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Design and development of a manual potato cum sweet potato slicer

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ABSTRACT

Promotion of small scale potato processing machinery in the potato growing region would be an opportunity to reduce post-harvest loss. Making potato chips making can be a potential processing technique at house hold and cottage industry levels. In spite of a high acceptance of chips among all ages of people, the number of small scale potato processing industries in Bangladesh is not notable. One of the main reasons for such outcome is the non-availability of low cost, simple and high capacity potato processing machinery like potato slicer at local market. Therefore, a manual potato slicer was designed and fabricated in Farm Machinery and Postharvest Process Engineering (FMPE) Division of Bangladesh Agricultural Research Institute (BARI) during 2013-14. Overall dimension of the slicer was 360x390x780 mm. The slicing efficiency, throughput and non–uniform slices of the manual slicer for potato were found to be 88.80%, 59.90 kg/h and 11.22%, respectively. The capacity of the slicer for sweet potato was 42.93 kg/h. In consideration of cost, weight, ease of operation and capacity, the slicer was found suitable for cottage industry and restaurant uses.

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I. Introduction

Potato (*Solanum tuberosum* L.) is one of the most important food crops in the world. Potato in terms of production ranks third as food crop in Bangladesh (BBS, 2012). In the country, 461 thousand hectares of cultivable land is under potato cultivation and its production was 8.3 million tones in 2010-2011 with an average yield 18.0 tha^{-1} (BBS, 2012). It is a cheap source of nutrients, income and employment to guarantee food security (Lutaladio and Castaidi, 2009). A large quantity of potato (8000-10000 tons annually) is also being used in processing industries (Hossain *et al*., 2008). Potato is a semi-perishable commodity. Therefore, it needs processing for both short and long term storages. Postharvest losses of potato in Bangladesh are, respectively, 25% and 31% in home storage and cold storage systems (Hossain and Miah, 2011). It is reported in different newspapers that thousands of tons of potatoes are damaged due to lack of adequate cold storage facility. To elongate the shelf life of potato, it can be dehydrated in the forms of slices, sticks, cubes or powder instead of fresh form of potato used for making vegetables and curry. Potato chips or wafers are also popular forms of potato consumption. It has high acceptance among all categories and ages of people in present urban, semi-urban and to some extent, the village levels. Quality of potato products has an important role on the acceptance to consumers. Poor qualities of potato products as well as high post-harvest loss of potato often result from the use of low grade processing machineries. Poor end potato slicer produces uneven thickness of slices due to design fault which causes uneven drying followed by fungal infestation. To reduce this huge loss, promotion of small scale potato processing at home, cottage industry and SME level at rural areas would be a substantial opportunity. Usually potato farmers have no other option without selling their potatoes at farm gate prices to the middlemen to get at least minimum return before spoilage. Low return discourages farmers and production per head is greatly reduced in the following years. To overcome this problem, potato farmers can peel, blanch and dry their tubers either in lumps or in slices and store them for better profits (Ehiem *et al.,* 2011).

Slicing is mainly done with a sharp blade to cut the potato into desired thickness followed by drying to impart better shelf life. Drying of potato could be enhanced by increasing the surface area of the tubers. Leo and Balogun (2009) reported that in drying of fruits and vegetables, the vegetables and fruits must be sliced into smaller pieces to facilitate heat transfer and removal of moisture from the pieces. For commercial slicing process, mechanical slicer is needed (Kamaldeen and Awagu, 2013). Akomas and Otti (1988) found that sharpness of knife used for potato slicing could reduce the potato tissue damage. Slicing depends on the physical properties of the potato tuber like shape, size, length and moisture content. The conventional method of potato slicing practiced by the farmers or rural women done by placing the potato tubers on a chopping board and cut with a sharp knife through desired thickness estimated by their eyes only. This method is injurious, laborious, unhygienic, and produces non–uniform slices, and thereby giving poor end products. Sweet potatoes are sliced to dry quickly to make powder of it. Flour of sweet potatoes are used for baking in home and small cottage industry (Padmaja et al, 2012). But there is no suitable slicer for slicing sweet potato. The quality of chips plays a vital role in the hotel management. Due to uneven thickness of the slices arising from improper tools a lot of wastage of vegetables is happening leading to loss of productivity and other miscellaneous damages to vegetables. The main objective of the design is to develop a fast, safe, and simple machine with cost effectiveness. It is also required to prepare slices that are aesthetically appealing. The present design also helps in reducing the rejection rate.

Manual processes are slowly being converted to semi-automated and automated nature. Manual cutting of potato is still prevalent, in hostels of educational institutions, marriage catering services and even in restaurants, which can cater to a whole set of varying customer tastes and preferences. In recent times, some slicers have been developed for reducing the size of agricultural products such as electrically operated ginger slicer (Gegede, 2000); rotary draw banana slicer (Kachru, Baksubramania and Natchiket, 1996); Cassava Chipper (Gyuse, 1997); Potato slicer (FAO, 1991) and foot operated yam slicer (Ehiem, 2000). These technologies are slow and labor intensive. Easily operated, low-cost and labor-saving processing machinery especially potato slicer would be highly beneficial to the farmers and small village enterprises. But efficient and safe slicer is not readily available for this level of processing. Development of the slicer will increase quantity of sliced material per unit time, conserve time and energy, and increase hygiene in the slicing process. Under this circumstance the research work was done with the following objectives to design and fabrication of a manually operated slicer for potato and sweet potato as well as performance test of the slicer at laboratory and field levels.

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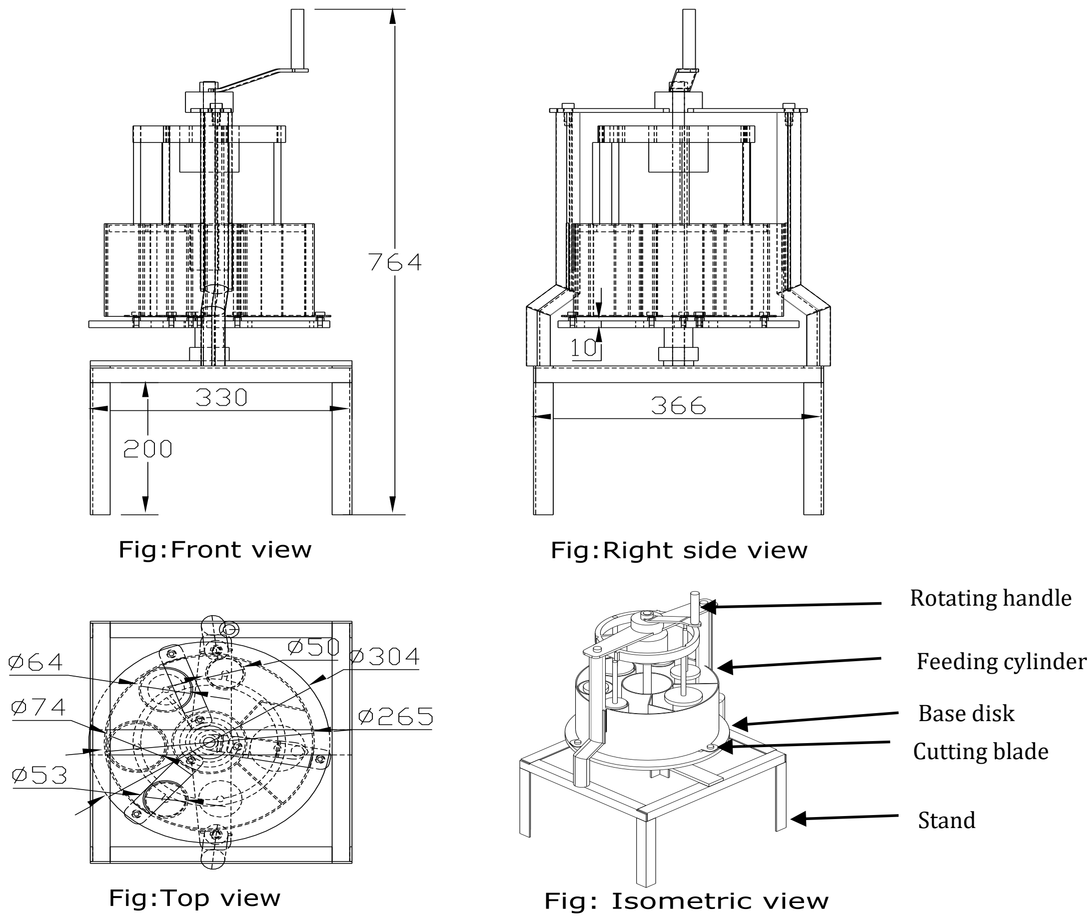
II. Materials and Methods

A manual slicer was designed and fabricated at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during 2013-14. A number of factors were considered in the design of the slicing machine which include the physical and mechanical properties of the materials for construction. The slicing component of the slicer is usually expected to be thin and sharp enough to penetrate the tubers easily. Further, the materials needed for construction of the device must neither contaminate the tubers nor be itself corroded when in contact with water. Stainless steel materials were therefore used for fabricating components. Other considerations in designing the machine included the cutting resistance of the tubers, moisture content, thickness of slice, speed of cut, maximum power requirement, power source and contamination.

Design sketches were drawn with SolidWorks software. The orthographic views of the slicer are shown in Figure 01. The slicer was fabricated with MS angle bar, MS flat bar, MS rod, MS sheet, MS shaft, SS sheet, SS pipe, rubber sheet, ball-bearing, and small spares. The functional parts of the machine are (1) Stand; (2) Rotating handle; (3) Feeding cylinder; (4) Base disc and (5) Cutting blades. Figure 02 shows the photographic view of the slicer in operation.



All dimensions are in mm

Figure 01. Orthographic views of the slicer

The functions of the parts of the slicer are described briefly as follows:

(1) Stand: All components were supported by a stand which was made by MS angles.

(2) Rotating handle: A rotating handle with length of 120 mm was made by MS flat bar and pipe. The handle attached with a shaft which connected with the blade bearing disc. Slicing of potatoes was performed with the clockwise manual rotation of the handle.

(3) Feeding cylinders: The chutes serve as the hopper and provide means of feeding tubers to the device. It was made of galvanized steel pipe. Length and diameter were designed based on average length and diameter of tubers. Length of the feeding chute was 210 mm. Four cylinders and two hexagonal hoppers were made. The diameters of the cylinders were 50, 53, 64 and 74 mm. It is opened through the top of the blade housings. Valve like grippers were made to prevent wobbling into the cylinder.

(4) Base disc: The blade housing disc holds the rotating blades. A door way was provided to facilitate easy access to the blades by the side of the housing. Diameter of the base disc was 304 mm.

(5) Cutting blades: Three blades were made of stainless steels coated with aluminum. They are used for effecting slicing. The blades are 120 mm long and 30 mm wide. The blades were sharpened and bolted to the base disc. The slicing blade must be washable so that quality chips can be obtained. Therefore, the blades were made of stainless steel as approved by World Health Organization (WHO) to guide against corrosion.

a. Working Principle of the Slicer

The slicer was manually operated and power was transmitted to the blades through the shaft via rotating handle. It was fed manually with one tuber at a time through the cylinder. The whole tuber dropped vertically as it was manually fed by the operator against the rotating blades and became sliced. The thickness of each slice was predetermined by the opening of the cutter bar. The potato slices were collected below the blade housings.

b. Determination of the diameter of feeding cylinder

The mean of the circumferences of potato tubers was used to determine the average diameter (d) of the feeding cylinder of the slicer.

$$\pi d = C \qquad (1)$$

Where, C = mean circumference of potatoes; d = mean diameter of potatoes. The diameter (d) becomes the diameter of the slicer cylinder.

c. Performance evaluation

Slicing efficiency (η_s): This is defined as the ratio of weight of uniform sliced potato (Q_u) to the weight of the potato fed (Qf).

$$\eta_s = \frac{Q_u}{Q_f} \times 100 \qquad (2)$$

Slice capacity (S_c): This is the quantity of potato sliced (Q_t) in a given time (T).

$$S_c = \frac{Q_t}{T} \qquad (3)$$

Percent non–uniformity: Percentage of non–uniformity of the sliced potato (%) is the ratio of weight of non-uniform sliced potato (Q_n) to the total fed (Q_f) into the slicer and is given by:

$$\text{Non-uniformity (\%)} = \frac{Q_n}{Q_f} \times 100 \qquad (4)$$

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III. Results and Discussion

According to design considerations and SolidWorks drawings, a manual slicer was developed. The 3D isometric view of the machine and photographic view in operation of the manual slicer are shown in Figure 02 and Figure 03, respectively. Different parameters of the manual slicer are shown in Table 01. There are options for feeding different sizes of potatoes in six different cylinders (47 to 82 mm dia.). The slicer produces twelve pieces of potato slices in one revolution of the handle using three cutting blades and four feeding cylinders. It was observed that the slicer produced slices with thickness of more than 3 mm without griping the potatoes. Gripping of whole potato was essential for fine thickness (<3 mm) of the slice for which an additional gripping arm with a load of 3.5 kg was suspended on the slicer. The price of the slicer was US$ 120.

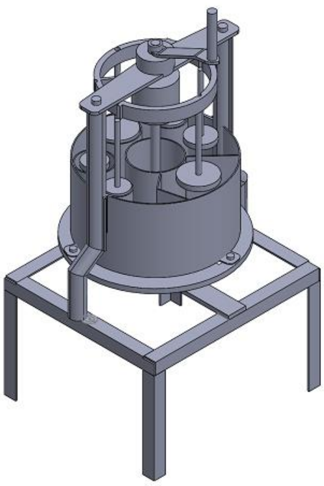

Figure 02. 3D isometric view of manual slicer

Figure 03. A photographic view of manual slicer in operation

Table 01. Different parameters of the potato slicer

Parameters	Value
Overall dimension	360 × 390 × 780 mm
Number of the feeding cylinder	06
Diameter of the main cylinder	260 mm
Diameter of the feeding cylinders	50, 53, 64 and 82 mm
Length of the main shaft	410 mm
Length of the handle	120 mm
Diameter of the cutter base	315 mm
Number of the cutter blade	03 No.
Length of the cutter blade	140 mm
Length of the pressure valve	145 mm
Weight of the gripping load	3.50 kg
Weight of the slicer	18.5 kg
Price of the slicer	120 US$

Comparative performance of the potato slicer and the traditional method is presented in Table 02. Average thickness of the slices was 2.25 mm and 2.5 mm for the slicer and traditional method, respectively. The thickness of slice required for the quick and more uniform slicing was determined as 2 mm (Ogbobe et al. 2007). Capacity of the potato slicer and traditional method were 59.90 kg/h and 4.86

kg/h, respectively. The higher capacity of the potato slicer was found due to less operating time. Hatwar et al. (2016) also found similar capacity for manual slicer.

Table 02. Comparative performance of the potato slicer and the traditional method (*Boti*)

Observation	Weight of potato tubers (kg)		Total time (minute)		Thickness of slices (mm)		Capacity (kg/h)	
	Slicer	Traditional	Slicer	Traditional	Slicer	Traditional	Slicer	Traditional
1	2.50	1.00	2.60	11.28	2.18	3.1	57.69	5.32
2	2.50	1.00	2.41	12.76	2.25	2.5	62.24	4.70
3	2.50	1.00	2.51	12.81	2.32	2.3	59.76	4.67
				Average	2.25	2.50	59.90	4.86

Performance of the slicer is shown in Table 03. Average slicing efficiency and non-uniform sliced potato were 88.80% and 11.22%, respectively, which indicated the effectiveness of the slicer for better quality slices. This might be due to wobbling effect of the potato with the chute walls when the potato diameters were closed to that of cylinder wall. Higher percentage of non-uniform slicing efficiency was observed for smaller diameter potato. Percentage of non-uniform slice could be reduced by using uniform round shaped potatoes. Kamaldeen and Awagu (2013) designed and developed a manual tomato slicing machine and it was capable to slice tomatoes in 2 mm thickness. Their reported capacity and slicing efficiency of the slicer were 32.41 kg/h and 70%, respectively.

Table 03. Performance results of the potato slicer

Observation	Weight of potato tubers (kg)	Wight of uniform sliced potato (kg)	Wight of non-uniform sliced potato (Kg)	Slicing Efficiency (%)	Non-uniform sliced potato (%)
1	2.50	2.23	0.268	89.28	10.72
2	2.50	2.21	0.294	88.24	11.76
3	2.50	2.22	0.280	88.80	11.20
			Average	88.80	11.22

Performance of the manual slicer for sweet potato is shown in Table 04. Average thickness of the slices was 3.07 mm. Capacity of the slicer was 42.93 kg/h whereas capacity of manual slicing was very less as found as for potato. The slicer was operated for sweet potato without the gripping load for which the thicknesses of the slices were more than 3 mm.

Table 04. Performance of the manual slicer for sweet potato

Observation	Weight of sweet potato tubers (kg)	Total time (minute)	Effective slicing time (minute)	Thickness of the slices (mm)	Capacity (kg/h)
1	5.00	7.00	4.45	3.05	42.86
2	5.00	6.58	4.50	3.09	43.06
3	5.00	7.00	4.40	3.07	42.86
			Average	3.07	42.93

V. Conclusion

The slicing efficiency, throughput and non–uniform slices of the manual slicer for potato were found to be 88.80%, 59.90 kg/h and 11.22%, respectively. The capacity of the slicer for sweet potato was 42.93 kg/h. Considering cost, weight, ease of operation and capacity of the developed slicer was found suitable for cottage industry and restaurant. However, efforts to be taken for further development of the machine.

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