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Design and Construction of Potato Peeling Machine for Domestic Use

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ABSTRACT

Peeling potato is a process of removing the skin which normally protects the pulp. Since the different types of fruits have different shapes and size hence different machines are to process them. The potato peeling process faces numerous problems of consuming time since it is done manually using sharp objects like knives. This manual method of peeling results in fruit flesh wastage, especially fruit with thin skin, and sometimes makes peeling tiring. This work focused on the design and construction of a potato peeling machine using a stationary abrasive drum, with a rotating shaft and stirrer capable of peeling 5kg of potato using locally available raw materials at a relatively low cost. The machine constitutes an electric motor, drum, shaft built with stirrer, couplings, and abrasive base peeling section.

Key words: Potato, abrasive, peeling, peeling machine, stirrer, couplings

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1. INTRODUCTION

Potato peeling is a widespread process in air households, restaurants, food processing factories, and large kitchens [1,2]. Potato is a very rich source of starch. It also contains phosphorus calcium, iron, and some vitamins. Apart from the use of fresh potatoes for the purpose of making vegetables and gravy, they are dehydrated in the form of slices, sticks, cubes, or powder to impart better chef life. Hence, the peeling method of potato is a point of interest due to reducing the size of the tuber and its time-consuming process tiring [3,4]. The peeling of vegetables is usually carried out by a particular machine. Hence, development is very much required to promote timely large-scale processing and to overcome unhygienic environmental problems which result in the development of various types of peeling machines [5;6].

The three categories of peeling methods include:

i. Thermal peeling: which is done either wet heat (steam, refrigerant) or dry heat (fire, hot gases). These methods are particularly for tough and thick skin fruit and vegetable [7,8].
ii. Chemical peeling: This involves the use of caustic soda, such as NaOH and it is generally used in factories and industries [3].
iii. Mechanical peeling: this method does not require the use of chemicals or heat in the peeling process. This method is based on the mechanism used for peeling such as knife or blade, abrasive, rollers, milling, or rotary cutters [2,3]. The mechanical peeling method minimizes product losses, minimizes energy, reduction in chemical usage, minimizes pollution load and heat ring formation. The mechanical peeling method is preferable due to customer satisfaction. Potato peeling is based on different characteristics like weight, dimensions, density and volume, shape and size, which may be the peeling criterion that many researchers have been doing in this field [8].

2. MATERIALS AND METHODS

i. Design theory and principle: the apparatus was designed for peeling the potatoes. The peeling action is done by rotating the abrasive lower plate which is mounted on the main shaft. The main shaft is coupled to an electric motor through coupling. The shaft is built with a stirrer [4,5].
ii. Design and construction of the potato peeling machine consist of cylindrical drum; abrasive lower plate, top lid, stirrer, shaft, coupling, electric motor, and steel frame.

2.1 Cylindrical drum:

The main body is constructed in a cylindrical shape with the flat round bottom inside surface of the drum is coated with silicon git for abrasive action. Generally, silicon powder with grits is recommended [6,7]. A removable top lid with

recess is provided on top of the main body to facilitate the loading and prevent potatoes from falling. A chute is provided for removing peeled potatoes. Later is also provided for locking the machine while in operation for the purpose of safety. Stainless steel was used because of its corrosive resistance, high tensile strength, durability, and attractive appearance as shown in Fig.1a.

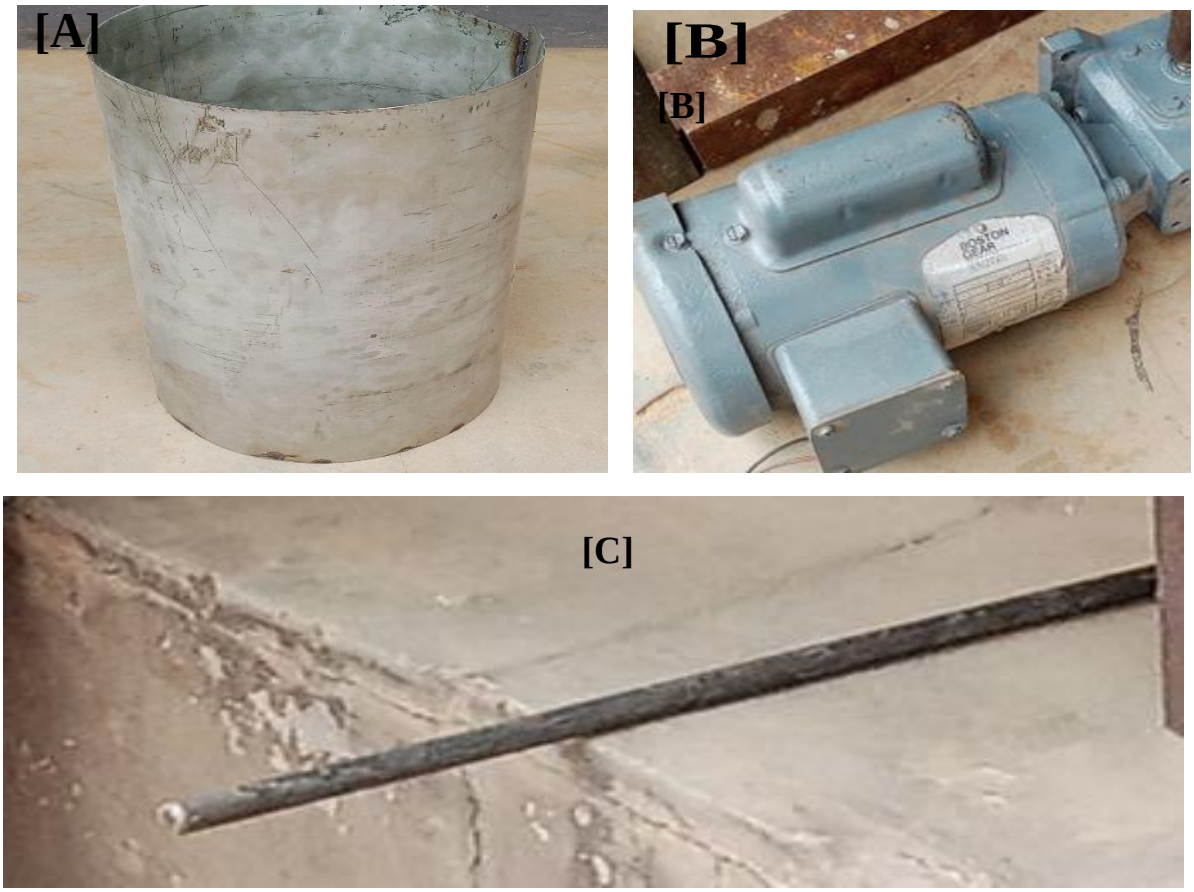

Fig. 1 Cylindrical drum (a), Electric motor (b), and Shaft (c).

2.2 Drive for Shaft and Stirrer

A machine that is used to convert electrical energy into mechanical energy is called a motor. A single or three-phase induction motor with a rating of 0.37KW (0.5HP) 50Hz and 1,440r.p.m was used. The shaft and stirrer were driven with the motor directly driving through coupling. The shaft is made of solid iron measuring 7.5mm and 120mm in diameter and length (Fig. 1b and c).

Torque was calculated from the expression in equation (1)

$$\text{Torque } T = \frac{P \times 60}{2 \times 3.14 \times N} \quad (1)$$

Where;

Speed N=1440rpm

Power P=0.5hp = 373Watts

The primary function of the stirrer shaft is to transmit torque from the stirrer motto to the impeller. Torque is the tendency of a force to cause an object to rotate. Water Inlet Drain: water inlet drain connection will be provided to the machine provision is made for draining of water along with potato skins. The drain shall be large enough to prevent any chance of its being clogged with waste potato skin. The stirring shaft diameter was calculated as follows:

Using the general torsional equation [6,7,8]

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{R} \quad (2)$$

Where;

T is the torque acting on the shaft

J is the polar moment of inertia of the shaft about the axis of rotation

τ is the torsional shear stress (for mild steel) = 42MPa

R is the distance from neutral axis to the outer most fibre

$$R = \frac{d}{2} \quad (3)$$

Where d is the diameter of the shaft.

$J = \frac{\pi \times d^4}{32}$ (4)

Substituting for J in the general torsion equation

$T = \frac{\pi}{16} \times \tau \times d^3$ (5)

$P = \frac{2\pi NT}{60}$ (6)

Where P is the power from the electric motor (0.5hp)

N is the speed of shaft in rpm (25r.p.m)

Hence, T = 0.191Nm = 191 Nmm

The maximum torque T_{max} is Torque ×the service factor of the electric motor

$Tmax = 191 \times 1.25 = 238.75Nm$

$d^3 = \frac{16T}{\pi\tau}$ (7)

$d = 3.07mm \cong 3mm$

From $\frac{T}{J} = \frac{G\theta}{L}$

L is the length of shaft (mm) =450mm

G is the modulus of rigidity of the shaft material for stainless steel. It is 77.2GPa

θ is the angle of twist of the shaft (in radian)

$\theta = \frac{TL}{JG}$ (8)

$J = 7.95$; therefore, $\theta = 0.18rad$

Therefore, the permissible twist angle (in radian) of the shaft is 0.18rad.

Since the shaft undergoes vibrations torsional spring constant (K_t)

$K_t = \frac{\pi G d^4}{32T}$ (9)

Therefore; $K_t = 1.36KNmm$

The natural frequency of vibration is given as:

$W_n = \sqrt{\frac{Kt}{J}}$ (10)

$W_n = 13.10Nmm^2$

The centrifugal force of stirring blade F_b is given as:

$F_b = mw^2r$ (11)

Where;

r is the radial distance between tip blades tip and center of shaft which is 90mm.

M is a constant and for stainless steel is 1.44

$F_b = 1.44 \times 13.10^2 \times 90 = 22.24KN$

2.3 Machine Assemblage

2.3.1 The Frame

The frame is made of corner iron 40×40mm with a thickness of 3mm. the frame has dimensions of length, width, and height of 360mm, 360mm, and 380mm respectively. The following criteria were considered in the design and fabrication

Simplicity: The construction of the components is very simple in design.

Very affordable: locally made materials are used which make it very affordable to small and medium entrepreneurs.

Low maintenance: the machine is easy to maintain since there are no complex components.

Very reliable to use since it can peel a given amount of potato at a given time.

Very effective: the machine is very effective compared to the manual method of peeling.

Safety: the safety of the user is guaranteed since the process is not manual where the knife is involved in peeling the potatoes.

Fig. 2 Frame (a)

Fig. 2 Machine Assemblage (b)

3. RESULTS

The results present in Table 1, show the geometric mean of the machine performance test on the potato of the relatively same size. The machine was designed to peel 10 kg of potato per hour. The finding agrees with the studies [5,6,7] The developed machine is still under trial tests using potatoes of different diameters. The generated results will be compared with the convectional method.

Table -1 Potato sample with a relatively uniform size was used in testing the machine

Sample	Major dia. (cm)	Intermediate dia. (cm)	Minor dia. (cm)	Geometric mean (cm)
1	5.56	4.55	4.45	4.82
2	5.42	4.65	4.26	4.75
3	5.53	4.46	3.86	4.57
4	5.64	4.54	4.21	4.76
5	5.35	4.53	3.82	4.52
Average	**5.50**	**4.54**	**4.12**	**4.69**

4. CONCLUSION

The machine has been designed, constructed, and tested. The machine can also be used to peel vegetables of similar properties. This machine is designed with the capacity to peel 5kg of potato chips in one go. This machine will replace the manual peeling method which is a time-consuming and very tiring process. The speed of the peeling process can be automated using a fully designed potato peeling machine. The relevance of this research work is to develop very efficient potato peeling machines for local use with locally sourced materials.

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