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Development of power-operated continuous-feed green-pea sheller

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ABSTRACT

Shelling of green-peas from pods is still a manual operation among vegetable vendors in India making shelling operation a crucial and time consuming task. There was a need for a machine that would accept a variety of green-pea pods as input and produce green-peas as output, with a little to no work required by the operator. Therefore, a machine was specially designed, fabricated, and tested to master shelling management in 2018 in New Delhi. It was a vertical free-standing unit and consisted of electric motor, feeding tray, two shelling rollers, and outlet-tank. The capacity of the machine was 106.8±6.3 kg/h by engaging single labourer and the cost of operation ₹ 9/h while cost of machine was ₹ 30,000 as on April 2018. Shelling efficiency was found to be 97.5±1.9% with negligible mechanical damage and the physical parameters of machine-shelled peas were at par with manually-shelled ones. Shelling through machine gave 79.4% cost-saving, and 99.8% time-saving and break-even point for utility of this machine was 30 t/annum while pay-back period was 1.4 year. The capacity, ergonomics, and performance of the machine met the standards. The machine was recommended for small farm holders and vegetable vendors around the nation since the machine can provide efficient shelling of grean-peas commercially.

Key words: De-poding machine, Green-pea shelling, Pods, Shelling machine

Green pea *(Pisum sativum)* is an important frost-hardy, cool-season, nutritious, leguminous vegetable that is widely cultivated throughout the world. It is a rich source of proteins (25%), amino acids, sugars (12%), carbohydrate, vitamins A and C, calcium and phosphorus, apart from having a small quantity of iron. Dry weight is about one-quarter protein and one-quarter sugar. Pea seed peptide fractions have less ability to scavenge free radicals than glutathione, but greater ability to chelate metals and inhibit linoleic acidoxidation.

Manual removal of shells from pods is time consuming, laborious as one person can de-pod about 3–3.5 kg of green peas from pods in an hour (Prem 2017). The de-poding machine not only helps to reduce the time for de-poding of pea pods, but can also be used as a good opportunity for small farmers. By packing the de-poded green pea grain, they are able to get more income on investment. Some attempts were made to make a machine for shelling the peas and similar leguminous crops on commercial and large scale as well as on small scale. But various types of functional problems were observed during their operation. The observed efficiency of pea shelling was also not recorded (Kamboj *et al.* 2012, Prem 2017, Sonboier K K. 2016, 2018). Hence, there is an immense need of making a new model of pea shelling machine which could be easily used on farmer level as per Indian conditions (Anon 2015). Considering the above facts in view, a power-operated green-pea sheller was designed, fabricated, and tested for its performance to address the shelling operation.

MATERIALS AND METHODS

Design of prototype

A. Conceptual design

1) Power: The power is required for two major operations, viz. i) shelling mechanism and, ii) vibrating mechanism. Rolling force to the lower roller to rotate one revolution (1:3 ratio for rotation of rollers)

$$\text{Shelling force } F = \mu(w + 2\ m\ G\omega^2)$$

where, μ, co-efficient of friction= tan ϕ =tan 25 = 0.47; w, mean wt of complete pod = 0.0047 N; m, average mass of feed = 0.48 g; Gω, angular velocity= 180 rpm = 3 rps;

Therefore, F = 0.47 (0.0047 + (2×0.48×3×3)) = 4.05 N. This force is appropriate to shell the pods. Hence,

$$\text{Power required for shelling mechanism} = F \times G\omega X\ r$$

Power required for shelling mechanism, 1 pod/s = 4.05 × 3 C 0.4= 4.86 Nm/s = 4.86 W for one pea at a time

Therefore, power required for shelling mechanism,

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50 pod/s = 50×4.86 W = 0.25 kW

Considering factor of safety and market availability an electric motor of 0.746 kW was adopted.

B. Material design

1) Roller

Roller length: Overall length of pea pods varies from 50 to 60 mm (Zaki and Minai 2007). If we feed the pea pods it can pass though the roller laterally or/and longitudinally. Hence, fix 5 pods pass between the rollers at a time.

Roller length = 5×mean pod length = 5 ×55 = 275 mm (approx. 300 mm)

Roller diameter: The total length of the pea pod should contact the surface area of the rollers.

So, Roller diameter = max length of the pod + free board = 60+25% of 60 =75 mm (app 80 mm)

Roller clearance: Pea grain size is the geometric mean of the three dimensions i.e. length, breath and thickness. The size was calculated using given (Kachru et al, 1994).

$$\text{Size} = (lbt)^{1/3}$$

where, l, b, and t are length, breadth, and thickness. Fresh peas were procured from market and dimensions of peas were measured by using Vernier caliper. Overall size of pea grain was 8.32 mm. On the basis of pea grain dimension the clearance between two rollers was set as 9 mm. Corrugations provided for easy shelling.

Number of slats provide on the roller = 2πr / pod width = 24

2) Gears: Some researchers tried to make depoding machines. The roller should rotate in 1:3 ratio. The market availability (teeth and diameter) of the gears nearer to the present design: 22, 66 & 108 mm, 43 mm

$$N_2/N_1 = T_1/T_2 = 3:1$$

3) Tray: The inlet tray is inclined for easy feeding at an angle of 30° considering the angle of repose of peas (27.8°). Slope of outlet tray helps in moving the shells and trash to the waste discharge end which works on the principle of discharge by gravity. It was observed that a slope of 30° was ideal for this purpose (CIGR Journal June 2012). The dimensions of tray are designed as 400×120×20 mm considering the roller dimensions. The tray was also connected with the drive wheel with cam for providing vibrating mechanism to the feeding tray for ease of feeding.

4) Outlet tank: It is designed according to the working area of the machine for collecting the peas. The dimension of outlet tank was designed as 300×140×20 mm.

5) Power: The power is required for two major operations, viz. i) shelling mechanism and, ii) vibrating mechanism.

Power required for shelling 1 pea at a time = Force ×Velocity = FGXr = 0.486 W

So, power required for shelling 50 pea pods/s = 50 × 0.486 W = 0.25 kW

Power required for vibrating mechanism (cam) = Weight of feed × lifting force = 0.16 kW

Total power required for the sheller machine = 0.41 kW

According to this calculation, 0.746 kW was fitted.

Cost economics

The cost of operation per hour of the sheller was worked out using the procedure recommended by RNAM test codes (Anon 1995). This cost was compared with the cost of operation of the same by conventional method for 10 selected varieties.

RESULTS AND DISCUSSION

Physical properties of green pea pods: The pods of the improved variety are long dark green with a minimum of nine seeds (Table 1).

Physical properties of pod and pea-seeds: The physical and mechanical properties of pods and green pea-seeds for moisture content range of 45 to 55% (wb) were determined at laboratory following standard procedure for ten major varieties (Agropedia, 2015, Elashhab 2016, Wikipedia 2015). Reducing the loading speed and loading deformation in the longitudinal orientation was at its highest value, so these condition is suitable for shelling because deformation takes longer to breakdown.

Construction of the prototype: The foundation frame was selected which carries the entire load of the machine so as to make the machine stand-alone (Fig 1). The rollers with shaft were fixed on top face of the foundation frame with the help of pedestal bearing which was fasten using nut and bolt. Knurling was done on the two rollers to enhance pulling of the beans and shelling. The distance between the rollers was adjustable permitting efficient shelling without excessive cracking of the pod and seed coat (Schoenleber and Taylor 1954). The motor (0.746 W/single phase) was connected with the lower gear with the support of ball bearing. The above arrangement ensures that all element of the project are balanced and also center of the gravity assembly was on axis that of the center of gravity of human body that is on the spinal cord.

Performance of evaluation of the unit

Shelling capacity: The capacity of the gender-friendly machine was 106.81±6.34 kg-pod/h by engaging single labourer (Fig 2, Table 2). The highest shelling capacity was observed with variety VL-3 followed by variety Ooty-1 and the lowest shelling capacity was observed with Lincoln followed by variety Jawahar Matar 4 for both batches of experiments with weight of sample of pods as 5 and 10 kg.

*Shelling efficiency:*Shelling efficiency was found to be 97.5±1.95%. The variety Arkel registered highest shelling efficiency of 99.4±1.95 and 99.5±1.95% in the batch of 5 kg feed and 10 kg feed, respectively, while shelling efficiency

Table 1 Physical properties of green pea-pods and pea-seeds

Variety	Pod dimensions			1000-pod weight (g)	Angle of repose of pods (°)	Rupture force (N)	Green pea dimensions				1000-pea weight (g)	Angle of repose of pea (°)
	Length (mm)	Width (mm)	Thick-ness (mm)				Length (mm)	Width (mm)	Thick-ness (mm)	Geometric mean diameter (mm)		
Lincoln	50	23.5	9.8	435	42.5	36.8	8.9	7.4	6.9	7.69	371	29.5
Pant Uphar	52	24.5	1.2	447	44.5	38.6	8.3	7.9	7.4	7.86	392	27.5
Jawahar Matar 1	53	24.8	9.9	463	48.2	48.7	8.8	7.2	6.9	7.59	421	26.4
Jawahar Matar 4	59	24.9	9.7	448	42.6	39.4	7.8	6.8	6.6	7.05	432	25.8
P-8	60	23.1	1.7	460	39.8	38.4	7.5	8.3	7.8	7.86	389	26.4
VL-3	50	24.9	10.5	452	42.8	42.6	7.9	7.6	7.4	7.63	465	28.9
Ooty 1	59	24.8	10.4	449	42.1	48.2	8.7	7.9	7.5	8.02	395	26.5
Bonneville	57	24.1	9.9	462	46.8	45.7	8.6	7.1	6.8	7.46	395	26.7
Arkel	58	23.8	10.8	439	42.8	38.6	8.7	8.3	7.9	8.29	398	29.7
Azad	50	25.0	10.5	446	39.8	37.6	9.0	7.9	7.6	8.15	448	30.4
Mean	55.2 ±4.18	24.34 ±0.68	8.44 ±3.70	450.1 ±9.39	43.19 ±2.69	41.5± 4.52	8.42± 0.52	7.64± 0.51	7.28± 0.45	7.77±0.36	410.6± 29.72	27.8± 1.68
CV	0.076	0.028	0.439	0.021	0.062	0.109	0.062	0.067	0.062	0.046	0.072	0.060

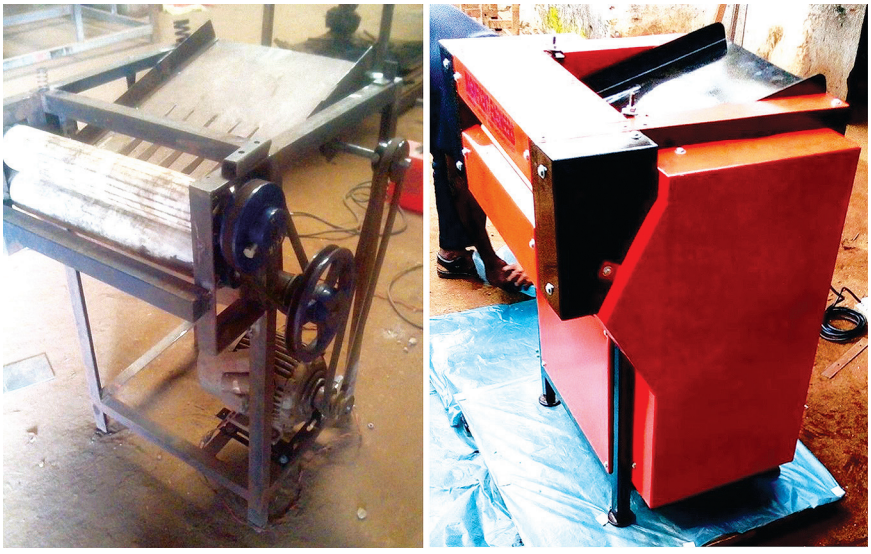

Fig 1 Prototype of green-pea sheller

was the lowest with the variety Jawahar Matar 1 in both the batches.

Mechanical damage: The mechanical damage varied between 1.6±0.52and 3.4±0.52 % and was found negligible (2.3±0.52%) for all the ten major varieties studied.

Physical parameters: Physical parameters of machine-made peas were at par with manually-made ones (Table 3).

Cost economics: The machine capacity was 100 kg pod/h by engaging one woman labour and the cost of operation works out ₹ 9/h. While considering the cost of machine of ₹ 30,000, shelling through machine worked out 79.4% cost-saving and

a) Produce (input) b) Green peas (output) c) Shells

Fig 2 Shelling of grean-pea

Table 2 Performance evaluation of the unit

Variety	Weight of pods (kg)	Weight of shelled peas (kg)	Weight of unshelled pods (kg)	Shelling efficiency %	Mechanical damage %	Shelling capacity (kg pod/h)
Lincoln	5.0	4.930	0.070	98.6	2.1	94.7
	10.0	9.870	0.130	98.7	2.4	98.4
Pant Uphar	5.0	4.955	0.045	99.1	2.7	101.4
	10.0	9.910	0.090	99.1	1.9	104.2
Jawahar Matar 1	5.0	4.725	0.275	94.5	1.6	108.5
	10.0	9.460	0.540	94.6	2.7	108.9
Jawahar Matar 4	5.0	4.890	0.110	97.8	1.8	99.4
	10.0	9.660	0.340	96.6	2.8	101.4
P-8	5.0	4.840	0.160	96.8	1.7	109.1
	10.0	9.550	0.450	95.5	2.4	109.1
VL-3	5.0	4.955	0.045	99.1	1.6	117.6
	10.0	9.950	0.050	99.5	3.4	120.8
Ooty 1	5.0	4.915	0.085	98.3	2.8	112.5
	10.0	9.670	0.330	96.7	2.8	114.3
Bonneville	5.0	4.920	0.080	98.4	2.4	105.9
	10.0	9.810	0.190	98.1	2.4	106.4
Arkel	5.0	4.970	0.030	99.4	2.9	106.5
	10.0	9.950	0.050	99.5	1.7	107.1
Azad	5.0	4.770	0.230	95.4	2.1	104.3
	10.0	9.480	0.520	94.8	1.8	105.7
Mean				93.50±1.95	2.30±0.52	106.81±6.34
CV				0.021	0.226	0.059

Table 3 Physical parameters of machine-made peas

Variety	Machine-shelled peas				Manual-shelled peas			
	Length (mm)	Width (mm)	Geometric mean diameter (mm)	1000-pea weight (g)	Length (mm)	Width (mm)	Geometric mean diameter (mm)	1000-pea weight (g)
Lincoln	8.7	8.3	7.05	398	8.7	6.8	8.02	395
Pant Uphar	7.9	7.8	7.86	448	9	8.3	7.46	395
Jawahar Matar 1	7.5	6.8	7.63	432	7.8	7.4	8.29	398
Jawahar Matar 4	8.3	7.9	8.02	389	8.1	7.9	7.96	448
P-8	8.7	7.6	7.46	465	7.9	7.2	7.86	371
VL-3	8.6	7.9	8.29	395	8.7	7.6	7.59	392
Ooty 1	8.7	7.1	8.15	395	8.9	7.9	7.05	421
Bonneville	9.0	7.4	7.69	371	8.3	7.1	7.63	432
Arkel	8.9	7.9	7.86	392	8.8	8.3	7.69	389
Azad	8.3	7.2	7.59	421	8.6	7.9	7.86	465
Mean	8.46± 0.47	7.59± 0.46	8.02± 0.42	410.60± 29.72	8.48± 0.43	7.64± 0.51	8.05± 0.41	410.60± 29.72
CV	0.055	0.060	0.050	0.072	0.050	0.067	0.044	0.050

99.8% time-saving compared to manual method of shelling. The break-even point for utility of this machine was 26.8 t/annum and pay-back period was 1.4 year.

The developed green pea sheller enables easy separation of peas in a desired quality. The capacity of the gender-friendly machine was 100 kg/h by engaging single labourer and the cost of operation works out ₹ 9/h. Shelling efficiency was found to be 97.5% while damage was negligible (1.5%). Physical parameters of machine-made peas are on par with manually-made ones. While considering the cost of machine

of ₹ 30,000, shelling through machine worked out 79.4% cost-saving and 99.8% time-saving compared to manual method of shelling. The break-even point for utility of this machine was 26.8 t/annum and pay-back period was 1.4 year. The capacity, ergonomics, and performance of the machine met the standards. The machine is recommended for small-farmers and vegetable sellers.

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