DESIGN, CONSTRUCTION AND EVALUATION OF MOTORIZED OKRA SLICER

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ABSTRACT

A motorized okra slicer was designed, constructed and tested. It has a capacity of 42.8 kg/hr and efficiency of 95% when compared with the manually operated machine and hand slicing methods. It produces slices of uniform thickness with standard deviation and variance of 0.13 and 0.14, respectively.

Keywords: Okra Slicer, Designed, Fabricated And Evaluated.

1.INTRODUCTION:

Okra, gumbo or okra is known botanically as hibiscus esculentus. The importance of okra to man and animal cannot be overemphasized. Okra is a vegetable grown on commercial scale during wet and dry seasons. Nutritive value of okra includes supply of vitamins, protein and minerals. This accounts for its acceptability by many of the tribes in the country [1] Okra is utilized in both fresh and dried forms for soups/stew making and the seed can be used to fortify non- protein foods. Okra also in powdered form has the properties of an emulsifier and can be useful in making emulsified prepared foods [2].

Okra farmers and marketers experience a lot of annual posts harvest losses caused by poor handling, inadequate storage facilities because of the high perishability nature of fresh okra fruits. To reduce losses and derive maximum utilization and economic gains from okra, adequate preservation by way of processing the produce is needed to preserve its quality and enhance long shelf life

Unit operations involved in the traditional processing of okra are carried out using traditional techniques. Kitchen knife is usually used for slicing okra. This traditional technique of slicing okra using kitchen knife exposes the user to the danger of knife cut. The output of the traditional technique has been found to be low due to the drudgery of the process. It was in recognition of the need to remove drudgery, injury and associated rigours to the user and to enhance quality, hygiene and efficiency in Okra processing that National Agricultural Research Project through Federal Institute of Industrial Research Oshodi (F l l R O) conceived and initiated a research into the development of suitable processing method and equipment of which Okra slicer is a part.

Objective of the study:

The objectives of this work are to design, construct and carry out comparative evaluation of motorized okra slicer

2. PHYSICAL AND MECHANICAL PROPERTIES OF OKRA

Okra has some characteristic physical properties like diameter and length (shape and size), volume, density and surface area which vary from specie to specie. The length, maximum diameter, mass, density and percentage moisture content were determined as shown in Table 1.

The thickness of slice required for the quick and more uniform slicing was determined as 2mm. The static angle of repose of okra was determined by allowing the fruits to fall freely from a height, and the angle made by the cone with the horizontal base was measured using a sliding protractor. The result obtained for mean static angle of repose was 32.07° (with standard deviation of 3.33°). Dynamic angle of repose is given as 70% of the static one (22.34°).

Table 1: Some Physical Characteristics of Okra

	Big Fruit	Medium Fruit	Small Fruit
Length (mm)	84	73	28
Maximum Diameter(mm)	37	25	16
Mass (g)	25	19	3
Density(g/cm^3)	0.086	0.056	0.068
Moisture Content(%w.b)	86.75	85.90	86.65

3 DESIGN CONSIDERATIONS

The slicer is made up of the following units (Figure 2): (a) the hopper (b) the slicing unit, and (c) the frame

3.1 The Hopper (Feeding Unit):

The hopper has a conical upper part connected to a cylindrical lower part such that it has a "Y" cross- section. The base of the hopper opens into the channeling chamber from the top so that feeding of the Okra is aided by gravity. This was achieved through a proper choice of the angle of inclination of the hopper to the horizontal, which was made greater than the angle of repose. An angle of 45° was chosen (Figure 2 Component 12 Plate 1).

3.2 The Slicing Unit

The slicing unit has the following components: (i) the cutting disc; (ii) the power drive mechanism; (iii) the transmission shaft; (iv) the bearing assembly. Fig. 2, components 13, 9a,9b, 10,7,8

3.2.1 The Cutting Disc

This is the primary or basic component that does the slicing (Figure 2 Component 13). Some basic empirical properties were determined as shown below.

Diameter of the disc = 200mm (about 5 X the diameter of Okra) as recommended by Myer [3].

Speed of rotation of disc: To determine this the following equations were used.

$$V = WR \quad (1)$$

$$W = \frac{2\pi N}{60} \quad (2)$$

where, V = Linear Velocity of the disc, m/s

W= angular Velocity, *rad/*s

R = radius of the disc, m

N = number of revolution per minute

3.2.2 The Power Drive Mechanism

The power required by the cutting disc was calculated using the following expression as recommended by Spots. (4)

$$P = TW \quad (3)$$

$$T = FR \quad (4)$$

Where, **P** = power required by the cutting disc, hp

W = angular velocity, rad/s

T = torque, N -.M

F = Force required to the slicing, N

A single phase electric motor of 0.3hp was selected. This is to take care of power losses. Also, total kinetic energy stored in the disc is given as

$$KE = 1/2IW^2 \quad (5)$$

$$where, W = \frac{2\pi N}{60} from\ equation (2)$$

I=moment of intertia, kg-m-S^2

$$= \frac{W_d R^2}{g} \quad (6)$$

$$= \pi R^2 \rho t \quad (7)$$

where, g = acceleration due to gravity, *m/s*

W_d = Weight of the disc, kg

ρ = Density of disc material

t = Thickness of the disk, mm

The power transmission of the machine is by pulley and belt arrangement. as shown in figure 1. The selected motor of 0.3hp delivers at speed of 1450 rpm which was stepped down to the required speed by appropriate pulleys. A diameter of the motor shaft pulley of 75mm was selected. The motor shaft pulley diameter, D_r was calculated as follows [5].

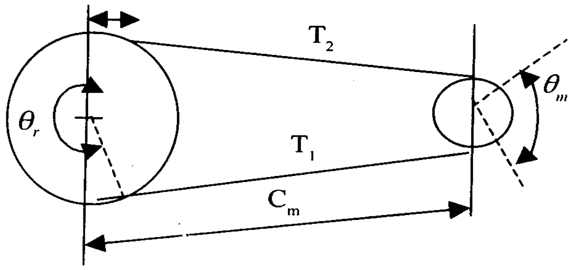


Figure 1: Configuration of rotor-motor shaft pulley.

$$D_r = \frac{N_m D_m}{N_r} \quad (8)$$

Where N_m = speed of the motor shaft, rpm

D_m = diameter of the motor pulley,mm

N_r = speed of the motor shaft, rpm

The minimum center distance. C_m

$$C_m = \frac{D_m + d_r + D_m}{2} \quad (9)$$

Length of the belt, L_b

$$L_b = 2C_m + 1.57\left(\frac{D_r + D_m}{2}\right) + \left(\frac{D_r - D_m}{4}\right) \quad (10)$$

Calculation of the tension in the belt

$$Sin\beta = \frac{R_r - R_m}{C_m} \quad (11)$$

where, R_r = radius of the rotor shaft pulley, mm

R_m = radius of the motor shaft pulley, mm

C_m = minimum center distance, mm

the angle of contact of belt on small pulley, which is the angle of wrap of the belt on the motor pulley is given by

$$\theta_s = 180 + 2\beta$$

Angle of wrap of the motor shaft pulley,

$$\theta_r = 180 + 2\beta$$

Angle of wrap of the motor shaft pulley, θr

Power transmitted by the motor is given by

$$p = (T_1 - T_2)wr \quad (12)$$

where, p = power transmitted by motor 0.3 hp

T_1= Tension at the slack side, N

T_2 = Tension at the tight side, N

W = angular Velocity of the motor pulley, rad/ s

r = radius of the motor pulley, mm

From equation (12)

$$\frac{T_1}{T_2} = \ell\, \mu\, \theta_s \quad (13)$$

Where μ = coefficient of friction of leather on steel.

Inertial tension, $T_{max} = 2T_1$ (14)

Maximum stress in leather δ_{max}

$$\delta_{max} = \frac{T_{max}}{bt}$$

Where t = belt thickness $t = \frac{T_{max}}{d_{max} \times b}$ (15)

Mass of one meter, M is given by

$$M = \int bt \quad (16)$$

Where ∫ = density of leather belt

The centrifugal force, F_C acting on the belt in given

by $F_c = MV^2$ (17)

From the above analysis, a belt width, thickness and length were selected. A factor of safety of 2.0 is applied for high reliability factor. Hence the maximum allowable workings load T_{max} is given as $T_{max}= T_1$

3.2.3 The Transmission Shaft.

Shaft design consist primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. ASME codes for the design of commercial shaft was used in determining the diameter of the shaft. The diameter is given as [6]

$$d^3 = \frac{16}{PS_s}\sqrt{[(K_b m_b)^2 + (K_t m_t)]^2} \quad (18)$$

where, M_t = torsional moment, Nm

$$= (T_1 - T_2)R \quad (19)$$

K_b=combined shock and fatigue factor applied to bending.

K_t = combined shock and fatigue factor applied to torsional moment.

M_b = bending moment, Nm.

S_s = allowable shear stress, as specified by ASME

for commercial shaft with key ways.

Bending moments, M_b is evaluated by considering loading condition of the shaft. The standard shaft (ϕ= 25mm) available in the market was selected based on the calculated value of diameter that satisfied the designed condition.

3.2.4 The Bearing Assembly

The machine has two bearing located at both ends of the frame. Static and dynamic load conditions and design life requirement were the factors considered in selecting the bearing, sealed pedestal bearing, diameter of bore was selected as it satisfied the design requirement.

3.3 The Frame

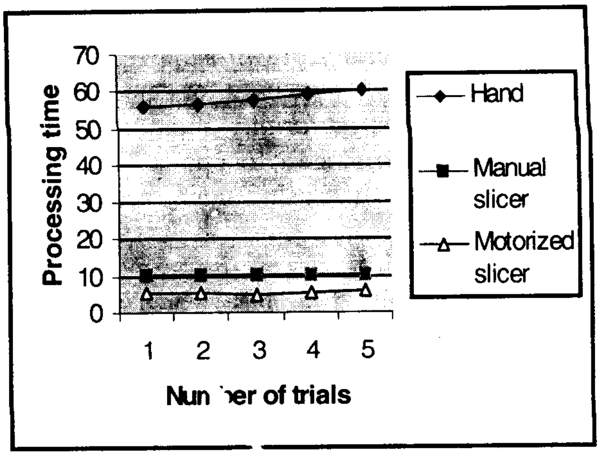
Weight of the shaft, the hopper, the bearing and of the material (okra) were considered in designing the frame

A 38 mm. x 38mm angle iron having the strength and rigidity to withstand the load was used.

4.0 MATERIALS SELECTION

Table 1 Material Specifications

S/N	PART NAME	QUANTITY	MATERIAL	OVERALL DIMENSION
1	Main Housing	4	Galvanized steel sheet(gauge 16)	400mm x 500mm
2	Feeding unit	1	" " "	150mm x 200mm x 500mm
3	Disc Housing	2	" " "	5mm x 210mm x 195mm
4	Cutting disc	1	Mild steel plate	6mm x Φ 200mm
5	Power transmission shaft	1	Mild steel	Φ 25 x 800mm
6	Discharge outlet	1	Galvanized steel sheet	50mm x 155mm x 200mm x 300mm
7	Motor pulley	1	Mild steel	Φ75mm x 20mm
8	Rotor pulley	1	Mild steel	Φ253mm x 20mm
9	Bearing	2	Pedestal ball bearing	Bore = 25mm
10	Prime mover	1	0.3hp phase motor	
11	Belt	1	Leather	L = 768mm W = 9mm T = 15mm
12	Frame	1	Angle mild steel	500mm x 400mm x 500mm



5. OPERATION FEATURES OF THE SLICER

The slicer is powered by 0.3hp single-phase electric motor. This is transmitted through a v-belt and pulley arrangement. The engine is mounted at the base such that its weight gives stability to the machine. The rotating disc slices the loaded okra by shear and cutting force. The machine is self- feeding. The okra flows to the cutting disc due to the vibration of the machine and gravitational force. The hopper is placed offset from the center and inclined at an angle; this is to ensure flowability and easy discharge of the slices.

6. Test performance evaluation and Result

0.5kg of fresh okra was fed into the machine through the hopper and timed to determine the slicing time. Also two women sliced the same quantity of the okra and the average time taken to slice the okra was recorded.

The same 0.5kg of the okra was sliced using an existing manual slicer, the slicing time was also recorded.

The above test evaluation for the motorized slicer, manual slicer and hand slicing were repeated five times and average time recorded as shown in Table 2 and figure 3. Actual capacity of the machine was also determined by feeding okra into the machine and finally weighing all the slices irrespective of damage. The damaged slices were later selected and weighed and the efficiency was evaluated.

Also, the efficiency with respect to theoretical (design) capacity as compared to the hand sliced was evaluated as presented in Table 3.

Three randomly drawn samples of each containing 30 slices were used for determination of slice thickness, uniformity and shape. Slice thickness was determined at four points around the periphery of the slice using micrometer screw gauge.

Statistical analyses were used to evaluate the standard deviation and variance, which was found to be 0.13 and 0.14 respectively as shown in Table 4.

<u>Table 2</u> Time of Slicing a Given Quantity of Okra for Motonzed, Manual and Hand Slicing

No of trials	Hand	Time (mins) Manua' slicer	Motorized slicer
1	56.05	10.15	5.52
2	56.20	10.12	5.50
3	57.40	10.10	5.05
4	59.00	10.14	5.65
5	60.10	10.20	5.30

Figure: 3 *Graph of processing time versus the number of trials.*

The variation in thickness of the slices was more in motorized because in motorized; the feeding cannot be adequately controlled.

Table 3 Capacities/Efficiencies

	Hand	Manual slicer	Motorised slicer
Theoretical capacity (kg/hr)	-	15	50
Actual capacity (kg/hr)	2.2	13.2	42.8
Efficiency **WRT**, Capacity Ec (%)	-	88%	85
Percentage of damaged slices(%)	2	5	11
Efficiency **WRT** hand sliced (%)	-	84	95

Table 4 Uniformity of the slices

	Hand	Manual slicer	Motorised slicer
Mean thickness	3.05mm	1.99mm	1.86mm
Standard deviation	1.00	0.05	0.13
Variance	1.03	0.06	0.14
Limits	3.05 ± 1.05	1.990.05	1.860.132

4.0 CONCLUSION

The design, development and performance evaluation of a motorized Okra slicer has been reported. Based on the result of performance evaluation, the equipment performed well in slicing Okra fruits. The actual capacity of the machine was determined as 42.8kglhr which was below the design capacity of 50kg/hr. The difference is due to human factor delay in feeding Okra in the hopper. The variation in thickness of the slices was highest for hand compared to manually and motorized slicers.

The efficiency in terms of rate of slicing was highest in motorized compared to the conventional methods of slicing Okra fruits. The time required to slice a given quantity of okra using hands was considerably reduced from 57.75 minutes to 10.14 minutes and 5.5 minutes for manual and motorized slicer respectively.

The machine should be made more compact to reduce its space and material requirement and efficient feeding mechanism should be devised to ease the flow of okra to the cutting disc.

The modified machine, cost effective as it should be, should be commercialized so as to encourage post- harvest processing of okra.

REFERENCE

1. Tindall, J. Fruits and Vegetable in West Africa, Food Agriculture Organization of the United Nations, Rome, 1975.

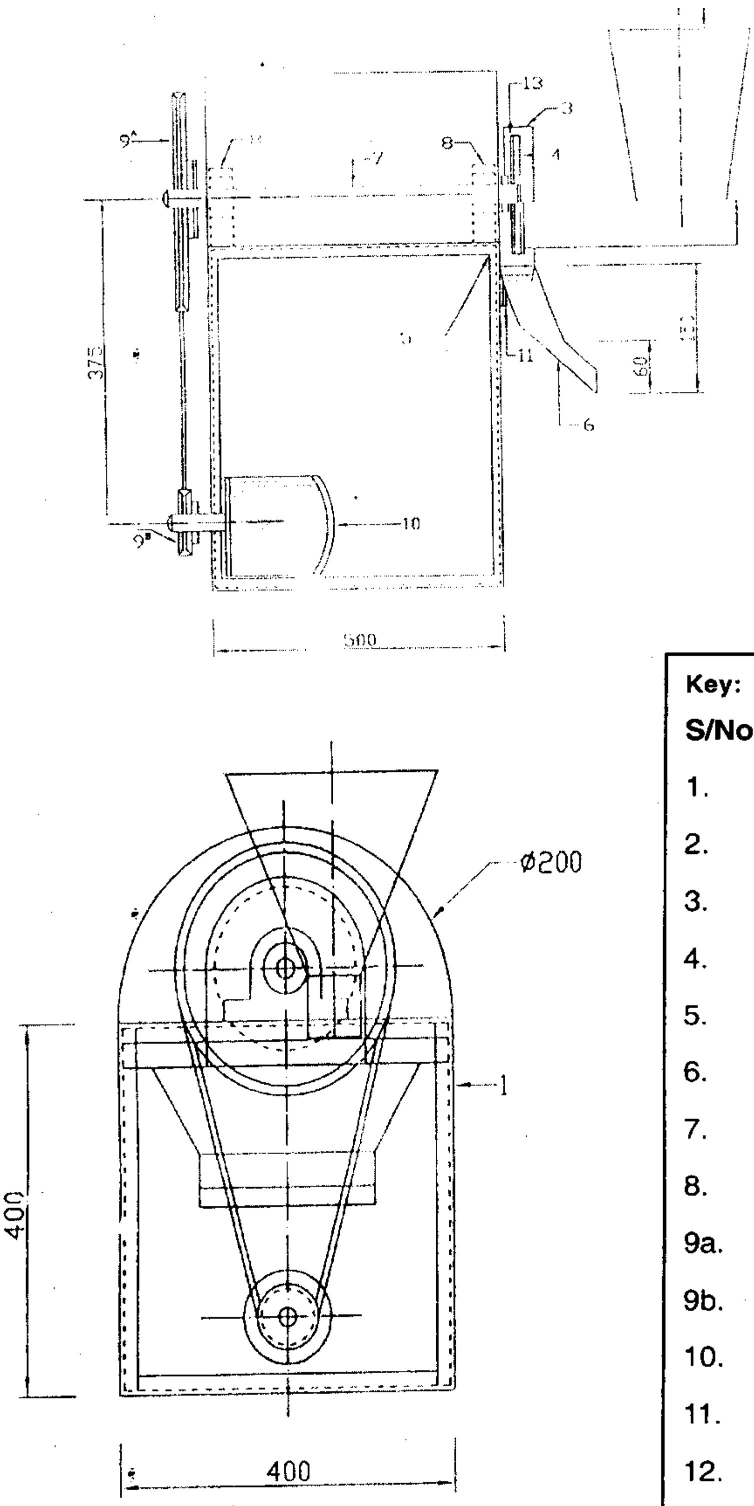
2. Douglas, M. L. *Food and Food production Encyclopedia.* dia Van Nostrand Reinhold Company. New yolk, Tomoto, 1982.

5. Joseph, E.S *Theory of Machine and Mechanisms,* MiCgraw- Hill inc., 1980.

6. Kashrus, R, P; Balasubramanian, D; Kotwaliwale, N. Design, Development and Evaluation of rotors slicer for Raw Banana Chips AMA Jnl 27(4) I 996, pp 61-64.

3. Myer, *K* .. *Mechanical Engineering Handbook,* John Wiley and sons, Inc. New York., 1986

4. Spots, M. F. *Design of Machine Element.* 6th edition prentice of India private ltd New Delhi., 1988

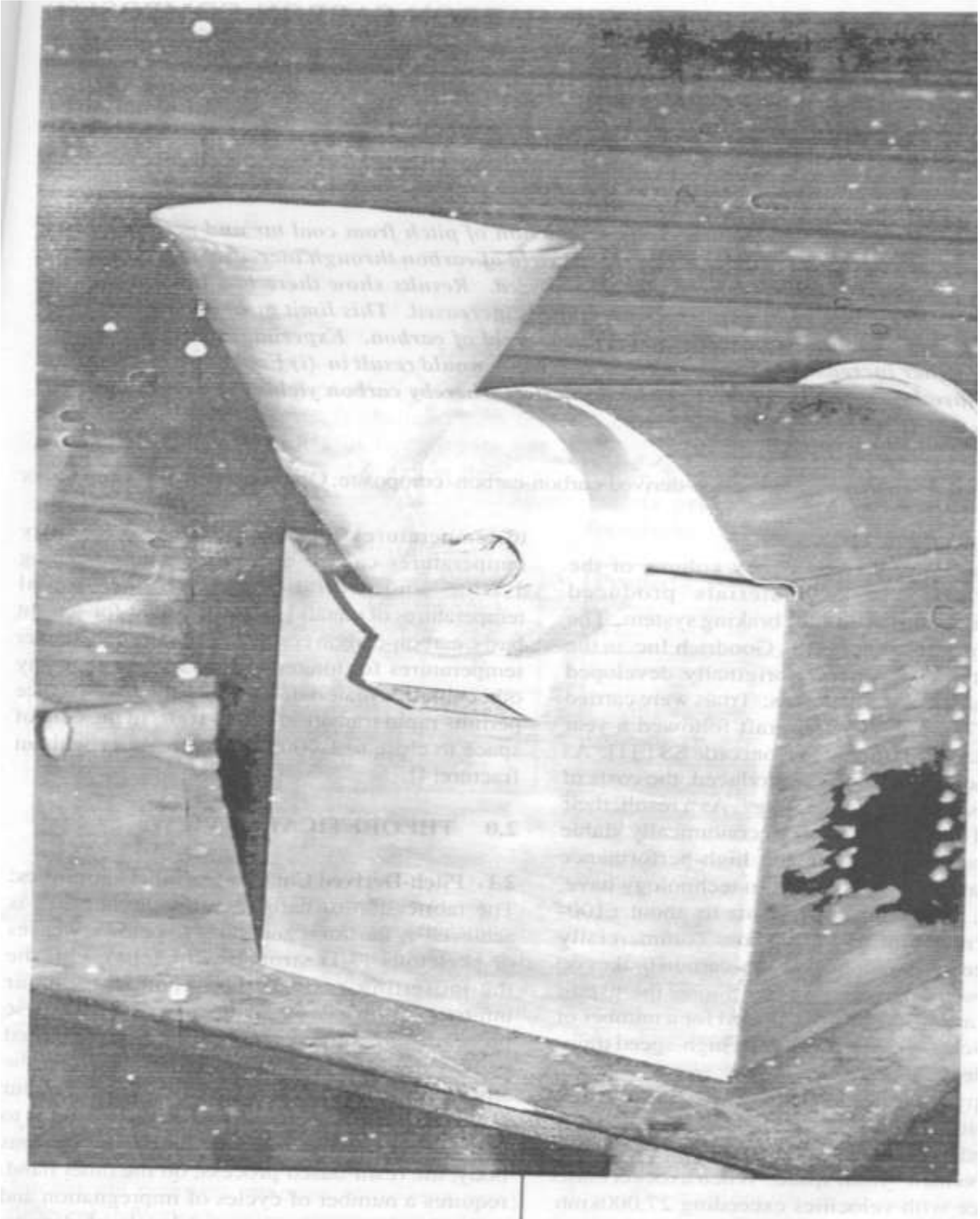


M

Key:

S/No.	Description
1.	Main Housing
2.	Top Cover
3.	Disc. Husing
4.	Cutting Blade
5.	BrassBrushing
6.	Discharge Outlet
7.	Main Shaft
8.	Pedestal Bearing
9a.	Drive Pulley
9b.	Driven pullry
10.	Electric Motor
11.	Disc Plate
12.	Feeding Unit
13.	Cutting Disc.

Fig. 2: Sectional Views



Appendix 2: Pictorial view of motorizd okra slicer.