

Hygienic Design and Fabrication of Vegetable Slicer Cum Shredder

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Abstract—The size reduction process involved a lot of physical labor and material wastes. Therefore, in order to improve the processing method and enhance its hygienic level, there is the need of mechanization of the slicing method. The present work focuses on development of an improved portable multipurpose slicer cum shredder that takes care of the problems mentioned above. Multipurpose vegetable slicer cum shredder constitutes mainly of the feeder assembly, cutter assembly and the power transmission assembly. The performance of developed slicer cum shredder was evaluated for slicing of potato and cucumber and for shredding of carrot and bottle gourd. The known amount of peeled product was sliced / shredded at four different rpm and three replications were made. The machine performance was evaluated with regard to the capacity, breakage per cent, thickness of sliced vegetables and wastage during processing. On 500 rpm, maximum performance efficiency (86.33 per cent), slicing efficiency (85.67 per cent), capacity (94.33 kg/h), and effective capacity (81 kg/h) was observed and on the other hand minimum mechanical loss (5 per cent) and breakage per cent (14.33 per cent) was observed. Potato slices for producing chips have 0.92 RI. The developed machine operated at 500 rpm gives best result for carrot shredding. On this rpm, maximum performance efficiency (98.66 per cent), capacity (70.63 kg/h) was observed and on the other hand minimum mechanical loss (2 per cent) was found. The cost benefit ratio for processing of potatoes was found to be 2.28 with a payback period of 4 years. It can be inferred that the processing unit for potatoes processing is techno- economically viable industry. The main goal is to create a quick, safe, and easy way to slice vegetable with increased productivity and cost effectiveness.

1. INTRODUCTION

In the era of industrialization, automatic machines become an integral part of human life. These machines help to reduce the time needed to do a specific task. Nowadays, human life becomes more competitive and fast. Automation brought about by technology has saved human effort and time to a large extent. The use of machines in industries and homes is gradually taking over manual means. While the industries are

being automated and computerized, the homes are gradually turning into a mini-industry where different types of machines are in use. The introduction of these machines in our homes has brought about effectiveness, efficiency and time and energy saving.

Slicing is one of the size reduction process commonly used for fruits and vegetables. It involves pushing or forcing a thin, sharp knife to shear through the material intended to be sliced (Owolarafe et al. 2007). This results in minimal deformation and rupture of the fruits cell wall. The main goal is to create a quick, safe, and easy way to slice vegetable with increased productivity and cost effectiveness. It is also required to prepare slices that are aesthetically appealing. The main problems with current Indian chip manufacturers are the wastage of vegetables and uneven thickness of the slices resulting in the low quality and there is a productivity loss in the manufacturing of chips due to non-availability of the proper tools. It is also required to prepare slices that are aesthetically appealing. The main problems with current Indian chip manufacturers are the wastage of vegetables and uneven thickness of the slices resulting in the low quality and there is a productivity loss in the manufacturing of chips due to non-availability of the proper tools. The chips makers are at the risk of injuring their fingers and having difficulty in producing the type of slices they wanted. In hotels cucumber, onions and carrots all are sliced in a different thickness and also it requires a skilled worker to slice them evenly. Shredding is pushing food across or through a shredding surface to make long, narrow strips.

For last few years, researchers are putting their efforts in developing technically feasible and economically viable multipurpose vegetable slicer cum shredder. The existing slicers and shredder are not meeting the actual requirement of small scale processing unit and there is need to develop

equipment in which both unit operations (slicing and shredding), can be taken place. Therefore, a need was felt to design equipment to slice/shred various vegetables at a small scale level.

2. DESIGNING AND DEVELOPMENT

When stress is applied to food material, the resulting internal strains are first absorbed, to cause deformation of the tissues. If the strain does not exceed a certain critical level named the elastic stress limit, the tissues return to their original shape when the stress is removed, and the stored energy is released as heat. However, when the strain within a localized area exceeds the elastic stress limit, the food is permanently deformed. If the stress continued, the strain reaches a yield point. Above the yield point the food begins to flow. Finally, the breaking stress is exceeded at the breaking point and the food fractures along a line of weakness. Some part of the stored energy is then released as sound and heat. About one per cent of applied energy may actually be used for size reduction. The amount of energy that is needed to fracture a food is determined by its hardness and tendency to crack (its friability) which in turn depends on the structure of the food. The compression forces are used to fracture friable or crystalline foods; combined impact and shearing forces are necessary for fibrous foods, and shearing forces are used for fine grinding of softer foods (Fellows, 2005). The hygiene is one of the important considerations for food processing equipment. The basic objective of the sanitary design is that it must not contaminate product. The basic requirements of food plant equipment are as follows:

1. All surfaces in contact with food must be inert and must not be absorbed by the food.
2. All surfaces in contact with food must be smooth and non-porous, otherwise tiny food particles, bacteria or insect eggs may become difficult to dislodge which eventually become potential surfaces of contamination.
3. All surfaces in contact with food must be visible for inspection, or the equipment must be readily disassembled for inspection, or routine cleaning procedures eliminate possibility of contamination from bacteria or insects.
4. All interior surfaces must be so arranged that the equipment is self-emptying or self-draining.
5. The exterior or non-product contact surfaces should be arranged to prevent harboring of soils, bacteria, or pests.
6. It is important to avoid dead space which trap food, prevent effective cleaning and may allow microbial growth to take place.
7. Noise suppression is important in providing acceptable working conditions.

The most common design faults which cause poor clean ability are: poor or nil accessibility, inadequate rounded corners (minimum radius should be 6.4 mm), sharp angles and

dead ends including poorly designed seals (Joshi, 1985; Shapton and Shapton, 1997). Strength is a major factor in the design and development of machine. The selection of material and selection of permissible stress are two important considerations. The maximum induced stress should not exceed permissible stress (Sharma and Agarwal, 1998). The failure of a machine element may be prevented if the maximum induced stress due to external loading does not exceed the failure stress. The stress applied to a material is the force per unit area. The equation below is used to calculate the stress:

$$\text{Stress} = \frac{F}{A}$$

Where, Stress is measured in Nm⁻², F is force in newton (N) and A is the cross-sectional area in m².

3. PERFORMANCE EVALUATION

The performance evaluation of the multipurpose vegetable slicer cum shredder was done by slicing/shredding the known amount of peeled vegetables. The mass of the peeled vegetables, sliced/shredded vegetables, time required for size reduction and revolution per minute (RPM) of the blade were measured with the help of mechanical weighing balance, stop watch and mechanical tachometer respectively. The weighing balance of 1 kg capacity with 1 g least count was used for weighing of the peeled vegetables and slices/shreds for evaluating the capacity and breakage per cent. A contacting type tachometer (Make: Prestige counting instruments, Pvt. Ltd., Mumbai) was used to measure the rpm of cutter plate.

Capacity of the machine

The capacity of the multipurpose vegetable slicer cum shredder is the amount of slices/shreds produced per hour. The time required to produce slices/shreds includes the time for feeding, compressing and cutting (Sonawane, 1997) as:

- a. Feeding time: It is the time required for lifting the vegetable from nearby tray and putting it into the feeder.
- b. Compressing time: It includes the time required for pressing and removing the pusher.
- c. Cutting time: It is the time taken for slicing/shredding the vegetables.

Roundness index

It is a measure of sharpness of the irregular shaped solid material. This index is useful for the round shaped slices only. Roundness index of slice was determined by using the following expression (Sonawane, 1997):

$$\text{Roundness} = \frac{A_p}{A_c}$$

Where A_p is the largest projected area of the particle and A_c is the area of smallest circumscribed circle in m². Ten samples were randomly selected from each batch of slicing and

projected area of these slices was measured by placing and tracing them on a graph paper.

Breakage per cent

Breakage per cent can be defined as the ratio of amount of the broken slices to the total amount of peeled vegetable taken for slicing and can be expressed as (Sonawane, 1997):

$$\text{Breakage per cent} = \frac{M_b}{M_t} \times 100$$

Where M_b is the amount of broken slices of vegetables and M_t is the total amount of vegetables fed in kg.

Slicing efficiency

The efficiency of slicing was determined by the following expression (Sonawane, 1997):

$$\text{Slicing efficiency} = \frac{W_T - W_d}{W_T} \times 100$$

Where, W_T is the mass of total slices and W_d is the mass of damaged slices in kg.

Effective capacity

The slicing efficiency is useful in the determination of effective capacity of the machine. The effective capacity was determined by following expression (Sonawane, 1997):

$$\text{Effective capacity, kg/h} = \frac{\text{OC} \times \text{slicing efficiency}}{100}$$

Where, OC is the operating capacity in kg/h and slicing efficiency is in per cent.

Mechanical loss

The mechanical loss during slicing and shredding of vegetables was calculated by the following expression (Sonawane, 1997):

$$\text{Mechanical loss, \%} = \frac{W_i - W_f}{W_i} \times 100$$

Where, W_i is the initial mass of vegetables and W_f is the mass of sliced or shredded vegetables.

Performance efficiency

The quality performance efficiency may be expressed by (Sonawane, 1997):

$$\text{Performance efficiency} = \frac{G}{G + B} \times 100$$

Where, G and B represent the good and bad quality slices where good quality means more than 80 per cent shape occurred by slices and bad quality means less than 80 per cent shape occurred by slices.

Net Present Worth (NPW)

The discount cash flow measure of project worth is its net present worth (NPW)

$$NPW = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

Where, NPW is the net present worth, B_t and C_t are the benefit and cost in t th year, t is the year and i is the discounted rate of interest (Khan and Jain, 2004).

Benefit Cost Ratio (BCR): The benefit –cost ratio was obtained after dividing the present worth of the benefit stream by present worth of incurred costs. The formal selection criterion for the benefit-cost ratio for measure of the project worth was to accept projects having benefit-cost ratio of one or more (Sharma, 2009):

$$BCR = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

Pay Back Period (PBP)

The payback period is the length of time from the beginning of the project until the net value of the incremental production stream reaches the total amount of the capital investment; and shows the length of the time between cumulative net cash outflow recovered in the form of yearly net cash inflows.

$$\sum_{i=1}^n B_i \geq P_w$$

Where, B_i = present worth of cash inflow

P_w = present worth of the total cash out flow

4. FABRICATION OF MULTIPURPOSE VEGETABLE SLICER CUM SHREDDER

The multipurpose vegetable slicer cum shredder machine constitutes mainly of the feeder assembly, cutter assembly and the power transmission assembly. The various parts of multipurpose vegetable slicer cum shredder are listed below as:

1. Feeder assembly
 - a. Feeder box
 - b. Pusher
2. Cutter assembly
 - a. Slicing blade
 - b. Shredding blade
3. Power transmission assembly
 - a. Electric motor
4. Frame

The basic data regarding the engineering properties of vegetables useful in design are discussed in this section. The size and dimensions of the various components of the machine are selected by keeping various facts in consideration before final fabrication. The dimensions of the feeder box were determined on the basis of maximum size of the vegetables that are required to be handled by the slicer/shredder. The

physical dimensions of potatoes, cucumbers, bottle gourds and carrots were measured by the standard procedure with the help of digital vernier calipers of 0.01cm least count. Ten pieces of all four vegetables were randomly selected and their dimensions were measured. The selected physical and mechanical properties of potatoes, cucumbers, bottle gourds and carrots are presented in Table 4.1 to Table 4.4 along with the standard deviation (SD) and coefficient of variance (CV). It can be seen from the Table 4.1 to 4.4 that the average diameter of potatoes, cucumbers, carrots and bottle gourds are 6.76, 2.9, 1.94 and 6.28 cm respectively.

Similarly, the average length of the potatoes, cucumbers, carrots and bottle gourds were measured as 11.00, 17.00, 36.00 and 31.00 cm respectively. The mass of ten selected vegetable pieces were measured with the help of digital balance of least count 0.1 g and it was found that the average mass of potatoes was 231.00 g, whereas the average mass of one pieces of cucumbers, carrots and bottle gourds was found as 158.0, 232.0 and 569.0 g respectively.

The vegetables were peeled manually and the mass of peel and pulp was determined and it was found that the potatoes has the maximum pulp to peel ratio of 10.48:1 and cucumber has minimum pulp to peel ratio of 8.30:1, whereas the pulp to peel ratio of carrots and bottle gourds was found as 8.84:1 and 8.80:1 respectively. These physical parameters are in accordance with the results as reported by Tabata baeefar (2002) for potatoes, Mirzabe *et al.* (2017) for cucumbers, Veggio (2017) for carrots and Pradhan (2013) for bottle gourds.

The force required to cut the vegetables was measured with the help of texture analyzer and it was found that average force required to slice/cut the cucumber was minimum (80.0 N), whereas the force required to slice the carrot was maximum (89.0 N). The force require to slice the potatoes and bottle gourd were found to be 88.2 N and 87.0 N respectively. The data obtained for physical and mechanical properties of all the four vegetables were statistically analyzed and standard deviation and coefficient of variance were predicted and it can be seen that the standard deviation for potato varied from 0.056 to 1.032 and the coefficient of variance ranged between 0.003 and 1.066, for cucumber standard deviation varied from 0.131 to 1.316 and the coefficient of variance ranged between 0.017 to 2.044, similarly for carrot standard deviation varied from 0.018 to 3.438 and the coefficient of variance ranged between 0.0003 to 11.822 and for bottle gourd standard deviation varied from 0.029 to 6.169 and the coefficient of variance ranged between 0.0008 to 37.288.

The diameter of the cutter plate and the size of the slicing blade/shredder blades were determined on the basis of the width of the cutting *i.e.* width of the feeder box. The total force required to cut the various vegetable were determined with the help of texture analyzer. The force per unit width was determined and total force required for cutting the vegetable was then calculated. The maximum torque requirement is

computed by multiplying the radius of the cutter plate and the total cutting force. The required rpm of the cutter plate is calculated by taking into account the average time required for each batch for the cutting operation. The nearest available values of the above components were selected for development of multipurpose vegetable slicer cum shredder.

5. MULTIPURPOSE VEGETABLE SLICER CUM SHREDDER

Multipurpose vegetable slicer cum shredder constitutes mainly of the feeder assembly, cutter assembly and the power transmission assembly. The feeder box is fixed to the cutter plate. The blades are mounted on the cutter plate with the help of the blade support. Two screws are provided for the blade support in order to change the clearance between the blades. Power is transmitted by the electric motor. The cutter plate and driven pulley are mounted on the frame. Vegetables are pushed against the cutter plate by simple mechanism provided on the feeder box.

Feeder assembly

As the existing slicer/shredder units can handle one piece of vegetable at a time that too of specific shape therefore it was thought to have two feeder boxes for feeding the vegetable of different shape and size. In order to feed the material in the slicing/shredding unit safely, two feeder boxes were attached. The length of each feeder box was taken as 145 mm, so that it won't obstruct the operator in the proper feeding the vegetables and it also provide the safe passage to the cutting unit without having the contact of hands of operator to the cutting tool. Two different feeding boxes were constructed so that different shape of vegetables can be accommodated. One feeding unit having 8.7 cm diameter can accommodate approximately 2-3 potatoes at one time similarly another unit of 7 x 13.5 cm cross section which can be used for long vegetables like bottle gourd and carrot.

Two feeding boxes were fabricated for the developed machine and for feeding the vegetables easily and safely in the developed slicer/shredder; pushing rod made of wooden was also developed with the unit. The feeder assembly guides the vegetables through lever so that the clogging in the feeder box is avoided and wastage during the operation may be reduced. The clear distance between push plate and open end of feeder was about 125 mm, so a wooden push rod of 125 mm was attached for easy handling of the vegetables. The pushing lever is also attached for smooth handling the equipment.

Cutter plate assembly

The cutting unit is one of the main components of any size reduction machine. The diameter the cutting blade and the gap between the slicing/shredding blades are main working component. The gap between the slicing blades and shredding units were decided by the thickness of slices and shreds required. Keeping these points in view the diameter of cutting plate was selected as 320 mm and then gap between the slicing units was maintained as 3 mm. Cutter assemblies comprises of

a slicing blade and shredding blade. The blades were made of stainless steel as working part. The two blades are mounted on the cutter plate with the help of the blade support. Power is transmitted by the electric motor through the belt and pulley drive. Vegetables are pushed against the vertical plane of the cutter plate. The machine was targeted to produce the slices and shreds. The blades were fabricated from the material generally used for making a cutting device. These blades were mounted on to the cutter plate by means of plate guide. The specifications of blade material are follows:

- i. Material: Stainless steel (SS 304)
- ii. Characteristics: General purpose, maximum corrosion resistance after heat treatment and hardenable by heat treatment etc.
- iii. Yield stress (min.): 21.0 kg/cm^2
- iv. Ultimate stress (min): 45.5 kg/cm^2

Cutter

The housing was made of 3 mm thick MS plate. The cutter housing has diameter of 320 mm with two mm clearance. A slant shreds chute is constructed at bottom of cutter housing for easy flow of slices.

Revolution per minute (RPM)

The revolution per minute of the cutting unit will decide the throughput capacity of the machine. However, at very high rpm the mechanical losses will be more and on the other hand, the low rpm not only reduces the capacity of machine, but may also not able to reduce the sizes. Further, in order to have variation in speeds for size reduction of different vegetables i. e. is required to vary the rpm of the machine, so speed controlling mechanism was also attached which can vary rpm 300 to 600 in phase wise manner. The RPM determination of cutter plate affects the capacity of the machine.

Power transmission assembly

The cutting unit of the machine should rotate at required rpm for which the power can be provided through the electric motor. One single phase electric motor was attached with the developed unit which can provide the required rpm and capacity of the machine. The regulator is also attached with the motor which varies the revolution of the blades.

Frame

The machine was made steady though kept light in weight by using suitable sizes of angles. The dimensions of the frame were computed considering the dimension of cutter plate and motor, weight of the cutter, feeder and motor. These sections were joined by gas welding. The cutter plate shaft, cutter housing cover and prime mover were mounted on this frame. All these accessories were mounted with the help of fasteners (hexagonal nuts and bolts).



Fig. 1: Multipurpose vegetable slicer cum shredder

6. RESULT AND DISCUSSION

Multipurpose vegetable slicer cum shredder constitutes mainly of the feeder assembly, cutter assembly and the power transmission assembly. The feeder box is fixed to the cutter plate. The blades are mounted on the cutter plate with the help of the blade support. Two screws are provided for the blade support in order to change the clearance between the blades. Power is transmitted by the electric motor. The cutter plate and driven pulley are mounted on the frame. Vegetables are pushed against the cutter plate by simple mechanism provided on the feeder box.

The performance of a size reduction machine can be evaluated for capacity, power requirement per unit of material handled, range, size and shape of product before and after size reduction.

Design Calculation

(A) Total force required to cut vegetables

- (1) Potato: We know the force required to cut the potato per unit width = $88.2 \text{ N}/67.6 \text{ mm}$
= 1.304 N/mm

Therefore the total force required to cut the 110 mm width of Potato = $1.304 \times 110 \text{ N}$
= $143.52 \text{ N} \approx 145 \text{ N}$

- (2) Cucumber: We know the force required to cut the potato per unit width = $98 \text{ N}/29 \text{ mm}$
= 3.379 N/mm

Therefore the total force required to cut the 170 mm width of cucumber
= $3.379 \times 170 \text{ N}$
= $574.43 \text{ N} \approx 575 \text{ N}$

- (3) Carrot: We know the force required to cut the carrot per unit width = $88.2 \text{ N}/19.4 \text{ mm}$
= 4.546 N/mm

Therefore the total force required to cut the 360 mm width of carrot
 $= 4.546 \times 360 \text{ N}$
 $= 1656.56 \text{ N} \neq 1670 \text{ N}$

- (4) Bottle gourd: We know the force required to cut the bottle gourd per unit width = $127.4 \text{ N} / 62.8 \text{ mm}$
 $= 2.028 \text{ N/mm}$

Therefore the total force required to cut the 310 mm width of bottle gourd
 $= 2.028 \times 310 \text{ N}$
 $= 628.68 \text{ N} \neq 680 \text{ N}$

(B) Torque at the outer periphery of the cutter plate

(1) Potato

Torque = Force \times perpendicular distance (radius of the plate)

Torque (T) = 145×160
 $= 23200 \text{ N} \times \text{mm}$
 $= 23.20 \text{ NM}$

(2) Cucumber

Torque = 575×160
 $= 92000 \text{ N} \times \text{mm}$
 $= 92 \text{ NM}$

(3) Carrot

Torque = 1670×160
 $= 267200 \text{ N} \times \text{mm}$
 $= 267.2 \text{ NM}$

(4) Bottle gourd

Torque = 630×160
 $= 100800 \text{ N} \times \text{mm}$
 $= 100.8 \text{ NM}$

(C) Determination of the cutter plate RPM for Potato:

Maximum effective length of the Potato = 110 mm

Required chips thickness = 2 mm

Number of slices = $110/2 = 55$

Number of blades attached on the cutter plate = 2

Therefore number of cuts in one revolution of cutter plate = 2

No. of revolution required to make = $55/2 = 27.5$

Assume the time taken for the completion of a single

batch operation = 3 seconds

RPM = $(60 \times 27.5) / 3$
 $= 550 \text{ rpm}$

The specific conclusions which have emerged from the present investigation are summarized below: On 500 rpm, maximum performance efficiency (86.33 per cent), slicing efficiency (85.67 per cent), capacity (94.33 kg/h), and effective capacity (81 kg/h) was observed and on the other hand minimum mechanical loss (5 per cent) and breakage per cent (14.33 per cent) was observed. Potato slices for producing chips have 0.92 RI. In the case of cucumber slicing, it may be concluded that 400 rpm gives best result. On the above mention rpm, maximum performance efficiency (83 per cent), slicing efficiency (83 per cent), capacity (150 kg/h) and

effective capacity (124 kg/h) is observed and on the other hand minimum mechanical loss (13.33 per cent) and breakage per cent (16.66 per cent) was observed. Cucumber slices for producing salad have 0.95 RI. The developed machine operated at 500 rpm gives best result for carrot shredding. On this rpm, maximum performance efficiency (98.66 per cent), capacity (70.63 kg/h) was observed and on the other hand minimum mechanical loss (2 per cent) was found. It may be concluded that 450 rpm gives best result for bottle gourd shredding. On the same rpm, maximum performance efficiency (5.66 per cent), capacity (51.44 kg/h) is observed and on the other hand minimum mechanical loss (94.33 per cent) was observed. The cost benefit ratio for processing of potatoes was found to be 2.28 with a payback period of 4 years.

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