Design and development of maize peeler for farmers in Bangladesh

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Abstract: Hand peeling of maize is common practice before shelling in Bangladesh. The main problems of hand peeling are that these require more time and increase labour cost. A maize peeling machine has been designed and fabricated in Farm Machinery and Postharvest Process (FMP) Engineering Divisional workshop, Bangladesh Agricultural research Institute (BARI), Gazipur during 2016-2017 which reduces the human power in peeling operation of maize. This maize peeler can be very helpful for medium and small scale farmer. Two rubber and two spiral rollers were used for peeling of cobs. The functional parts of the machine are hopper, spiral roller and rubber roller. For the peeling operation moisture content of maize cobs were taken 20%-24% (wb). The peeling capacities of the manual and power peelings were 87 kg h^{-1} and 1008 kg h^{-1} respectively when the moisture content of maize cobs was 22% (wb). The highest peeling capacity was 1107 kg h^{-1} when the moisture content of the maize cob was 20% (wb). The average machine speeds were found to be 1.41 m s^{-1}. During peeling operation, it was observed that 1% of grains were injured and 3.2% of maize cobs were found to be unhusked which is very negligible. The efficiency of the machine was found to be 96%.

Keywords: maize peeler, speed, peeling capacity and peeling cost

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1 Introduction

Maize (*Zea mays*), the American Indian word for corn, is one of the main staple crops grown around the world. It belongs to a grass family (Gramineae) which originated from Mexico and South America. It is the third major cereal crop in Bangladesh after rice and wheat. Maize has versatile uses in different sectors like food, fuel and industrial products. During the last decade in Bangladesh due to increase of poultry and livestock farms, the popularity for maize has expanded notably. At present, maize growing area, maize production, and average yield of maize are 0.35 million hectares, 2.36 million ton, and 6.65 ton ha^{-1}, respectively (AIS, 2016). The present demand of maize in the country is about 2.5 million tons whereas the production is 2.178 million tons (AIS, 2014).

When the ear of corn reaches maturity, the individual grains swell and then harden to form a closely packed cylindrical cob. The kernels on the cob are within the husks, which endow some degree of protection from damage caused by insects, fungi and the ambient climate. Grain recovery includes the following process such as removal of husks, a reduction of moisture content from the grain for storage and finally removal of the grains from the cob. It is a common practice to manually dehusk the maize cobs and after drying shelling is being done either manually or with the help of power sheller. Peeling is to remove the husk from the maize cob. The current practice of hand peeling of cobs is laborious which is done mostly by women. This practice requires more time and labour.

Early 1990s, maize is not a popular crop among the farmers due to its usages and operational constraints. During that period, there was no mechanical maize peeler or shellers in Bangladesh and female workers

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engaged in maize peeling and shelling work, which was very tedious task and human drudgery (Hossain et al., 2017). Farm machinery and post-harvest process engineering division of BARI has been working on the development of hand and power maize sheller since 1993 and has successfully developed different types of sheller with the capacity of 1-3.5 t h^{-1} (Abdullah et al., 1995). But those machines have no any peeling part. Therefore, the proposed study has been undertaken to design and fabricate roller type maize peeler machine to facilitate the effective peeling operation before shelling of the maize cob.

2 Materials and methods

A roller type maize peeling machine was designed and drawn with SolidWorks software. According to drawing, its fabrication works completed at the workshop of FPM Engineering division of BARI, Gazipur. It was made of locally available materials. The materials used for the fabrication of different parts of the machine were mild steel roller, mild steel rod, mild steel angle, mild steel flat bar, mild steel sheet, mild steel shaft, rubber sheet, ball bearing, pulley, v-belt and other small items.

2.1 Design considerations

Some factors which were taken into account while designing the maize peeling machine are given below

i. Finding out the problem regarding the agriculture field.

ii. Crop factors such as size, shape, moisture content were considered in the design of the machine for the purpose of peeling of husk from the unhusked maize.

iii. Machine factors such as friction, wear, corrosion, weight, grasping ability, and stability were considered in the selection of appropriate material and in sizing and shaping of the various machine components for reliability.

iv. Determination of possible mechanisms which were used to give the product motion.

v. Preparing the rough sketch or layout of selected machine.

vi. Selection of the suitable material for each element of the product. Machine was constructed of locally available material to enhance the possibility of replacing damaged parts with less expensive but equivalently satisfactory parts that is readily available.

vii. Determine the standard dimension of elements and modify if required.

viii. Prepare the actual drawing of each component and assembly of this component with all the specification.

ix. The overall cost was considered through critical value analysis in the phases of design and production which at the end would make it affordable by farmers and other users.

2.2 The specifications and functions of the parts of the maize peeler

Power source: A 3 kW motor or engine was used as the source of power which was shown in Figure 1.

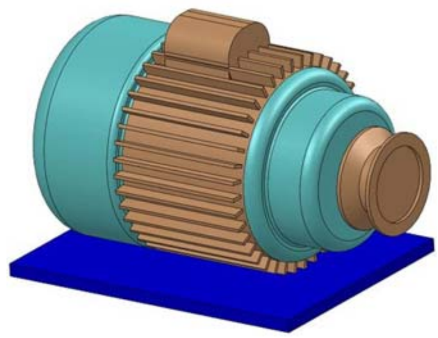


Figure 1 Isometric view of motor

Frame: The length, width, and height of the frame were 1000 mm, 450 mm and 845 mm respectively. The materials used for fabrication of frame of the peeler are mild steel (MS) angle bar. The total weight of the frame is 35 kg. The isometric view of the frame of maize peeler is given in Figure 2.

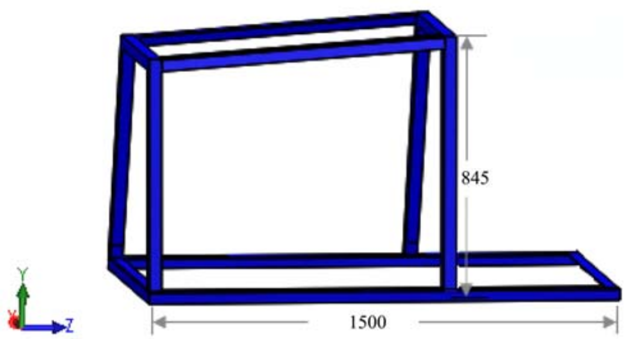


Figure 2 Isometric view of the frame of maize peeler

Hopper: The overall length, width and height of the hopper were 1473 mm, 430 mm and 470 mm respectively. Feeding hopper is placed at the top of the machine and provides maize cobs into the rotating roller portion. The capacity of hopper is around 3 kg. The isometric view of hopper frame of the maize peeler is delineated in Figure 3.

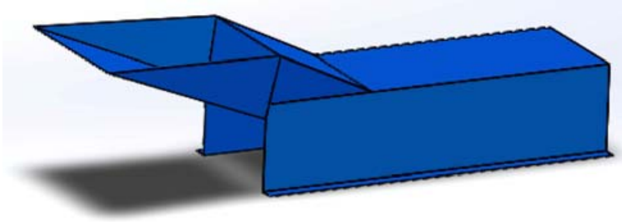


Figure 3 Isometric view of hopper frame of the maize peeler

Rubber and spiral rollers: Four rollers are used for peeling purpose (Figure 4). Working performance of the peeling part of this machine greatly depends on roller materials. As rubber is elastic, the friction coefficient of rubber is big than the metal, so the grasping force and the capacity of tearing husk of maize cobs increase for using rubber roller and the seed broken rate is also low. There is a height difference between the two pair of rollers. Each pair of rollers is in one high and one low-layout. So the weights of maize cobs have to face a different pressure of the two peeling rollers (Zhao et al., 2013). The relative rotation of the two pair of rollers clamped the bracts and torn the maize cobs. Spiral roller can help push the corncobs to the machine outlet. The rpm of rubber and spiral roller were almost same which around 1.39-1.43 m s^{-1}. The diameters of spiral and rubber rollers are 75 mm and 82 mm respectively and length of these rollers are 900 mm.

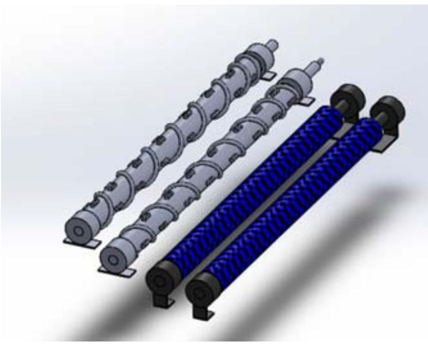


Figure 4 Isometric views of spiral and rubber rollers of the maize peeler

Pulley: Two V-grooved pulleys are used for power transmission as well as rpm reduction (Figure 5).

Figure 5 Isometric view of Pulley

Bearing: Eight 6206 zz bearing are attached at both ends of four rollers to ease of revolving section.

V-belt: One B section V-belt is used for power transmission.

2.3 Power transmission systems

Power transmission system included motor or engine, pulleys, self-center bearings, V-belt and pulley. A 3 kW electric motor or diesel engine was used as power source. Engine rpm was stepped down from 1400 to 360 by belt-pulley. Shaft of driven pulley were attached with the self-center bearings those fixed on the frame of MS angle. Power was transmitted to the roller from shaft by V-belt and pulley. The following equation was used to calculate the dimension of pulley of machine and engine to obtain the required rotational speed in the spiral and rubber roller (Amin, 2013)

$$\frac{D_1}{D_2} = \frac{N_2}{N_1} \quad (1)$$

where, D_1 is diameter of the driver pulley, mm; D_2 is diameter of the driven pulley, mm; N_1 is rpm of the driver pulley, m s^{-1}; N_2 is rpm of the driven pulley, m s^{-1}.

2.4 Testing and performance evaluation

The following parameters are calculated using the standard formulas which are given below:

$$P_c = \frac{60W_h}{T} \quad (2)$$

where, P_c is peeling capacity, kg h^{-1}; W_h is weight of husked cobs, kg; T is operating time, minutes.

$$I_r = \frac{W_i}{W_h} \times 100 \quad (3)$$

where, I_r is injured percentage, %; W_i is weight of injured cobs, kg; W_h is weight of husked cobs, kg.

$$Un = \frac{Wu}{Wt} \times 100 \quad (4)$$

where, Un is unhusked cobs, %; Wu is weight of unhusked maize cobs, kg; Wt is weight of total feed, kg.

$$E\ (\%) = 100 - Un - Ir \quad (5)$$

where, E is peeling efficiency, %.

2.5 Working principle

Maize peeler is mainly made up with two spiral and two rubber rollers, which can effectively remove the husk of corns. The outer surface of rubber roller is uneven and rough. There are number of corrugated teeth between the gaps of every two spiral rod of metal roller. The top of these corrugated teeth is slightly higher than the surface of spiral. This design improves the grasping ability of metal roller. In operation, the maize cobs will get into the working space through hopper. As tooth end is higher than the outer surface of the rollers, in the peeling process, first of all, peeling tooth tore ear bract. Then, the relative rotation of the two pair of rollers are clamped the bracts. The two rollers used rotating force to pull the bracts. A metal rod is spirally welded around the metal roller. The design of spiral roller pushes the maize cobs to the machine outlet and delivered into shelling part. Connected to the motor by pulley and V-belt, the driving shaft can be reached at a speed of 1.39-1.43 m s^{-1}. The height difference between spiral and rubber roller and the isometric view and front of the maize peeling machine are given in Figure 6 and Figure 7 respectively.

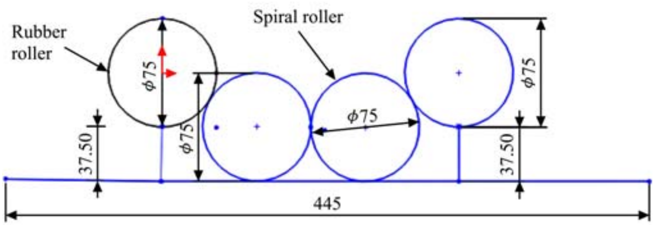
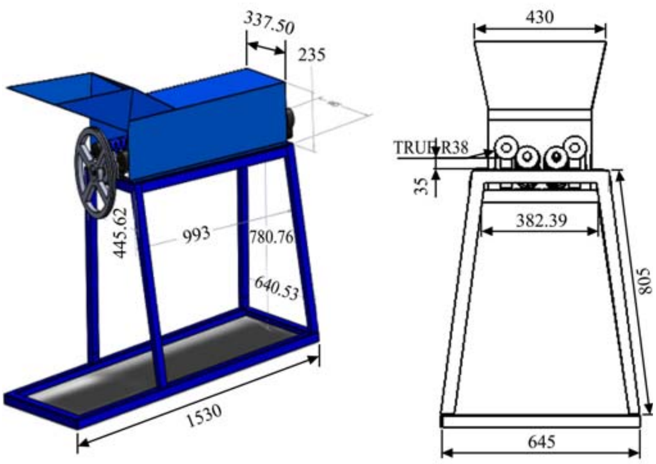


Figure 6 Height difference between spiral and rubber roller



a. Isometric view b. Front view of peeler

Figure 7 Isometric view and front of the maize peeling machine (All dimension are in mm)

2.6 Cost analysis

Economic analysis of the peeler machine was done by straight line method. Cost analysis included the fixed and the variable cost.

Fixed costs

Fixed costs are independent of use. Fixed costs included depreciation (*D*), interest on the machinery investment (*I*) and shelter (*S*).

(a) Depreciation

Depreciation measures the amount by which the value of a machine decrease with the passage of time whether used or not. The value of declination of the machine with the passage of time is called depreciation cost. In calculation of the fixed cost, straight line depreciation is assumed and to calculate the following equation was used (Hunt, 1995).

$$D = (P - S)/L \quad (6)$$

where, D is depreciation, Tk yr^{-1}; P is purchase price of maize peeling machine, Tk; S is salvage value, Tk; L is life, Year.

In this study salvage value was assumed as 10% of purchase price.

(b) Interest on investment

This is a direct expense item on borrowed capital. Interest on investment in farm machinery is included because the capital used to purchase machinery cannot be used on other productive enterprise. The interest on investment is usually included in operational cost since money is used to buy a machine and cannot be used for other productive enterprises. Using the following formula interest on investment was calculated (Hunt, 1995).

$$I = (P+S)/2\times i \quad (7)$$

where, i is rate of interest, decimal.

(c) Shelter

Shelter (S) is 3% of the purchase price of machine, Tk.

$$\text{Total fixed cost } \left(\frac{Tk}{hr}\right) = (a+b+c) \quad (8)$$

Variable cost

The variable or operating cost of the machine is reflected by the cost of fuel, lubrication, daily service, power and labor cost. These cost increase with increased use of machine and vary to large extent in direct proportion to hours or days of use per year.

(d) Labour Cost

Two labours are required for operating the machine. One labour is required for delivering maize cob to the hopper and another helps to collect grain of the maize from the outlet part.

$$L = TK\ per\ person \quad (9)$$

where, L= Labour cost.

(e) Fuel and lubrication cost

Factors affecting fuel cost are (i) the prevailing market price, (ii) engine condition, (iii) load factor or ration of used power to available power. Proper lubrication and the use of good quality lubricants are very important in reducing wear and repair costs of the machine (Rahman et al., 2014).

$$Fuel\ cost\ (F) = Lh^{-1} \quad (10)$$

where, L = liter, h = hour.

(f) Lubricant oil cost per hour

$$\text{Oil cost } (O) = 3\% \text{ of fuel cost} \quad (11)$$

(g) Repair and maintenance cost

Repair and maintenance expenditures are unavoidable for keeping a machine in running condition against wear, failure of parts and accidents. Repair costs are expenditures for parts such as installing replacement parts after failure and reconditioning renewable parts as a result of wear. Maintenance cost is cost of labour required for maintenance should be included as a repair cost (Rahman et al., 2014).

Repair and maintenance cost (RPM) per hour,

$$RPM = 3.5\% \text{ of purchase price} \quad (12)$$

$$Total\ variable\ cost\ (\frac{Tk}{hr}) = (\text{d+e+f+g}) \quad (13)$$

$$Total\ cost = Annual\ fixed\ cost + Variable\ cost \quad (14)$$

3 Results and discussion

Peeling capacity depends on peeling roller's structure parameters, movement parameters, moisture of maize cobs, feeding rate etc. In this experiment, data was taken at different moisture content. The angle between frame axis and horizontal direction was 6° which enhanced the forward movement of cobs and increased the peeling capacity. Performance of maize peeling machine is given in Table 1 and comparative performance of power peeling and manual peeling are shown in the Table 2.

From the Figure 8 it was observed that the peeling capacities were 900-1107 kg h^{-1} when the percentage of moisture content of maize cobs was decreasing from 24% wb.-20% wb. That means peeling capacity decreases with the increases of moisture content. Table 2 implied that the average capacity of the manual and power peeler was 87 kg h^{-1} and 1008 kg h^{-1} respectively when moisture content of maize cobs was around 22%. Peeling capacity of maize cob also depends on the number of the cob per kg. The numbers of maize cobs per kg were found to be 6, 7, 8, 9 and 11. During tearing husk of the cob, operator should try to avoid the vertical feeding, clear up the bract and cluster timely inside and outside of the machine. Otherwise, the outlet would be easily blocked. With the increment of machine rpm, peeling capacity is increased which accelerate the number of unhusked percentage of cobs as well. During peeling operation, it was observed that 1% of grains were injured and 3.2% of maize cobs found to be unhusked which are very negligible. The efficiency of the machine was found to be 96%. The pictorial view of manual peeling by labour and peeling operation by power peeler are shown in Figure 9 and Figure 10 respectively.

Table 1 Peeling performance of the maize peeling machine

Performance parameter	Measured value
Axis angle of the frame with horizontal	6°
Weight of the cobs in every trial (kg)	20
Moisture content, (wb) %	20-24
Time required (sec)	48-60
Machine speed (m s^{-1})	1.39-1.43
Peeling capacity (kg h^{-1})	900-1107
Unhusked cob (%)	3.2
Injured grain (%)	1
Peeling efficiency (%)	96

Table 2 Comparative performance of power and manual peeling

Parameters	Power peeling	Manual peeling
Moisture content (wb)%	22	22
Weight of the maize cob (kg)	20	20
Time required (min)	0.85	10.31
Machine speed (m s^{-1})	1.39-1.43	-
Peeling capacity (kg h^{-1})	1008	87

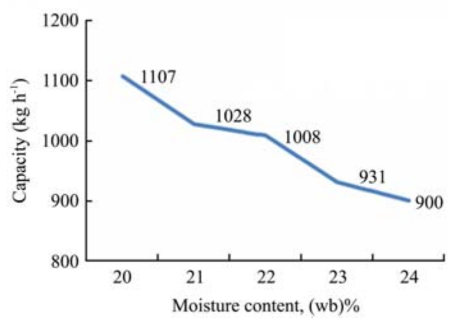


Figure 8 Effect of moisture content on peeling capacity of maize cob

Figure 9 Manual peeling by labour

Figure 10 Peeling operation by power peeler

3.1 Peeling cost of the machine

The peeling cost of the machine is shown in the Table 3. The price of the machine without engine is around TK 20,000 (USD 250) (Note: 1 USD = 80 TK). The fix cost consists of three cost item namely depreciation, interest and shelter whereas variable cost consists of fuel cost, oil cost, labour cost, repair and maintenance cost. The total cost was found to be 156.10 Tk h^{-1} and the peeling cost of the maize husk was 0.15 Tk kg^{-1}.

Table 3 Cost analysis of maize peeling machine

Cost factors and items	Cost value (Tk)
Price (Tk $unit^{-1}$)	20000
Life of the maize peeler (year)	5
Annual use (hour)	900
Annual Fixed cost	
a) Depreciation (Tk yr^{-1})	3600
b) Interest (5%) (Tk yr^{-1})	550
c) Shelter (Tk yr^{-1})	600
Total fixed cost (Tk yr^{-1})	4700
Total fixed cost (Tk h^{-1})	5.22
Total fixed cost ($ h^{-1})	0.06
Operating cost	
a) Fuel cost (T h^{-1})	48.75
b) oil cost (T h^{-1})	1.46
a) Labour (2 persons) (T h^{-1})	100
b) Repair and maintenance (T h^{-1})	0.67
Total operating cost (T h^{-1})	150.88
Total operating cost ($ h^{-1})	1.89
Total cost (T h^{-1})	156.10
Total cost ($ h^{-1})	1.95
Peeling cost (Tk kg^{-1})	0.15

4 Conclusion

The peeling capacities of maize peeler were varied from 900-1107 kg h^{-1} depending on moisture content. The peeling efficiency of the machine was found to be 96%. The peeling capacities of the manual and power peelings were 87 and 1054 kg h^{-1} respectively when moisture content of maize cobs was 22% (wb). It reveals that the capacity of power peeler is 12 times more than that of the manual peeling. So use of the machine can save time and labour dependency. The price of the machine is Tk 20,000 (USD 250) and peeling cost of the maize cob is 0.15 Tk kg^{-1}. By this machine peeling operation is possible at low and high moisture content of the maize cobs. The service provider can also use this peeler which will generate income source of rural people.

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