



Design and Fabrication of a Manually Operated Vegetable Leaf Slicing Machine

*¹IKPOZA, E; ²USIOBAIFO, EJ; ³ERHUNMWUN, ID

Department of Production Engineering, University of Benin, Benin City, Nigeria.

*Corresponding Author Email: emmanuel.ikpoza@uniben.edu; Other Authors Email: edosabrainu@gmail.com; iredia.erhummwun@uniben.edu

ABSTRACT: This paper entails the design and fabrication of a manually operated vegetable leaf slicing machine. The developed machine consists of a hopper, the cutter housing, the cutting blades, the rotating shaft, and a wooden handle. The machine was designed to enhance the hygienic slicing of vegetable leaf materials and for prevention of knife-related injuries for both domestic and commercial use. The machine was tested with a slicing efficiency of 95.52 % with a provision of an alternative quick vegetable cutting process with no injuries, no electric power supply and with little or no noise to the operating environment.

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According to Smith (2013), cooking/kitchen knives has constituted 36% of knife-related injuries treated in United States emergency departments, between 1990 and 2008. Vegetables consist of large groups of plants consumed as food by both human and animals. Vegetables can be perishable when fresh but be preserved by a number of processing methods. They are excellent source of certain minerals and vitamins and are often the main source of dietary fibre. Vegetables can be divided into edible roots (e.g., Carrots and potatoes), stem (Asparagus and celery), leaf (lettuce, pumpkin, spinach and fruited pumpkin), immature flower bud (broccoli and Brussels sprouts) and fruits (tomatoes and cucumbers) etc., (Britannica encyclopaedia, 2008). From time immemorial, knives and graters were the major tools for slicing and grating vegetables such as, pepper, carrot, onions, and so on. However, it was noticed that, usually more time is required for slicing vegetables using knives, and in some cases, injuries occur. Vegetable slicing with knife is known to be hazardous, increasing the number of people who gets hurt while using knives in slicing their vegetables (Cliver *et al* 1994). But as time went on, technology began to advance and different manufacturers began to research on new and more efficient ways of achieving the same goal while saving time and associated hazards caused by knife usage (Bird, 1995). Awili *et al* 2009, designed a manual vegetable slicing machine. It was however not specified what type of vegetable the simple machine was designed to slice. Shittu *et al* (2017), developed a

motorised tomato cutter with an output capacity of 468kg/h, percentage loss of 28.40%, and slicing efficiency of 60.34%.

MATERIALS AND METHODS

In this design, stainless steel was used. The stainless steel was used in the frame, the cutter, the cutter housing and in part of the handle due to its ability to resist corrosion, thereby preventing food contamination. The different parts of the Vegetable Slicing Machine were fabricated according to design specifications and assembled together mainly by welding, and use of nuts and bolts for ease of assembly and disassembly. Detailed Engineering drawing. There were various components that made up the whole design concept (Figures 1, 2, 3) of the manual vegetable leaf slicing machine. These parts are:

Handle: The handle is connected to a rotating shaft which rotates the cutter as the impeller pushes the vegetables to the cutter.

Impeller: The impeller is a component part of the vegetable slicing machine whose main function is to push the vegetables towards the rotating cutter.

Rotating Shaft: The rotating shaft is connected to the handle which aid the cutter (blade) to easily rotate in order to cut the vegetables

*Corresponding Author Email: emmanuel.ikpoza@uniben.edu

Cutter: Its function basically is to cut the vegetables being introduced by the impeller into smaller pieces

hole is drilled at the middle of the cover. It is fitted screws.

Outer Cover: The outer cover made of stainless steel is used to enclose the cutter (blade). A small diameter

Main Body: This is the body (frame) of the design with the various components assembled together.

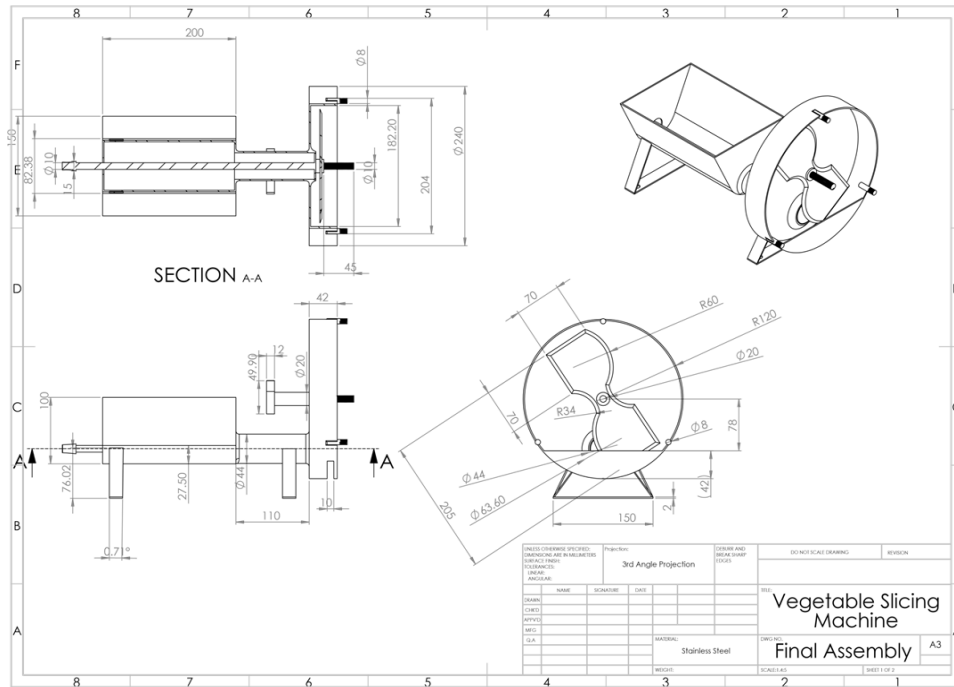


Fig 1. Design concepts

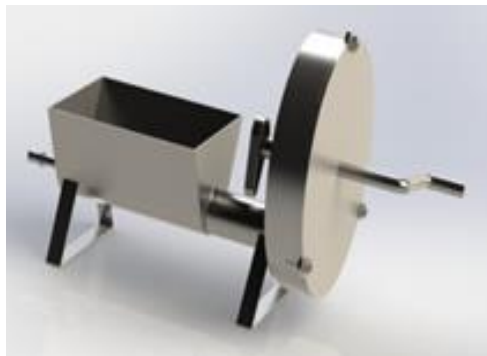


Fig 2. Assembled Machine

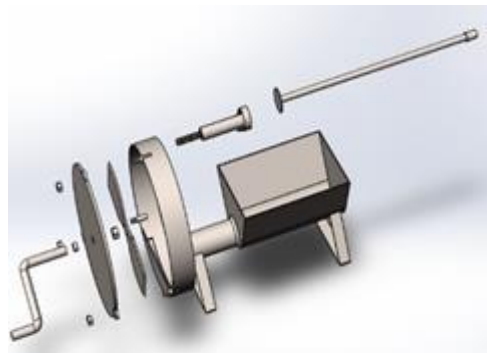


Fig 3. Exploded view

Mode of Operation: The machine is bolted securely onto a flat platform by means of nuts and bolts. The plucked vegetables forming a bunch are introduced by hand into the receiving compartment. With the aid of the impeller, the vegetables are pushed into the cutting compartment through the cylindrical channel. The vegetables are cut by means of the rotating stainless steel cutter blades as they come in contact with the vegetables as they exit the cylindrical chamber into the cutting compartment. The rotary motion of the cutter blade is produced by the manual circular turning of the handle. The rotating shaft serves as a support and gives stability to the cutter. The size of cut required is obtained by adjusting the feed rate of the impeller.

Components Design Vegetable compartment design: The volumetric capacity for the vegetable compartment was calculated in relation to the volume of material it occupied. The compartment was designed to contain about two bunches of vegetables per unit operation.

The volume was calculated from the relationship

$$\rho = \frac{m}{v} \quad (1)$$

Where, v = volume of material in m^3 , m = Mass of the vegetable in kg = 0.7kg (Approx.), ρ = Bulk density of vegetables = 561 kg/m^3

$$\text{Therefore, } v = 0.0012m^3 \quad (2)$$

Knife thickness design: Selection of right thickness of slicing knife is very essential as it directly affects the slicing effectiveness. The thickness of slicing knife was calculated using expression if given by Khurmi and Gupta (2005):

$$t = \frac{W_k}{L_k \times B_k \times g \times (\rho_k - \rho_v)} \quad (3)$$

Where t = thickness (m); W_k = Knife Weight = 250g = 0.25kg; L_k = knife length = 20.15cm = 0.2015m and B_k = knife width = 84mm = 0.084m

ρ_k = knife density = 7700 kg/m^3 (Stainless Steel)

ρ_v = vegetable density = 561 kg/m^3 (measured).

$$t = 0.00021m = 0.2mm \text{ (Approx.)} \quad (4)$$

It should however be noted that we could not readily obtain a stainless-steel material with the calculated thickness of 0.2mm. Therefore, a thickness of 1mm was used during fabrication.

Slicer stand thickness design: For the slicer stand we use the slender ratio formular:

$$F = \frac{\pi^2 EI}{(KL)^2} \quad (5)$$

Where F = maximum force

$$F = W_{ic} + W_{hf} \quad (6)$$

Where W_{ic} = Entire vegetable compartment weight inclusive of knife = 5.44N (measured); W_{hf} = average human effort exerted by hand which is given as 12.38N (Bernhard & Roemer, 1969)

$$F = W_{ic} + W_{hf} = 17.82N \quad (7)$$

Where E = modulus of elasticity (stainless steel) = 186 to 200 kN/mm^2 and I = Area moment of Inertia

$$I = \frac{bd^2}{12} \quad (8)$$

Where $b = d$

$$I = \frac{d^4}{12} \quad (9)$$

Where K = effective length factors whose value depends on the condition of the support.

Both ends pinned $K = 1$

Both ends fixed $K = 0.5$

One fixed and the other is free $K = 2$

Where L = length of the column (slicer stand) = 0.4m. This was selected for ergonomic reason.

$$\text{From (5), } I = \frac{F(KL)^2}{\pi^2 E} \quad (10)$$

$$I = \frac{F(KL)^2}{\pi^2 E} = \frac{d^4}{12} \quad (11)$$

$$d = \sqrt[4]{\frac{12F(KL)^2}{\pi^2 E}} \quad (12)$$

$$d = \sqrt[4]{\frac{12 \times 17.82 \times (0.5 \times 0.4)^2}{3.14^2 \times 200 \times 10^3}} \quad (13)$$

$$d = 0.0456m = 46mm \text{ (Approx.)} \quad (14)$$

Efficiency of the Machine: Average size of Original Vegetable leaf = 91.6mm

Average size of sliced Vegetable leaf = 4.1mm

$$\text{Slicing Efficiency} = \frac{\text{Original} - \text{final}}{\text{Original}} \times \frac{100}{1} =$$

$$\frac{91.6 - 4.1}{91.6} \times \frac{100}{1} = 95.52\%$$

From the results, a slicing efficiency of 95.52% was achieved for the machine. This implies that the newly developed machine is reliable.

Table 1: Bill of Engineering Materials and Evaluation

S/N	Material	Quantity	Net cost (Naira)
1	stainless steel metal	4ft x4ft	8,500
2	Stainless steel electrode	28	5,600
3	Cutting abrasive	3	3,000
4	Angle grinder abrasive	3	650
5	Impeller	1	550
6	Blade	1	1,500
7	Bolt and nuts	5	1,950
TOTAL			21,750

RESULT AND DISCUSSION

The vegetable slicing machine as designed and manufactured is effective and efficient in its function. Dimensions of 10 samples of the original vegetable leaves were taken before being sliced. Also dimensions of the sliced vegetable leaves from the machine were taken. The experimental results are as shown in Table 2.



Fig 3. Machine with sliced vegetables

Table 2: Experimental results for slicing efficiency

S/N	1	2	3	4	5	6	7	8	9	10
Size of Unsliced Leaf (mm)	72	74	87	110	80	100	90	105	85	113
Size of Sliced Leaf (mm)	9	8.5	7	6	5	2	2	3	3	2.5

Conclusion: The manual vegetable slicing machine has been designed, fabricated and evaluated. It is manually operated and therefore will save domestic power consumption. It is gratifying to know that it has been proven that this machine performs its function satisfactorily. Time consumption is less when compared to manual cutting using knives. This work has tried in providing the desired output.

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The result of evaluation gave slicing efficiency 95.52 %. Thus, this work provides an alternative to the existing conventional use of knives. The cutter is fully enclosed thereby eliminating the risk of injury caused by direct exposure of hands to the cutting edge of the knives.

It was seen that the sliced vegetable leaves obtained from using this machine was way better than those obtained from the traditional method, as the one obtained from this machine was evenly sliced. The total cost of the materials used in the fabrication of this machine is as shown in Table 1.

This cost is exclusive of the cost for labour. It is pertinent to add that some of the materials used for the fabrication may not be adjudged as the best in the market but were selected based on the constraint of cost. This machine will therefore help to produce sliced vegetable faster and safer.