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Design And Development of a Modified Sugarcane Juice Extracting Machine (Trapiche) for Small Scale Farmers



Abstract: - Small scale farmers are facing challenges with the current sugarcane juice extracting machine due to its constrained feeding capacity, resulting in reduced product output and loss of raw materials since significant amount of juice is left in the bagasse, which is eventually disposed of. The goal of this project is to create a modified trapiche, a machine that extracts sugarcane juice, for small-scale farmers. The sugarcane juice extraction machine was created to either completely remove or, if that is not feasible, to reduce issues with the use of the current equipment, such as the feeding system, juice production, and the quantity of juice that was left in the bagasse for disposal. Most of the parts of the locally developed sugar cane juice extracting machine were locally fabricated like rollers, conveyor and its rollers, bearings, shafting, and bushing. Additionally, the layout and diagrams of the system were key factors in the development of the machine, ensuring its safety and functionality. The findings indicate that the operating time, speed and capacity of the developed sugarcane juice extracting machine with the values 23.67s, 30rpm and 168.99g/s are much better than the existing trapiche with the values of 36s, 15rpm and 83.37g/s respectively which proved that the developed sugarcane extractor is more efficient and reliable. Similarly, the average production rate, extraction efficiency and percent yield of the developed sugarcane extracting machine with the quantities of 55 ml/s, 86.30 percent and 34.59 percent are better than the existing trapiche with the values of 21.29 ml/s, 52 percent and 32.89 percent respectively. Since laboratory testing revealed that the E. Coli bacteria was absent with a detection limit of less than 3.0 MPN/g and the Salmonella bacteria was absent from the sample juice of 25 ml, the juice extracted from the developed sugarcane juice extracting machine is safe from both bacteria. With detection limits of less than 0.02 ppm, less than 0.01 ppm, and less than 0.015 ppm, respectively, metal concentrations, in particular nickel, copper, and chromium, were also examined but were not found.

Keywords: Sugarcane Juicer, Juice Extractor.

I. INTRODUCTION

Western Batangas is predominantly as agricultural land best known for growing sugarcanes. Due to the copious produce of these crops the sugarcane industry started in this region and two sugar plants producing raw and refined sugar in Batangas, Philippines are Batangas Sugar Central Incorporation, Balayan, Batangas and Azucarera Don Pedro, Nasugbu, Batangas. Therefore, the majority of big and small-holder farmers in this region of the province of Murang'a have found a source of income in sugarcane cultivation. Sugar mills typically handle sugarcane plants, involving five main areas: cane pointing machinery, milling, juice extraction, sugar boiling, and crystallization. When preparing sugarcane juices to be utilized as feedstock for other operations, milling is a necessary unit activity. The existing sugarcane juice extractors being used by the sugarcane plants today are more energy intensive and are comprises of mechanically operated complex mills beyond the reach of most growers, especially the small holders (Olaoye, 2012). Usually, planters coordinate with the sugar plants the schedule for pick-up of their sugarcanes during the period of harvest. From the sugar fields, these trucks will deliver the crop directly to the sugar mills for additional processing. However, because big-scale farmers are given preferred time due to their comparatively vast farm yields, this strategy gives them a bias. The little planters are the least of their concerns because they receive the pick-up schedule first. Small-scale farmers are thus forced to wait for their haulage schedule, which occasionally may require more waiting time. This sporadic delay in output quality results in decreased profit.

Another is the trucks' access to the sugar estates, which makes it more difficult to harvest sugarcane. Many farming operations occur in isolated locations where it is challenging for trucks and lorries to reach and harvest crops. Consequently, sugarcane is not processed when the amount and quality of juice are thought to be at their best. By doing this, the sugarcane dries out and loses moisture, which results in a low yield of sugar during extraction. The ripeness of the stalks has an impact on the amount of cane juice and the moisture content (Olaoye, 2011). The tiny planters in those areas have turned to using a machine called a trapiche to harvest sugarcane juices in order to address these problems.

The trapiche is primarily comprised of rollers with three slots and with bearings. They are disposed triangularly such that two rollers are at the base while the third roller is at the top (Gbado 2013). The current trapiche is propelled by a carabao that pulls the wing of the apparatus in question, or it might be propelled by the vehicle engine. Although the trapiche has been used for the longest time, making it one of the devices as an alternate method of processing sugarcane, it has several drawbacks. However, because it can only feed two or three pieces of sugarcane at a time, the current trapiche has a relatively poor feeding capacity. One or two operators handle the feeding. Except for that, all the processes right from feeding process for a set of sugarcane through to the disposal of the bagasse are slow; it takes four hours to extract the juice for one ton of sugarcane where it can only produce almost 50kg of muscovado.

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Since sugarcane juice is the raw material used to make key goods like muscovado and other sugar products, small-scale farmers' needs are not met by the trapiche's feeding capacity and processing time as it is currently constructed.

However, the present trapiche has a non-ergonomic design and is hazardous to the users of the product. Because feeding the sugarcane into the trapiche requires force and constant movement from the operator, users experience shoulder ache. Additionally, they run the danger of developing back pain from standing for extended periods of time while the trapiche is operating, as well as bursitis or extreme wrist twisting during the feeding procedure. In addition, users may suffer from severe accidents like crushing their hands when putting the sugarcane in the machine, as well as arm and neck ache. However, because carabao power is used to work this machinery, trapiche production is dependent on the animal's strength and ability. Carabaos are unable to work for a set duration of hours, unlike machinery, which impacts the trapiche's operational hours. The third internal condition in processing of sugarcane is climate. Under performance, leads to delay and this is instigated by extreme weather, especially when it is hot and depending on the type of climate throughout the harvest seasons, carabaos under perform. Thus, difficulties in the field of harvest time and sugarcane treatment are still present in the scheme of using trapiche.

Regarding the product, if the sugarcane juices are not completely extracted using this approach, losses may still occur in the current equipment. Typically, the carabao's force is what drives the rolling pins that smash the sugarcane. The carabaos are unable to draw the wing all the way to the trapiche when the rollers are close to one another. Because of this, part of the juices that are generated are not entirely separated from the sugarcane, which might have been utilized to make molasses, alcoholic contents, brown sugar or muscovado, and other goods. This method leaves untouched the possibility of up to 1.5 liters of sugarcane juice every three kilograms of sugarcane. As a result, farmers lose money, time, and effort, among other things.

However, the 42 small-scale farmers who refused to utilize carabao in their operations now use the engine-type trapiche. However, he pointed out that a limited feeding capacity, like that of the carabao-driven trapiche, slows down the sugarcane's processing. Only one ton of sugarcane can be processed by this engine-type trapiche in two hours, which is insufficient to produce the necessary volume of goods. In addition, there is a significant amount of juice taken from sugarcane regardless of whether it is present in all of the juice. It is estimated that during the process, around one liter of juice is left in the bagasse as an extra raw material that may be used to make the primary sugar products, for every three kilograms of sugarcane. The small-scale farmers that use the engine-type trapiche lose out on raw products since the bagasse, which still includes a significant amount of the juice, is disposed of. However, this engine type trapiche still requires human power, much as the traditional technique of feeding, therefore machine workers continue to have bodily problems. Since the prime mover and trapiche need to be positioned correctly, a larger area is also needed for the machine's location.

This encouraged the researcher to find a remedy for these incidents, which small-scale sugarcane producers obviously cannot detect. A modified sugarcane juice extraction machine (trapiche) was designed and developed with this goal in mind.

II. MATERIALS AND METHODOLOGY

A. Materials

In Batangas, Philippines, stores and hardware stores sold stainless steel, steel pipes, motors, bearings, speed reducers, shafts, sprockets, and conveyor belts as examples of materials. The aforementioned materials were used to manufacture the rollers, bushings, and gears. The aforementioned materials served as the main or essential components of the sugarcane juice extraction equipment. We also bought other electrical components locally, such as contactors, capacitors, relays, cables, coils, push buttons, pilot lights, and circuit breakers.

B. Methodology

The research employed real engineering design, planning, and analysis to accomplish its objectives. By examining the information gathered from the documentary study of the sugarcane extractors that are currently on the market, it also evaluated the design of the suggested alteration. The researcher thus wanted to obtain large measures of inputs and diagnosed the problems that users faced while using these machines and the areas of weakness. Additionally, the researcher inquired about the issues faced by users of the trapiche now in use in Western Batangas. To find out what goes on when the trapiche really functions, informal interviews were conducted. These comments provide pertinent and helpful information on how the commercially available sugarcane juicers and trapiches that are now in use operate. Therefore, an inspection was done to see how the current trapiches work and what condition the new trapiches that would house the suggested machine will be in.

The existing trapiche was then redesigned based on the parts of the trapiche that plays a big role in the overall running and efficiency of the machine. It was modified based on the number of pieces of sugarcane to be fed at once in the modified trapiche such that the issues implementing the feeding system in the existing machine would be addressed. One of the elements in the operation was paid special attention so as to enhance contribution to the extraction efficiency in this phase. Changes on strategic areas of the operation that support in the rate of production were also focused in the development of trapiche. The rigidity and compactness of the machine used in manufacturing was also incorporated in the safety control and devices of the machines to in order to prevent causalities in the machine.

Several testing and modifications exercises were conducted once the sugarcane juice extracting machine had been developed. The initial part of testing focused on running motor, conveyor system and control devices of the machine and the results were compared with the design. Motor operation was tested with regards to viability of operating the various materials/components for rotation of the rollers as well as normal operations of motors. Sensors and relays of the control devices were inspected if they operate on the various set modes and values. The aforementioned components' corresponding functionality and operation were examined using the no-load testing methodology. Preliminary testing of the machine under load conditions was then conducted, giving careful consideration to the feed's mass and running speed. The likelihood of how much sugarcane could be fed at a given time and throughout operations was the main focus. As a consequence, the new feeding technique was implemented in a way that only permits the maximum amount of sugarcane to be fed simultaneously. In order to determine which operating speed would result in a larger volume, three experiments were conducted on the three sets of mass at various speeds. Operating time of one whole process of extraction involving feeding of sugarcane up to disposal of the straw of a given quantity of sugarcane was also determined. Operating capacity in this case was determined by the following formula.

$$OC = \frac{M_f}{T} \quad (1)$$

where OC is the operating capacity, M_f is the mass of feed and T is duration of extraction of a certain mass of sugarcane. It aided in the negotiation that the redesigned trapiche's whole operation would operate faster and with a shorter running period than the current juice extraction equipment. It was also claimed that the created sugarcane juice extraction equipment will outperform the trapiche now in use in Western Batangas in terms of operation time, volume, and speed. To make sure the protection offered was sufficient for the operation, other protective features of the different protective devices were also examined.

The following factors were taken into account while assessing the machine's performance: extraction efficiency and production rate. They assessed the quantity of processed sugarcane they sourced during a specific time period and compared it to the output rate utilizing the machine that was already in place. This was done in order to establish a close relationship between the production rate and the designed machine, which was greater than the current one. The following formula was used to calculate the production rate:

$$Pr = \frac{V_{ej}}{T} \quad (2)$$

where Pr is the production rate, V_{ej} is the volume of the extracted juice and T is the time of operation. The parameters employed in the evaluation of the production rate were derived from the speed at which the highest yield of extracted juice per mass of feed and time of extraction was achieved. The amount of juice extract using the modified machine was also guaranteed to be of better quality.

Stated differently, the mass of the extracted juice was compared to the total volume of the extractable juice in the sugarcane in order to determine the extraction efficiency. The volume extracted was calculated after three batches of a specific quantity of sugarcane were made, each of which generated the highest amount of juice extraction when fed into the machine at a specific operating speed. Before the samples were dried until there was no more moisture in the bagasse, the weight of the wet bagasse sample was noted. To estimate the amount of juice in the bagasse, the weight of the dry bagasse was subtracted from the weight of the wet bagasse. The following formula was used to calculate the machine's extraction efficiency:

$$Ef = \frac{M_{ej}}{M_{ej} + M_{mb}} \times 100\% \quad (3)$$

where Ef is the juice extraction efficiency (%), M_{ej} is the weight of extracted juice (g), M_{mb} is the weight of the juice left in the bagasse. The weight of the juice left in the bagasse (M_{mb}) is computed using the formula:

$$Mmb = Mw - Md \tag{4}$$

where the weights of the wet and dried bagasse are denoted by Mw and Md , respectively. Furthermore, samples of extracted juice from subdivisions were gathered and analyzed in an approved laboratory to determine that they satisfy food safety quality criteria for use as raw materials in the creation of molasses, muscovado (sugar), and other products.

III. DESIGN OF THE MACHINE

A. Components of the Juice Extraction System

The volume of juice extracted was one of the main considerations in designing the juice extraction system. As presented in Figure 1, five (5) sets of rotating rollers are attached to the center of the casing through bushings that are connected to the gears. The sugarcane feeding guide and the bagasse guide for the disposal of the bagasse are placed near the conveyor. The other components of the juice extraction system such as side plate of 2.54 cm thick, tension rod, bushing adjuster and juice filter are positioned under the sets of roller while the sugarcane juice pan is located where the sugarcane cane outlet is attached

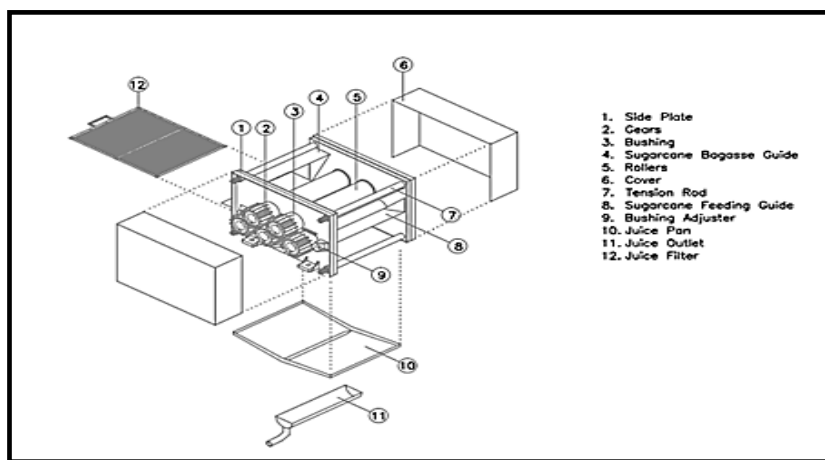


Figure 1. Juice Extraction System

B. Pulley Drive System

The design of the pulley drive system is shown in Figure 2. Based on the figure, the drive pulley is connected to the motor through the belt with a speed reduced using the 1:11 gear ratio through the speed reduction system. The speed reducer is connected to the driven pulley for the rotation of the rollers. All these materials and components are placed below the base of the juice extracting system.

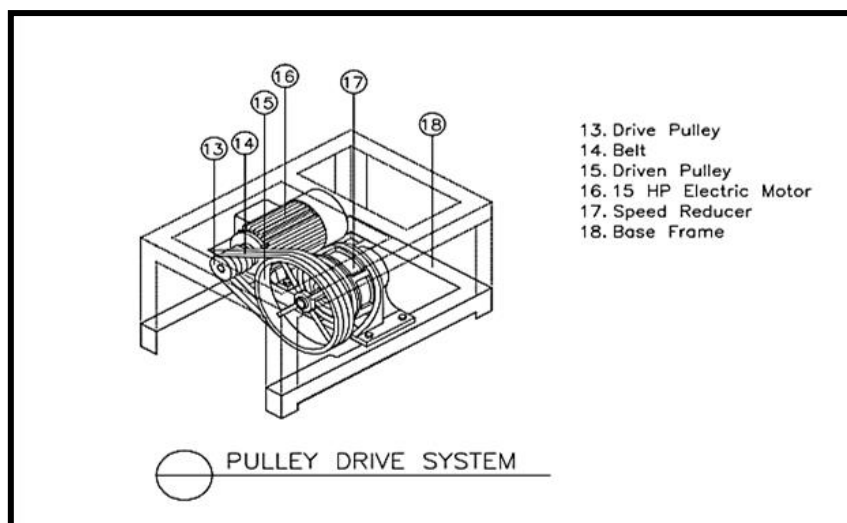


Figure 2. Pulley Drive System

Figure 3 illustrates the driving pulley which is connected to the 15HP, 1760rpm motor. The 3in driving pulley is connected to the 16in diameter driven pulley through the belt. The said interconnections reduce the speed from the driving pulley to the driven pulley which is computed as (Olaniyan, 2011):

$$\frac{1760 \text{ rpm}}{\text{RPM OUT}} = \frac{40.64 \text{ cm}}{7.62 \text{ cm}}$$

to get the output speed of 330rpm. Then the driven pulley is connected to the speed reducer with the ratio of 11:1 which further reduces the speed to 30rpm. The speed reducer is connected to the rollers through the gears and bushings for the forward and reverse motions of the rollers.

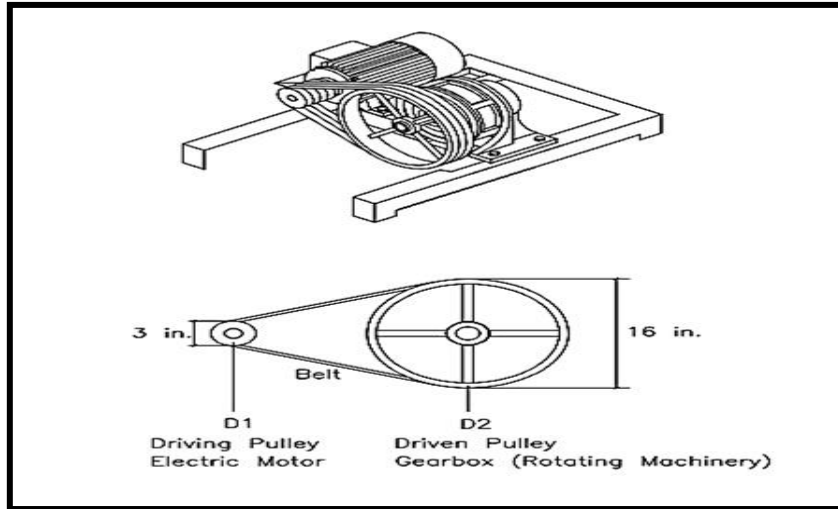


Figure 3. The Driving Pulley

The torque applied to the driving pulley by the motor is (Hartman, 2009):

$$T = \frac{11,190 \times 9.5488}{1760} = 60 \text{ Nm.}$$

The 60Nm torque applied to the driven pulley is increased to 320Nm at the side of the driven pulley due to increased diameter of pulley from 7.62 cm to 40.64 cm. The driven pulley is connected to gearbox with 11:1 ratio which further increased the output torque of the rotating gears to 3530Nm. The design ensures that the machine requirements for operation such as low speed but high torque is achieved for proper feeding and extraction of juice from the sugarcane.

C. Feeding of Sugarcane

The feeding of the sugarcane, with the aid of an operator, was the main function of the conveying system. The conveying system (Figure 4) is composed of different components: the motor is positioned under the base of the conveyor which is connected to the drive gear, and the drive gear is connected to sprocket through the chain. The said interconnections are responsible for the rotation of the conveyor rollers and at the same time, they are located under the conveyor belt to drive the feeding of the sugarcane. Conveyor paddles are also attached to aid in inserting the sugarcane into the sugarcane extracting system. The other components/materials utilized for the feeding process are the pillow block and flanged bearings that are connected to the conveyor rollers.

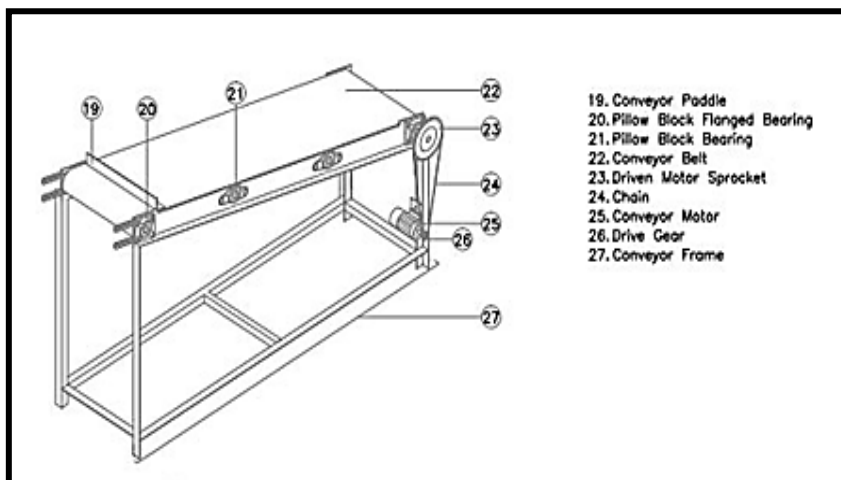


Figure 4. Feeding System

D. Electrical System

Figure 5 shows the circuit diagram for the power and control of the built sugarcane juice extraction machine. From the figure below, it becomes clear that the machine requires 220V single phase power supply. When the toggle switch is pushed the 220V supply is initiated and the pilot lamp is lit thus indicating that the machine is ready to be operated. By releasing the forward button, it moves up the forward contactor to hold the contacts energizing the starting capacitor which regulates the starting current and torque. Also, the running capacitor is used at the same time to afford higher safety of the motor.

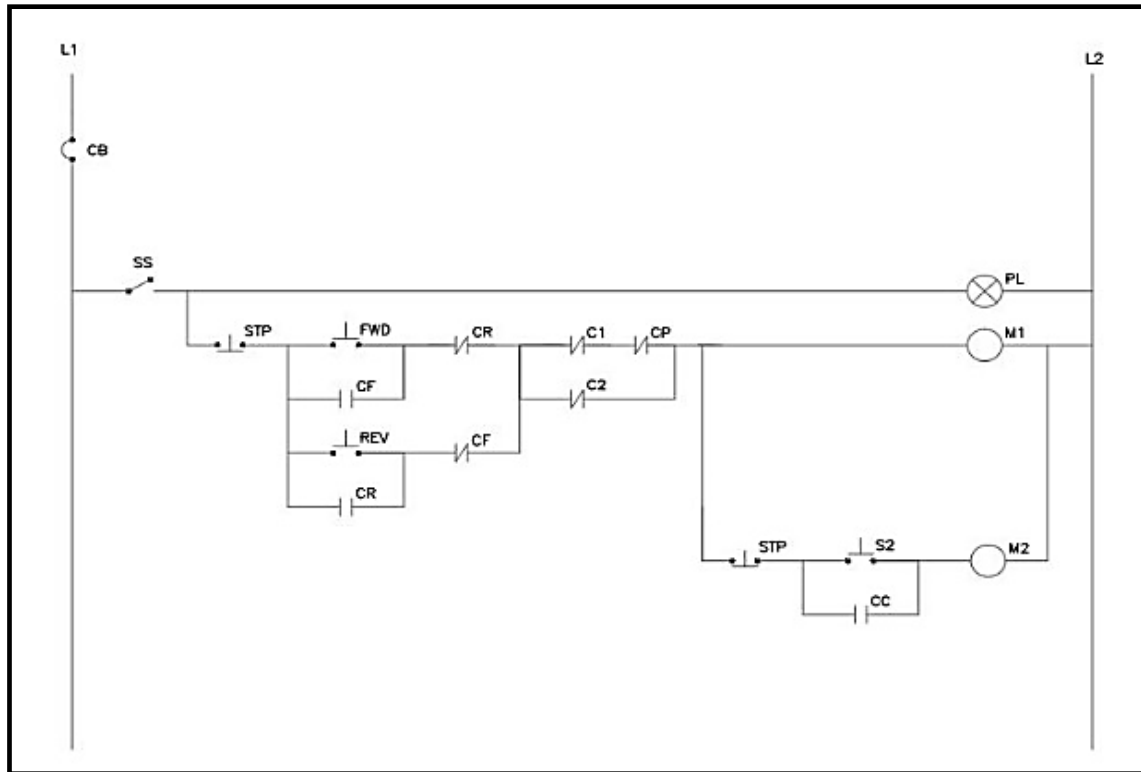


Figure 5. Control System Schematic Diagram

Then, the motor will run in forward direction. Simultaneous with these, the normally closed forward contactor will open to ensure that the circuit in reverse direction of the motor will not energize while it is running in forward direction. 75% of the full load speed, the normally closed potential relay opens to switch off the starting capacitor. This time the capacitor stays active to ensure the safety and reliability of the operation of the motor. The electric motor rotates in a forward direction as it provides the power that rotates the gears that rotates the rollers coupled to it.

IV. DEVELOPED MACHINE

The locally designed modified sugarcane juice extraction machine (trapiche) is shown in Figure 6. The locally constructed conveyor, which consists of four (4) sets of revolving conveyor rollers for the conveyor belts, is used to feed sugarcane simultaneously. With the aid of the pillow block and flange bearings, the aforementioned sets of spinning conveyor rollers are mounted in the conveyor's base. The motor located at the base's lower end is responsible for the conveying components' forward and backward motion. Sugarcane stalks weighing up to 5,000 grams or five (5) pieces may be put onto the conveyor belt and transported all at once into the juice extraction system. In order to feed the sugarcane into the rollers during the feeding operation, the conveyor paddles were also fastened onto the conveyor belt. The main component of the sugarcane juice extraction machine was the juice extraction system, which consisted of five sets of revolving rollers. Stainless steel 304 was used for the juice extraction stage since it is a food-grade material that is extremely corrosion-resistant. Four steps of juice extraction are made possible by the aforementioned sets of rollers being positioned appropriately and at different distances. All of the first juice extraction processes are carried out by the first and second rollers, which are situated at the feeding side. In an effort to extract the juice, the second and third stages of the juice extraction process were used by the second and third rollers, as well as the third and fourth rollers.

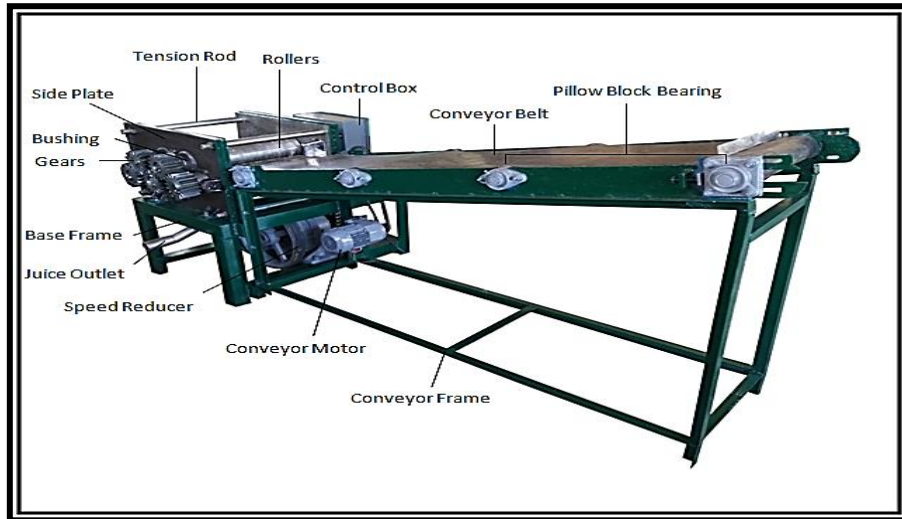


Figure 6. Developed Modified Trapiche

The fifth and the fourth rollers are to be adjusted to the minimum clearance in the final stage of juice extraction. The rollers are arranged in groups, and their positions might be controlled to allow for adjustments based on the amount of clearance required for the machine to be extracted efficiently. The mashed bagasse and other components are filtered by the juice filter, which is positioned underneath the rollers. The filtered juice was stored in the juice pan just beneath the juice filter. Through the juice outlet that is attached to the Human juice pan, it would flow outside.

V. DISCUSSION OF RESULTS

The table below displays the outcomes of a series of tests conducted to determine the ideal speed to mass of feed and the overall performance of the designed sugarcane juice extraction machine in comparison to the engine-type trapiche. The results of the laboratory tests were also disclosed.

A. Mass of Feed and Operating Speed

As can be shown from table 1 below, the average yield of 1306.33 ml and 1300 ml for the extraction of juice at operating speeds of 20 rpm and 30 rpm at 4000 g mass of feed was quite comparable. It was clear that at any working speed and feed mass, they produced the largest ratio of the volume of juice extracted to the mass of feed, which was 0.33 ml/g. The results show that the amount of extracted juice is unaffected by lowering the operating speed from 30 rpm. Consequently, a feed mass of 4000g and an operating speed of 30 rpm are the ideal working parameters.

Table 1. Volume of juice extracted for mass of feed at different operating speed

Mass of Feed (g)	Operating Speed (rpm)	Average Mass of Juice Extracted (g)	Average Volume of Juice Extracted (ml)	Average Volume of Juice Extracted per mass of feed (ml/g)
2000	50	650	500	0.25
	40	780	566.67	0.29
	30	833.33	633.33	0.32
	20	846.67	636.67	0.32
3000	50	1050	850	0.28
	40	983.33	800	0.27
	30	1133.33	933.33	0.31
	20	1136.67	936.67	0.31
4000	50	1083.33	933.33	0.24
	40	1180	1100	0.28
	30	1383.33	1300	0.33
	20	1390	1306.33	0.33

B. Juice Extraction Efficiency

From Table 2 we are able to deduce that the developed machine has juice extraction efficiencies of 88.89 percent for trial one, 83.33 percent for trial two and 86.67 percent for trial three giving a mean accuracy of 86.30 percent. Similarly, the table displays the findings from the three experiments that were carried out to ascertain the

effectiveness of juice extraction on the current engine-type trapiche that small-scale farmers are now using. The trapiche noted the following efficiency for the three trials based on the table: the first trial made 51.87 per cent; the second trial 53.84 per cent and; the third trial 50 percent, and; therefore, the average efficiency for the trapiche was 52 per cent. The results indicate that the engine type trapiche is inferior to the designed juice extraction machine. The proposed machine's juice extraction efficiency is also higher than the results of Gbabo's (2013) comparative analysis for the various trapiches, which showed extraction efficiencies ranging only from 50 to 65 percent.

Table 2. Juice extraction efficiency of the developed sugarcane juice extracting machine and the engine – type trapiche

Type of Extractor	Trial	Mass of Feed (g)	Mass of Juice Extracted (g)	Mass of Wet Bagasse (g)	Mass of Dried Bagasse (g)	Mass of Juice Left in the Bagasse (g)	Juice Extraction Efficiency (%)
Developed Sugarcane Juice Extracting Machine	1	4000	1600	2300	2100	200	88.89
	2	4000	1250	2650	2400	250	83.33
	3	4000	1300	2500	2300	200	86.67
Average		4000	1383.33	2483.33	2266.67	216.67	86.30
Engine – Type Trapiche	1	3000	970	2000	1100	900	51.87
	2	3000	1050	1900	1000	900	53.84
	3	3000	950	2000	1050	950	50
Average		3000	990	1966.67	1050	916.67	52

C. Production Rate

The engine-type trapiche and the produced sugarcane juice extraction machine's output rates in three trials are shown in Table 3. With an average production rate of 55 ml/s, the table showed that the first trial's production rate was 54 ml/s, the second trial's was 56.82 ml/s, and the third trial's was 54.17 ml/s. During the three trials, the current engine-type trapiche produced 20.83 ml/s, 21.62 ml/s, and 21.43 ml/s, with an average of 21.29 ml/s. According to these findings, the created trapiche's production rate is more than twice as high as the engine-trapiche's current production rate. The modified trapiche's output capacity of over 210 kg/hr is significantly higher than the 12.75 kg/hr output capacity found in Olaoye's (2011) study on the development of sugarcane juice extractors for small-scale companies.

Table 3. Production Rate of the Developed Sugarcane Juice Extracting Machine and the Engine – Type Trapiche

Type of Extractor	Trial	Mass of Feed (g)	Volume of Juice Extracted (ml)	Operating Time (s)	Production Rate (ml/s)
Developed Sugarcane Juice Extracting Machine	1	4000	1350	25	54
	2	4000	1250	22	56.82
	3	4000	1300	24	54.17
Average		4000	1300	23.67	55
Engine – Type Trapiche	1	3000	750	36	20.83
	2	3000	800	37	21.62
	3	3000	750	35	21.43
Average		3000	766.67	36	21.29

D. Result of Laboratory Testing

Salmonella and E. Coli bacteria, as well as the metal level of the extracted sugarcane juice from the modified sugarcane juice extraction equipment, were also examined. The Optimal Laboratory, a reputable bacteriological analytical laboratory in the Philippines, tested the material. According to the laboratory test, the juice sample's iron concentration was around 0.27 mg per 100 g of sugarcane. The multiple tube fermentation methodology result showed that the number of E. Coli in the sample juice was less than 3.0 MPN/g. According to the standard detection limit, it demonstrated that the E. Coli bacterium was either absent from the sample or below the detection limit. The findings confirmed that the 25 ml sugarcane juice extract sample was free of salmonella. The conventional approach

has been used to check if the said bacteria are present or not in the sample. The acid digestion method is applied to determine the availability of nickel, copper and chromium content also. In the extracted juice sample, the concentrations of nickel, copper, and chromium were less than 0.02 parts per million, 0.01 parts per million, and 0.015 parts per million, respectively. This indicated that the levels of nickel, copper, and iron were either below the standard detection limit or not identified at all.

VI. CONCLUSION

The sugarcane juice extraction machine's compact design is based on the placement of various components and materials. The majority of the parts are made locally. Based on the system layouts and schematics, the designed sugarcane juice extractor is determined to be safe and operational. The improved sugarcane juice extractor's feed mass and working speed are significantly higher than those of the current trapiche. Additionally, because the modified sugarcane extracting machine's average production rate and extraction efficiency are higher than those of the trapiche currently in use in Western Batangas, the improved sugarcane extractor is dependable and efficient. Additionally, the juice from the modified sugarcane juice extraction equipment is devoid of metals, including nickel, copper, and chromium, and is safe against Salmonella and E. Coli germs.

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