Development of Fruit and Vegetable Slicing Machine

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Abstract – *Slicing of fruits or vegetables is the important unit operation in Agro processing industry. Slicing is kind of size reduction which helps in the extraction of desirable constituents from raw materials. Slicing is most suitable for making of chips (wafers), crushing fruits for juice or for fermentation. Manual slicing is relatively slow operation, unhygienic, low quality and needs special attention, so the fruit and vegetable slicing machine was developed by considering physical properties of selected fruits and vegetable. For development of slicing machine & its performance potato and banana were selected.*

The physical properties of Banana and Potato such as size, sphericity, angle of repose (G.I sheet surface), angle of repose(wooden surface), bulk density, true density and porosity were calculated. The slicer machine conceptually designed and developed by considering physical properties of fruit & vegetables. The slicer machine works on cutting mechanism for size reduction. The machine consists of four units viz. Feeding unit, Slicing unit, Collection unit and Power transmission unit.

Developed slicer machine performance has evaluated for slicing Potato & Banana in terms of slicing capacity, broken percentage and uniform slicing. The average slicing capacity for banana & potato was about 68.78 kg/hr and 91.8 kg/hr respectively. Sliced product by slicing machine is far better than manual slicing in terms of quality & quantity.

Key Words: Fruit, Vegetables, Slicing machine, Slicing Capacity, Broken Percentage, Uniformity etc.

1. INTRODUCTION

India's diverse climate ensures availability of all varieties of fresh fruits & vegetables. It ranks second in fruits and vegetables production in the world, after China. In India only 3% work force had find employment in agro processing sector.

Fruit and vegetable processing main objectives is to supply safe, nutritious and acceptable food to consumers throughout the year. Generally, the size of food materials is often reduced during processing for many unit operations which are drying, boiling or steaming and frying or roasting. Slicing of crops before drying reduces the drying time by exposing more surface area to the air. The preservation of almost all processed root and tuber crop products depends slicing. Crops are often sliced before cooking and steaming, either for direct consumption or as one step in a processing system[10]. The process of cutting or slicing the crops gives rise to faster processing. Crops are commonly sliced and prepared by frying in hot oil or roasting. This practice of roasting food items without slicing the product takes longer time than when they are sliced. Slicing as unit operations helps in preparation of the raw material for further processing like cleaning, trimming, peeling followed by cooking, canning or freezing. Processing (canning, drying, freezing, and preparation of juices, jams, and jellies) increases the shelf life of fruits and vegetables.

Slicing is a form of size reduction and the general term "size reduction" includes slicing, cutting, crushing, chopping, grinding and milling. The slicing is brought about by mechanical means without change in chemical properties of the material and uniformity in size and shape of individual units of the end product. Such processes as slicing of fruits or vegetables for canning, slicing sweet potatoes for drying, onion slicing for salad, slicing corn fodder, grinding grain for livestock feed and milling flour are size reduction operations. Reducing the size of food raw materials is an important operation to achieve a definite size range [3]. Slicing may help in the extraction of desirable constituents from raw materials easily due to its reduction in size e.g. for making of chips (wafers), crushing fruits for juice or for fermentation. Slicing operation is achieved by cutting, which involves moving, pushing or forcing thin sharp blade or knife through the materials resulting in minimum rupture and deformation of the materials [7].

1.1 Justification

The purpose of slicing fruits or vegetables is to aid in standardization and to facilitate processing. The slices produced by traditional methods are not uniform and this may result in non-uniform drying or infected dried slices. With technological advancement, there is progressive increase in awareness of the importance of using mechanical devices to slice agricultural produce. Due to high demand for root and tuber crops for various domestic uses, it became imperative that slicing machine to slice these crops be developed. Traditional methods slicing is time consuming, tedious and unhygienic for processing.

To overcome this problem, many fruit or vegetable slicer machines are designed and developed. For operating these machines requires less human power with less time. At present most existing slicing system have the disadvantage of low efficiency, high cost and complexity. The small scale processor is not strong to afford all the high class machinery. Slicing machine available in market is not economically afforded for the small enterprises. It is significant to develop time efficient and low cost fruit and vegetable slicing machine for all kind of fruit & vegetables. The main aim of this project is to develop a compact, safe and easy use fruit and vegetable slicing for small scale enterprises. The phase of the new slicing machine start with the research of existing slicer to understand the functioning, reliability, durability, and mechanism.

1.2 Objectives

To develop fruit and vegetables slicing machine.

To evaluate the performance of developed slicing machine.

2. Literature Review

Clarke (1987)[1] reported that Several slicing and chipping machines have been designed and tested in various developing countries especially the Caribbean and South East Asian countries.

Philippines has designed a simple slicer which is said to cut sweet potatoes much faster than manual methods. The sweet potato is held on the cutting platform against a plate, which controls the thickness of slice. Slices are then cut off with the hinged cutting blade [8].

Raji and Igbeka (1994)[7] designed, fabricated and tested a pedal-operated chipping and slicing machine for tubers and it was reported that the machine performed satisfactorily with production of slices of uniform thickness ranging from 1 mm to 13 mm thickness and a throughput of about 376 kg/h at an efficiency of about 83 percent.

Ukatu and Aboaba (1996)[9] designed, constructed and evaluated a machine for slicing yam and it was reported that the machine's thickness of cut can be varied from 2 mm to 20 mm and the slicing efficiency ranged from 82 to 93 percent and the rate of work is 45 cuts per minute.

There are also several manually operated kitchen–size chipping and slicing machines in the market. Some of these chipping and slicing machines are either imported or fabricated locally. Furthermore, some of these slicing machines are designed for only a particular type of vegetable and fruit and cannot be used for others because of their peculiar rheological properties.

Olajide *et al.* (1997)[6] evaluated an okra slicer and found out that there are higher losses in the manual knife slicing of okra than in the okra slicer.

3. Material & Methods

3.1 Fruits & Vegetable:

India is second largest in production of potatoes, onions, etc. Amongst fruits, the country ranks first in production of Bananas. Slices are generally used for chips or wafers making. Potato and Banana chips have great market demand as compare to other. Hence Banana and Potato is selected for development of slicing machine & its performance evaluation. Most used variety for chips making for Banana are Dwarf Cavendish, Basrai, Robusta, Lal Velchi, Safed Velchi, Rajeli Nendran, Grand Naine, Shreemanti, Red Banana.Most used varieties of Potato chips are sindhuri, chandramukhi, Kufri sindhuri M Kufri Chipsona, Kufri Chandramukhi, Kufri Lauvkar.

Fig -1: Sample for determination of Engineering Properties

3.2 Physical Properties:

Determination of some Physical properties of fruit & vegetables are important for development of any kind of handling equipment (Mohsenin, N.N. 1986) [5].

Size: Size is the measurement of dimensions or the dimensional characteristic of the material. Size is measured by using Vernier Calipers, having least count is 0.01cm.

$$\text{Size} = (a*b*c)^{1/3}$$

Where,

a, b and c are the project area in three mutually perpendicular directions.

Sphericity: It is the cube root of volume of solid and the volume of circumscribed sphere.

$$\text{Sphericity} = (a*b*c)^{1/3}/a$$

Where,

a = Largest intercept,

c = Largest intercept perpendicular to a and b

Angle of Repose: Angle of repose is the angle between the base and the slope of cone formed on a free vertical fall of

the granular material to the horizontal plane. It is measured with the help of angle of repose apparatus.

Bulk Density : It is ratio of weight in air of fruit or vegetable divided by volume of bulk fruit or vegetable. It is density of fruits and vegetables when stacked or packed in bulk. It is calculated by using following equation.

Bulk Density$=W_b/V$,

Where,

Wb- Bulk Weight of fruit/vegetable, kg

V-Bulk Volume of fruit/vegetable, m^3

True Density: True density was measured by the water displacement method. The weight of numbers of individual sample was measured in an electronic balance and was dropped into the water in 100 ml measuring cylinder.

True Density = W_i/V_i,

Where,

W_i - Weight of individual fruit/vegetable, kg

V_i - Volume of individual fruit/vegetable, m^3

Porosity: Porosity or void fraction is a measure of the void (i.e. "empty") spaces in a material.

Porosity (%) = (T. D.- B. D.)/T. D. * 100

Where,

T.D. – True Density, kg/ m^3

B.D. - Bulk Density, kg/ m^3

3.3 Primary Considerations for development of Slicing Machine:

1. **Quality:** Due to unavailability of the proper tools the vegetables are not sliced uniformly leading to poor quality. The present design overcomes this design deficiency.

2. **Productivity:** This new fruit and vegetable slicer is capable of producing more number of slices in a single stroke. This cutting area can accommodate wide range of vegetables of different sizes.

3. **Cost Effectiveness:** Slicing of fruits and vegetable should be cost effective than other slicing machines/methods.

4. **Ergonomics:** Ergonomics was given due consideration while designing the product. The fatigue on the operator can be reduced by increasing the productivity.

5. **Safety:** The chance of injuring the finger is high in the conventional chip manufacturing methods. Developed machine should be safe to operate.

3. 4. Working Principle of Slicing Machine

Machine works on low energy, portable and easy to operate by all kind of operators. Different fruit or vegetable have different size and shape. Machine able to slice all kind of fruits & vegetable having different size. The slicing machine works on the principle of simple cutting and slicing mechanisms.

As initial moment of inertia is overcome by manual feeding and hopper inclination. Machine consists of feeding unit, slicing unit, collection unit and power transmission unit. Fruit or vegetables are fed through the feeding unit. Fruit/vegetable once come in contact with slicing disc, they get sliced due to sharp blade. Thickness of slice adjusted by using the clearance and inclination of blade over disc. Slicing capacity can be controlled by rotation of shaft and feeding rate. Sliced pieces pass through clearance of blade and falls on inclined collecting pan. By application or without application of water the sliced pieces slide over collecting pan and moved towards outlet of slicer machine. Uniform rotation of shaft will be operated through 1/12 Hp motor.

3. 5 Performance evaluation:

Performance of machine is calculated in terms of slicing capacity of machine with application of water, Broken percentage, Uniform slicing percentage.

1. **Slicing Capacity of machine:**

Machine capacity is calculated by total amount of mass sliced per unit time.

Slicing capacity (kg/hr) =

Weight of sliced material/ Time required

2. **Broken Percentage:**

It deals with number of damaged or broken slices with respect to total number of sliced pieces.

Damage percentage (%) =

(Damaged Pieces/ Total sliced pieces)* 100

4. RESULT AND DISCUSSION

4.1 Some physical Properties of Banana & Potato

The physical properties related to slicing machine development such as size, sphericity, angle of repose, weight, bulk density and true density, porosity of banana & potato were measured and tabulated as shown in Table -1 and Table- 2.

Table -1: Some Physical Properties of Banana

Some Physical Properties	Average	Min.	Max.	SD, 6
Effective length, a, cm	121.85	110	129	5.94
Effective width, b, cm	30	28.2	33	1.58
Effective height, c, cm	33.7	32.2	34.8	0.846
Size, cm	5.02	4.73	5.2	0.1512
Sphericity	0.41	0.39	0.43	0.012
Angle of repose (G.I.Surface) ,Φ º	13.2	10	16	1.77
Angle of repose (Wooden surface), Φ º	21.1	22	27	1.374
Bulk Density, kg/m³	514.27	504.7	522.14	6.153
True Density, kg/m³	1004.9	958.32	1053.77	29.114
Porosity, %	48.3	45	51	1.7

Table -2: Some Physical Properties of Potato

Some Physical Properties	Average	Min.	Max.	SD, 6
Effective length, a	80.2	52.8	96.9	12.01
Effective width, b	49.76	45.8	57.8	3.54
Effective height, c	61.62	48.7	68.6	6.30
Size, cm	6.24	4.91	6.86	0.542
Sphericity	0.79	0.67	0.93	0.076
Angle of repose (G.I.Surface),Φ º	8.8	7	11	1.24
Angle of repose (Wooden surface), Φº	12.2	10	16	1.72
Bulk Density, kg/m³	813.5	649.72	904.85	75.83
True Density, kg/m³	1039.5	987.75	1156.66	45.79
Porosity, %	21.5	10.03	39.18	8.94

4.2 Developed slicing Machine:

With consideration of physical properties of Banana and Potato and design parameter, slicing machine has been developed. Based on working function, Slicing machine parts are divided into four major units viz.

1. Feeding Unit,

2. Slicing Unit,

3. Collection Unit and

4. Power transmission unit.
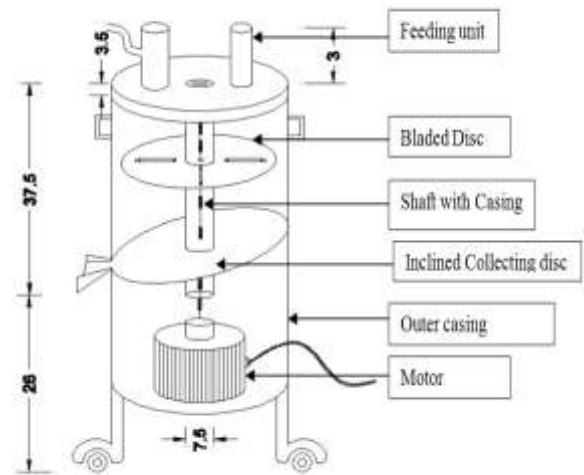
All machine components are shown in Fig-2 & Fig-3.

Fig -2: Developed Slicing Machine with its Parts

Fig -3: Developed Slicing Machine

4.3 Performance evaluation of developed slicing machine:

The performance of machine has been evaluated in terms of Slicing capacity, Uniform slicing percentage and Broken percentage for banana and potato. The performance of machine is tabulated Table-3 and Table-4 for banana and potato respectively.

Average slicing capacity of machine for banana and potato was found 68.78 kg/hr and 95.66kg/hr respectively. Banana peel texture is very hard and sticky so slicing capacity is less as compare to potato. Slicing capacity of machine will vary with kinds of produce, as different produce have different physical and chemical properties. e.g. raw banana peel have less stickiness than ripe banana pulp.

Average uniform slicing percentage for banana and potato was 72.05 % and 66.22% respectively. More uniform slicing is achieved in banana than potato is due to round diameter of banana than potato. It also depends upon the uniform feeding rate and operator skill for feeding.

Average broken (damaged) percentage for banana and potato was found as 27.95 % and 33.78 % respectively.

Table-3: Performance evaluation of slicing machine for Banana.

Obs. No.	Weight of fed Banana, (g)	Time for slicing, (sec)	Weight of uniform pieces, (g)	Uniform slicing percentage (%)	Weight of Broken Pieces (g)	Broken percentage (%)	Total slicing capacity (kg/h)
1	245	11	190	77.55	55	22.45	80.18
2	252	12	188	74.60	64	25.40	75.60
3	241	14	170	70.54	71	29.46	61.97
4	255	16	167	65.49	88	34.51	57.38
Average				72.05		27.95	68.78

Table-4: Performance evaluation of slicing machine for Potato

Obs. No.	Weight of fed Potato (g)	Time for slicing (sec)	Weight of uniform pieces (g)	Uniform slicing percentage (%)	Weight of Broken Pieces, (g)	Broken percentage, (%)	Total slicing capacity (kg/h)
1	235	8	170	72.34	65	27.66	105.75
2	244	9	162	66.39	82	33.61	97.6
3	243	10	155	63.79	88	36.21	87.48
4	255	10	159	62.35	96	37.65	91.8
Average				66.22		33.78	95.66

4.4 Comparison of slicing by traditional method and by slicing machine:

The slicing capacity of slicing machine for Potato varies from 87.48 to 105.75 kg/hr whereas by traditional method slicing capacity varies from 4.67 to 5.32 kg/hr. Thus, this concludes that the slicing machine is more relevant and efficient than traditional method of slicing. Also, Slicing machine maintain the hygiene and quality of sliced pieces than traditional slicing method.

Observation No.	Capacity(kg/h)	
	Slicing machine	Traditional method slicing
1	105.75	5.32
2	97.6	4.70
3	87.48	4.67
4	91.8	4.85
Avg.	95.66	4.88

5. CONCLUSION

With the help of engineering properties of banana & Potato the Slicing machine has been developed. Machine can slice all kind of fruits/vegetable. The manufacturing cost of slicing machine was calculated for the developed slicer and it was Rs. 7000/-.This developed machine is beneficial to all small entrepreneur, food handlers, food manufacturer where slicing and cutting operation are involved. Further modification of the machine is necessary to improve the performance of the machine.

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