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A manually operated lady's finger (okra) *(Abelmoschus esculentus)* slicing device suitable for on-farm use was designed, fabricated and tested based on the engineering properties of the vegetable. The machine, simulates the traditional method of okra slicing, consists of the feeder, slicer and receiver. It was made simple for ease of operation and maintenance. The machine was tested with replicated experimental runs using 100, 200, 300, 400 and 500 g of okra. The thickness of the slices (about 10 mm) corresponds evenly to the spacing of the cutting discs. The machine has a slicing efficiency of about 77.4% and throughput of about 8.4 kg/h

Keywords: Okra, Lady's finger, Drying, Preservation, Slicing device

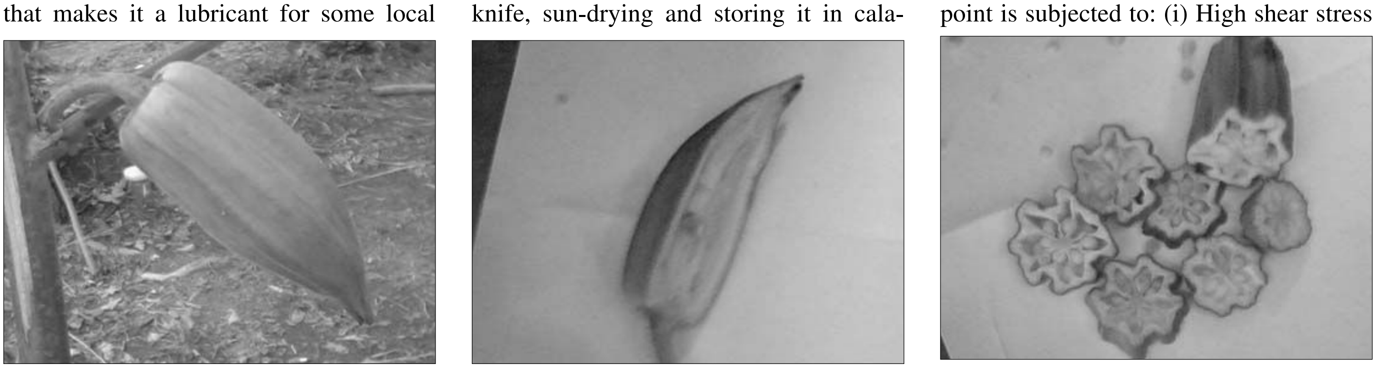
Okra (*Abelmoschus esculentus)* commonly referred to as lady's finger, is a warm season plant, usually planted on warm soils (Scheweers and Sims 1976). The immature fruit (pod), which has valuable economic and nutritional importance, is the major part of the plant. It is usually harvested when the plant is actively growing during which it is tender and non-fibrous (Sanders 2002). The average fruit length, width and thickness of an okra pod are 54.6, 28.6 and 26.7 mm, respectively (Owolarafe and Shotonde 2004). The picture of a fresh pod of okra is shown in Fig. 1a. A longitudinal or transverse section through the pod shows its internal structure as a mesh of plant membranes, which holds small specks of seedlings (Fig. 1b and 1c, respectively).

Okra is rich in iron, calcium, vitamins A, B complex and C (Adebooye and Oputa 1996, Okra food 2003). It is a highly consumed food complement in some parts of Africa owing to its elastic behaviour when chopped with knife and cooked into draw-soup; a characteristic that makes it a lubricant for some local diets, which are swallowed as balls. The small specks of seedlings are extracted and used for cheese spreading, salad dressing and candies. Okra is also used as an additive in the manufacture of some essential drugs in the pharmaceutical industry. Okra is therefore, a highly used vegetable product and a major source of income for rural farmers and substantial foreign exchange can also be earned from export.

In Nigeria and most other African countries, the traditional method of storage involves spreading it in the open for few hours during cold weather or by refrigeration; but this can only preserve okra for a limited period of time (usually 3 - 4 days), it depreciates rapidly thereafter because of its perishable nature. As a result, bulk of the harvest gets wasted every year and much revenue accruable to the farmer is lost. The common method of preservation among the Yorubas of the Southwestern Nigeria is to process the pods into a crispy dry product, this involves slicing the fresh fruit with a sharp knife, sun-drying and storing it in calabash gourds. The dry slices are pound into granules, mixed with water and cooked with other ingredients to prepare draw soup when fresh okra is off-season. The entire process is quite laborious and time consuming but it goes a long way to reduce wastage and losses during peak harvest.

Slicing is a cutting process for size reduction of fruits and vegetables; it involves pushing or forcing a thin, sharp knife to shear through the material. The result gives minimum deformation and rupture of the cell wall. Biological materials commonly subjected to cutting could be classified as: (i). Non-fibrous, liquid cell materials having uniform properties in all direction at the time of cutting, (ii). Fibrous materials with high tensile strength fibers oriented in a common direction with comparatively low-strength materials bonding the fibers together.

In the first category, the compressive stress applied by the cutting tool to the cell will cause pressure in the cell wall at the point of contact with cutting tool. This point is subjected to: (i) High shear stress



a b c

Fig. 1 (a) A ripe okra pod (b) longitudinal section through a pod of okra (c) Transverse section through a pod of okra showing sliced pieces because of the applied compressive stress in one direction. (ii) Tensile stress due to addition of bending stresses at the point of indentation to the hydrostatic stress. (iii) Movement of the tool in a direction parallel to its edge and perpendicular to the direction of the compressive force applied (slicing action) which can further add to the shear stress applied to the cell wall at the point of contact.

However, manual slicing with knife is still a common practice in both domestic and commercial okra processing. The pod is first cut straight from tip of the cone down to the base of the stub and then cut perpendicularly to the first cut to obtain tiny bits of shredded okra. Fresh okra usually has an array of tiny, harmful spines on the surface of the pod, which irritates at fingertips and this makes women who are usually involved in the shredding uncomfortable during and after the slicing process. The process is slow and laborious and the product is often not very hygienic.

The development of an appropriate technology is therefore attempted to improve the existing traditional method of slicing, drying, pounding and packaging. The objective of this work was to develop a simple, manually operated okra slicing device as the first phase in developing an appropriate technology for okra processing.

Materials and methods

The machine consists mainly of the following parts:

i) *Feeding unit:* This feeds the okra pods into the slicing chamber. It is made up of the following.

a. Hopper: From the traditional method of slicing it is proposed that the machine should be able to hold 500 g of okra fruit at a time. Thus the hopper (Fig. 2) was designed to hold 500 g of okra fruits. The dimensions of the hopper were specified as 203 mm × 52 mm × 152 mm based on the volume of 1.11×106 mm^3 obtained from the bulk density of okra fruit 450 kg/m^3 (Owolarafe and Shotonde 2004). A fresh experiment was also conducted to confirm this.

b. Plunger: This was fabricated using mild steel sheet and the dimension is 200 mm × 45 mm × 170 mm.

The plunger is fitted with a holder at the top for easy handling while in the feeding unit as in Fig. 2.

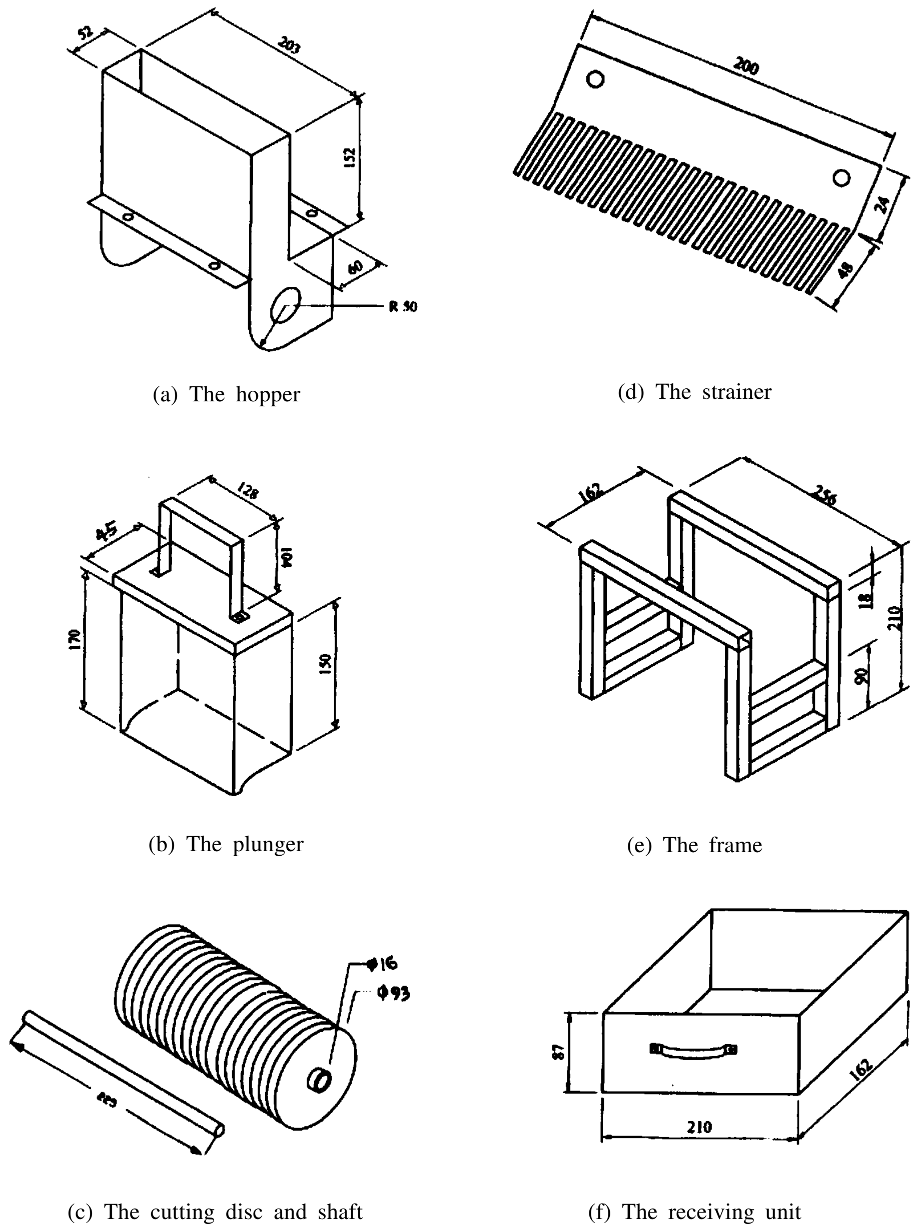


Fig. 2: Different parts of the okra slicing machine

ii) *Slicing unit:* The primary purpose of this unit is to slice the okra pods and discharge it into the container underneath. It consists of:

a. Slicers (cutting discs): The discs were constructed from mild steel sheet metal of 2 mm thickness. The cutting discs are of diameter 93 mm each, with 20 of them equally spaced by a distance of 10 mm along the length of a pipe through which the shaft is placed. The small tapered pin passing through the drilled hole on the pipe carrying the cutting discs and the one on the shaft makes it possible for the two to rotate as one.

b. Shaft: The shaft used was of 10 mm diameter. One end of the shaft has been pinned to the crank, which rotates the shaft manually. The assembly of the shaft, crank and cutting discs is supported by two bearings.

c. Strainers / scrapper: This was constructed and incorporated into the slicing unit so that the slice will be scrapped down from the cutting disc due to the gummy and sticky nature of okra (Fig. 2).

iii) *Frame:* The frame acts as support for other parts of the machine. It is made of a hollow 18 mm × 18 mm square pipe, 256 mm long, 162 mm wide and 210 mm high.

iv) *Receiving unit:* The receiving unit (Fig. 2) consists of the container which is 210 mm × 162 mm × 87 mm with a handle attached to it.

v) *Drive:* The driving component of the machine consists of the crank and crank handle. The crank is of 110 mm diameter and the handle is 114 mm long.

The orthographic projection of the okra slicer is presented in Fig. 3.

Strength analysis of the shaft

The properties of the selected shaft material are:

Allowable shear stress, $S_s = 4 \times 10^6$ N/m² (for shaft with a keyway)

Length of shaft, L_s = 225 mm = 0.225 m

Density of mild steel = 7622 kg/m³

For a rotating shaft with gradually applied load, the bending fatigue factor, k_b = 1.5 and the torsional fatigue factor, k_t = 1.0 (Hall et al 1983). The loads on the shaft are due to:

(a) Plunger: The mass of the plunger was determined by weighing.

Mass of plunger = 1.25 kg

Weight of plunger =1.25 kg ×9.81 m/s² =12.2625 N.

(b) Okra fruits: The mass of okra fruits was determined by weighing.

Mass of okra fruits = 500 g = 0.5 kg

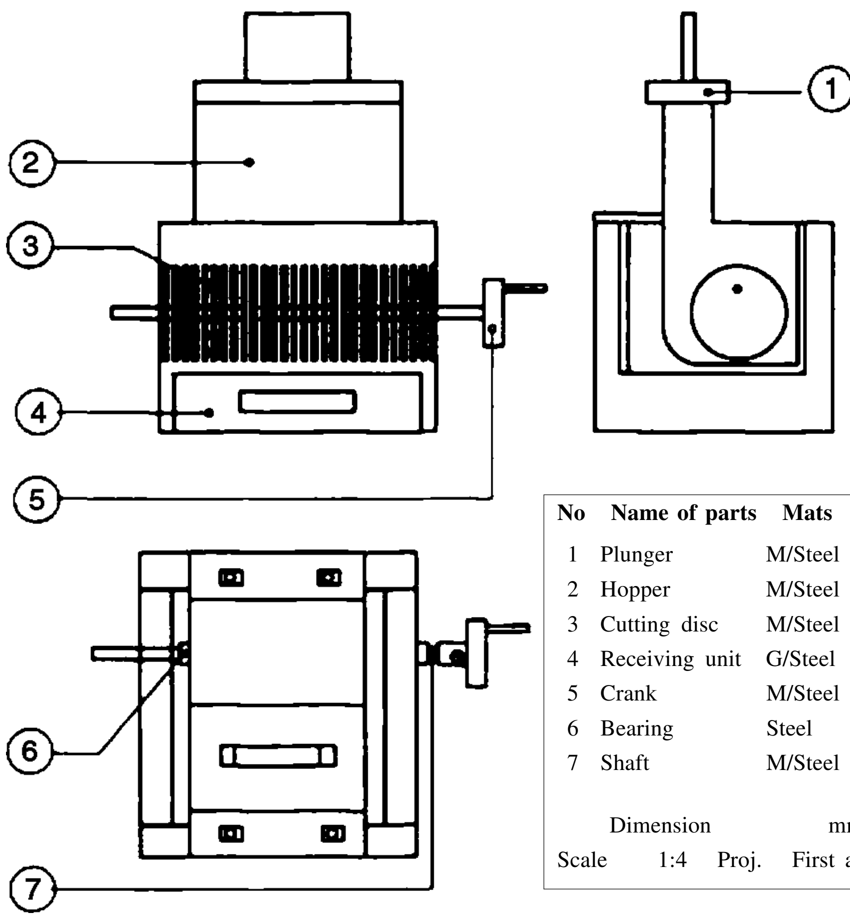
Weight of okra fruits = 0.5 kg×9.81 m/s² = 4.905 N.

(c) Cutting discs: The mass of the cutting discs was determined through the analysis as shown below.

Number of cutting discs, n = 20

Thickness of a cutting disc, t =2 mm =0.002 m

Diameter of a cutting disc, d = 93 mm = 0.093 m



No	Name of parts	Mats	Qty
1	Plunger	M/Steel	1
2	Hopper	M/Steel	1
3	Cutting disc	M/Steel	20
4	Receiving unit	G/Steel	1
5	Crank	M/Steel	1
6	Bearing	Steel	2
7	Shaft	M/Steel	1

Dimension mm
Scale 1:4 Proj. First angle

Fig. 3. Orthographic projection of the okra slicing machine

Therefore, surface area of a disc,

$$A_d = \frac{\pi d^2}{4}$$

$$A_d = \frac{\pi (0.093)^2}{4} = 0.006729 m^2$$

Vol of a disc, $V_d = A_d \times t$

$V_d = 1.35858 \times 10^{-5}$ m³

Volume of 20 discs

= 20 × V_d

= 0.000271716 m³

= 2.71716 ×10⁻⁴ m³

Mass of 20 discs = density × vol of 20 discs

=7622 kg/m³ × 2.71716 ×10-⁴ m³

=2.071 kg

Wt of 20 discs = 2.071 kg × 9.81 m/s² = 20.31651 N

Therefore equivalent load on shaft, W_t is given by

Wt = wt of 20 discs + wt of plunger + wt of okra fruits

= (20.31651 + 12.2625 + 4.905) N

= 37.48401 N

The analysis of the total load on the shaft is shown in Fig. 4.

Sum of upward forces = sum of downward forces.

$R_A + R_B = W_t$ ...(i)

where, R_A and R_B represent reactions at points A and B, respectively.

Taking moment about point B,

Sum of clockwise moments = sum of anti-clockwise moments

0.225 R_A = (37.48401 × 0.1125)

$$R_A = \frac{4.21695}{0.225} = 18.742\text{N}$$

From eq (i), $R_B = W_t - R_A$ ... (ii)

= 37.48401 – 18.742

= 18.742 N

Therefore, the maximum bending moment, M_b = 2.108 Nm.

But, Torsional moment, M_t =9550 kW/ rev/min Nm (Hall et al 1983)

Human effort in Watts = 75 W = 0.075 kW

Expected rpm = 60

Therefore, M_t = 9550 × 0.075 / 60 Nm =11.938 Nm

The required shaft diameter is determined by employing the formula,

$$d^3 = \frac{16}{\pi S_s}\left[(M_t K_t)^2 + (M_b K_b)^2\right]^{1/2} \quad \text{... (iii)}$$

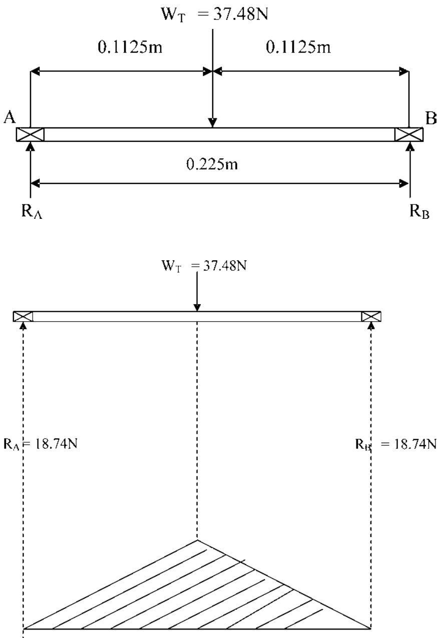


Fig. 4. The analysis of the total load on the shaft

(Hall et al 1983)

(Note: for a rotating shaft with gradually applied load, the bending fatigue factor K_b = 1.5 and the torsional fatigue factor K_t =1.0)

Hence, applying the formula yields:

d^3 = 0.000001572 m^3

d = 0.011628 m

d = 11.63 mm

The hopper cage

Bulk density of okra fruit = 450.42 kg/m^3

Max allowable mass of okra = 500 g

= 0.5 kg

Required volume of hopper = maximum volume of okra that can be loaded at a time

$= \dfrac{0.5 \text{ kg}}{450.42 \text{ kg/m}^3}$

= 1.11 x 10-3 m^3

Machine testing and evaluation

The machine was loaded with okra and the shaft was turned clockwise at 60 rpm. It was observed that faster speed of operation increases the rate of slicing. The plunger retains the okra fruits in the hopper and also presses them against the cutting discs. An appreciable force is needed to keep the okra fruits pressed on the cutting discs during slicing operation.

The machine testing was replicated thrice with 100, 200, 300, 400 and 500 g of okra fruits, respectively and its performance was evaluated on the basis of the slicing efficiency of the machine and the through-put for 500 g of okra fruits.

Results and discussion

The results of the experiments are shown in Table 1. The average slicing efficiency (η_s) was 77.4 % and was obtained from the expression:

$$\eta_s = \frac{m_s}{m} \times 100\%$$

where, m_s=Mass of sliced okra pods, m = Total mass of okra pods loaded into the hopper

The through-put of the machine was obtained as a ratio 500 g of okra pods to the time it takes to slice the pods completely, and this was found to be 8.4 kg/h. Some of the okra pods were sliced along the fruit length and there was slight mechanical damage to some of the materials (Fig. 5). This may be due the fact that the okra pods fed into the machine were of different sizes.

Conclusion

A manually operated okra slicing device has been developed based on previously determined physical parameters of okra fruits. This was undertaken as a first step in the development of an appropriate technology for okra processing and preservation with a view to stop seasonal wastage of okra at rural level in Nigeria and other producing countries in sub-Saharan Africa. The machine was constructed from locally available materials and it is simple to operate. The device has an average efficiency of 77.4% and through-put of 8.4 kg/h.

Table 1. Test results of the machine efficiency

Okra loaded into hopper, g	Mass of sliced okra pods, g	Efficiency, %
100	75	75
200	160	80
300	230	77
400	300	75
500	400	80

(n=3)

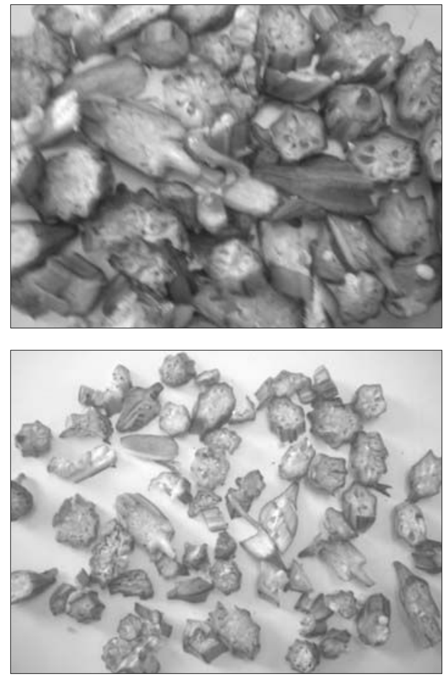


Fig. 5. Pictures of okra pods sliced with the machine showing the sliced pieces and extent of mechanical damage

References

Adebooye OC, Oputa CO 1996. Effects of galex on growth and fruit nutrient composition of okra. Ife J Agric 18(1/2):1-9

Hall AS, Hollowenko AR, Laughlin AG 1983. Theory and problems of machine design. Schaum's outline series. McGraw Hill Book Co, New York, p 113-117

Okra food 2003. www.foodreference.com,

Lorenz DA, Mynard DN 1988. Knott's Handbook for vegetable growers. Wiley & Sons, New York

Owolarafe OK, Shotonde HO 2004. Some physical properties of fresh okra fruit. J Food Eng 3:299-302

Sanders DC 2002. Okra production. N.C. State University of Horticulture Information leaflet (HIL-19), p 1-3

Scheweers VH, Sims WL 1976. Okra production, Leaflet. 2679 (5p), UC DANK Oakland, CA

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