Development and Performance Evaluation of an Okra Seed Extractor

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ABSTRACT

A prototype extractor was developed for extraction of okra seeds. Studies were conducted on effect of different cylinder speed (5, 6 and 7 m/s), concave clearance (7, 10 and 13 mm), moisture content of okra fruit (12.3, 15.8 and 18.8 % db) and type of extraction drum at a feed rate of 70 kg/h on machine performance and seed quality. Three types of extractor drums namely; square head bolted, rubberized and rasp-bar were used. Seed quality was evaluated for vigour index, dead seed, normal and abnormal germination. The performance of seed extractor was evaluated for its extraction efficiency, cleaning efficiency, seed loss and energy consumption at different crop and machine variables. Extraction efficiency (99.3%) caused by square head bolted drum was found highest among all the three extraction mechanisms. Cleaning efficiency was found in the range of 97.9 to 99.6% for all crop variables. The value of seed loss (4.7 %) was low with the square head bolted drum in comparison to rasp-bar and rubberized extraction mechanism. The average energy consumption per quintal (100kg) seed was found to be 1.9 kWh. It was found that germination and vigour index decreased with increase in pod moisture content. Higher germination was found with square head bolted drum as compared to the rasp-bar and rubberized drum. The germination decreased, whereas dead seed percentage increased with cylinder speed. The best seed quality machine performance was found at 12.3 percent moisture content (d.b.), 7 mm concave clearance and 5 m/s cylinder speed with the square head bolted drum extraction mechanism.

Keywords: Okra Seed, Extractor, Extraction Mechanism

1. INTRODUCTION

Okra is an important vegetable crop grown from seed in tropical and sub tropical regions. It is one of the major vegetable crops grown in India. India is the largest producer of okra in the world. It is grown in about 0.32 m ha with a production of 3.4 million tonne (1998 - 99). It is cultivated for its immature (green) fruits, which are generally cooked as vegetable.

The added value of seed has been attributed to advances in seed extraction technology. This has been achieved by creating new solution for issues relating to germination, vigour and life improvement of seed. The application of a suitable seed extractor in advancement of extraction process will hasten to produce healthy and set higher standards for various seed parameters. Commercial seed production has increased to large extent on both Government and Private Seed Farms in India. It has increased from 1.8 to 7 million tonne during 1991 - 1999 within a short span of time. The annual okra seed requirement is about 4878 tonne. Traditionally, extraction of okra seed involves manual plucking of mature fruits, drying and beating of these dried fruits with sticks for separating seeds from pod, then cleaning it by manual winnowing. The operation is low in out put and also the quality of seed, thus obtained is poor. Some times, available wheat thresher / tractor treading method are used for okra seed extraction. However, no information is available on its performance with reference to various

machine-crop parameters for okra crop.

2. LITERATURE REVIEW

Several investigators reported studies on moisture dependent characteristics namely size, shape and coefficient of friction as well as mechanical properties of cereals (seed/grain) and legume (pod), which are important parameters to design a seed extractor. Tandon (1981) studied the effect of machine, crop and operational variables on threshing efficiency, visible and invisible grain damage of black gram crop. It was reported that threshing efficiency and invisible grain damage were profoundly affected by the plant characteristics. Higher the grain to straw ratio, the lower was the threshing efficiency. Spreading type varieties had better threshing performance compared to erect type. The threshing efficiency and invisible grain damage were directly proportional to cylinder speed and inversely proportional to concave clearance. The moisture content was observed to be directly related to invisible grain damage and indirectly to threshing efficiency. The visible grain damage was found to be negligible in the range of parameters studied. However, the invisible grain damage was high and it ranged from 2 to 31 %. Berlage *et al*. (1986) designed and constructed a vertical belt thresher and tests were conducted on legume and grass seed crops, individual flower seeds and vegetable seeds. Thresher was designed in such a way that threshing aggressiveness was due to speed difference and/or the contact pressure or spacing between the two belts. In the machine three different types of interchangeable textured belts were used. The effect of changes in belt clearance, speed ratio, and texture were evaluated. All three variables were evaluated in the test of seed coat removal for lentils. The threshing efficiency was reported maximum 70.4 % with medium textured, 10:1 speed ratio, and 3 mm clearance.

Anwar *et al*. (1991) developed a multi-drum thresher consisting three rasp-bar cylinders, delivery augers, rubber flap elevator, aspirator fan for cleaning and oscillating screen. The machine was powered from tractor PTO and mounted on its three-point linkage for transport. It was reported that the machine had an average intake crop capacity of 1500 kg/h, cleaning efficiency 94 %, grain damage 8.5 % and grain loss 3 %. The thresher was tried for other crops like soybean, sunflower and safflower. The average grain damages reported for these crops were 1.5, 1.1 and 0.5 %, respectively. Mesquita and Hana (1993a,b) studied the mechanics of soybean threshing based upon the idea of not extracting the plant from the field. They developed a test stand to analyze the mechanical actions of frictional rubbing and impact on soybean plants by simulating the movement of experimental units over a row of soybean plants, and obtained 93 and 92% threshing efficiencies, respectively. Mesquita *et al*. (1997) used a commercially available blast wheel to throw plastic pellets laterally against an established crop of soybean plants. With the blast stream hitting only one side of the plant row, over 92% threshing efficiency was obtained with 12 % moisture, with 7.7% of MOG (material other than grain) removed and 0.1% of seeds broken. Mesquita *et al.* (2000) built an experimental device for threshing standing uncut soybean plants. Impact energy was provided by nylon-cords, fixed on counter-rotating shaft, striking the soybean plants from both sides. The device threshed up to 99 % of the beans depending on the ground speed. The material other than grain (MOG) removed at slower speeds was significantly more than that removed at faster ground speed. Speed had no effect on seed vigour. It was reported that the vigour of seeds harvested with the experimental device was significantly higher compared to those harvested conventionally. Average estimated energy required by the device was 4 MJ/ha.

3. METHODOLOGY

The okra seed extractor was designed and developed. It consisted of extraction and cleaning

unit mounted on a single frame is shown in Figure 1. Since the unit is to be used for seed purpose, minimum loss of quality was the major criteria in development and evaluation. Extraction of seed may be achieved using one of several modes: impact, rubbing, squeezing or a combination of the three. In these three, the rubbing action would produce seed with minimal damage. To achieve minimal seed damage it is essential to apply least impact with rubbing action. The extractor drum was designed in such a way that it produced more rubbing action. Three types of extractor drums like square head bolted drum, rubberized and rasp bar designed are shown in Figure 2. All the three-extractor drums were fabricated with effective diameter of 350 mm and 500 mm length bolted on supporting rings. The basis of considering these dimensions of the drum was considering machine capacity and its power requirement.
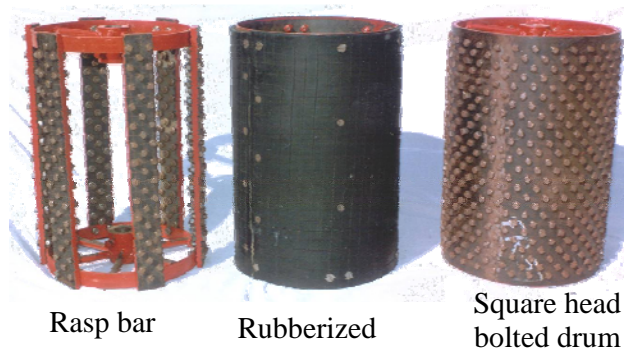

Figure 1. Prototype okra seed extractor

Rasp bar   Rubberized   Square head bolted drum

Figure 2. Different types of extraction mechanism

3.1 Extraction Mechanisms

3.1.1 Square Head Bolted Drum: Square head bolted drum was fabricated using mild steel sheet. It is cylindrical in shape (340 mm diameter, 500 mm length and 3 mm thickness) having 5 mm size holes on its periphery. The mild steel bolts of 100 mm^2 section head with 5 mm height were fixed in these holes. The plan of square heads on the cylinder constituted 13 and 58 rows in lateral and longitudinal direction, respectively. Complete view of square head bolted drum assembly is shown in Figure 3.

The arrangement of the heads (bolts) on the drum was such that gap between the heads on the drum and perforation on concave was greater than the width of okra seed. In the process of extraction, pods strike the ridge of the concave and were dragged into the space between concave and cylinder. The seed was released and the pods are crumpled and shredded.
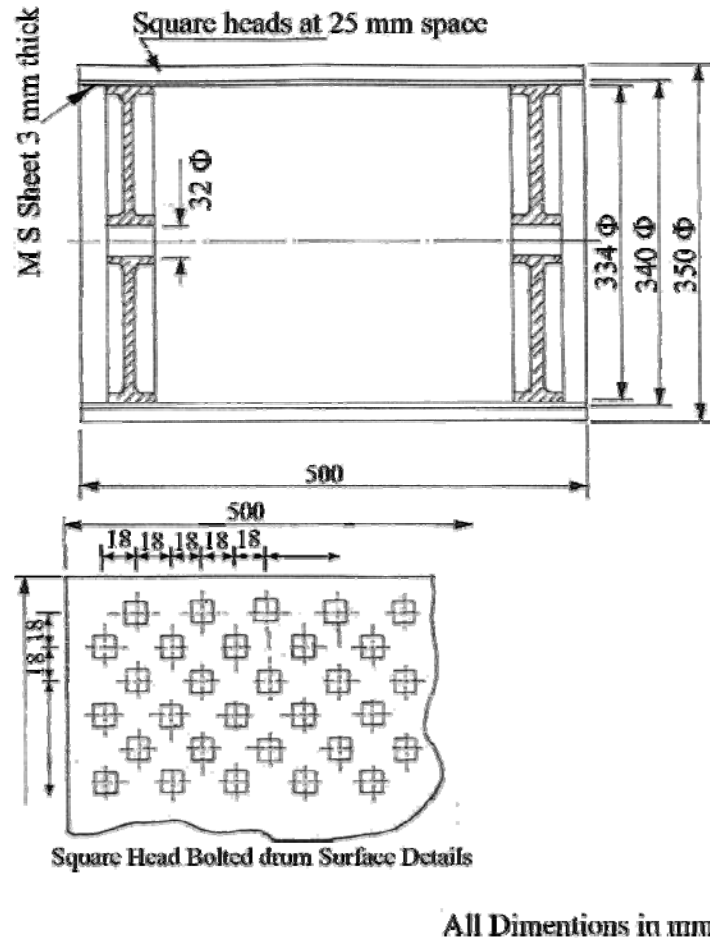
Figure 3. Details of Square Head Bolted drum

3.1.2 Rubberized Drum: The rubberized drum was made of 15 mm thick, 3-ply nylon cord conveyer belt, which was pasted over a 320 mm diameter and 500 mm long cylinder made of 3 mm thick mild steel sheet is shown in Figure 4. The drum was bolted over supporting rings with the help of nuts and bolts and the whole assembly was fixed on main shaft. The rubberized drum was exerted the same degree of force/compression on the pod, as if the seed it was being extracted by the rubbing action.

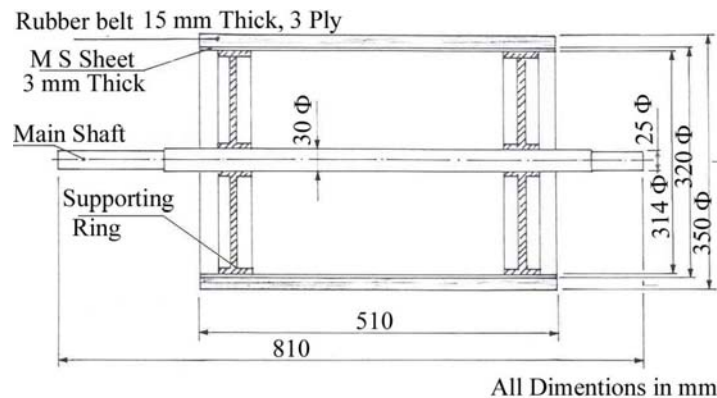Figure 4. Details of Rubberized drum

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3.1.3 Rasp Bar: The number of rasp bars was kept six maintaining their total area equal to one third of total peripheral area of the square head bolted drum. The rasp bars were fabricated (each size 500×55×10 mm) using mild steel flat having the same profile as square head bolted drum is shown in Figure 5. The rasps were made from square head bolts fixed in profile of 13 and 3 rows in lateral and longitudinal direction, respectively. The rasp bars were bolted over two supporting rings and the whole assembly was fixed on main shaft. The impact of the rasp bars and their sliding motion over the pods followed by the sliding action of pod layer over the ridge surface of concave, which resulted in extraction of the seed as well as breaking, crushing and grinding of the pod straw.
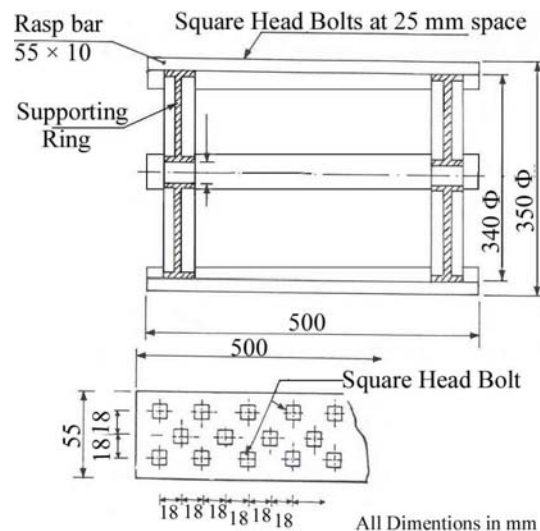

Figure 5. Details of Rasp bar

3.2 Concave

An open type semicircular concave covering 140-degree angle of the cylinder circumference was fabricated using angle iron (size, 35×35×3 mm), mild steel flat (size, 35×5 mm) and 6 mm square bar is shown in Figure 6. The screen was made of 33 longitudinal square bars, spaced 8 mm apart. The lateral members were made of mild steel flat and fixed at an interval of 120 mm whereas angle iron was provided at the outer end. Concave was made perforated so that extracted seeds fall down immediately without any damage. The concave was situated beneath the cylinder against, which the cylinder rotates and gives rubbing action. A provision was made to adjust the concave clearance.

The concave clearance influences extraction efficiency and seed damage. It is known that increase in clearance would result in low extraction efficiency whereas, reduced clearance would cause seed damage. Therefore, optimum concave clearance is required to be determined. Three concave clearances 7, 10 and 13 mm were tried by using three different size spacers.
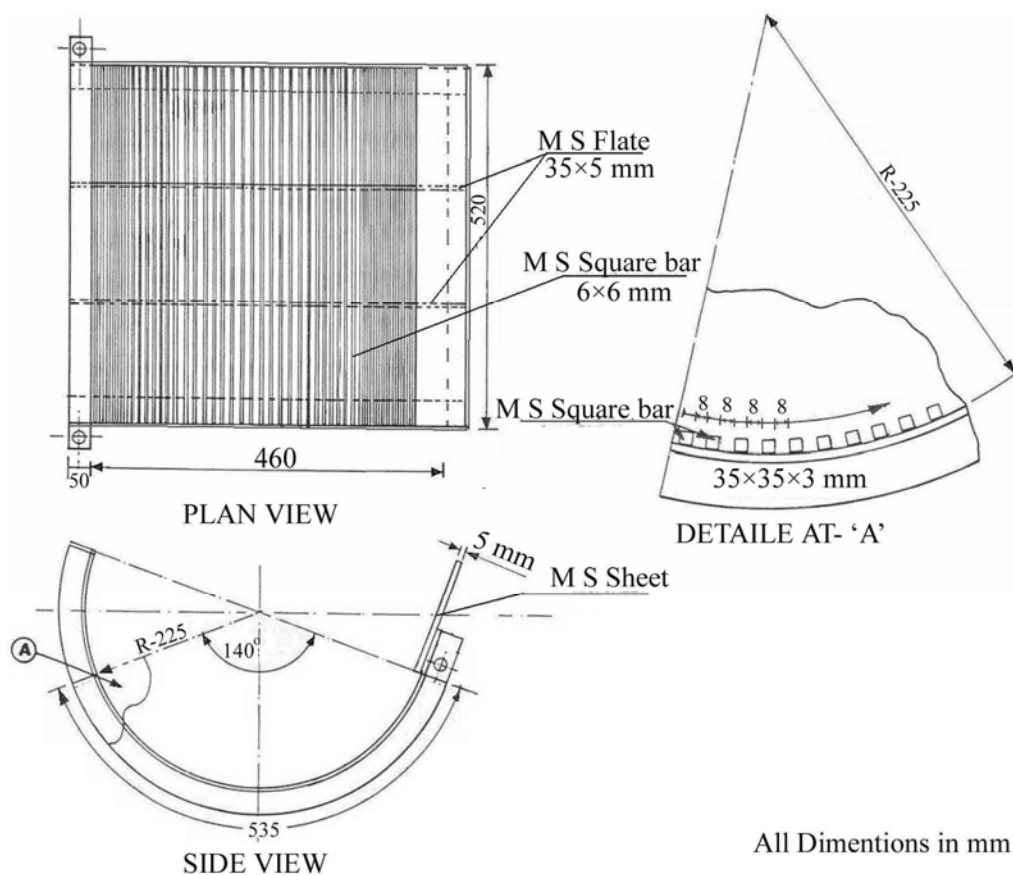
Figure 6. Details of concave

3.3 Power Transmission

A 2 hp single–phase AC motor having 1440 rpm was used to drive cylinder, blower and oscillating sieve assembly using V-belt-pulley arrangement. The electrical circuit consisted of a voltmeter, an ampere meter and an energy meter to measure energy consumption. The motor is mounted on a base frame. A driving pulley of 63.5 mm diameter was mounted on the motor shaft. Using three different driven pulleys of diameter 280, 233 and 200 mm the cylinder speed was varied. To obtain requisite rpm for blower and oscillating sieve the size of driven pulleys were selected (100 and 290 mm). The cylinder extractor, blower and oscillating sieve were run by a common V-belt. As the distance between the motor and the cylinder was quite large, an idler pulley was provided for causing necessary belt tension.

3.4 Experiments

The experiments were conducted as per test code for stationary power thresher for cereals (IS: 6284-1985) recommended by Bureau of Indian Standards. The following variables were taken for experiments:

Variable	Level
• **Extraction mechanism**	: Square head bolted drum, rasp-bar and rubber drum
• **Pod moisture content, % (db)**	: 12.3, 15.8 and 18.8
• **Concave clearance, mm**	: 7, 10 and 13
• **Cylinder speed, m/s**	: 5, 6 and 7

Machine parameters   : Extraction efficiency, cleaning efficiency, seed loss and energy consumption

Seed parameters   : Germination, seed damage and vigour index

For each test, a sample of 3 kg pods was fed into the hopper at the rate of 70 kg/h. Three replications were taken at each combination of the variables. The samples from seed and straw outlets were collected and weighed. Energy consumption was measured using single-phase energy meter, volt-meter and ampere-meter. The energy consumption in kWh/q of extracted seed was calculated. Extracted and un-extracted pods were separated manually and weighed to determine the following parameters:

3.4.1 Extraction Efficiency: The extraction efficiency was determined on the basis of extracted and un-extracted seed. All detached seeds from the pod were collected from the outlet of seed extractor and total weight was measured with the help of digital balance. Seeds, which were still in the pod straw after passing through the cylinder assembly were extracted manually, cleaned and weighed using the same digital balance. The extraction efficiency was determined using the following expression:

$$\text{Extraction efficiency (\%)} = 100 - \% \text{ un-extracted seed}$$

$$\text{Un-extracted seed (\%)} = \frac{C}{D} \times 100 \tag{1}$$

where,

C = Weight of unextracted seed, g

D = Weight of total seed input, g

3.4.2 Cleaning Efficiency: To determine the cleaning efficiency, sample of seed along with chaff/ straw was collected from seed outlet and weighed. Later on it was cleaned manually to find out the chaff quantity. The cleaning efficiency was determined using the following relationship:

$$\text{Cleaning efficiency (\%)} = \frac{E}{F} \times 100 \tag{2}$$

where,

E = Weight of clean seed in the sample, g

F = Total sample weight, g

3.4.3 Seed Loss: Quantity of clean seed obtained at pod straw outlet, were blown by air. The over flowed seed with straw were collected and recorded. The seed loss was determined using the following relationship:

$$\text{Seed loss (\%)} = \frac{J}{H} \times 100 \tag{3}$$

where,

J = Free clean seed collected from straw outlet, g

H = Total seed input, g

3.4.4 Seed Damage: Since the unit was essentially developed for the seed purpose, damage of seed was considered as major criteria. To determine seed damage, samples of 50 seeds from each replication were properly placed between moist filter paper and wrapped in wax paper. These were kept in germinator (25^0 C $\pm$ 1^0 C) for 7 days and then taken out to count the number of normal germination, abnormal germination and dead seeds. Normal germination included those seedlings, which showed continued development and grew into normal plant, whereas abnormal germination seedlings did not grow into normal plant when grown under similar conditions in germinator. The dead seeds did not produce seedlings. The vigour index was determined by measuring the root and shoot length of 10 randomly selected germinated plant from each replication. Per cent seed damage was calculated using the following expression:

$$\text{Seed damage (\%)} = 100 - \text{germination percentage}$$

Results obtained were statistically analyzed for their significance for all combination of variables.

4. RESULTS AND DISCUSSION

4.1 Extractor Performance

The seed extraction efficiency increased with increase in cylinder speed and decreased with increase in concave clearance and moisture content. The extraction efficiency was found higher with square head bolted drum followed by rasp-bar and rubberized drum is shown in Table 1. The square head bolted drum imparted energy in the form of low impact and shearing, and rasp-bar by more impact and shear, whereas the rubberized drum used mostly shear action for extraction of seed from pod. Almost same (99.3 and 99.0 %) extraction efficiency for both square head bolted drum and rasp-bar may be due to identical corrugation of peripheral surface and action. Firm gripping of pods in the bolted drum extraction unit resulted in high capacity and enhanced extraction efficiency. The rubberized drum applied predominantly the shear action only and therefore resulted in least extraction efficiency of 95.5%. At low moisture content the pod favoured extraction by complete detachment of seed. Lower moisture content of the pod facilitate easy split of carpel joints to release seeds. Therefore, reduction in extraction efficiency at higher moisture content could be expected. The increase in extraction efficiency with speed could be expected due to increased impact and shear. The energy in term of impact and shear in different proportion are required to extract seed from pod for an optimal extraction action. Larger concave clearance allowed un-extracted pod, resulted in low extraction efficiency.

The variation in cleaning efficiency (mean) was found in the range of 97.9 to 99.6% for all four variables. The cleaning efficiency increased with increase in moisture content, concave clearance and decrease in cylinder speed from 7 m/s to 5 m/s. The cleaning efficiency in case of rasp-bar mechanism was found lower due to excess of finer straw mixed with seed, which was not completely blown. The excessive finer straws increased the volume of material being handled and therefore caused lower cleaning efficiency. Finer straw was generated in the rasp-bar mechanism due to more impact action compared to shear action predominant in case of square head bolted drum and rubberized drum.

The seed loss increased with increase in moisture content, cylinder speed and concave clearance. The peripheral velocity increased with increase in cylinder speed, which pushed the seed through straw outlet. At higher moisture content roundness and sphericity of the seed facilitated its easy roll over on the screen and spilled to mix with straw causing higher seed

loss. The seed loss in case of rasp-bar was high due to finer straw generated, which increased the volume of seed-chaff mixture making separation of seed and straw difficult. Larger concave facilitate larger straw out let, which increase possibility of some seeds flowing through straw outlet.

The energy consumption increased with increase in moisture content due to fact that at higher moisture content the pods were more inelastic and resisted breaking. The energy consumption in case of rasp-bar was least followed by square head bolted drum and rubberized drum. The rasp-bar extract the seed with both more impact and shear action, whereas in case of rubberized drum it was mostly due to shear action that caused shearing of pods. Maximum energy consumption was recorded in case of rubberized drum. The increased energy consumption with cylinder speed could be expected due to increased rate of energy and pod resistance inside the extractor. At larger concave clearance the energy consumption was recorded less due to enough space between concave and cylinder.

4.2 Seed Quality

The range and mean of seed quality at different levels of variables are given in Table 2. The germination of seed was influenced (significant at 0.1%level) by the moisture content and cylinder speed. The mean germination was found to be 94.7, 93.1 and 92.9 % at the moisture level of 12.3, 15.8 and 18.8 % respectively. Germination percentage reduced with increase in moisture content and vice-versa. The mean germinations corresponding to peripheral speed 5, 6 and 7 m/s were 94.2, 93.8 and 92.7 %, respectively. At higher peripheral speed there was increased deformation and scarification of seed and may be the possible cause of the lower germination.

The abnormal germination was found influenced most by moisture content of seed (4.6 % at 18.8% moisture content). The effect of moisture content and cylinder speed on the dead seed was observed higher than the effect of concave clearance and extraction mechanism. The average dead seed was observed to be 2.1, 2.8 and 3.6 % corresponding to cylinder speed 5, 6 and 7 m/s, respectively. This was due to increase in the impact and shear energy, which caused more invisible injuries to the seed.

The values given in Table 2 indicate that the moisture content affected vigour index the most followed by the cylinder speed. The vigour index of manually extracted seed was lower than the seed extracted by seed extractor due to scarification, which reduced the dormancy of the seed. The average vigour indexes were 121.9, 114.2 and 97.2 for the moisture levels of 12.3, 15.8 and 18.8 %, respectively. The influence of cylinder speed on seed damage can be predicted quantitatively with normal range of variables; a higher peripheral speed causing more internal seed damage and deformation at higher moisture level. The increased internal damage and deformation of seed at higher speed was expected to cause the lower vigour index.

4.3 Recommended Values Crop-Machine Variables

Based on above discussion and adopting best approach of higher extraction and cleaning efficiency, lesser seed damage, higher germination, lower energy consumption the final recommended parameters were square head bolted drum, pod moisture content of 12.3 per cent, cylinder speed 5 m/s and concave clearance 7 mm. The germination and energy consumption were 94.7% and 1.9 kWh/q, respectively.

5. CONCLUSIONS

Based on the finding of this study, the following conclusions are made:

- The extraction efficiency increased directly with increase in cylinder speed and decreased with increase in moisture content of okra pod and concave clearance. Extraction efficiency caused by square head bolted drum was found higher among all the three extraction mechanisms.

- Cleaning efficiency reduced with increase in the moisture content of the pod. The configuration and shape of extraction mechanism influenced the cleaning efficiency significantly. Cleaning efficiencies for all the cylinder speeds and concave clearances were found almost similar.

- The seed loss was higher at higher moisture content, concave clearance and cylinder speed. The value of seed loss was low with the square head bolted drum in comparison to other extraction mechanism (rasp-bar and rubberized).

- The energy consumption due to rubberized drum was more than other two extraction mechanisms. The moisture content influenced energy consumption the most followed by the cylinder speed and concave clearance.

- The germination of extracted seed reduced with increase in moisture content and cylinder speed. The seed obtained with square head bolted drum extraction mechanism caused higher germination as compared to the seed extracted using rasp-bar and rubberized drum extraction mechanisms.

- The abnormal germination and dead seed were higher at the higher moisture content. Dead seed also increased with increase in cylinder speed. The concave clearance speed and extraction mechanism did not influence the abnormal germination and dead seed.

- The vigour index of extracted seed decreased with increase in moisture content and cylinder speed. The effect of extraction mechanism and concave clearance on vigour index was found non-significant.

6. ACKNOWLEDGEMENTS

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Table 1. Performance parameters of okra seed extractor at different level of variables

Level of variables	Extraction efficiency, %		Cleaning efficiency, %		Seed loss, %		Energy consumption , kWh/q	
	range	mean (SE)	range	mean (SE)	range	mean (SE)	range	mean (SE)
Extraction mechanism								
Square head bolted drum	91.5-100.0	99.3 (0.3)	95.9 - 99.7	98.0 (0.2)	2.0 - 7.8	4.7 (0.3)	1.3 - 2.4	1.7 (0.1)
Rasp - bar	94.4 - 100.0	99.0 (0.2)	95.2 - 99.4	97.9 (0.2)	3.0 - 7.6	5.5 (0.2)	1.1 - 2.1	1.5 (0.1)
Rubberized drum	80.1 - 99.9	95.5 (0.9)	98.8 - 99.9	99.6 (0.1)	3.5 - 7.0	5.2 (0.2)	1.6 - 2.7	2.1 (0.1)
Moisture content, % (d.b.)								
12.3	91.0 - 100.0	98.9 (0.4)	96.0 - 99.8	98.4 (0.2)	2.0 - 7.2	4.7 (0.2)	1.5 - 2.4	1.9 (0.1)
15.8	91.1 - 100.0	98.1 (0.4)	95.2 - 99.7	97.9 (0.3)	3.6 - 6.4	5.1 (0.1)	1.1 - 1.9	1.4 (0.1)
18.8	80.1 - 99.9	97.0 (1.0)	97.8 - 99.9	99.2 (0.1)	3.4 - 7.8	5.6 (0.3)	1.4 - 2.7	2.0 (0.1)
Concave clearance, mm								
7	94.4 - 100.0	99.3 (0.2)	95.2 - 99.7	98.2 (0.3)	3.4 - 7.8	4.9 (0.2)	1.1 - 2.7	1.8 (0.1)
10	93.6 - 99.9	98.8 (0.3)	95.9 - 99.9	98.5 (0.2)	3.0 - 7.8	5.2 (0.3)	1.1 - 2.6	1.8 (0.1)
13	80.1 - 99.9	95.8 (0.9)	95.9 - 99.9	98.8 (0.2)	2.0 - 7.3	5.2 (0.2)	1.1 - 2.4	1.7 (0.1)
Cylinder speed, m/s								
5	80.1 - 100.0	96.9 (0.8)	95.9 - 99.9	98.8 (0.2)	2.0 - 7.4	4.6 (0.2)	1.2 - 2.7	1.8 (0.1)
6	85.9 - 100.0	98.3 (0.6)	95.2 - 99.8	98.4 (0.2)	3.4 - 7.0	4.9 (0.2)	1.1 - 2.6	1.8 (0.1)
7	89.1 - 100.0	98.8 (0.4)	95.9 - 99.9	98.3 (0.2)	3.8 - 7.8	5.8 (0.2)	1.1 - 2.4	1.7 (0.1)

SE= Standard Error of Mean

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Table 2. Influence of machine variables and pod moisture content on okra seed quality parameters.

Level of variables	Germination, %		Abnormal germination, %		Dead seed, %		Vigour index	
	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)
Extraction mechanism								
Square head bolted drum	90.0 - 97.3	94.0 (0.4)	1.3 - 7.3	3.7 (0.3)	0.7 - 5.3	2.4 (0.2)	84.0 - 149.8	113.0 (3.2)
Rasp - bar	89.3 - 98.0	92.9 (0.3)	0.7 - 7.3	3.8 (0.3)	1.3 - 6.0	3.3 (0.3)	83.4 - 145.5	109.6 (3.0)
Rubberized drum	88.7 - 96.0	93.8 (0.3)	1.3 - 5.3	3.5 (0.2)	0.0 - 8.0	2.8 (0.3)	87.2 - 160.4	110.8 (3.6)
Moisture content, % (d.b.)								
12.3	91.3 - 98.0	94.7 (0.3)	0.7 - 5.3	3.1 (0.2)	0.0 - 5.3	2.2 (0.3)	91.9 - 149.8	121.9 (2.7)
15.8	88.7 - 97.3	93.1 (0.4)	1.3 - 5.3	3.3 (0.2)	0.7 - 8.0	3.7 (0.3)	93.4 - 160.4	114.2 (3.2)
18.8	89.3 - 95.3	92.9 (0.3)	1.3 - 7.3	4.6 (0.3)	1.3 - 5.3	2.5 (0.2)	83.4 - 113.7	97.2 (1.6)
Concave clearance, mm								
7	91.3 - 97.3	94.0 (0.3)	1.3 - 7.3	3.3 (0.3)	1.3 - 5.3	2.7 (0.3)	84.0 - 149.8	110.6 (3.6)
10	90.0 - 96.7	93.1 (0.3)	1.3 - 7.3	3.8 (0.3)	0.7 - 6.0	3.0 (0.3)	86.2 - 142.4	111.8 (3.0)
13	88.7 - 98.0	93.5 (0.4)	0.7 - 7.3	3.8 (0.3)	0.0 - 8.0	2.6 (0.4)	83.4 - 160.4	110.9 (3.2)
Cylinder speed, m/s								
5	90.7 - 97.3	94.2 (0.3)	1.3 - 7.3	3.8 (0.3)	0.0 - 5.3	2.1 (0.2)	83.4 - 160.4	113.4 (3.5)
6	89.3 - 98.0	93.8 (0.3)	0.7 - 6.7	3.4 (0.3)	0.7 - 5.3	2.8 (0.2)	91.5 - 145.5	112.1 (3.3)
7	88.7 - 96.7	92.7 (0.3)	1.3 - 7.3	3.8 (0.3)	0.7 - 8.0	3.6 (0.3)	84.0 - 149.8	107.9 (2.9)
Hand extracted seed		94.7	-	3.3	-	2.0	-	80.4

SE= Standard Error of Mean