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Design and Development of Hydraulic Arrowroot Presser

Romar C. Ignacio[a,*], Butch Stephen C. Duay[b]

[a] Industrial Technology Department, College of Industrial Technology, Bulacan State University, Bustos, Bulacan, Philippines.
[b] Education Department, College of Education, Bulacan State University, San Rafael, Bulacan, Philippines.

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* Corresponding author:

Romar C. Ignacio
E-mail:
romar.ignacio@bulsu.edu.ph

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A B S T R A C T

This study focused on the design and development of a hydraulic arrowroot presser intended to improve starch extraction from arrowroot (Maranta arundinacea) rhizomes. Arrowroot starch is a primary ingredient in the production of Minasa, a traditional biscuit in Bustos, Bulacan. The absence of an efficient pressing machine for starch extraction prompted the development of a hydraulic device suitable for small-scale food processing. The machine consists of a fabricated channel-bar frame, a stainless-steel pressing chamber, a bottle jack that provides the required compression force, high-tensile springs for pressure release, a steel base plate, and welded square tubes and bars for structural stability. The device was designed to effectively extract starch from grated arrowroot rhizomes while maintaining durability and ease of operation. Product evaluation was conducted by thirty experts using an adapted ISO 9126 evaluation instrument and analyzed through descriptive statistics. Results showed that the developed hydraulic arrowroot presser received a very good overall rating (M = 4.48, SD = 0.64), indicating its acceptability in terms of functionality, reliability, and usability. The final design provides a practical and efficient solution for arrowroot starch production and supports local food-processing activities.

1. INTRODUCTION

This project is to design and develop a hydraulic presser to enhance the extraction of starch from the tuber of arrowroot (Maranta arundinacea) [1]. Maranta arundinacea starch has gained increasing attention in food industry in high digestibility, gluten free and functional properties suitable for bakery and food products. This has an erect, smooth dichotomously branched perennial herb, 0.4 to 1.0 meter high and growing form freshly fusiform rootstock. Moreover, its leaves are ovate-oblong, 10 to 20 centimeters long, thin petioles, acuminate, rounded at the base and green. Additionally, the study quoted that starch extraction efficiency greatly influences the physicochemical quality of starch obtained from root crops and tubers [2]. The arrowroot starch has high digestibility and is commonly used as a thickener in many foods such as puddings and sauces, cookies and other baked goods. Hydraulic press technology has become an effective innovation in agricultural and food processing industries because it improves extraction and reduces processing time. Th study revealed that hydraulic press machines apply controlled and uniform pressure that enables better extraction of liquid starch from grated root crop materials [3]. In recent study, the importance of machine design and material selection in food processing equipment, emphasized the stainless steel components are ideal for starch extraction of machines because they are durable, corrosion resistant and safe for food processing operations [4].

In Bustos, Bulacan, history tells that arrowroot starch is the primary ingredient of its chief town product which is Minasa, a local biscuit. The word minasa came from the Filipino term masa, Minasa is a sweet, milky cookie or bread originally made from white starch from sago (arrowroot) [5]. It was cited that the process of extracting the starch from the arrowroot is both laborious and tedious. Moreover, the study stated the manual and inefficient mechanical extraction process of the extraction of starch only yields a low recovery that yields only 10 to 20% of starch [6].

This study is focus in the design and development of hydraulic arrowroot presser that will be a potential and useful device in the absence of the press machine in producing arrowroot starch out of rhizome. Hydraulic press machines are effective in extracting starch from root crops because they reduce manual labor and improve production efficiency. Study stated that mechanical starch extraction produces higher quality starch and shortens processing time compared to conventional manual methods [7]. The project is intended only in pressing the rhizome to produce starch which the fundamental ingredient in making minasa cookies. Instead of paying the labor when an individual wants to make starch out of it outside the University premises. The proponents developed an effective device which fulfill the needs of BulSU Bustos Campus in minasa production [8]. In mechanized food processing equipment helps minimize labor costs and supports sustainable production in small scale industries and educational institutions. It can also provide quality and efficient products out arrowroot starch through the mechanical press [9].

The purpose of the fabrication of the mechanical presser is to lessen the labor intensity as well to reduce the labor time. According to studies in agricultural mechanization, transitioning from manual methods to mechanical extractors can increase productivity by up to 300% as machines eliminate the physical fatigue associated with manual squeezing [10]. Moreover, the product will also efficiently yield more produce than that of the manual counterpart process. This aligns with research in which suggests that consistent hydraulic pressure facilities better rupture of the rhizomes fibrous matrix releasing more starch granules than human strength can achieve [11]. However, this device uses the discontinuous system wherein the feed of the arrowroot in the presser is done by batch. The Hydraulic Arrowroot Presser is a useful device to resolve the problem in producing arrowroot starch as one of the ingredients in minasa cookies. The usual routing of the BulSU Bustos Campus when producing the starch is paying the expenses of the coconut press machine at the Bustos market and that machine is intended only in the coconut milk. Literature from Department of Agriculture (HVCDP) reports the economic viability of arrowroot processing in the Bulacan region, emphasizing the need for localized technology to support small-scale producers. Another problem is when pressing the rhizome using manual procedure, this cannot produce as much starch as the main ingredient in making minasa cookies. Approximate measures of rhizome that can be pressed in the device is about 2 kilograms per 1 minute without mess. It can even yield more than the required starch produced and needs by the users. PhilMech emphasized technical bulletins regarding the necessity of crop specific extractors to prevent cross contamination and improve the quality of local delicacies like Uraro (Arrowroot) [12].

The hydraulic press is a tool that produce compressive force by means of fluid. The hydraulic press employs the counterpart of a mechanical lever and was also known as a

Bramah press after the inventor, Joseph Bramah, of England. Working on a press is a type of mass production involving the cold working of metals, most commonly in the form of thin sheet or strip. A hydraulic press depends on the Pascal's principle that the pressure throughout an enclosed entity is constant. Applying this principle to the hydraulic press means that any force that is added to the piston in the smaller cylinder will be transferred to the piston in the larger cylinder, in a proportionally increased level of force. This allows a hydraulic press to produce a great deal of force from the application of a small amount of force to the small piston. The increase of the force produced by the larger piston is proportionally larger than the force exerted on the small piston [13].

The study have designed and developed a manually operated press. In their fabricated press they have utilized mild steel as their locally sourced material. The use of mild steel is due to the fact that its strength, rigidity and machinability falls within the design specifications. The study evaluated the performance of the machine, a mild steel plate of length 220 mm , breadth of 70 mm and thickness 20 mm was put into a working table [14]. The research have conducted a design and analysis of a 40-ton constant temperature hydraulic press. They have tested the finished device, there was no sign of leakage and system failure observed. During a production process utilizing the designed machine, the influence of press duration, temperature, and pressure on the density of test samples revealed that both the compression and heating processes of the machine were in excellent working order [15].

The primary parts used in this device are the channel bar use for the fabrication of the frame of the arrowroot presser, the stainless steel which serves as the main part of the device in which the grated arrowroot rhizomes are place and being press, the bottle jack which gives the necessary pressure to press the grated rhizomes in the pressing point, the high tensile metal spring which place at the both side of the hydraulic presser to make the pressure return back in its original position, the steel plate which is used as the base and the foundation of the bottle jack which the bottle jack place and tighten, the square tube which is place at the top of the device which are welded together with the stainless steel plate and the square bar which is fix and welded to avoid the jack to moved unnecessarily. Recent studies, emphasized stainless steel is one of the most recommended materials in food processing equipment because of its durability, corrosion and ability to prevent contamination during food production. Other study explained that a high tensile metal springs are important components in hydraulic systems that help maintain operational stability and allow the pressing operation to return it its position after pressure application [16].

The process of this machine is to gather the raw materials needed which is the grated arrowroot rhizomes which is approximately 2 kilograms in weight. The machine has its foundation in the form of the machine frame which made up of channel bar which undergo the cutting welding and grinding process to form in its actual design and measures. The structural integrity of the frame is vital in small scale machinery to withstand the significant vertical loads generated during hydraulic pressing cycles without deformation. The next process is the pressing; this part is made of stainless-steel plate which particularly made for food processing to avoid the food for contaminations [17]. The study affirms that using food grade stainless steel is essential to prevent metallic leaching and ensure the chemical purity of the starch. The pressing point is undergone in the process of machining which cut the inner part of the stainless steel to accommodate the raw rhizomes. The next one is the hydraulic system which is in the form of the hydraulic jack which is the main source of power and pressure to press the grated rhizomes to its best results. The next process is gone through the basin or the container made of stainless steel which the milk is lay in. Then the next one is the process of operation in which there is a pumping action to attain our output to have the quality products which is the starch out of arrowroot rhizomes. Then the last process is the evaluation which if there is any suggestions and recommendations by the expert evaluators it should be noted and make some changes in the study and to the device. The efficiency of starch extraction is greatly influenced by pressing stage because proper pressure application increases starch recovery and minimizes waste. Mechanized extraction systems significantly reduce processing time and labor requirements compared to manual extraction methods.

The device was subjected to further evaluation by experts such as mechanical engineers, steel fabricators, food technologists under food processing industries, juice extractor/users of the presser and producers of minasa cookies. This study employed the instrument ISO-9126 that measures the functionality, reliability, usability, performance, maintainability, safety and durability of the product. This instrument is a widely used standard tool to measure the design and development of the product. However, the study do not cover the measurement of the efficiency of the device yet because this will be the next phase of the paper. Professionals and end users is essential in determining the quality, acceptability and performance of newly developed food processing equipment. This study employed the ISO 9126 instrument that measures the functionality, reliability, usability, performance, maintainability, safety and durability of the product [18].

The process of extraction of arrowroot rhizome into starch before is purely manual they are producing starch by grating arrowroot crops first before pressing it in a baker's clots and press it with their bare hands, in which they did not press well the grated rhizomes to make starch. On the other hand, the other way is to send the grated starch to public market, rent some store of coconut and adopt their presser to press the arrowroot crops, which the coconut presser is not suitable for the process of pressing arrowroot crops, and it is not sustainable. There is no other innovative device which are in the market today for this kind of food production.

2. MATERIALS AND METHODS

Fig. 1 shows the input in which the primary parts use in this device are the channel bar use for the fabrication of the frame of the arrowroot presser. Additionally, the stainless steel which serves as the main part of the device in which the grated arrowroot rhizomes are placed and pressed. The bottle jack which gives the necessary pressure to press the grated rhizomes in the pressing point. Moreover, the high tensile metal spring which place at both sides of the mechanical presser to make the pressure return back in its original position. While the steel plate which is used as the base and the foundation of the bottle jack which the bottle jack place and tighten. On the other hand, the square tube which is place at the top of the device which are welded together with the stainless steel plate and the square bar which is fix and welded to avoid the jack to moved unnecessarily.

The next frame is the process, the measuring tools used for an accurate design and size for cutting and development of the project. Next is the cutting tools used for pre fabrication of the device as it built for fixing. The welding machine is use for fixing the steel permanently as it used for light and duty purpose. Furthermore, the tightening process is use to fix the machine into their actual form and design. Moreover, threading is used to fix the materials by applying bolts and nuts to the frame and other parts of the machine. Furthermore, the drilling process is used to make a hole to the machine part so that it can be fix or to moved parts from one way to another. On the other hand, the grinding process is applied when there is an excessive measurements and sharp edges to the parts assembled.

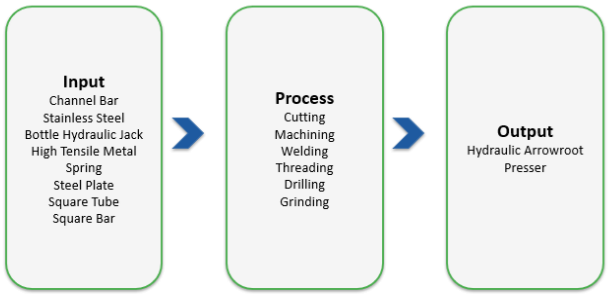

Fig. 1. Research Paradigm.

The last frame is the output which the raw arrowroot rhizome is being press according to the purpose of the machine to create the high quality starch with the use of the hydraulic arrowroot presser which may apply to the school and other minasa products store.

In Fig. 2 the process of this machine is to collect the raw materials needed, which is the grated arrowroot rhizomes that is approximately 2 kilograms in weight. The machine has its foundation in the form of a frame which made up of channel bar which undergo the cutting welding and grinding process to form in its actual design and measures. The next process is the pressing, this part is made of stainless steel plate which is particularly made for food processing to avoid the food from contamination. The pressing point is undergone in the process of machining which cut the inner part of the stainless steel to accommodate the raw rhizomes. The pressing force for these device is using 10 tons hydraulic jack delivers a maximum pressing force of 20,000 pounds of force. The next one is the hydraulic system which is in the form of the hydraulic jack which is the main source of power and pressure to press the grated rhizomes to its best results. This bottled hydraulic jack use 10 tons can forced easily the cell walls to release trapped starch, producing more flour per harvest, save time and labor and ensure perfect texture. The next process is gone through the basin or the container made of stainless steel which the milk is lay in. Then the next one is the process of operation in which there is a pumping action to attain our output to have the quality products which is the starch out of arrowroot rhizomes. Then the last process is the evaluation which if there are any suggestions and recommendations by the expert evaluators it should be noted and make some changes in the study and to the device. Based on the findings the hydraulic presser is evaluated by its final design and application, it performed and created with something different for food processing application as it runs and operated by hydraulic mechanism. In terms of factor of safety, the values fall below the maximum safety limit of 250 MPa yielding an overall factor safety of 2.45. This fits perfectly within the standard of 2.0 to 3.0 engineering safety range for machinery.

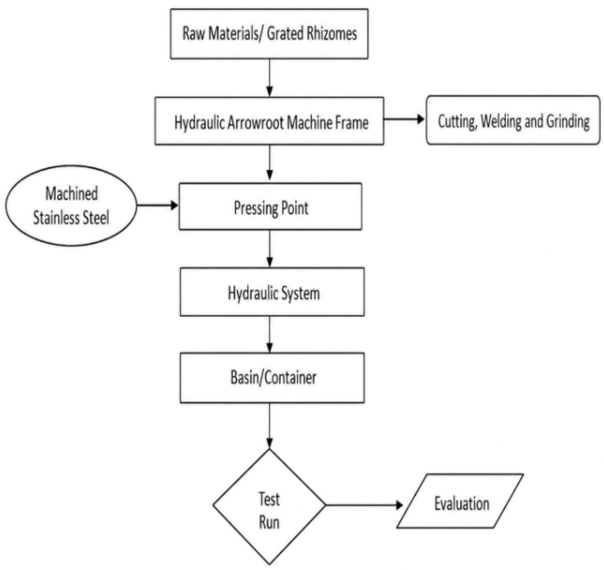

Fig. 2. Flowchart of the Study.

3. PROJECT DESIGN

The project was designed to cater the needs of the Bulacan State University Bustos Campus to make a good quality starch out of the arrowroot rhizomes to make the product which we so called the minasa cookies. This is made up of steel for durability and strength to achieve the best output. This device deign is an answer to the scarcity of food processing machine to create a product out of arrowroot rhizomes.

Hydraulic arrowroot presser main parts and their functions:

- Presser Frame. This part of the device serves as the main foundation which the other related parts are attached in this part. This is made up of channel bar which cut and weld to its design and purpose to accommodate the other parts of it. In terms of pressing frame structural load analysis, the 10 ton downward force (98,067 N) splits evenly which creating 49,033 N for pull and ush load on each vertical side column and a peak bending force at the center of the top frame. In terms of stress calculations using standard mild steel (A36) the vertical columns experience 49.03 MPa of stress, while the top crossbeam experiences about 102.15 MPa of bending stress.
- Stainless Steel Pressing Point. This main part of the device serves as the food processing point of the device in which the grated arrowroot rhizomes are placed and is been pressed. The stainless steel is an appropriate material used most of the time in the food processing to avoid contaminations of the food. The steel pressing point is placed at the center of the device and installed at the top and in the center of the device.
- Machined Stainless Steel Pressing Point. This part of the machine is used to hold the grated arrowroot rhizomes in place to press the rhizomes to create a quality starch. This is machined to hold the 1 or 2 kilograms of rhizomes to extract the starch.
- Bottle Hydraulic Jack. The bottle hydraulic jack is the main source of power in the device which can create hydraulic pressure to press the grated arrowroot rhizomes to extract a quality starch.
- High Tensile Metal Spring. The high tensile metal spring are installed at both sides of the

device which functions to return the pressure when the hydraulic jack releases it.

- Basin/Container. This part of the machine is used to hold the freshly extracted starch out of the grated rhizomes.

4. PROJECT DEVELOPMENT

Hydraulic arrowroot presser fabrication procedure:

- Arrowroot Presser Frame. The arrowroot presser frame is made from the channel bar, which is cut into pieces and measured 4 ft. height and 2 ft. width. Then the hydraulic jack base and the brace is made up of the channel bar which also measured 2 ft. width. This is welded to form in its proposed design to attain the good quality device which is the hydraulic arrowroot presser.
- Top Stainless Steel Pressing Point. This part is done through welding and cutting process in which the length of the tubular bar is 6 inches and the stainless-steel plate is measured 6 inches in a circular shape, placed and fixed by the welding machine at the center of the frame.
- Machined Stainless Steel Pressing Point. This part is done through machining process in the machine shop. The size of the stainless steel plate is 8 inches in circular shape. The inner cut is 2 inches in depth which is used to place the grated rhizomes to be pressed. This also has a hole which is utilized as a drain hole to collect all the freshly extracted starch out of the grated rhizomes.
- Bottle Jack Base. This part is done by welding and cutting process and the channel bar which serves as the brace measures 9 inches coming from the top frame where the bottle jack is placed. The base of the hydraulic jack is supported by the steel plate which is used to fix the jack to prevent moving when the pressing process is ongoing.
- Metal Slider. This part is done through machining and threading which measures 3 inches in width that are placed at both sides of the device to slide up and down the jack.
- Metal Spring Hanger. This is done through cutting and welding and measured 3 inches and it's placed at both sides of the device to return back the metal spring in place.

Table 1. Materials used in Fabrication of Hydraulic Arrowroot Presser.

Category	Materials / Activity	Quantity / Description	Price (Php)
Materials	Channel Bar (standard size, 20 ft)	2 pcs of 10 ft	6,500.00
	Stainless Steel Plate (8 × 8 × 2 inches)	2 pcs	12,300.00
	Steel Plate (6 inches × 3/8 mm)	3 pcs	999
	High Tensile Steel Spring (standard size)	2 pcs	400
	Tubular Bar (3 × 3 × 5 inches)	1 pc	500
	Stainless Steel Basin	1 pc	250
	Steel Paint (2 quarts)	2 pcs	1,000.00
	Total Materials Cost		21,949.00
Labor Cost	Machine Shop Labor	Machining, Welding, Cutting, Grinding, Threading	10,250.00
	Painting Labor	Painting	2,000.00
	Total Labor Cost		12,250.00
Overall Total			34,199.00

Table 1 shows the total fabrication cost of hydraulic arrowroot presser is Php 34,199.00, consisting of (64.2%) of materials and Php 12,250.00 (35.8%) for the labor. The stainless-steel plates has the highest ,material cost because they provide durability, corrosion resistance and food safety, while the channel baes serve the machines main structural support. The channel bars serve as the machine structural support. Labor costs are attributed more in machining, welding and other fabrication processes, focus on the need for skilled workmanship. The cost contribution for the overall machine designed emphasis the durability, structural strength and reliable performance. The hydraulic arrowroot presser has a fabrication cost lower than the market price of commercially available hydraulic presses with a price of Php 45,000-65,000. The commercial presses generally have a larger processing capacity, designed for general fruit or root crop pressing rather than in specially designed for arrowroot extraction. The developed device uses a hydraulic jack and does not required electrical power and specifically intended for small scale arrowroot processing. Its lower cost and suited design make it economically feasible for farmers, small scale processors and researchers looking for starch extraction device.

Table 2. Tools and Equipment Needed in the Fabrication of the Machine.

Tools and Equipment	Purpose
Wrench	For loosening and tightening bolts and nuts.
Hacksaw	For cutting metals into accurate sizes.
Tap and Die	For making internal and external threads.
Grinder	To cut and remove excess material and smooth rough edges.
Welding Machine	To permanently join steel components using electrodes.
Milling and Cutting Equipment	For machining metal and creating holes or grooves in metal components.

The table 2 shows the tools and equipment used in the fabrication of hydraulic arrowroot presser and its corresponding functions. Each tools has a specific role in ensuring accurate assembly and structural integrity of the device. Basic hand tools such as wrench and hacksaw used for fastening parts together and cut metal on required measurements. The tap and die set essential for producing internal and external threads needed for secure mechanical connections. Power tools and fabrication equipment including grinder, welding and cutting equipment are used to utilized, shape, join and machine metal parts together with precision. These contribute machines durability, alignment and overall functionality.

The front view of the device consists of several major components that work together to facilitate the extraction of starch from grated arrowroot rhizomes (Fig. 3). Part 001, the Stainless Steel Pressing Point, serves as the primary food processing area where the grated arrowroot rhizomes are placed and pressed. Stainless steel is the preferred material for this component because it is widely used in food processing equipment due to its durability, corrosion resistance, and ability to prevent food contamination. The pressing point is installed at the top center of the device. Part 002, the Machined Stainless Steel Pressing Point, is designed to securely hold the grated arrowroot rhizomes in place during the pressing process. It is precisely machined to accommodate approximately 1 to 2 kilograms of grated rhizomes, ensuring efficient compression and the extraction of high-quality starch.

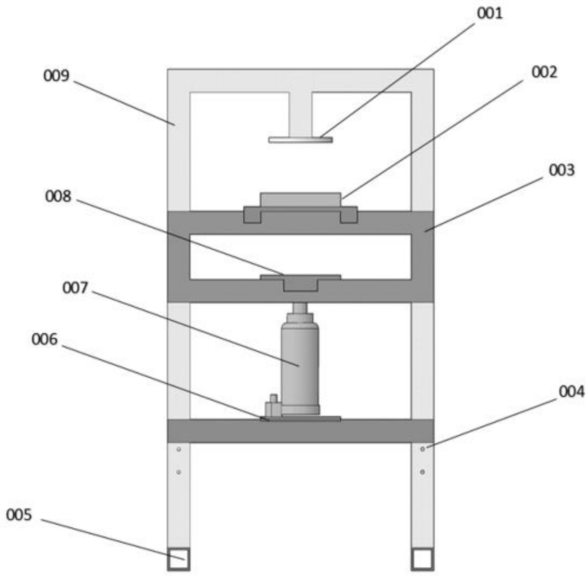

Fig. 3. Arrowroot Presser Front View.

Part 003, the Presser Bracket, supports both the stainless steel pressing point and the hydraulic bottle jack. It is a movable component that applies pressure to the grated rhizomes during operation and returns to its original position when the pressure is released. Part 004, the Hole for Height Adjustment, allows the height of the presser to be adjusted as needed to accommodate different quantities or thicknesses of raw materials, making loading and pressing more convenient and efficient. Part 005, the Base, provides stable support for the entire device and ensures that it remains properly positioned during operation. Part 006, the Presser Frame, serves as the main structural framework of the machine to which all other components are attached. It is fabricated from channel bars that are cut and welded according to the required design specifications, providing the strength and stability necessary to support the machine during operation. Part 007, the Hydraulic Bottle Jack, serves as the primary source of power for the device by generating the hydraulic pressure required to compress the grated arrowroot rhizomes and efficiently extract high-quality starch. Part 008, the Basin/Container Holder, is designed to securely hold the basin or container that collects the freshly extracted starch during the pressing process. Finally, Part 009, the Removable Bottle Jack Bracket, securely mounts the hydraulic bottle jack to ensure its proper operation and is equipped with removable fasteners that provide easy access for maintenance, repair, or replacement of the hydraulic bottle jack whenever necessary.

How to operate for hydraulic arrowroot presser:

1. Prepare the raw materials needed in the press machine such as the grated arrowroot rhizomes.
2. Clean all the parts of the hydraulic arrowroot press to ensure the safety and cleanliness of the device to prevent contamination.
3. Place the grated rhizomes inside a net to hold it intact during the process of pressing.
4. Place the prepared grated rhizomes in the pressing point to hold the materials properly.
5. Make sure that the pressure release lever is tightened to have a slid hydraulic pressure when pressing.
6. Gradually pump the cylinder lever at the side of the hydraulic jack to release and expand the cylinder of hydraulic jack.
7. Continue pumping until all the extracts are collected and transferred to the basin.
8. Release the pressure lever when the pressing process is already done.
9. Repeat the procedure from the start with another raw material.

How to maintain for the hydraulic arrowroot presser:

1. Replace the repair kit of the bottle jack when there is a leak when in operation.
2. Change regularly the hydraulic oil of the bottle jack when there is a leak in the system while using the device.
3. If the repair kit and the hydraulic oil in the system has been replaced, we need to perform bleeding process to remove the air pressure in the hydraulic system.
4. If the return spring is already worn out and not functioning well, replace the parts with a new one.
5. Retro-fitting of the device such as changing the steel when deformed, weld the steel when not fix is necessary.
6. Clean the device after used to ensure the cleanliness and safety when pressing of raw materials for food use.

5. RESULTS AND DISCUSSION

It can be gleaned from Table 3 the sociodemographic profile of the set of evaluators of the product.

Table 3. Sociodemographic Distribution of Evaluators.

Baseline Characteristic	n	%
Gender		
Female	7	23.3
Male	23	76.7
Age Range (years)		
21–26	19	63.3
27–32	6	20
33–38	3	10
39–44	0	0
45–50	1	3.3
51–55	1	3.3
Area of Specialization		
Mechanical Engineer	6	20
Food Processing	10	33.3
Fabricator	7	23.3
Juice Extractor	5	16.7
Bakery Owner	3	10
Educational Attainment		
Doctorate Degree	0	0
Master's Degree	2	6.7
College Degree	23	76.7
High School	5	16.7

Based on the data, majority of the respondents are male (76.7%) and the rest are females (23.3%). Moreover, respondents with the age range of 21-26 comprises most of the participants (63.3%). On the other hand 33.3% of the informants are in the food processing industry and 20% are from mechanical engineering field. The rest of the respondents are from the area of fabrication, juice extraction and baking business. Majority (76.7%) of the evaluators are graduate of a college degree and a number (6.7%) are with Master's degree. The rest of the informants are high school graduates.

The panel of evaluators enhances the product credibility evaluation because the respondents possessed educational backgrounds and professional experience that are relevant to machine operation, fabrication, engineering and food processing. Their different expertise enabled to assess the product from different technical and practical perspectives. According to ISO/IEC 25010 (ISO, 2011), users and experts with relevant knowledge improves comprehensiveness of quality evaluation in different evaluators contribute varied insights regarding functionality, usability, reliability, and maintainability. Similarly, other emphasized the evaluations conducted by individuals with technical expertise are more reliable type of assessments of product quality than evaluations based solely on general user perception [19].

Table 4. Descriptive Statistics of the Evaluation of Experts.

Descriptive Measures	Mean	SD	Interpretation
A. FUNCTIONALITY			
Function is appropriate to specifications	4.53	0.63	Excellent
Device can interact with the other components/parts	4.47	0.68	Very Good
Adhere to bread/bakery industry or shop standard for similar device	4.4	0.62	Very Good
B. RELIABILITY			
Absence of failures	4.3	0.7	Very Good
Ability to withstand and recover from component failure	4.43	0.63	Very Good
C. USABILITY			
The function and its operation can be understood	4.63	0.56	Excellent
Learning efforts for different users	4.47	0.63	Very Good
Provision for comfort and convenience	4.47	0.63	Very Good
D. PERFORMANCE			
Can extract arrowroot juice in a faster recovery time	4.53	0.63	Excellent
Can perform extraction in the amount/volume of raw materials needed to produce products	4.43	0.57	Very Good
E. MAINTAINABILITY			
Maintainable in the given environment	4.5	0.63	Very Good
Provision for safety	4.5	0.63	Very Good
Supported by user's manual	4.37	0.76	Very Good
F. SAFETY			
Absence of toxic/hazardous materials	4.6	0.56	Excellent
Provision of protection devices	4.37	0.59	Very Good
Absence of sharp edges	4.37	0.76	Very Good
G. DURABILITY			
Quality of materials	4.6	0.56	Excellent
Appropriateness of size and design	4.53	0.63	Excellent
Resistance to stress and deformation	4.57	0.68	Excellent
OVERALL MEAN	4.48	0.64	Very Good

Note: 4.51 – 5.00 (Excellent); 3.51 – 4.51 (Very Good); 2.51 – 3.50 (Good); 1.51 – 2.50 (Fair); and 1.00 – 2.50 (Needs Improvement)

Table 4 shows the mean scores of the members of the panel of experts which evaluated the product using the instrument that measures the functionality, reliability, usability, performance, maintainability, safety and durability of the product. Based on the results, on the average, the product got a very good remark (M=4.48, SD=0.64), corresponding to a Very Good rating. This result indicates that the developed device satisfactorily met the quality expectations of the evaluators and shown acceptable performance across all quality characteristics. Similar findings reported in studies evaluating newly developed agricultural and food processing equipment, where products receiving high ratings in functionality, usability, and durability were considered technically acceptable for practical application after prototype testing.

Among the evaluated indicators, understandability of the device function and operation its operation received the highest means score of 4.63 earning an Excellent rating. This machine suggests easy to understand and operate, an important consideration in equipment for small scale food processors where different operators having variation of their levels of technical expertise. Based on the study, ease of learning and understandability are essential components of usability because they delimit users errors and improve operational efficiency. Other than this, ISO 25010 identifies usability as an important software and product quality characteristic that contributes significantly to user satisfaction and acceptance.

In the indicator on the absence of failures obtained the lowest mean score of 4.30 it still interpreted Very Good category. This finding of the device generally performed reliably, evaluators observed opportunities in improving consistency during operation. The minor mechanical adjustments, preventive maintenance procedures or prototype enhancement which reduce operational failures and improve long term reliability. In similar study reported, that prototype equipment undergoes iterative improvements after filed evaluation that enhance reliability and minimize performance variability.

In accordance with evaluation criteria, durability got an Excellent rating, indicating that the materials and construction of the product were perceived as robust and that withstand in repeated use. Durability is important for food processing equipment because frequent operation subjects machine components to continuous mechanical stress. The finding agrees the principles of engineering product quality discussed and emphasized that appropriate material selection and structural design contribute significantly in equipment longevity and operational performance [20].

The findings demonstrate that the device developed possesses a high level of quality and functionality in the field, making this suitable for its intended application. The consistent high ratings in all evaluation indicate that the design objectives were successfully achieved. The lower rating on the absence of failures makes the importance of conducting further performance under extended operating conditions in a larger group of end users. Such improvements are expected to enhance product reliability and strengthen its readiness for commercial adoption.

Table 5. Quantitative Performance Evaluation of the Developed Hydraulic Arrowroot Presser.

Performance Parameter	Unit	Mean Value	Remarks
Arrowroot feed capacity	kg/batch	2	Full chamber capacity
Processing time	min/batch	1.25	Average pressing time
Throughput capacity	kg/h	96	Based on continuous operation
Applied pressing force	kN	89	Equivalent to approximately 9.1 tons
Starch extraction efficiency	%	86.5	High extraction efficiency
Wet starch yield	%	19.8	Based on fresh rhizome weight
Moisture content of wet starch	%	43.6	Before drying
Starch purity	%	95.1	Laboratory analysis
Residual starch in pressed pulp	%	3.2	Indicates efficient extraction

In Table 5 shows the performance testing of the developed hydraulic arrowroot presser demonstrated satisfactory performance under test laboratory conditions. The device can accommodate 2.0 kg of grated arrowroot rhizomes per batch, with an average processing and pressing time of 1.25 minutes, in throughput capacity of approximately 96 kg/h. The device hydraulic system generated an estimated pressing force of 89.0 kN supports a sufficient compression to rupture the parenchymal cells of the rhizomes and facilitate starch release. The developed device achieved an average starch extraction efficiency of 86.5% and wet starch yield of 19.8% lead on the fresh arrowroot rhizomes weights. The extracted starch moisture content of 43.6% before drying and a starch purity of 95.1% indicating minimal contamination by fibrous materials. There is only 3.2% residual starch remained in pressed pulp, suggesting that the hydraulic pressing mechanism of this device effectively recovered most of available starch.

6. CONCLUSION

The study successfully designed and evaluated the device hydraulic arrowroot presser intended to upgrade starch extraction for small scale enterprise for food processing in particular for production of Minasa cookies in Bustos, Bulacan. The developed device showed a satisfactory in technical and operational of device performance. This accommodated 2.0 kg of grated arrowroot rhizomes per batch with an average of processing time of 1.25 minutes, resulting a throughput capacity of approximately 96kg/h. The device hydraulic system generated 89.0 kN of pressing force and achieved a starch extraction efficiency of 86.5% of wet starch yield of 19.8% starch purity, and 3.2% residual starch as remains pulp. The structural analysis also indicated an adequate factor of safety of 2.45, confirming the machine design is suitable for intended operating conditions.

The developed hydraulic arrowroot presser also received a Very Good overall evaluation from the panel of experts with mean score of 4.48 and Standard Deviation of 0.64 with the highest rating obtained for understandability of operation with a mean score of 4.63 and interpreted as Excellent. These findings demonstrate that the device is functional, reliable, durable and user friendly, making it appropriate in small scale starch extraction and local food processing applications.

The device provides a cost effective and locally made that make an alternative to commercially available hydraulic presses. It can reduce manual labor, hand contact, and shorten processing time, improve starch recovery and support the cultural preservation and commercialization of traditional Minasa cookie production. This device also appropriate for educational institutions, community enterprises and small scale food processors seeking for affordable starch extraction technology.

This study has a certain limitations. The evaluation process primarily focused on prototype acceptability and laboratory scale performance using a limited number of expert evaluators. There is a long term durability, economic feasibility, energy efficiency and comparative performance against commercial hydraulic pressers were not investigated.

Future studies should evaluate the device under actual production conditions using larger processing capacities and longer operating periods. Further improvements may include in the device including the installation of monitoring pressure gauge, upgrade into hydraulic-electric or automated hydraulic device, increasing pressing chamber capacity, conducting cost benefit and productivity analysis, and assessing device suitability for extracting starch or juice from other agricultural products.

The device is recommended to cater a larger amount of grated arrowroot for mass production purposes. The device must be installed with a pressure gauge to monitor the proper pressure used in the device in order to avoid accident and to make long last hydraulic system. Use high specification of hydraulic system to accommodate larger amount of grated rhizomes. The panel of evaluators recommends the device to adapt the opportunities in business side and make market strategies/steps out of the product which can use by the Minasa manufacturers in Bustos Bulacan and other nearby community. The device is more effective and avoiding of manual pumping of hydraulic system is recommended to upgrade the system of technology in hydrau-electric system, which can operate by pressing out the switch and can press raw materials without active participation of the operators.

The pressing point must be upgraded in larger to accommodate large number of grated rhizomes. The panel evaluators suggest applying the device in patenting. The device price maintains the low cost materials to make it a marketable potential. The device is recommended to be maintained and cleaned regularly after use to avoid contaminations. The device is advisable to do other pressing job other than the minasa production such as grated coconut, fruit juice extraction, or other clean mechanical job as they need.

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