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Gagan Kumar Sahu
NIFTEM, Sonipat, Haryana, India

Mandeep Yadav
NIFTEM, Sonipat, Haryana, India

Dr. P Chandra
NIFTEM, Sonipat, Haryana, India

Ankit Gajbhiye
NIFTEM, Sonipat, Haryana, India

Correspondence
Gagan Kumar Sahu
NIFTEM, Sonipat, Haryana, India

Development and performance evaluation of a walnut Sheller machine

Gagan Kumar Sahu, Mandeep Yadav, Dr. P Chandra and Ankit Gajbhiye

Abstract
The traditional method in India of cracking walnut manually, using harmer or knife cutter is labor-intensive, slow and tedious; besides, most mechanical crackers do not give satisfactory results in terms of kernel extraction quality. A prototype machine was developed to crack walnut. A walnut cracker was designed, constructed and tested to evaluate its performance. The cracker, which consists of a hopper fitted, a cracking unit and power system, operates on the principle of attrition using crushing force from a cylinder and screw conveyor. The percentage of whole kernels produced was 56.02 %. The capacity of the machine was estimated to be about 15.05 kg/hr. A device of this nature can be manufactured for small entrepreneurs and for self-help group's applications in the developing countries where bulk of the world walnut is produced. This paper describes the design and performance evaluation of the cracker as well as the implication of the results obtained.

Keywords: Growth, phosphorus, sesamum, sulphur, yield

Introduction
Walnut (Juglans sp.) is the most important temperate nut fruit of the country. India is ranked seventh in the world (FAO 2012) with 40,000 tones of walnut (Juglansregia L.) production. Walnut harvesting and cracking are still carried out manually in India. Breaking the walnut shell is a very difficult task due to a very hard shell and complicated shape of the inner nutmeat. After shelling, the price of walnut is almost doubled. So, if harvesters start taking out the nutmeat themselves from the walnuts by using machinery then they can get higher profits. Traditionally, breaking the shell is carried out manually either by stones or hammers. But manual shelling has many disadvantages like it is very risky, tedious and requires too much of human effort. Farmers don't get enough money for their hard work. This can be eliminated if a machine is developed which can at least break the shell, so that most of the tedious work is done by the machine and human effort is reduced to a large extent. So, a electrically powered shelling machine was developed and shelling capacity and efficiency was evaluated.

Materials and Methods
Sample Procurement
Walnut was procured from OM kiryana store in Sonepat local market. The walnut was of average Kaagzi variety.

Description of Machine Components
Hopper
A hopper is a container that tapers downward and is able to discharge its contents at the bottom. In this machine, the hopper is supposed to feed the nuts one by one. The hopper outlet is 45 mm.

Screw conveyor: A screw conveyor with 20 mm shaft diameter, 45 mm pitch length, 25 mm screw height above the shaft and 500 mm screw conveyor length is used to transport the material from the inlet to the outlet while encountering a tapered surface.

Tapered Cylinder: The main role of the tapered cylinder is to first easily accommodate the nut in the groove or the pitch area and then move it through the whole screw conveyor where clearance between the nut and cylinder wall goes on decreasing, which imparts compressive force to the nut and nut breaks during this process. The length of the cylinder is 500 and the larger and smaller diameters are 110 mm and 80 mm respectively.

The Power System: The screw conveyor is driven by pulleys, which are powered through a 0.5 hp single phase motor of A type. This motor is bolted to the stand at both ends with the help of nuts and bolts.

The Stand: The motor and the cracking unit were firmly bolted and welded to the stand respectively. The stand was made from Iron and the entire surface was painted to prevent corrosion and rusting.

Pulley and Belt: Two 8 inch and two 2 inch pulleys were used to reduce the rpm of motor and two B type belts were used to transmit the power from motor to the screw conveyor.

Estimation of force required to break the kernel

The force required to break the walnut shell was measured on the Texture analyzer instrument with compression plate with a trigger force of 100g and speed 0.02 mm. This device has three main components, which are a moving platform, a driving unit and a data acquisition (load cell, PC card, software and monitor). The device was equipped with a load cell of 1 KN. The pistachio nut and kernel was placed on the moving platform at the 5 mm/min speeds and pressed with a plate fixed on the load cell until rupture occurred. The value 250 N was estimated as required force.

Power requirement of Walnut Sheller

The power requirement, P, can be divided into two parts;

(1) Power required in cracking the walnuts, P_h and

(2) Power required to drive the screw conveyor, P_c.

The power required in cracking was obtained from the following equations:

$P_h = \tau.\omega$

And

$\tau = F\ d$

So,

F = 250 N

d = 0.07 m

$\tau = 250*0.07 = 17.5$ Nm

ω = Angular speed; it is given by

$\omega = 2\pi N/60$

Here,

N = 100 rpm

So,

$\omega = 2*3.14*100/60 = 10.47$

So, the power required in cracking comes out to be

$P_h = 183.225$ W

Now,

For the power needed to drive the screw conveyor, P_C

$P_c = W_c.\ R$

Here,

$W_c = 50$ N

R = 0.035 m

So, the power required to drive the screw conveyor comes out to be

$P_c = 50*0.035 = 1.75$ W

So, the total power comes out to be

$P = P_h + P_c = 183.225 + 1.75 = 184.975$ W

Considering 10% friction losses the total power needed becomes 203.48 W = 0.27 hp

So, 0.5 hp motor is used in this machine.

Selection of Pulley

For selection of pulley the following equation is used

$N_1XD_1 = N_2XD_2$

Where:
N_1 = maximum speed of driven pulley; N_2 = speed of driving pulley; D_1=diameter of driven pulley; D_2=diameter of driving pulley
So,
Motor rpm was 1440
$1440 * 2 = N_2*8$
$N_2 = 360$
Now, to further reduce the rpm one more set of 2 inch and 8 inch pulley was fitted
So, now
$360*2 = N_3*8$
$N_3 = 90$. So, finally desired rpm was achieved.

Results and discussion

Shelling capacity

Shelling capacity was calculated by measuring how much quantity of walnuts is shelled in how much time. So, the shelling capacity of the Sheller was calculated by using following equation:
Shelling capacity (kg/h) =

Table 1: Data of Time required in shelling this quantity of walnuts

S. No.	Time (min.)	Shelled quantity (kg)	Shelling capacity (kg/h)
1.	15	3.6	14.40
2.	20	5	15.15
3.	30	7.8	15.60

By taking average of Shelling capacity = = 15.05 kg/hr.

Performance evaluation of Walnut Sheller

Performance evaluation of Walnut Sheller was determined by shelling 1 kg of walnuts for 3 times at three different speeds (105, 95 and 85 rpm) and after each round the weight different components was precisely weighed and noted. And the percentage of kernels extracted was calculated by the following equation:
Percentage of kernels extracted =
Percentage of Shells =
Percentage of Broken =
Percentage of half kernels =

Table 2: Data of different components of walnut at 105 rpm

Weight of kernels (g)	Weight of shells (g)	Weight of broken(g)	Weight of half kernels (g)	Percentage of kernels extracted	Percentage of shells	Percentage of broken	Percentage of half kernels
414.64	464.82	120.75	210.91	41.45	46.47	12.07	50.86
428.56	476.69	127.32	218.87	41.50	46.17	12.69	51.07
422.21	454.72	123.52	207.45	42.20	45.45	12.34	49.13

Average value of percentage of kernel extraction = = 41.72%
Average value of percentage of shells = = 46.03%
Average value of percentage of broken = = 12.36%
Average value of percentage of half kernels = = 50.35%

Table 3: Data of different components of walnut at 95 rpm

Weight of kernels (g)	Weight of shells (g)	Weight of broken(g)	Weight of half kernels (g)	Percentage of kernels extracted	Percentage of shells	Percentage of broken	Percentage of half kernels
518.4	551.2	103.2	292.38	44.20	46.99	8.79	56.40
454.36	482.83	99.61	249.22	43.82	46.57	9.60	54.85
449.93	479.34	90.55	258.04	44.12	47.01	8.87	57.35

Average value of percentage of kernel extraction = = 44.05%
Average value of percentage of shells = = 46.85%
Average value of percentage of broken = = 9.08%
Average value of percentage of half kernels = = 56.20%

Table 4: Data of different components of walnut at 85 rpm

Weight of kernels (g)	Weight of shells (g)	Weight of broken(g)	Weight of half kernels (g)	Percentage of kernels extracted	Percentage of shells	Percentage of broken	Percentage of half kernels
428.80	466.57	109.15	266.40	41.78	45.46	10.63	52.80
427.68	453.63	114.32	221.07	42.35	44.92	11.32	51.69
434.12	465.74	110.07	227.44	42.83	45.95	10.86	52.39

Average value of percentage of kernel extraction = = 42.32%
Average value of percentage of shells = = 45.44%
Average value of percentage of broken = = 10.93%
Average value of percentage of half kernels = = 52.29%

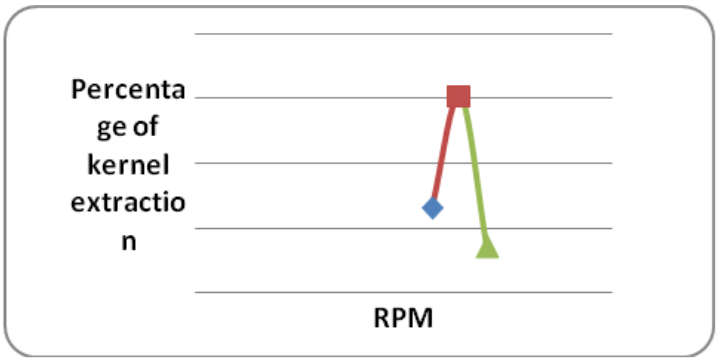

Fig 1: Effect of rpm on kernel extraction

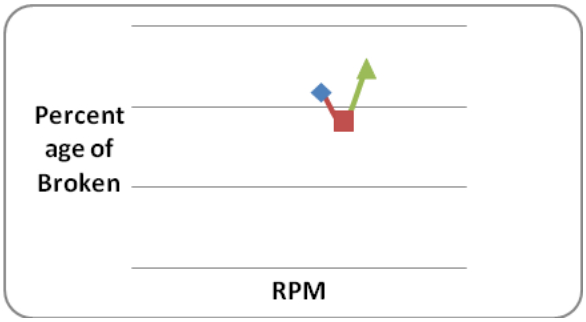

Fig 2: Effect of rpm on broken

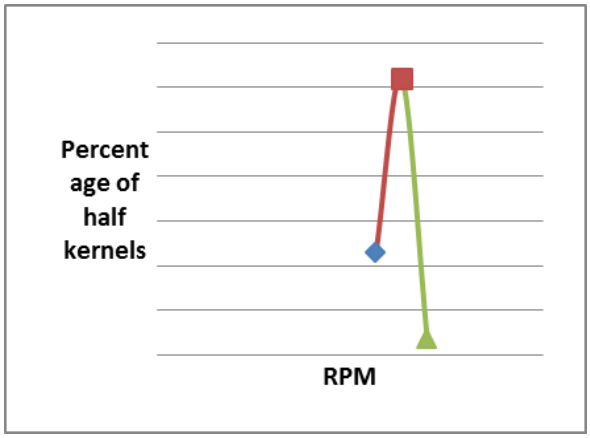

Fig 3: Effect of rpm on half kernels

Shelling efficiency of Walnut Sheller

The shelling efficiency was assessed by taking three separate experimental samples of 100 walnuts poured into the hopper while the machine was running at three different speeds (105, 95 and 85 rpm). After each group was passed through the machine, the output was analyzed by physically counting the shelled, unshelled, partially shelled, broken or shattered walnut. The sum of the shelled and shattered walnuts makes up the shelling efficiency

Table 5: Data of shelled walnut at 105 rpm

Shelled	Unshelled	Partially	Broken	Percentage Shelled
67	2	5	26	93
71	3	3	23	94
64	3	6	27	91

The shelling efficiency of machine is calculated as follows:
Average percentage of walnut shelled = = 92.66%

Table 6: Data of shelled walnuts at 95 rpm

Shelled	Unshelled	Partially	Broken	Percentage Shelled
77	2	4	17	94
80	1	1	16	96
79	1	2	18	96

Average percentage of walnut shelled = = 95.33%

Table 7: Data of shelled walnuts at 85 rpm

Shelled	Unshelled	Partially	Broken	Percentage Shelled
63	15	6	16	79
68	14	4	14	82
71	14	3	12	83

Average percentage of walnut shelled = = 81.33%

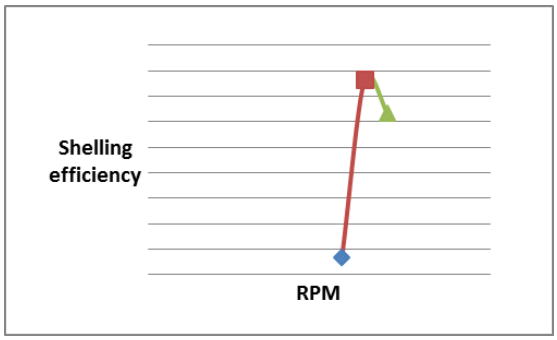

Fig 4: Effect of rpm on shelling efficiency

The test result showed that the machine can shell a total of 15 kg of walnuts in an hour. The test results also showed that best results were obtained on speed of 95 rpm. On lower speed a large portion of them were not broken and they passed cracking unit without breaking and also it needed long time. So, higher speeds are more suitable. However, with increasing the speed of screw conveyor to 105 rpm, the percentage of kernel extraction and percentage of half kernels decreased while the percentage of broken increased. This is mainly because of sudden stresses forced on walnut; the kernels were crushed and broke. The percentage of whole kernels produced was 56.20

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