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Design and Development of Mango (*Mangifera Indica.* L) Fruit Peeler Machine

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Abstract: Mango fruit is the most popular fruit on the planet and most likely fruit cultivation grown in Ethiopia. The peeling of the mango is one process that is done traditionally and time-consuming. Not only this but also, during peeling, there is the loss of pulp within seed and peel. A process of peeling is removing the peel from mango pulp which is commonly done manually which results in a waste of time, low and fewer quality products and hand hurt. To make the peeling process easy, a peeler machine was designed and developed. The peeler machine consists of the frames, spur gears, sample shaft, blade shaft, screw shaft, blade, and handling which has been made of locally sourced materials to making it cost-effective. After the design of the peeler machine, the efficiency of the developed prototype was carried out by using mango fruit. The abstract focused on designing and developing an effective peeler machine for both commercial and household use with the main objective of improves the hygiene of any mango product processes, increase supply of mango fruit in restaurants, reduce environmental waste and may reduce the highest cost of processed mango product in market.

Keywords: Design, Machine, Mango, Peeler, Process

1. Introduction

Mango is a tropical fruit of highly seasonal and one of the most popular fruits in Ethiopia [10]. Peel contributes about 15-20% of the fruit Peel is not currently utilized for any commercial purpose, it is discarded as a waste and becoming a source of Pollution [12]. A preliminary study showed that the seed represents from 20% to 60% of the whole and the kernel inside the seed which represents from fruit weight [3]. Peels are the major by-products obtained during the processing of various fruits [5]. Peel is rich in phytochemicals, fibre and vitamin C [8] which makes it suitable to be processed and used in food and pharmaceuticals [5]. In the scientific community, mango peels have recently attracted considerable attention due to their high content of valuable compounds, such as phytochemicals, polyphenols, carotenoids, enzymes, vitamin E and vitamin C, predominantly functional antioxidant. Currently, several initiatives concentrate on the use of industrial waste in the production of new food ingredients with a good source of organic compounds as raw material.

This project contains the designing and manufacturing of a mango peeler machine. Mango peelers are kitchen utensils used to peel any kind of fruit such as apple, orange papaya, etc that needs peeling and their use is not restricted on mango. There is a difference in mango peelers with current use in the market place. In this project, a new mango peeling style within a simple method and simple force were introduced. The Mango peeler has been designed to contain two framers from both sides and the basement to hold the peeler as the supporter. The sample shaft is rolled by spur gear which is interconnected within handling. The machine is using a manually pedal system rather than a motor. This is to make all customer beneficiaries within its price. Spur gears are moving within single handling to save effort applied and material used. The distance between the spur gear depends on the diameter of the mango. The sample shaft should be small diameter to increase the efficiency of the machine and by changing only the blade length, it is possible to make the peeler flexible for orange, potato apple guava peeling. The blade is roll over the screw shaft and the length of the blade is based on the radius of the fruit ready to peel. The basement of the peeler should be heavy metal with appropriate thickness to fix the peeler at a place.

The peeler is placed on a table to make it suitable for move handling. The first aim of this project is to solve the lack of a fruit peeler machine in the Food process laboratory at Bahir Dar Institute of Technology. The machine also solves the problem of hand peeling and saves the time of peeling. Besides this, it decreases the oxidation of fruits during peeling and versatile for many fruits.

1.1. General Objective

The main objective of this project is to design and manufacture of mango fruit peeler machine.

1.2. Specific Objectives

1) To study feasibility of peeler machine.
2) To sizing peeler machine and each parts its machine
3) Develop the Prototype and check efficiency of peeler machine.

2. Materials and Methods

2.1. Experimental Site

The prototype of the machine was conducted at Bahir Dar Institute of Technology and parts of machines (bearing, shafts, and blades) were bought from the square part shop in Bahir Dar city. Some parts of the machine such as super gears, drum shaft, screw shaft were also designed and produced in the mechanical laboratory at Bahir Dar Institute of Technology.

2.2. Equipments

The equipment used for design and manufacturing of mango peeler were saw, grinder machine, nuts, welding machines, electrodes, laze machine, nail, revote, revote pusher, cutter and so on.

2.3. Methods

The design of mango peeler follows some prescribed design procedures. The following are the main procedures to be followed.

1. Force analysis of the machine parts
2. Calculate appropriate dimensions of each part based on capacity and make reasonable assumptions if necessary.
3. Select appropriate materials based on the analysis.
4. Select standard parts like bearing those fit the requirement of the analysis.
5. Assemble the parts based on the dimensions provided.
6. Cost analysis of the mango peeler compared with the component.
7. Make some recommendations to modify the design if necessary.

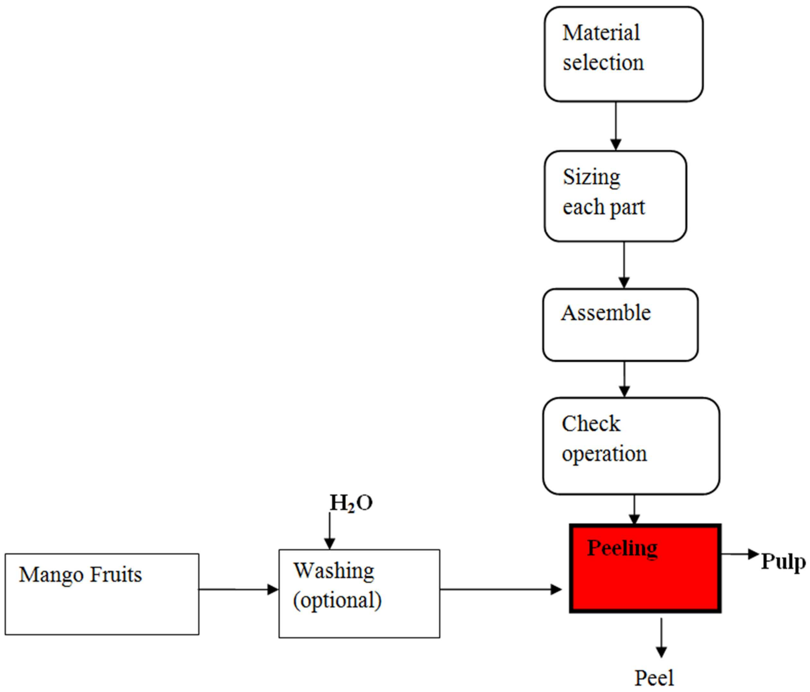

Figure 1. *Process flow diagram of mango peeler machine development.*

2.4. Working Principle the Machine

Mango peeler is a machine that removes the skin /peel from mature mango. Matured mangoes (which are containing round shape) are inserted between sample shafts that contain a needle at the tip. The left side sample shaft moves clockwise and also back and forward for inserting matured mango and to deliver peeled mango. The sample shaft moves back and forward but, during peeling, it only rotates clockwise with screw shaft.

As the gear moves by handling, the screw shaft roll within the mango fruit, and the blade is moving over the surface of the mango over the axis of the blade shaft. Via doing so mango peeling is completed. The peeling speed and blade moving are based on the rolling of handling. The skin removed has a rope-like shape based on the shape of bled used. In short, peeling is a process carried out by moving blade on the surface of mango. It is safe, quick, and reduces pulp loss that is removed with skin.

2.5. Design of Peeler Machine Parts

2.5.1. Spur Gear Design

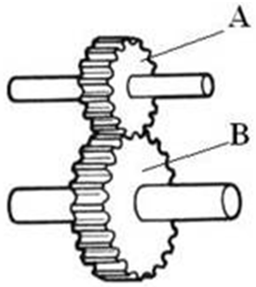

Figure 2. *Spur gear.*

Given Gear A – driven gear
Number of teeth=34
Internal diameter=3 cm
Hole diameter /shaft diameter=1.5 mm
Rpm=120 or 12.56 radian per second
Gear B – driver gear
Internal diameter=8 cm
Hole diameter /shaft diameter=1.5 mm
Required Number of teeth=?, Gear velocity=?

1) Number of teeth

To determine number of teeth on both the gears, we have to assume number of teeth on one gear (T1), say the smaller gear. Now using the relation given below we can determine number of teeth on other gear, T2 [13].

$\frac{T1}{T2}=\frac{D2}{D1}$ where D_1 and D_2 internal diameter of gear A and B respectively.

$T2=\frac{D2}{D1}*T1$, $T2=\frac{8\ cm}{3\ cm}*34$, T2=86 number of teeth for gear B

2) gear ratio is ratio of driven gear teeth to driver gear teeth

Where there are two gears of different sizes, the smaller gear will rotate faster than the larger gear. The gear that is closer to the source of power is called the *driver*, and the gear that receives power from the driver is called the *driven gear*. The difference between these two speeds is called the velocity ratio, or the gear ratio, and can be calculated using the number of teeth. The formula is:

$$\text{Gear ratio}=\frac{\text{driven gear teeth}}{\text{driver gear teeth}},\ \text{Gear ratio}=\frac{34}{86},=0.4 \text{ or } 2:5$$

Because gear "A" has 34 teeth and "B" has 86 teeth "A" will travel through *five* complete turns for every *two* complete turn of gear "B" this would give a ratio of 2:5. This is because gear "A's" rotational speed is 0.4 that of gear "B".

3) Gear velocity

Gear B velocity$=\frac{\pi*d*rpm}{60}$, $v=\frac{3.14*3\ cm*48\ rpm}{60}$, v=0.2m/s

Gear A velocity$=\frac{\pi*d*rpm}{60}$, $v=\frac{3.14*3\ cm*120\ rpm}{60}$, v=0.5m/s

4) Force and Power

Gears transmit force from tooth of the driving gear on to the meshing driven tooth. The tooth of the driving gear 1 pushes the meshing tooth on gear 2 along the line of action.

4) Torque applied

Torque is a measure of how much force acting on an object causes that object to rotate.

Torque$=\frac{power*60}{2\pi*rpm}$ based on this formula torque of gear A and B are 36.5 Nm and 90.5 Nm respectively. Since man power is used in place of motor and average human power applied per day is 0. 6 HP=447.6 Watts due to 1hp=745 watts. Human power is work or energy that is produced from the human body. It can also refer to the power (rate of work per time) of a human. Power comes primarily from muscles. The average human, at rest, produces around 100 watts of power. This equates to around 2000 kcal of food energy, which is why your recommended daily intake of calories is around 2000 kcal [7].

2.5.2. Bearing

Bearing is a machine element that constrains relative motion and reduces friction between moving parts to only the desired motion. Many bearings also *facilitate* the desired motion as much as possible, such as by minimizing friction. The bearing is not designed; simply selected based on diameter of shaft or screw shaft.

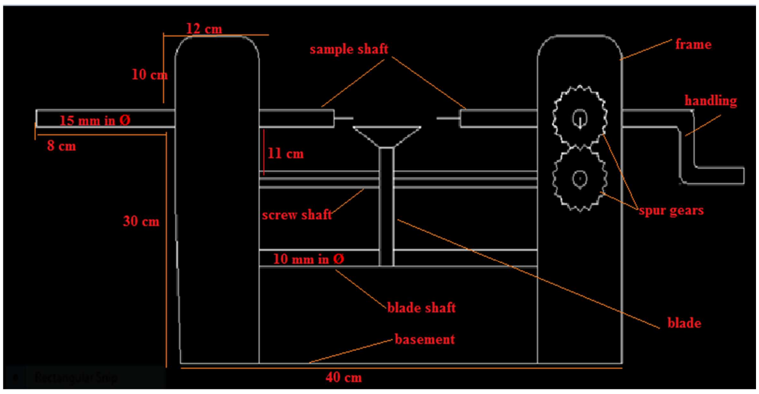

Figure 3. *Peeler machine specification and its 2D- auto CAD.*

2.6. Cost Analysis and Price of Mango Peeler Machine

In order to analysis the cost I determined the cost of the material by referring their density and their related volume. Due to the cost of steel metal is found by its mass; the mass of each parts of machine is calculated [15]. In all calculation 1 kg of steel metal=2.7 $ or 89.1 ETB is used. So that each part was calculated as follow [6, 7, 11].

A) Handling of peeler machine Diameter=15mm Length=15cm

M=ρv where M is mass of steel material and ρ is density of steel material, for all steel material, ρ =7.92g/cm^3. V=2πr^{2}L, V=2 (3.14 * 0.15^{2}cm * 10cm) V=1.413cm^3 were v is volume

Then mass of steel is M=7.92g/cm^3 * 1.413cm^3, M=0.373kg since one kilogram of steel material cost is 89.1 ETB. So that, 0.373kg * 89.1 birr=33.23 birr

B) Sample shaft Diameter=15mm, Length=25cm

M=ρv where M is mass of steel material and ρ is density of steel material, for all steel material, ρ =7.92g/cm^3. V=2πr^{2}L, V=2 (3.14 * 0.75^{2}cm * 25cm) V=44.15cm^3 were v is volume

Then mass of steel is M=7.92g/cm^3 * 44.15cm^3, M=0.3496kg. Since one kilogram of steel material cost is 89.1 ETB. So that, 0.3496kg * 89.1 birr=31.15 birr

C) Blade shaft Diameter=10mm, Length=25cm

M=ρv where M is mass of steel material and ρ is density of steel material, for all steel material, ρ =7.92g/cm^3. V=2πr^{2}L, V=2 (3.14 * 0. 5^{2}cm * 25cm) V=1.963cm^3 were v is volume

Then mass of steel is M=7.92g/cm^3 * 1.963cm^3, M=0.155kg. Since one kilogram of steel material cost is 89.1 ETB. So that, 0.155kg * 89.1 birr=13.81 birr.

D) Driven (spur gear A) - Internal diameter (d)=3 cm, Thickness 3 mm, External diameter (D)=3.3cm

Volume=$\frac{\pi}{4}$ * T * (D$_{average}$)^2, where T is thickness of gear

$$\text{Then volume}=\frac{3.14*0.3*(3.15)2}{4}\text{cm}^3,\ V=5.33\ \text{cm}^3$$

So, M=ρ * v, M=7.92g/cm^3 * 5.33 cm^3=0.42 kg. Since one kilogram of steel material cost is 89.1ETB then, 0.42kg * 89.1 birr=37.42 birr

E) Driver (spur gear B) Internal diameter (d)=8cm, Thickness 3 mm, External diameter (D)=8.2cm

Volume=$\frac{\pi}{4}$ * T * (D $_{average}$)^2, where T is thickness of gear

$$\text{Then volume}=\frac{3.14*0.3*(8.2)2}{4}\text{cm}^3,\ V=103.38\ \text{cm}^3$$

So, M=ρ * v, M=7.92g/cm^3 * 103.38 cm^3=0.822 kg. Since one kilogram of steel material cost is 89.1ETB then, 0.822kg * 89.1 birr=73.24 birr.

Table 1. *Parts of peeler machine and their prices.*

Peeling Part	Quantity	Material	Measurement	Mass in kg	Price in ETB
Frames	2	Wood	40cm x12cm x10mm		80.00
Handling	1	Steel	15mm in Φ	0.373kg	33.23
Sample shaft	2	Steel	15mm in Φ	0.349kg	62.30
Screw shaft	1	Steel	15mm in Φ	0.349kg	31.15
Blade	1	Steel	10 mm in Φ	-	12.00 from market
Bearing	2	Steel	From standard	-	160.00 from market
Basement	1	Wood	25cmx12cm x20mm	-	40.00
Gears 1	1	Steel	3cm in Φ	0.42	37.42
Gear 2	1	Steel	8 cm in Φ	0.822	73.24
Blade shaft	1	Steel	40cm in ɭ	0.155kg	13.81
Total					543.15

Hint Φ - diameter ɭ - Length ɧ - Height.

The price of the mango peeling machine is including the manufacturing costs and the raw materials [6, 9].

Price of peeler machine=manufacturing cost + profit

The estimated price of mango peeling machine is eight hundred fifty birr (850.00 ETB) for the machine capacity three mangoes per minutes. This machine can be considered problem solver of time consuming during peeling especially in juice house process.

3. Results and Discussions

3.1. Evaluation of the Mango Peeling Machin

The machine having completed, in terms of the design and manufacturing, it was tested to verify if the efficiency of peeling is satisfactory [4]. Machine peeling capacity, peeling efficiency and the percentage of removed peels were the main items of the peeling machine performance evaluation. These parameters were evaluated at different mango sizes (small, medium, large); the sample was weighed before peeling to determine the initial mass. The mango sample was weighed again after peeling process to determine mass after peeling the machine.

3.2. Percentage of Peel Removed

Percentage of Peels removed was defined as the ratio of the mass of peels removed by the machine to the initial mass of the sample expressed as percentage as follows [2].

$$R_p=\frac{Mi-Mm}{Mi}x100,\ R_{p=}\frac{230-52}{230}*100,\ R_p=77.39\%$$

Where Mi=initial sample mass (g).

Mm=sample mass after peeling (g).

Rp=the removed peels by the machine (%).

3.3. Peeling Efficiency

Peeling efficiency was defined as the ratio of the peels removed by the machine (%) to the calculated peels mass (%), to be removed [14]. It could be computed as follows:

$\eta_p = \frac{Rp}{Mc.p} x100$, $\eta_p = \frac{77.39}{100} * 100$ =77.39% by assuming all peel should have to removed.

Where: ηp=peeling efficiency (%), Mc.p=the calculated peels mass (%), to be removed.

Rp=the removed peels by the machine (%).

4. Conclusions and Recommendations

4.1. Conclusions

The conclusion of the design starts with power transmission from the handling to the sample shaft through spur gears. The suitability of the man power selected to make suitable price in market. Some of the parts of the mango peeler were designed by considering property of mango fruit and force analysis. Driven and driver spur gears are designed as 86 and 34 number of teeth respectively, 2:5 gear ratio and peeled mango holder steel metal is used to reduce contamination. Standard parts like bearings were selected from international standardization based on diameter of shafts. The price of machine is fixed based on cost of machine parts. This project was done by observing the habits of our country hand peeling system. Most of the juice house in our country using a traditional hand peeling. Their productivity also increases by using this machine. From those the whole communities are benefited through a direct and indirect ways, hence juice houses, universities laboratory will save their labor force and the time they spent in using traditional system. The other benefit of this project is aids the development of the country in food hygiene, food handling by reducing of food born disease in our country.

4.2. Recommendations

For the mango peeler, a machine wood frame is used. This is aimed to reduce the cost of the machine but the age of the machine may decrease due to this. To solve this further study should be done to specify the type and Variety wood used as a frame. The pitch of the screw is one factor that influences the speed of the blade and should be studied further. The efficiency of the peeler machine is estimated by the peeling efficiency and percentage of the removed peels but due to the shape of the mango fruit efficiency of the machine is varied. At the sample shaft, there is a needle-like which used to hold the sample on motion so, caution should be taken during loading and unloading mangoes. Peeling efficiency is affected by rotation speed and skin size whereas pulping efficiency is affected by batch load, pulping residence time. To increase the amount of mango peeled per minute using a motor rather than manpower.

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