PERFORMANCE EVALUATION OF A MANUALLY-OPERATED BANANA SLICER FOR SMALL SCALE FOOD PROCESSING INDUSTRIES

Consorcio S Namoco Jr, Cerilo Buna Jr

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Consorcio S. Namoco Jr.* **and Cerilo Buna Jr.**

College of Technology, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines

*Corresponding author's email: consorcio.namoco@ustp.edu.ph

ABSTRACT: *The study aimed to develop and evaluate a manually operated banana slicer to be utilized by small-scale food processing industries. The banana slicer is designed to be portable, heavy-duty and safe. The device is composed of angle bars, hand crank, pillow blocks, flange bearings, shafting, bevel gear, cover plate, turntable, cutter blade and stainless tube as a feeder or chutes. After the prototype development, it is then subjected to performance evaluation with regards to its capacity, the weight of good cuts, the weight of rejects and slicing efficiency. The average capacity of the portable banana slicer was observed to be about 60kg/h when operated by a two-blade cutter at 120 rpm. It was also observed that the effective capacity of the device increased with an increase in the number of blades at all operating speeds. Similarly, as the rpm of the cutter plate was increased there was an increase in the effective capacity of the slicer. The slicing efficiency obtained is 90-96% at a cutting speed of 120 rpm. Hence, based on the evaluation conducted, a cutting speed of 120 rpm and a two-blade cutter should be employed to attain an optimum capacity of 60 kg/h with excellent slicing efficiency. The best chip geometry is also obtained at this speed. With this manually operated banana slicer, it is expected that backyard and small-scale banana processing industries will be enhanced in terms of productivity and product quality.*

Keywords: banana, manually-operated slicer, slicing efficiency, effective capacity, small scale food processing industries

1. INTRODUCTION

Banana is a tropical plant that requires a warm humid climate. It can grow successfully at sea level to an altitude of 1,500 m. A mean temperature of 26.7 degrees Celsius and rainfall of 100 mm/month is satisfactory for its cultivation. Deep, well-drained, friable, loamy soil and adequate organic matter is the ideal condition for its cultivation [1] (Sonawane, *et al.*, 2011). Banana provides a well-balanced diet compared to any other fruits and satisfies the definition of good food which is easily digested and absorbed in our body. It is composed of several varieties and is one of the most popular fruit in the Philippines, which is a relatively inexpensive staple food. It is consumed both as ripe fruit and raw fruit and in processed form. Banana is one of the common snack foods of every Filipino people especially the Philippine banana of Saba variety.

Banana processed products such as wafers/chips are gaining wide popularity. There is tremendous scope for the banana processing unit to flourish further with increased acceptance of snack foods. Banana chips are one of the Philippines ' demand snack foods in the market today, the chips are produced from under-ripe bananas of which thin slices are deep-fried in vegetable oil which are then dried. Banana chips can be covered with sugar to have a sweet taste or they can be fried in oil together with spices and have a salty or spicy taste. Nutrition findings said that a banana chip is a healthy snack and aside from its nutritional benefits it is safe to eat than junk foods and other snack chips [1].

In the production of banana chips, a slicing device is needed to produce rippled and plain chips. There is an existing banana slicing machine that is motor-operated [2 - 7]. Normally, only banana chip factories can only afford to acquire them due to the high cost involved. These banana slicer machines utilize ½ HP for single heads and 1 HP 3 phase motor for twin heads. Aside from the cost, these slicing machines cannot be carried or transferred easily owing to their heavy weight.

For the backyard or small-scale banana chips processing industry, procuring a motorized slicing machine is quite difficult for them due to the inherent cost of the machine as well as the electricity cost involved during production. Hence, they resorted to the traditional way of slicing the banana manually using slicers or knives. Such practice is very time-consuming. Traditional slicing of banana chips may also result in uneven thickness of the chips which consequently affects the quality of the finished product. Moreover, handling during cutting or slicing may also result in food contamination. All these limitations will result in low productivity and quality of the product.

Aiming to address these concerns, a manually operated banana slicing device is designed and developed. The device functioned similarly to a motorized slicer. Instead of using an electric motor, a hand crank is designed and developed which drives the shafting connecting to the turntable and cutter blade during slicing operation. Such manually operated banana slicing device is intended to help the backyard and small-scale banana processing industries who cannot afford to purchase a slicing machine that is motor-operated in increasing their productivity and quality. In this paper, the performance and efficiency of this newly developed manually operated banana slicing device is presented.

2. MATERIALS AND METHODS

2.1. Design considerations

The design of the manually operated banana slicer is based on the existing power-operated banana slicer. Some of its components have similarities but it has been redesigned to be portable, heavy-duty, and manually operated using a hand crank. Some of the considerations in designing include safety, contamination-free and convenience. The device is safe to operate because the blades attached to the turntable are built inside and the mainframe is being guarded by an aluminum cover plate to prevent the operator from injury during operation. The turntable and the cutter blade are made of corrosion-resistant and food-grade materials. The material used in the turntable is made of plastic. The cutting blade is made up of stainless steel since it is highly resistant to corrosion thus avoiding food contamination. Further, the device is easy-to-use because of its minimal size; the feeder is located near to the hand crank that a single person can operate at a given time.

2.2 Design of the device

Figure 1 shows the perspective view of the manually operated banana slicer. In Figure 2, the exploded view of the device with its components is shown. It is composed of angle bars, hand crank, pillow blocks, flange bearings, shafting, bevel gear, cover plate (aluminum plate & stainless plate), turntable, cutter blade and stainless tube as a feeder or chutes. Figure 3 shows the top view of the manually operated banana slicer with the corresponding dimension. The framing of the device is mostly made up of aluminum to prevent the corrosion of the materials.

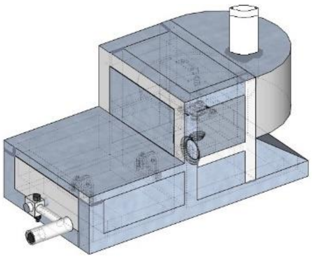


Figure 1. The perspective of the Innovative Manually Operated Banana Slicer

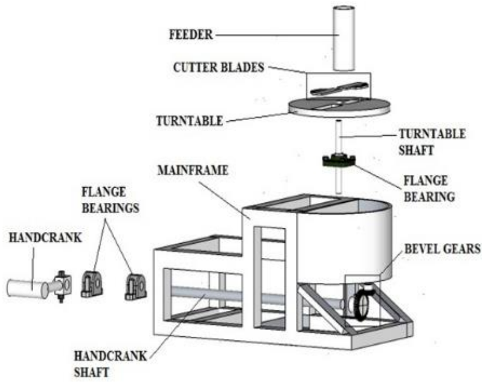


Figure 2. Exploded view of the device

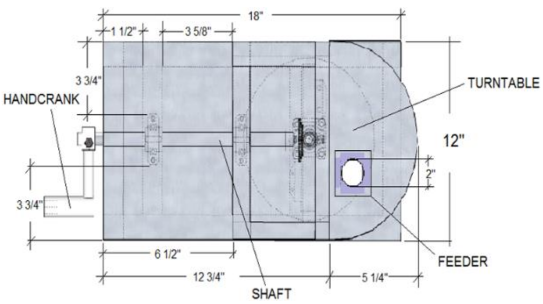


Figure 3. Top view of the design and dimensions

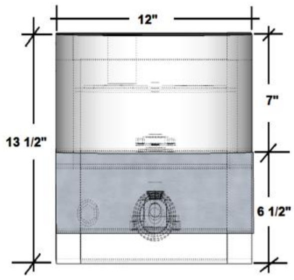


Figure 4. Front view of the design

Figure 4 shows the front view projection of the manually operated banana slicer. The front part which where the raw banana chips exit consists of a stainless plate. It also shows its dimensions.

Figure 5 shows the right-side view of the manually operated banana slicer. The slicing chamber is separated from the mechanism chamber of the device using angle bars and an aluminum plate to avoid contamination during operation. It also shows its dimensions and some parts.

Figure 6 shows the design of the cutter blade of the manually operated banana slicer. The cutter blade has a width of 7/8 inch, 4 inches in length, and a thickness of ¼ inch. The material used for the blade is made up of stainless steel. Since stainless steels are high corrosion and rust-resistant, they are a good cutter for food processing and contamination will be avoided.

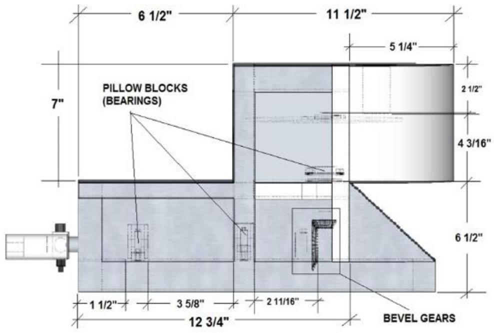


Figure 5. Right-side view of the design and dimensions

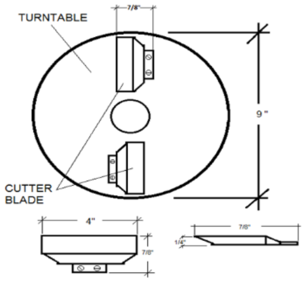


Figure 6. The design of the turntable and cutter blade

2.3 Assembly description of the device

Cutter and Feeder Assembly: Cutter assembly comprises of turntable and cutter blades. The blades are made up of Stainless Steel from a hygienic point of view. The blade length was the basis of the diameter of the turntable. The Turntable serves as the flywheel of the device to facilitate the cutting action of the blades and also it would indicate the thickness of the banana chips. The material of the turntable is made up of plastic due to its lightweight, material availability, non-corrosive property and least cost. The thickness of the turntable is suggested to be ¾ inch as prescribed. The thickness of the blade was kept at 4mm as the desired thickness of the slice would produce. The dimensional details of the two cutter blades and turntable are shown in Figure 6. A 12" inch by 2" cross-sectional area of the pipe-feeder was selected for round and longitudinal slice, respectively, by considering the maximum effective width and diameter of the peeled banana. 3 bananas can be accommodated at a time in the feeder. The length of the pipe feeder was taken as 12" for providing sufficient space for feeding bananas from the top.

Main Frame**:** The frame of the device is made to be sturdy by using 1-inch x 1-inch angle bars made of Mild Steel and is fabricated with its design. The dimensional details of the frame of the device are shown above. These sections are joined by Shielded Metal Arc Welding (SMAW). The pillow block, bevel gears, turntable shaft, hand-crank shaft, turntable with 2 blades, and aluminum plate cover can be mounted with this frame. All these accessories can be mounted with the help of fasteners.

Bevel Gear Assembly**:** The two meshing bevel gears comprise with speed ratio of 1:2 and 1:3 for evaluation purposes, and assumed having 60 RPM on the hand-crank shaft and 120 RPM and 180 RPM on turntable shaft, respectively. The bevel gears are built below the turntable and fastened in shafts through setscrews.

Manual Transmitting Assembly**:** It constitutes a hand crank, hand crank shafting, pillow blocks, bevel gears, and turntable shaft. The hand crankshaft is being revolved which drives the turntable shaft using a rotating hand crank. The shaft is made of CRS and has ¾ inches as prescribed. The bearing is suggested based on the diameter of the shaft and mounted on the frame to facilitate the rotation of the shaft.

2.4 Prototype development

A prototype of the device is then developed and assembled based on the design. Some of the machines and tools used in the fabrication are Lathe machine, milling machine, drilling machine, complex-end milling machine, welding machine, grinding machine, angle grinder, hacksaw, flat screw/Philip screw, adjustable/combination/open wrench, bench vise, driller, riveter, Vernier caliper, hand taps, and steel rule/tape measures. – is used to measure the desired length of cuts for angle bars.

2.5 Evaluation of the performance and functionality of the device

The device is evaluated through its performance, capacity, the weight of good cuts (based on thickness and roundness of chips), and its slicing efficiency. The time consumed and weight of the slices would be the basis of the performance evaluation of the device. The capacity of the device is evaluated at two levels of cutting speed and the number of cutting blades.

3. RESULTS AND DISCUSSION

3.1. The innovative manually operated banana slicer

Figure 7(a-e) shows the actual photo of the innovative manually operated banana slicer. Figure 7(b) shows the top view of the device. The hole serves as the feeder or chutes in which the peeled banana is fed during operation. Figure 7(c) shows the right-side view of the device covered with an aluminum plate. In Figure 7(d), the front view of the device is shown. The inclined stainless part serves as the exit chamber of the raw banana chips. Figure 7(e) shows the inside view of the device. It shows the 1:2 ratio of the bevel gear being meshed, the flange bearings and pillow blocks that support the shafting and the turntable together with the blade cutter that is connected from the shafting.

3.2 Performance Evaluation

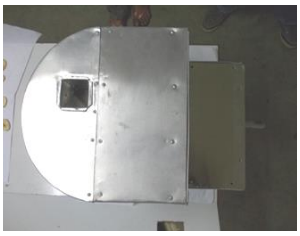
The manually operated banana slicer is tested with two varieties of banana; the unripe *Saba (Musa acuminata)* and the Green banana (*Bungulan* unripe). These varieties (Figure 8) are the most commonly used for banana chip making commonly in the household or backyard level. The device produces slices of the round shape.

The performance of the device is evaluated with regards to its capacity, the weight of good cuts (based on thickness and roundness of chips), the weight of rejects (deform cuts) and slicing efficiency. Figure 9 shows the sliced banana after subjecting them to the device.

The capacity of the device is determined by feeding the two varieties of peeled banana into the device at a different speed (rpm) and several cutting blades; and weighing the slices produced irrespective of damage. The capacity of the device is expressed as kg of peeled banana sliced per unit time. Figures 10 and 11 show the effects of several blades and cutting speed on the capacity of the device for *Saba* and *Bungulan* varieties, respectively.

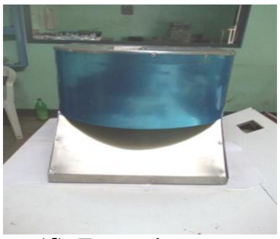
The average capacity of the portable banana slicer was observed to be about 60kg/h when operated by a two-blade cutter at 120 rpm. It was also observed that the effective capacity of the device increased with an increase in the number of blades at all operating speeds. Similarly, as the rpm of the cutter plate was increased there was an increase in the effective capacity of the slicer.

(a) Manually operated banana slicer



(b) Top view

(c) Right-side view



(d) Front view

(e) The mechanism of the device

Figure 7. Actual photos of the manually operated slicing device

(a) Saba variety

(b) Bungulan variety

Figure 8. The varieties of banana used in testing

(a) Saba variety

(b) Bungulan variety

Figure 9. Sliced banana after subjecting a peeled banana into thedevice.

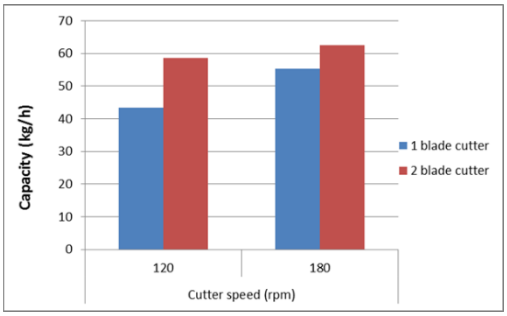


Figure 10. Effect of number of blades and cutter speed on the capacity of the device *(Saba variety)*

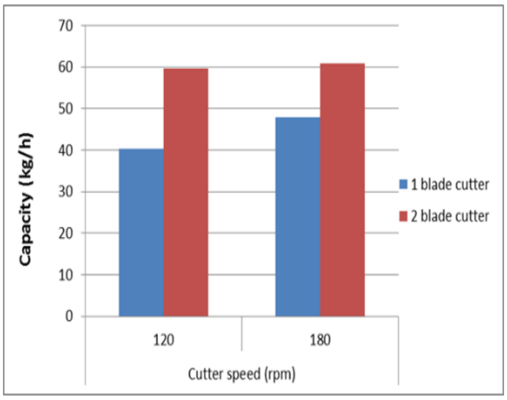


Figure 11. Effect of number of blades and cutter speed on the capacity of the device *(Bungulan variety)*

Slicing efficiency is the inverse term of breaking percentage. The efficiency of slicing is determined by the following expression [8]:

$$\alpha = \frac{W_T - W_D}{W_T} \text{ x } 100$$

where: α – slicing efficiency
W_T – weight of total slices
W_D – the weight of damaged slices

Figures 12 and 13 show the effects of several blades and cutter speed on the efficiency of the device for *Saba* and *Bungulan* varieties, respectively.

As shown in the above graphs, the slicing efficiency obtained is 90-96% at a cutting speed of 120 rpm. Hence, based on the evaluation conducted, a cutting speed of 120 rpm and a two-blade cutter should be employed to attain an optimum capacity of 60 kg/h with excellent slicing efficiency. The best chip geometry is also obtained at this speed.

4. CONCLUSION

A manually operated banana slicer is designed and developed. With the chosen cutting speed of 120 rpm and a two-blade cutter, a slicing efficiency of 90-96% is obtained and a capacity of 60 kg/h. The best chip geometry was obtained at a moderate speed of the device with 120 rpm of the turntable and blade cutter using a 1:2 ratio of the bevel gear that serves as the driver and driven mechanism of the portable banana slicer. Further research for the design of the device for more portability and convenience is recommended. It is further suggested that the blades attached to the turntable must be adjustable to regulate the thickness of the chips calibrated from a range of 2mm to 5mm.

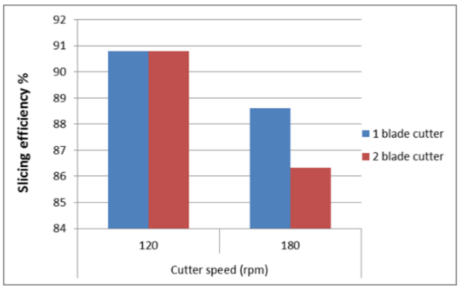


Figure 12. Effect of number of blades and cutter speed on the slicing efficiency of the device *(Saba variety)*

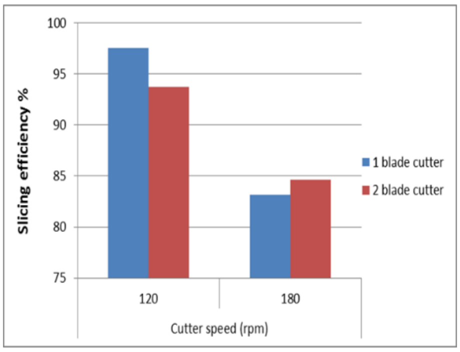


Figure 13. Effect of number of blades and cutter speed on the slicing efficiency of the device *(Bungulan variety)*

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