Development of Ginger Juice Extractor

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ABSTRACT

A small scale motorized ginger juice extractor was designed and fabricated, using locally-available construction materials. The essential components of the machine include feeding hopper, ginger grinder, screw conveyor, strainer, pulley and transmission belt, electric motor, base and stand. In operation, the ginger will be fed through the grinder to reduce its size. Then, the worm shaft or screw conveyor conveys, crushes, presses and squeezes the grinded ginger to extract the juice. The juice extracted is filtered through the juice sieve into juice collector while the residual waste is discharged through waste outlet. Result showed that for every 1 kg of ginger the average juice yield was 80 ml. Powered by a 0.5 hp electric motor, the machine has a capacity of 1/2 kg/min. With a machine cost of about P45 000, it is affordable for small-scale ginger farmers in the rural communities.

Key words: *feeding hopper, ginger grinder, screw conveyor, strainer, pulley and transmission belt, electric motor, base and stand*

INTRODUCTION

Human awareness to health is given importance due to the-needs of the body for its daily activities. Many food supplements are available to support our body for its changing needs and one of this is ginger. Ginger juice may be extracted by boiling the herb with water.

According to Ibrahim (2006), ginger is a very useful herb plant which is said to be originated from India, China and Java, yet is also native to Africa and the West Indies. It is grown throughout the tropical areas of the world and also commonly found in South East Asia especially in Indo-Malaysia. Ginger is an herb that is used as a spice and also for its therapeutic qualities. The underground stem (rhizome) can be used fresh, powdered, dried, or as an oil or juice. Ginger is part of the Zingiberaceae family, as are cardamom, turmeric and galangal.

Ginger has been used for a few purposes during the early times. It is started to be used as medicine since many years ago. It is widely used as a cooking herb, condiment, spice and home remedy for a long time ago (Ibrahim, 2006).

Traditionally, ginger juice is produced by boiling the herb with water. To lessen the work and time, a juice extractor may be used. Juice extractor is a machine that mechanically separates juice from the solid part (pulp) of most fruits, vegetables, leafy greens, and herbs. The pulp can also be used in muffins, breads and ~~or~~ composting, but most of the time it is discarded.

Badmus and Adeyemi (2004) designed and fabricated a small scale whole pineapple fruit juice extractor. The machine consists of beater blades and a shaft in conjunction with a powered screw pressing mechanism. The machine successfully processed 12 kg of ripe pineapple fruit into 8 L of pineapple juice.

Ishiwu and Oluka (2004) developed and carried out performance evaluation of a juice extractor as a function of its extraction efficiency. The extractor consisted of screw jack, frame,

connecting screw rod, pressing mechanism, interlock, feeding pot, receiving pot and discharge mechanism. Performance tests revealed a juice yield, extraction efficiency and extraction loss of 76, 83 and 3%, respectively.

The work principle of a Juice extractor is the juice is collected in the cup through the strainer lid. Also, the pulp and skin is pushed out of the nozzle. Nozzle is used to separate pulp and collect juice at the same time and strong suction base keeps unit steady as you turn handle ("7 Types of Juicers", n.d.).

Screw conveyors are used to convey any type of bulk material and are found in thousands of applications. Screw conveyors are volumetric conveying devices. Each revolution of the screw discharges a fixed volume of material. The purpose of a screw conveyor is to transfer product from one point to the next. Screw conveyors are always control fed at the inlet by another conveyor or metering device. Rotary valves, screw feeders, belt conveyors, shredders, or even other screw conveyors typically connect to the inlet of a screw conveyor ("Screw Conveyor Advantages", n.d.).

Screw conveyor is a mechanism whose working member is a shaft with a continuous helical blade (the screw) or individual, pitched vanes. The rotating shaft, housed in a horizontal or inclined trough moves loose or small piece cargoes or liquids along the trough. Feeding is regulated by the frequency of rotation of the screw. A screw conveyor was used in Archimedes' screw, a device designed to raise water. Screw conveyors in which the screws of two adjacent machines rotate in opposite directions are used to mix materials ("Screw conveyor", n.d.).

There are some advantages of screw conveyor like that it can be used as a mixer or agitator to blend dry or fluid ingredients, provide crystallization or coagulant action or maintain solutions in suspension. They are compact and easily adapted to congested locations. They can be set up as Screw Feeders to control the flow of material in processing operations which depend upon accurate batching. Screw Conveyors can be sealed for dust free and vapor tight requirements ("Conveyor Engineering", 2014).

According to Olaniyan (2010), the traditional method used in expressing ginger juice is usually a manual process and involves pounding with mortar and pestle and hand pressing. This process is inefficient, unhygienic and tedious. These have affected the quality and quantity of ginger extract available in the market in Nigeria. Ginger juice obtained from mechanical expression of pulverized ginger rhizomes offers a value added ginger product which will increase market opportunity for farmers.

Nowadays, the common type of belt that are used in typical juice extractor is a V-belt. The advantages of V-Belt are it gives compactness due to the small distance between centers of pulleys. Also the drive is positive, because the slip between the belt and the pulley groove is negligible. Since the V-belts are made endless and there is no joint trouble, therefore the drive is smooth. Lastly, it can be easily installed and removed ("Advantages and Disadvantages of V-belt drive", 2013).

Some conveyor has a screw thread to pull out the dregs out of the casing. A screw thread is defined as a ridge of uniform section in the form of a helix on either the external or internal surface of a cylinder. Internal threads refer to those on nuts and tapped holes, while external threads are those on bolts, studs, or screws. The thread form is the configuration of the thread in an axial plane; or more simply, it is the profile of the thread, composed of the crest, root, and flanks. At the top of the threads are the crests, at the bottom the roots, and joining them are the flanks. The triangle formed when the thread profile is extended to a point at both crests and roots, is the fundamental triangle ("Screw Thread Design",n.d.).

The main part of a typical ginger juice extractor is the screw conveyor. Screw conveyor,

also known as spiral and worm conveyors, screw conveyor is used to transport materials along a plane. Screw conveyors consist of a helical screw element that rotates around a central shaft, driving the work material according to the screw design and rotational direction. The helical screw functions within a casing, trough or compartment in order to take full advantage of the rotational force. Squeezers are also used to press hard or to compress together. Also it is used to exert pressure on, as by way of extracting liquid (Thomas, 2015).

OBJECTIVES

The main objective of the study is to design and construct a ginger juice extractor machine that is capable of extracting ginger juice from ginger. Specifically, the study aimed: (1) to design and fabricate a prototype of ginger extractor with the following components: feeding hopper, ginger shredder, screw conveyor, strainer, pulley and transmission belt, electric motor, and base and stand; (2) to extract the juice from the ginger; (3) to evaluate the prototype in terms of: quality of extracted juice, speed of extraction, ease of operation and provision for cleaning.

MATERIALS AND METHODS

Research Design

This research used the experimental and descriptive methods of research. According to Sanchez (1998), the descriptive method is a general procedure employed in studies that have their chief purpose description of the phenomena. The description of the existing problems encountered in the library in relation to its application for accreditation and general usage, its facilities, standard used, researches and survey of the proposed place to be conditioned were therefore the primary tasks of this study. Experimental method was applied during which the researches devoted their time calculating the peak loads of their target site. It was the time when researches employed research strategies away from the laboratory conditions. Experimentations were done to come up with the specific designs to improve the extraction of ginger juice.

Design Phase

The researchers studied the existing design, analyzed the parts and functions of the existing design, designed the machine and its parts, lay-out the plan with dimensions and material's specifications and revised the documents.

Preliminary Investigation Phase

The researchers conducted research on existing ginger juice extractor's design and operation and materials for the fabrication and parts of the ginger juice extractor.

Description of the Ginger Juice Extractor

Fig. 1 Ginger Juice Extractor

Figure 1 shows the final design of the Ginger Juice Extractor. It is 24 inches long, 18 inches wide and 38 inches tall. The machine consists of main parts like the conveyor and shredder. Also it has hopper, pulleys, and combination of shafts, strainer, belt, casing and electric motor.

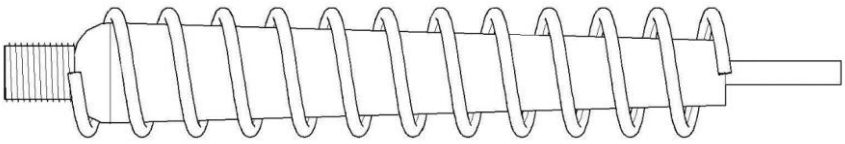

Fig. 2 Screw type Conveyor

The screw type conveyor as shown on Figure 2 was made from pure stainless steel. Stainless steel does not rust or corrode that makes it ideal for food handling. The worm shaft was fabricated from a stainless steel rod from a diameter of 1.4 inches and proportionately increasing to a diameter of 1.75 inches. Stainless steel 3/8 inches square bar wrought around the shaft to serve as the screw. It has 12 pitch across the root diameter of the shaft. The length of screw conveyor alone is 11.25 inches.

Fig. 3 Shredder

Like the screw conveyor, the shredder shown on Figure 3 is also made from the stainless steel for food handling. The design of shredder in the prototype was a male and female shredder. The spikes of male shredder are mating the spikes of female while it is rotating. The fresh ginger will fed to this shredder to reduce its size thus it will pass across the conveyor and will be pressed easily.

Fig. 4 Hopper

As shown in figure 4, the shredder is strategically mounted inside the hopper. The hopper is a stationary part mounted onto the machine which forms the feeding chute through which small ginger rhizomes are fed into the pulverizing unit by gravity. It is also used for food handling, so the material used is stainless steel. The size of the upper part of the hopper is 7in by 7.75in and the lower part is 4in by 4in. The researchers believe that these particular sizes are large enough to prevent choking of their product.

Fig. 5 Pulley

Pulleys as shown on Figure 5 are used in transmitting motion from the motor to the drive shaft and it is flexible that can transmit motion over distances. The size of pulley at the motor, conveyor and shredder are 2inches, 4 inches and 2 inches respectively.

The design of the V belt is computed as follows:

Pulley and belt:

For a V–belt to overcome slippage during power transmission, the maximum permissible ratio of diameter of shaft pulley to that of electric motor is 2:1 [8]. Therefore, the speed of worm shaft was determined from the following equation as:

$N_1 D_1 = N_2 D_2$

$(1740)(2) = N_2(4)$ (1)

$N_2 = 870\ rpm$

where, N1 is the rated speed of the motor in rpm, N2 is the speed of the worm or screw conveyor shaft in rpm, D1 is the diameter of the motor pulley in inches and D2 the diameter of the shaft pulley in inches. Given that N1 = 1740 rpm, D1 = 2 in and D2 = 4 in, hence N2 = 870 rpm. The required speed of the worm shaft is 870 rpm.

From table shown from APPENDIX A, the driving machine is a single phase electric motor and the driven machine is a conveyor, then the service factor N_{sf} = 1.6.

Design horsepower is the amount of work that a motor can do per unit time. It is needed to know the type of belt that should be used.

$Design\ horsepower = Nsf\ x\ HP$ (from Design of Machine Elements by Faires (1968)

$Dhp = 1.6\ x0.5$ (3)

$Dhp = 0.8\ HP$

$Vm = belt\ speed$

$Vm = 2\pi rN$

$Vm = (1740\ rpm)(\frac{2\pi c}{1\ rev})(1in)(\frac{1\ ft}{12\ in})$

$Vm = 911.062\ fpm$

With Dhp = 0.8 HP and $N_{small\ sheave}$ = 1740 rpm, Use type A V-belt.

Basically V-belts are classified into 5 types or sections i.e. ‘A’, ‘B’, ‘C’, ‘D’ and ‘E’. The categorization of this is based on the cross sectional size of the belt and the amount of power to be transmitted by the belt.

According to Faires (1968) the length of the transmission belt was calculated using Equation 4

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \qquad (4)$$

where, C and L are the center-to-center distance and length of the belt, respectively in inches(in). With C = 18.75 in, this center distance is enough to place the motor below the worm shaft, D1 = 2 in, D2 = 4 in and π = 3.142, $L = 2(18.75) + \frac{\pi}{2}(4 + 2) + \frac{(4-2)^2}{4(18.75)}$

$L = 46.978$

hence L = $46.978\ in$

The available standard V-belt pitch length are 43.3 for belt number A-42 and 47. 3 for belt number A-46. Because there is no available pitch length of belt number A-45, the researchers interpolated the value of the pitch length for A-45 and got the value equal to 46.3.

So the center distance will be adjusted,

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C}$$

$$46.3 = 2C + \frac{\pi}{2}(4 + 2) + \frac{(4 - 2)^2}{4C}$$

$C = 18.41\ in$

Hence C = 18.41 in

Therefore, use a V-belt of specification A-45, pitch length equals to 46.3

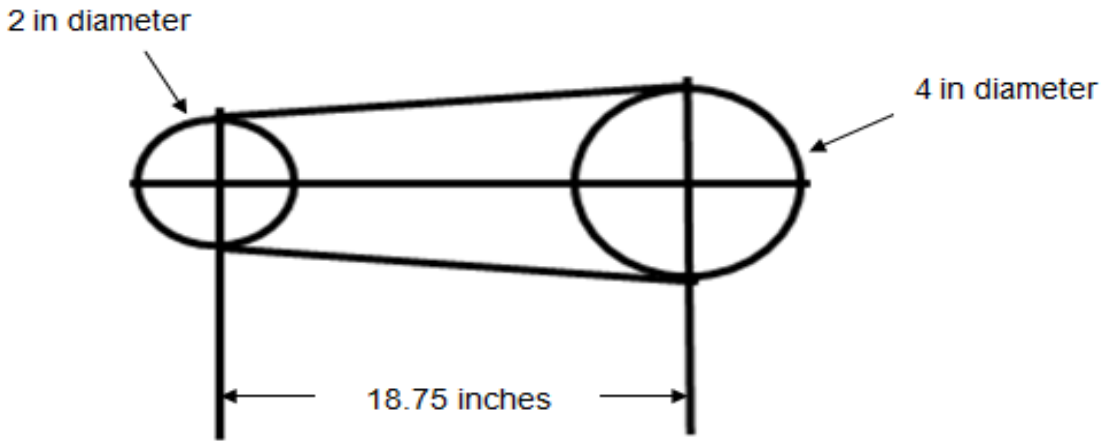

Fig. 6 Free Body Diagram of Belt

Fig. 7 Strainer

As shown on Figure 7, the strainer is made of pure stainless steel. The cylindrical strainer inside the casing is 10.25 inches length, 2.4 inches inside diameter and 2.84 inches outside diameter. The researches confirmed through experimentation that these dimensions are effective for proper separation of juice from dregs of ginger.

A ½ hp single phase electric motor is used to drive the rotating parts of this machine as shown in figure 8. The motor has a speed of 1740 rev/ min. The input is applied by means of the V-belt and pulley described earlier. The speed from the engine is reduced by the pulley. The pulley now transmits this reduced speed to the conveyor then increased the speed when transmitting rpm to the shredder by means of small pulley.

In determining the torque for the horsepower to be used in the Ginger Juice Extractor, the researchers used a lever and spring balance. The researchers placed the one side of the lever to the motor shaft and they put a spring balance under of it. The lever is 1.5 ft long and the force obtained on the spring balance is 0.87 lb. Hence,

The torque is equal to 1.5 ft x 0.87 lb = 1.305 ft-lb.

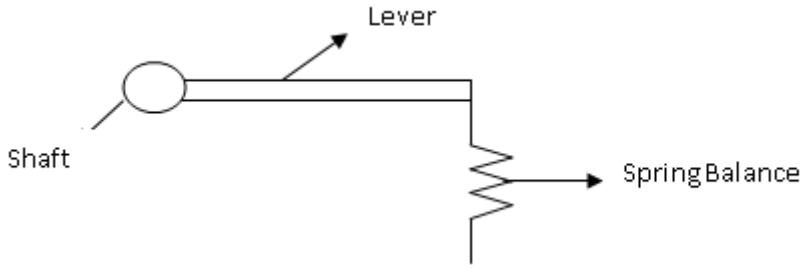

Fig. 9 Free Body Diagram of the measurement of Torque

Power is the rate at which electrical energy is converted to another form such as motion. It is given by the formula $P = 2\pi TN$ where T is the torque and N is the number of revolution per minute.

$P = 2\pi TN$

$P = 2\pi(1.305\ ft - lb)(1740\ rpm)$

$P = 0.432340269\ Hp$

The horsepower of the motor that is available to the market is 0.5 Hp. The horsepower to be used in the Ginger Juice Extractor is 0.5.

Fig. 10 The extractor frame

The two design factors considered in determining the material required for the frame are weight and strength. The weight of an object is the force measured by the operation of weighing it, which is the force it exerts on its support. The strength is the capacity of an object to withstand great force. The frame as shown on Figure 10 was constructed with 19 9/16 height, 17 13/16 width and 23 ¾ length. This part is mainly made with mild steel and angle bars.

Operation

1. Before assembling the machine parts, make sure that the machine and its parts are clean and free from any debris or dust.
2. Place a cup under the spout of the machine for collecting the juice.
3. Plug in the machine into 220volts power source.
4. Raise the hopper cap to feed the ginger into the hopper. The ginger must be in small sizes. To reduce its size, break the ginger by your hands.
5. Before turning on the switch, make sure that the machine is in safe condition. Remove all the debris that can trip the machine and make sure the bolts are tightened properly. Turn on the switch. And wait until the juice runs out the spout.
6. You can add ginger into the hopper with a rate of 1/2kg/min.
7. When you're done extracting the ginger juice, turn motor off and unplug wiring. Unbolt the screws and clean the parts by washing it with water.

RESULTS AND DISCUSSION

The researchers conducted series of experiments to analyze the Ginger Juice Extractor. On the first experiment, the researchers used screen in the shredder section. This screen located below the conveyor has very small holes. The screen serves as a barrier so only small grinded ginger will pass through the conveyor. When 1 kg of fresh ginger was placed in the shredder, the screen blocks the grinded ginger. The grinded ginger cannot pass through it because it has larger size than the

screen holes. The grinded ginger maintained only at the shredder. As a result, there was no juice extracted from the ginger.

The researchers decided to remove the screen below the shredder for the ginger to pass through the conveyor. On the second experiment, another 1 kg of fresh ginger was used. Figure 12 shows that although the gingers pass through the conveyor, it cannot get across the conveyor because the grinded ginger is big. The gingers just stuck in the middle of the conveyor so it cannot be compressed on the outlet of the juice.

Also, when the gingers are placed inside the shredder, some of the gingers just stuck in it or just bounce inside because of the angle in the hopper. As a result, there was still no juice extracted from the ginger. The researchers decided to add a steel plate on the two sides of the hopper to reduce the clearance on the walls of the hopper and the shredder.

After the improvement of design on the clearance inside the hopper, the researchers tested another 1 kilogram of fresh ginger. Even when improvements were done, the ginger that goes through the shredder is still large. The conveyor cannot transfer the ginger to the outlet because of the size of the ginger. Its tendency is to stop rotating because the ginger stuck inside the conveyor. Also, in the third experiment there are still no juices extracted from the ginger.

The size of the ginger is still large so the researchers decided to develop the shredder by adding a female shredder. This will help to reduce the size of the ginger entering the conveyor so that there will be grinded ginger to be compressed in the end of the conveyor.

On the fourth experiment, another 1 kg of fresh ginger was used; the male and female shredder crushed the gingers very well. The design of male and female shredder was efficient because almost all of the gingers that were placed in the hopper are grinded. Also, all of the grinded gingers were transported to the conveyor.

The grinded gingers were compressed in the end of the conveyor but the juice is going out on the outlet of the dregs. There is extracted ginger juice but it is not totally compressed. Only few juices were extracted from the ginger.

On the fourth experiment, the researchers found out that there are gingers going out at the end of conveyor that are not compressed well because the clearance in the outlet of the dregs are huge. The researchers decided to reduce the clearance so that the dregs of the ginger will not go out and be compressed.

After the reduction on the clearance in the outlet, the researchers conducted the fifth experiment and another 1 kg of fresh ginger was used. The grinded ginger goes through the conveyor and the conveyor transferred the grinded gingers at the end of the conveyor, however, the juice that has been extracted was going out of the dregs inlet instead of going to the outlet of the ginger juice.

There was little amount of ginger juice that was extracted. The researchers develop the design at the end of the conveyor with cone-shaped steel that will help in the compression of the grinded ginger. A screw thread was also added at the end of the conveyor to pull out the dregs of the ginger.

After the improvement at the end of the conveyor, on the sixth experiment, another 1 kg of fresh ginger was used. The grinded ginger was compressed well because of the cone-shaped steel and the juice extracted is going out on the proper outlet of the juice. Also because of the screw thread at the end of the conveyor, the ginger was pulled-out from the outlet of the dregs.

Even though the dregs that are going out are moisturized, it can't be extracted because of its sticky texture. The researchers concluded that the proper design for the ginger extractor contains a male and female shredder, screw conveyor with increasing pitch, a cone-shaped steel and screw

thread at the end of the conveyor.

Table 1. Amount of Extracted Ginger Juice

Experiment #	Ginger (in kilograms)	Juice extracted (in mL)
1	1 kg	0 mL
2	1 kg	0 mL
3	1 kg	0 mL
4	1 kg	15 mL
5	1 kg	25 mL
6	1 kg	60 mL

As shown on Table 1, on the first, second and third experiments, no juice were extracted even after improvements were done in the shredder. Using 1 kg of fresh ginger, 0 mL of ginger juice was extracted. On the fourth experiment, using 1 kg of fresh ginger, 15 mL of ginger juice was extracted after developing the design of the shredder. In experiment no. 5, 25 mL of juice was extracted from 1 kg of fresh ginger after reducing the clearance at the outlet of the dregs. On the sixth experiment, 26 mL of juice was extracted from 1 kg of fresh ginger after the improvement of the design at the end of the conveyor.

CONCLUSION

In this study, the researchers fabricated a Ginger Juice extractor that is 24 inches long, 18 inches wide and 38 inches tall. The machine is composed of its major component; the feeding hopper is made of stainless steel. The size of the upper part of the hopper is 7in by 7.75in and the lower part is 4in by 4in. The ginger shredder is also made from stainless steel for food handling. The design of shredder in the prototype was a male and female shredder. The spikes of male shredder are mating the spikes of female while it is rotating. The screw type conveyor is made from pure stainless steel. The worm shaft was fabricated from a stainless steel rod from a diameter of 1.4 inches and proportionately increasing to a diameter of 1.75 inches. Stainless steel 3/8 inches square bar is wrought around the shaft to serve as the screw. It has 12 pitch across the root diameter of the shaft. The length of screw conveyor alone is 11.25 inches. The strainer is made of pure stainless steel because of its ability to handle food materials without getting them contaminated. The cylindrical strainer inside the casing is 10.25 inches length, 2.4 inches inside diameter and 2.84 inches outside diameter. The size of pulley at the motor, conveyor and shredder are 2inches, 4 inches and 2 inches respectively. And a V-belt of specification A-45, pitch length equals to 46.3 is used in this prototype. A ½ hp electric motor is used in this machine. The motor has a speed of 1740 rev/ min. The base and stand were constructed with 19 9/16 height, 17 13/16 width and 23 ¾ length. This part is mainly made with mild steel and angle bars.

The machine can separate the juice from the dregs because of the screw thread at the end of the conveyor. The fibers of the grinded gingers loop around the threaded screw until it goes out in the outlet. This will prevent the gingers to be stuck inside the casing. The machine can extract 26 mL of ginger juice from 1 kilogram of fresh ginger.

The machine is easy to operate. The quality of the extracted juice is guaranteed clean and safe to drink because stainless steel is used to extract the juice. The machine has a capacity to extract juice from 1/2 kg of fresh ginger per minute.

RECOMMENDATIONS

The researchers recommend the following: (1) the shredder inside the hopper maybe modified for proper grinding of the ginger, (2) more experiment on the speed of the screw conveyor to determine the more effective compression, (3) thorough examinations of the noise and vibrations coming from somewhere may improve the efficiency of the machine.

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