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Development of a Saccharum Officinarum Juice-Extracting Machine for National Health Improvement and Economic Sustainability

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Abstract:

Direct consumption of refined sugar in many foods causes diabetes. The use of teeth to extract the juice could harm the gums and break the teeth; unfortunately, a limited quantity is extracted. Saccharum officinarum is the botanical name for sugarcane. It is a species of tall, perennial grass that is cultivated everywhere in the globe to produce refined sugar, sugarcane juice, and medicinal products for a series of diseases. A sugarcane juice extraction machine was designed and successfully fabricated to improve the health status of citizens and promote economic sustainability. The performance of the fabricated sugarcane juice extracting machine was evaluated. The design showed an isometric view, and the fabrication revealed a pictorial image of the extracting machine. The crushing, squeezing, and pressing force was effective on the sugarcane in extracting the juice from the saccharum officinarum. The results showed that an average bagasse weight of 313.77 g was produced when an average weight of 408.5 g of juice was extracted from a sugarcane of 772.2 g in an average time of 19.3 seconds. The efficiency of the juice extracting machine is 56.3%. The juice extraction could be commercialized to meet a wider production for national health benefit, economic development, and sustainability.

Keywords — **Crushing, extracting, health, juice, machine, saccharum officinarum**

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I. INTRODUCTION

Saccharum officinarum is the botanical name for sugarcane. It was an ancient crop of the Austronesian and Papuan people. Sugarcane is a species of tall, perennial grass that is grown in places around the globe to produce refined sugar, sugarcane juice, and medicinal products for different types of ailments [1]. It was also made known to southern China and India by Austronesian traders around 1200 to 1000 BC. The Persians and Greeks come across the renowned "reeds that produce honey without bees" in India between the sixth and fourth centuries BC, accepted and then spread sugarcane agriculture [2]. Merchants started to trade in sugar, which was known to be a luxurious and costly spice, from India. In the 18th century, sugarcane plantations started in the Caribbean, South America, the Indian Ocean, and Pacific island nations. Sugarcane juice is used to produce bioethanol and biofuels. The sugarcane-delivering nations in tropical Africa consist of some countries including Nigeria [3]. The necessity for sugar crop labourers became a main driver of large movements; some persons willingly accepted indentured slavery, and others were forcibly imported as slaves [4].

The sugarcane plant is the normal name of a type of spices having a place with the grass family (Poaceae). Sugarcane gives a high measure of energy for nourishment, with zero content of fat, cholesterol, fiber, and protein, yet contains sodium, potassium, calcium, magnesium, and iron for both animals and people. It represents around 62% of the total world's sugar, while just 38 % is delivered from beet [5]. After extraction, the sugarcane fiber

plant is called bagasse [6]. Sugarcane develops regularly up to the stature of 6 meters having bunched up, barrel shaped, strong, jointed, stringy stalks of 1.25 cm to 7.25 cm measurement [7]. Natural sugarcane juice is used to treat jaundice, urinary tract problems, and inflammation, aids digestion, and improves liver functions [8]. There are more than seven significant classifications and species of sugarcane found around the globe [9] [10]. Half of the sugarcane planted in the nation is utilized for the creation of sugar, 40 % for jaggery and khandsari making, and 10 % for seed and chewing purpose. Nigeria, which is situated inside the equatorial area has tremendous possibilities for sugarcane development.

Nigeria, being one of the main makers of sugarcane, has a land capability of in excess of 500,000 hectares of a reasonable sugarcane field. Nigeria has huge human and regular assets (land and water), to deliver sufficient sugarcane, not exclusively to fulfill the country's prerequisite for sugar and bio-powers yet additionally for exporting. The yield is generally developed in the Northern territories of Nigeria, where water system is promptly accessible. Because of the good environment of Nigeria, the sugarcane plant has developed greatly, and one would have anticipated that Nigeria should be a tremendous exporter of sugar due to high cultivation of sugarcane yet this isn't so as of now [11]. Sugarcane is additionally utilized for the development of sugar by removing a solid juice. The desire to drink the juice presently is diminished, as it is hard to track down a perfect and fitting interaction during juice make. The amount of the separated juice produced from the customary way won't be sufficiently adequate. The current upsurge of interest in the generation of biofuels from plant material has demanded current waves of desire in the partial mechanization of cane juice extraction in addition to the manufacturing of bio ethanol for domestic and industrial uses [12].

The machines used for the extraction of sugarcane juice in ancient times are known as the trapiche and the stone sugarcane roller. Atrapicheis amillmade of wooden rollers used to remove juice from fruit, originally olives, and since the Middle Ages, sugarcane as well. The stone parts looked like a stone sugarcane crusher. The sugarcane juice extractor has been evolving for 1800 years. Most common machines are made from cast iron, which causes corrosion of the material using simple mechanisms of rolling and crushing [13]. During the medieval historical time, sugarcane stone crushers were products of two fragments - a mortar and a pestle. Indians knew the process of extracting sugarcane juice to make jaggery and sugar since the early times [6].

Many machines that were privately manufactured and accessible in the market are utilized for extracting sugarcane juice from the cane. However, this machine comes with some challenge. The rollers are sufficiently able to separate juice from sugarcane when the wheel is pivoted physically. Taking these reports into consideration, the sugarcane extraction machines that have been fabricated to deliver hygienic juice, with an increase in the extraction effectiveness of juice, consuming less of energy drink. The traditional, mechanically driven sugarcane crushing units used in the Jaggary industries need high energy with less productivity and contamination in operation.

The use of teeth to extract the juice could harm the gums and break the teeth, and a limited quantity is extracted. The desire to drink the juice presently is reduced as a result of biting with their teeth and chewing the internal tissue for sucking juice at a consumption rate and difficulty of finding a hygienic and suitable method of extracting the juice, which result to mouth injuries. Sugarcane is mostly sold by the roadside fill with dust and germs, and the waste product called bagasse is used to litter the environment, causing land pollution. A sugarcane juice extractor is used to extract sugarcane juice from the stalk.

The currently available sugarcane juice extractors require high energy and sophisticated mills, driven mechanically. The concept of this work is to design and fabricate a sugarcane juice extracting machine for extracting sugarcane juice that will be consumed to improve the health status of the citizens.

II. MATERIALS AND METHOD

The selection of materials was done with the consideration of the purpose of the extracting machine. Suitable materials were utilized for the fabrication of the juice extracting machine. The machine was used for food processing; hence, a high-grade stainless steel was used for the fabrication to avoid rusting and food contamination. High-grade stainless steel was used for the crushing rollers. An electric motor of 3 KVA was used to provide the crushing torque to the rollers. The electric motor could be powered by electricity or a gasoline generator.

A reducing gear box was utilized to decrease the speed of the electric motor with a ratio reduction of 1:20. The electric motor is a single-phase electric motor; hence, it could be powered anywhere by the generator. The selection of a single-phase electric motor was to enable the mobility of the machine and make it available anywhere the service is needed. The juice collector is a stainless-steel container. The machine has a gear train that rotates the rollers for crushing of the sugarcane and effective extraction of the juice. A sieve of 100 microns was used for removing the crumps of the bagasse. The cutting machine was used to cut the materials into the right dimension. The materials that needed shaping were shaped properly.

Drilling of materials was carried out with precision. The machine frame was fabricated accordingly using the designed dimensions. The gears train was positioned and the crushing rollers were fixed on the gear train. The alignment was tested to ensure smoothness in rotation. The electric motor was positioned, and the base was firmly welded to the machine. The electric motor was connected to the rollers, and both the alignment and rotation were tested. The sugar cane was inserted in between the rollers to crush the sugarcane and extract the juice from it. The rollers crushed the sugarcane and extracted the juice from the sugarcane.

A. Crushing Force of the Roller

$Fc = Mr \times Sf$

Where:

Fc is the crushing force of the machine roller.

Mr is the mass of the roller.

Sf is the safety factor

Thus:

$Fc = 54.6 \times 1.6$

$Fc = 87.36$ N

B. Torque of the Crusher

$T = Fc \times r$

Where:

T is the torque

Fc is the crushing force of the machine rollers.

r is the radius of the crushing rollers.

$T = 87.36 \times 0.135$

$= 11.8$ Nm

C. Selection of Power for the Motor

$P = T \times \omega$

Where:

P is the power transmitted to the crusher.

ω is the angular velocity

Since,

$\omega = 2\pi N/60$

Where:

N is the speed of the electric motor in revolution per minutes (rpm)

$\omega = 2 \times 3.142 \times 2460/60$

$= 257.64$ rad/sec

$P = T \times \omega$

$= 11.8 \times 257.64$

$= 3040.2$ Kw

An electric motor of 3 KVA was selected for the extracting machine.

III. RESULTS AND DISCUSSION

The literature review carried out revealed that a sugarcane juice extracting machine was necessary to extract the juice for the consumption of the juice

to promote good health among the citizens. The design and construction of the sugarcane juice extracting machine also prevented the stress and discomfort of chewing the sugarcane and the occasional injury to the teeth and mouth.

The design showed an isometric view, and the fabrication revealed a pictorial image of the extracting machine. Physical observation of the operation of the sugarcane extracting machine showed the crushing, squeezing, and pressing effect of the machine on the sugarcane to extract the juice. The crushing force was effective on the sugarcane in extracting the juice. The knurled profile on the rollers was effective in pulling the sugarcane to pass through the two opposite rollers that rotate in the opposite direction. The dimensional characteristics of the sugarcane specimen are given in Table 4.1.

Table 4.1: Dimensions and weight of the sugarcane specimens

Sugarcane specimen	Head diameter (mm)	Middle diameter (mm)	Tail diameter (mm)	Average diameter (mm)	Length (mm)	Weight (g)
A	51	55	52	53	1587	604.5
B	52	57	54	54	1608	756.4
C	53	60	54	57	1684	805.8

The results of the performance evaluation tests showed that three sugarcane specimens were tested. The length of the specimen was 1587, 1608, and 1684 mm. The weights of the sugarcane specimens were 604.5, 756.4, and 905.8 g. The results showed that an average bagasse weight of 313.77 g was produced when an average weight of 408.5 g of juice was extracted from the sugarcane in an average time of 19.3 seconds. The efficiency of the juice extracting machine is 56.3%.

Table 4.2: Results of performance evaluation test

Sugarcane specimen	Length (mm)	Initial weight (g)	Bagasse weight (g)	Weight of juice extracted (g)	Extraction efficiency (%)	Extraction time (sec)
A	1587	604.5	278.1	326.4	54	17
B	1608	756.4	332.8	423.6	56	19
C	1684	805.8	330.4	475.4	59	22
Average	1626.33	772.2	313.77	408.5	56.3	19.3

Fig. 1 shows the front view of the sugarcane juice extracting machine.

Fig. 1 Front view of the fabricated juice extracting machine

Fig. 2 shows the side view of the sugarcane juice extracting machine.

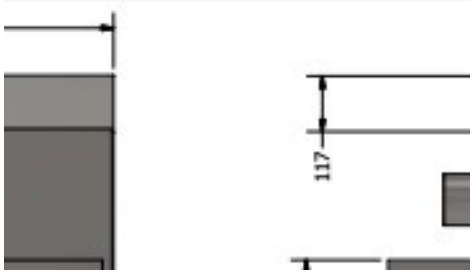

Fig. 2 Side view of the fabricated juice extracting machine

Fig 3 shows the rollers and the extracting mechanism.

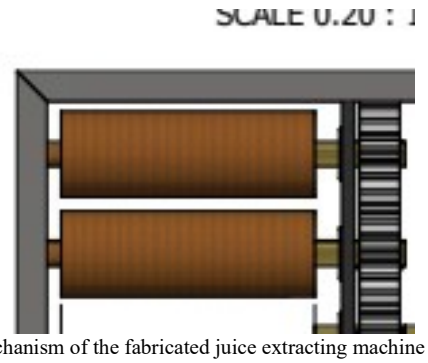

Fig. 3 Extracting mechanism of the fabricated juice extracting machine

IV. CONCLUSION

A sugarcane juice extracting machine was designed and successfully constructed. The aim of executing the project was to design and construct a sugarcane extracting machine to encourage the consumption of the juice and improve the health status of the citizens. The performance of the fabricated sugarcane juice machine was evaluated. Some sugarcane sample specimens were crushed, and juice was extracted. The results showed that the juice extracting machine performed satisfactorily. The juice extraction could be commercialized to meet a wider production for national health benefit, economic development, and sustainability.

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