg)	Milk extracted (kg)	Time of extraction (s)	Existing Screw Press Capacity (Kg/h)	Existing Screw Press Efficiency (%)
1	2.00	1.08	318.00	22.64	53.75
2	2.00	1.05	338.00	21.30	52.50
3	2.00	1.12	331.00	21.75	56.25
4	2.00	1.10	353.00	20.39	55.00
5	2.00	1.10	323.00	22.29	55.00
total	10.00	5.45	1,663.00	21.65	54.50
Ave	2.00	1.09	332.60	21.65	54.50

The capacity of the existing screw press utilized in the public market was 21.65 kg/h or a total of 173.20 kg grated coconut meat/day for an 8-hour operation equivalent to 347 nuts. The efficiency of the existing screw press utilized in the market was 54.50% by volume. On average, for 2 kg grated coconut meat used as input yielded to 1.09 kg of pure coconut milk. This extraction efficiency was 0.50% higher than the design, amounting to 10 grams of coconut milk per load, resulting in a longer time of extraction contributing to a higher amount of coconut milk.

At 54.50% efficiency, the screw press could also maximize the extraction of coconut milk from grated coconut meat, which could also protect the environment through the reduction of waste and air pollution.

Significant Difference in Extraction Capacity and Efficiency between the Improved Coconut Milk Extractor and Screw Press on Coconut Milk Extraction

Table 4 shows the significant difference in extraction capacity with two independent samples using a t-test. In addition, Table 5 shows the significant difference in extraction efficiency with two independent samples using a t-test.

Table 4. *Coconut Milk Extraction Capacity using Statistical Tool for Agricultural Research (STAR)*

Variable	Method*	Variances	DF	t comp	t value
Extraction capacity	Pooled	Equal	8	5.2029	3.355

* At 0.01 level of significance.

There was a significant difference in coconut milk extraction capacity between the improved coconut milk extractor and the screw press utilized in the market. The computed t value was 5.20, greater than the t value at 3.35 at a 1 % level of significance (Table 4). This only means that the capacity of the design, which was 50.77 kg/h, was significantly higher than the screw press at 21.64 kg/h; an increase of 29.13 kg/h in capacity was significant.

Maximizing the capacity of one labor force is a significant factor in reducing labor costs and attaining maximum productivity by utilizing the design of coconut milk extraction. The design increases the coconut milk extraction capacity to 235% compared to the screw press utilized in the market. The coconut milk extractor increases the operator's productivity, saving time that can be spent on other productive work.

Table 5. *Coconut Milk Extraction Efficiency using Statistical Tool for Agricultural Research (STAR)*

Variable	Method*	Variances	DF	t comp	t value
Amount of milk extracted	Pooled	Equal	8	0.5168	2.306

* At 0.05 level of significance.

However, there was no significant difference in extraction efficiency between the design and the screw press. The computed t value at 0.51 was lesser than the t value at 2.30 (Table 5). This proves that the design extraction efficiency, which was 54%, lower than the screw press efficiency at 54.50%, was not significant and that the extraction efficiency of the design was comparable with the screw press presently utilized in the market.

Cost of Production for One-unit Mechanical Coconut Milk Extractor

The improved coconut milk extractor’s cost of production for one unit amounted to Php. 14,599.00 (Appendix A). The reduced cost was based on the utilization of stainless steel materials for items with direct contact with the materials, such as buckets, upper press plates, screw plates, and nuts only; other parts, especially the frame, an ordinary steel plate used and covered with paint to comply to requirements of Food and Drug Authority (FDA).

The cost of production can be recovered within 72 days, at 4 hours of operation, by charging Php 1.00/kg load. With a machine capacity of 50.78 kg/h, the projected capacity /day would be 200 kg or equivalent to 400 nuts of average size per day.

CONCLUSION

The improved coconut milk extractor showed a highly significant difference in coconut milk extraction capacity at 50.78 kg/h and the screw press at 21.65 kg/h utilized in the market at a 1% level of significance. However, there was no significant difference in extraction efficiency between the improved extractor and the screw press. The innovation cost Php 14,599.00 using stainless steel materials directly from coconut meat.

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