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Research Article

Design and Development of Sesame Threshing Unit

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Sesame (Sesamum Indicum) is labeled as the queen of oil seeds. India ranks second in the world with 755,346 metric tons per ha area and 8.66 lakh tons of production. Threshing of sesame seeds from the harvested capsules is one of the most important operations in the post harvesting process. There is about a 5-10 % loss from the time of harvest to cleaning and storing. The major issue of sesame threshing is the uneven maturity of sesame seeds. A traditional method of sesame threshing is slow, labor-intensive, and cost-effective. Hence, we developed a portable sesame thresher. Our sesame thresher will overcome the traditional method. The features of our sesame threshing unit are quick to process, level of performance, improved quality of product, and economy. The physical properties of sesame plants were studied for developing sesame threshing units. The most popular variety of sesame TMV 7 is used for testing the sesame threshing unit. The average plant height was 1195mm. The average length and thickness of the capsule were 28mm and 11mm. The average weight of 1000 grains was 3.4 g. The average number of seeds in a capsule was 59. The average length, width, and thickness of sesame seed were 2.95mm, 1.85mm, and 0.7mm. The moisture content of the capsule was determined by the hot air oven method. Our sesame threshing unit was tested in the field and tests were conducted with different levels of variables. Its threshing efficiency was 94%, cleaning efficiency was 93% and its seed damage was 1.02% could be achieved by the combination of a 240 kg/h feed rate, 3mm clearance between two plates, 60 strokes per min, and 14% of moisture content. Its threshing efficiency was 94%, cleaning efficiency was 93% and its seed damage was 1.02%. Our sesame thresher results in 71% and 75% saving cost and time compared to manual threshing.

Keywords: Sesame, moisture content, threshing efficiency, cleaning efficiency.

1. Introduction

Sesame is largely produced for its oil content, with the longest history of cultivation in India. Sesame contains 50-60% of oil and 19-25% of protein with lignin such as sesamolin and sesamin. Sesame has highly in linoleic acid, vitamin E, A, B1, B2, and minerals including phosphorus and calcium. Sesame is cultivated over an area, of more than 7 million ha in the world with a yearly production of 4 million tonnes and a yield of 535 kg ha^{-1} (Status paper on oilseeds, 2014).

Sesame is grown in four seasons viz., June - July, October -November, January - February, April - May. [20]. Threshing is the process of detaching grains from the ear heads of crops like rice, sorghum, millet, wheat, beans, gingelly and maize, etc., Manual method of sesame threshing can be done by hand beating. As the result, the manual method consumes more time and obtains high loss. The delay in threshing operation affects the delay in the sowing of the next crop and it reduced sesame production yield. The available mechanical method of sesame thresher requires a high horsepower motor and tractor attached machine (PTO). Keeping given the problems rising in sesame threshing, we developed a sesame thresher. Electric motor used as a prime mover. During threshing, some of the parameters determine the final efficiency such as seed

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rate, moisture content, and threshing cylinder speed. High grain moisture content increases the elasticity of grain and low moisture also increases the brittleness of seed. Both mainly affected the efficiency. Fifty grains were selected randomly from the bulk of samples with three ranges of least, medium, and most extreme sizes for determining the diameter, surface area, bulk density, volume, and angle of repose[25]. The height of Sesame plants differs from 0.5 to 2m. The average length and thickness of capsules were 35 mm and 12 mm respectively. Per capsule has average 60 numbers of seeds. Thousand number of grain weight was 3.1g. The length, width, and height of sesame seed were 3×1.8×0.9 mm [1]. The average width of the sesame was 5.25mm [3]. Dessie Belay and Melkamu Fetene stated that When the grain moisture increases, fuel consumption also increased. The moisture content was determined by Ovendrying Method [24]. Kailash Kumar said that 16.8% (d.b) moisture content of sesame crop gave 99% of threshing efficiency[2].

P. Dhananchezhiyan et.al., (2020) developed a sesame threshing machine that was working by a double roller mechanism. As a result, threshing efficiency was obtained at 96.7% and output capacity was 18.2 kg/h which was driven by a 1hp electrical motor[1]. Yilmaz, et.al., (2008) used a rasp bar-type tooth in the threshing drum for evaluating the performance of sesame separation. The maximum threshing efficiency got from the combination of 11.7m/s of drum speed, 90kg/h of feed rate, and 20mm of concave open [15]. K.P. Singh, et.al., (2015) developed a minor millet thresher. They have conducted a test under six minor millets such as little milletM1, Kodo millet- M2, foxtail millet- M3, proso millet-M4, barnyard millet-M5, and finger millet M6. The maximum threshing efficiency (95.13%) was obtained under 7.79% (d.b) of moisture content, 105 kg/h of feed rate, and 625 rpm cylinder [7]. D R.K. Naik, et.al., studied different performances of thresher in various power sources. Here, three different power sources are used in threshing machines. Thresher – 1 was operated by a 5hp electric motor, Thresher – 2 was operated by a 10hp electric motor, and Thresher – 3 was operated by 35hp MF – 1035 tractor. The test result showed that the maximum threshing efficiency (96.8%) and output capacity (4.21q/h) were obtained by Thresher – 2(10hp) [38]. Timothy Adesoye Adekanye et.al., (2016) developed a soybean thresher. The cleaning unit consists of the fan assembly and a seed outlet. Fan assembly was made of mild steel which had a blower blade and shaft. Cleaning efficiency ranges from 90.81% to 64.25% of the speed between 320 r/min to 515 r/min through moisture contents of 10% to 22% (wet basis) [8]. Bhupendra Ghritalahre et.al., 2019, developed and tested a solar-powered winnowing machine. Frame, Speed controller, Battery, Fan, D.C. motor, Solar panel, Plywood, and Hopper were used in the paddy winnower. The overall dimension of the winnower has 750×600×1375mm. As a result, cleaning efficiency of 94-97% and the capacity of the winnower 320 to 367 kg/hr were obtained. The advantage of this winnower is the use of renewable energy, which reduces manpower and high cleaning efficiency [19].

2. Methods and Materials

2.1. Physical Properties

Determining the physical properties of grains is very important for developing the threshing machine. It includes weight, hardness, grain size, shape, and color. The capsules are square or oblong shape. Fifteen grains were selected randomly from the bulk of samples with three ranges of minimum, medium, and maximum sizes for finding the diameter, length, surface area, bulk density, volume, and angle of repose. The most popular variety in Tamil Nadu TMV 7 was used throughout the investigation.

Length of stalks: twenty sesame stalks were selected randomly from the harvested heap. The stalks' length was measured by the scale and the observations were noted. Length & moisture of capsule: One sesame capsule was selected randomly from the bulk sample and its length and thickness were measured with a scale after placing it on a horizontal platform in its natural rest position. This procedure was repeated for fourteen more capsules of sesame and the observations were recorded. The moisture content of the capsule was determined by a hot air oven.

The number of seeds per capsule: fifteen sesame capsules were selected randomly from the harvested heap. The capsule was separated manually and the seeds in the capsule were counted. This procedure was repeated for more capsules and the observation was recorded. Size and shape of seed: The size and shape of the seed are important parameters in designing the threshing drum. The size and shape of the TMV 7

variety were determined by a digital venire caliper having an accuracy of 0.02 micron. Fifteen seeds were selected at random from the harvested heap. The sesame seeds have an ellipsoid shape with three main dimensions, length, width, and thickness.

Thousand-grain weight: The weight of thousand grains randomly selected from a heap of sesame crops was weighed in an electronic weighing balance having a sensitivity of 0.1 g the experiment was repeated ten times and the observation was recorded.

2.2. Development of Sesame Thresher

Our sesame threshing unit was designed by solid works – 2012 x 64 edition. The sesame thresher consists of a feed chute, threshing unit, cleaning unit & power transmission system. The mainframe was a rectangular shape of 765 mm in length, 406 in width, and 750mm in height. It was made of mild steel. A feed chute was used for feeding the plant into the threshing drum which was trapezoidal. The feed chute was located 840mm in height from the ground surface. The feed chute outlet was fixed on the opening end of the drum. The diameter of the cylindrical drum was 177 mm and the length was 355mm. It was made up of 1.3mm stainless steel. Here we used a perforated drum. The diameter of the hole in the drum was 4mm and the distance between the holes was 20mm. The hole of the perforated drum was equal to the size of a sesame seed.

The purpose of a hole is to allow the sesame seeds into the collecting tray. The drum was fixed at a 25^{o} inclination for easy flow of the plant. Perforated drum rotated clockwise with v belt and pulley. For the stability and rotating of the drum, V-shaped, L-angled rod is fixed and bearings were fixed at each end of the V-shaped rod. There were two cams fixed inside the drum and two wooden plates were attached in the center of the drum in which one is movable and the other is stable. The plates are attached with springs on four ends. When the cam touches the bearing the movable plate starts compressing. As a result, it experiences a restoring force that tends to retract the spring back to its original position. The moving plate moves reciprocate inside the drum. A 1hp motor acts as a prime mover. A collecting tray was kept below the drum which was the length of the drum for collecting all the grains. The tray was fixed at 30^{o} to facilitate easy flow of sesame grains as it was fixed at 550mm from the ground level. A blower was fixed between the collection tray and the motor. It was fixed at 355mm from the ground surface. The blower had 4 blades used to separate the dust and sand from the threshed grains. Finally, pure grains were collected by collecting tray.

2.3. Selection of Machine Variables

The thresher with a stationary plate and a moving plate was evaluated to study the threshing performance. Some of the variables were affecting the threshing performance such as crop moisture content, plate moving speed, and clearance between plate and cylinder speed. The test was conducted with selected levels of variables viz., the peripheral velocity of the perforated cylinder was 30 rpm with varying 30 strokes per min and 60 strokes per min, clearance between two plates during threshing 3mm and 5mm, and moisture content of the capsule 14, 17,19% (dB).

From the observation, the threshing efficiency, cleaning efficiency, and % of damaged grains were computed. The maximum threshing efficiency of 94.1% and cleaning efficiency of 93% and 1.02% seed damage could be achieved by the combination of 240 kg/h feed rate, 3mm clearance between two plates, 60 strokes per min, and 14% of moisture content.

2.4. Performance Evaluation

The threshing unit has a perforated threshing drum and two wood plates used for beating the plant which are fixed inside the drum. The stationery wood plate and moving wood plate were evaluated to study the crop and its operational parameters. The performance of the thresher was affected by many variables, i.e, threshing drum speed, moisture content of capsule, feed rate, and clearance between the two wooden plates. The analysis was carried out to determine drum speed, blower speed, and clearance between wood plates to get maximum efficiency, output capacity and minimum grain damage.

a) Total grain output per unit time, **A = B+C+D**

Where,

A - Total grain output per unit time by weight
B - Weight of threshed grain per unit time collected from all grain outlet
C - Weight of broken grain per unit time collected from all outlets
D - Weight of un threshed grain from all outlets per unit time

b) Percentage of broken grain (%) = E /A *100

Where,

E - Quantity of broken grain from all outlets per unit time

c) Percentage of unthreshed grain (%) = H /A *100

Where,

H - Quantity of un threshed grain per unit time obtained from all outlets

d) Determination of efficiency

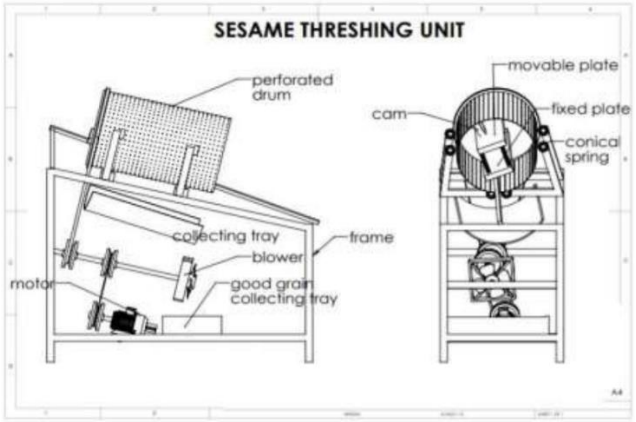
i) Threshing efficiency (%) = 100 – % of un threshed grain

ii) Cleaning efficiency (%) = M/F * 100

Where,

M - Quantity of clean grain per unit time taken from sample taken at the main grain outlet

F - Total quantity of the sample per unit time at main grain outlet.



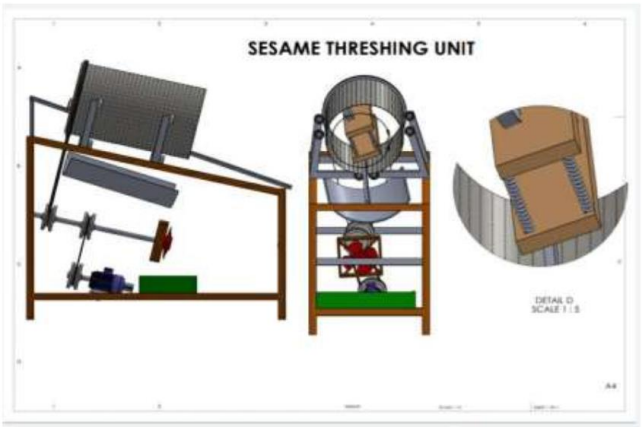


Fig.1. Design of sesame thresher

Figure 1. represents the Design of sesame thresher with parts.

3. Result and Discussion

The physical properties of the TMV 7 sesame variety were analyzed. The performance of the threshing unit was obtained under different sesame moisture content, feed rate, threshing cylinder speed, beating store per minute, and clearance between two wooden plates. Length and thickness of capsules, length, width, and thickness of sesame seed, Number of grains per capsule, size, and shape of grains, and thousand-grain weights were determined.

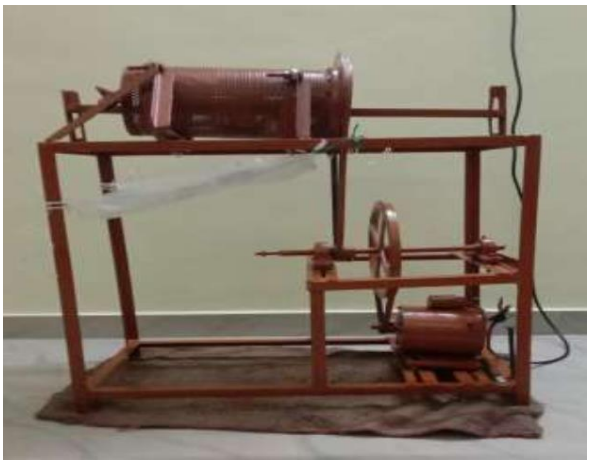


Fig.2. Fabrication of sesame thresher

3.1. Physical Properties

The average plant height was 1195mm. The average length and thickness of the capsule were 28 mm and 11mm. the average number of seeds in a capsule was 59. The average weight of 1000 grains was 3.4g. The average length, width, and thickness of the sesame seed were 2.95mm, 1.85mm, and 0.7mm (Table.1).

Table 1. Result of Physical properties of sesame

Physical properties	Min	Max	Avg
Length of plant (mm)	1040	1350	1195
Length of capsule (mm)	21	35	28
Thickness of capsule (mm)	7	15	11
Length of sesame seed (mm)	2.5	3.4	2.95
Width of sesame seed (mm)	1.6	2.1	1.85
Thickness of sesame seed (mm)	0.5	0.9	0.7
Number of seeds in one capsule	57	61	59
1000 grain weight, (g)	3.2	3.66	3.43

Table 2. Specification of Sesame Thresher

S.No	Components	Specification	Quantity
1	Threshing Unit		
	i) Type of drum	4mm perforation	1
	ii) Diameter	177 mm	1
	iii) Length	355 mm	1
	iv) Wooden plate	300 mm	2
	v) Cam	-	2
	vi) Conical spring	-	4
2	Power required	1 HP electric motor	1
3	Cleaning unit		
	i) Type of blower	Centrifugal type	1
	ii) No of blades	4	-
4	Power transmission V-belt & Pulley	Pulley 10" (2) & 2" (2)	4
5	Transport Wheels	Iron wheels	4

3.2. Combined Effect of Moisture Content, Clearance Between Two Plates, Number of Beats Per Min, and Feed Rate on Threshing Efficiency

Table 3 and Table 4 showed the combined effect of moisture content, clearance between two plates, beating time per min, and feed rate on threshing efficiency. It showed that the increase in feed rate and moisture content and cylinder speed affect the threshing efficiency. The mean threshing efficiency varies from 77.9% to 94.1%. The maximum threshing efficiency of 94.1% could be achieved by the combination of 240 kg/h feed rate, 3mm clearance between two plates, 60 strokes per min, and 14% of moisture content. The minimum threshing efficiency of 77.9% could be achieved by the combination of 280 kg/h feed rate, 5mm clearance between two plates, 30 strokes per min, and 19% of moisture content.

Table 3. Threshing efficiency of sesame thresher for cylindrical speed 30rpm and no of beats per min with a various feed rate (30 strokes per min)

Feed rate (R) Kg/h	Clearance between two plate(C), mm	Moisture content (M),%			Mean Threshing efficiency, (%)
		14	17	19	
		Threshing efficiency, (%)			
190	3	86.3	85.8	85.4	85.8
240	3	88.0	87.8	87.2	87.6
280	3	82.3	81.4	80.5	81.4
190	5	81.5	81.2	79.2	80.6
240	5	83.8	81.1	80.6	81.8
280	5	78.6	78.2	77.9	78.2

Table 4. Threshing efficiency of sesame thresher for cylindrical speed 30rpm and no of beats per min with various number of feed rate (60 strokes per min)

Feed rate Kg/h	Clearance between two plate(C), mm	Moisture content (M),%			Mean Threshing efficiency, (%)
		14	17	19	
		Threshing efficiency, (%)			
190	3	92.8	91.9	91.7	92.1
240	3	94.1	92.0	91.3	92.4
280	3	91.3	89.8	88.7	89.9
190	5	86.7	84.6	82.4	84.5
240	5	88.4	88.1	87.2	87.9
280	5	83.0	82.8	81.6	82.4

3.3. Cost Calculation of Manual Method and Mechanical Method of Threshing

The cost of threshing by manual method:
Number of labors required for manual threshing (240kg) = 4 labors
Time required to thresh crop stalks (240kg) =2 hour
Cost of threshing at @ Rs 50/man/hour (240kg) = 4x2x50 = 400

The cost of mechanical threshing:
Number of men labors required for threshing =2
Time required to thresh crop stalks (240kg) =1 hour
Cost of threshing @ Rs 50/man/hour =Rs.100/240kg.
Initial cost of prototype sesame thresher (P) =Rs. 17,000
Salvage cost 10% of initial cost (S) =Rs.1700Expected life period of thresher (L) =7 years
Annual working hours per year (A) =300 hours
Rate of interest (I) =14%

(i) Fixed cost:
Depreciation = (P-S)/(L X A)
= (17000-1700)/7 X 300 =7.28 Rs/hr
Interest = [(P+S)/2] X [I/100 X A]
= [(17000+1700)/2] X [14/100 X 300]
= 4.36 Rs/hr
Taxes, insurance and housing (2% of the initial cost of thresher)
= 2% of initial cost /A = 1.13 Rs/hr
Fixed cost of operation of thresher (Depreciation + Interest + TIH)
= 7.28 + 4.36 + 1.13 = 12.77 Rs/hr

(ii) Variable cost:
Cost of electricity 1unit = Rs.7
Output power of 1HP = 1 X 0.746 kW = 0.746 kW
Unit consumed = power in kW X no .of hr of operation

= 0.746 kW X 1 =0.746
Electricity cost = 0.746 X 7=5.22 Rs/hr
Total cost of operation = 12.77+5.22= 17.99 Rs/hr
Total cost of threshing = (FC+VC+OPERATOR COST)
=12.77+5.22+100=118
Cost saved over manual threshing =400-118=282
Saving in cost of threshing with our sesame thresher when compared to manual method of threshing = [(cost of manual threshing for 240kg – cost of threshing in our sesame thresher (240kg)) X 100/ cost of manual threshing for 240kg
= [(400-1180) X100]/400=71%
Saving in time of threshing with our sesame thresher when compared to manual method threshing
= [(8-2) X 100]/8=75%.

Table 5. The result of performance evaluation of sesame threshing is compared with manual method of sesame threshing [2].

S. No	Parameters	Manual method of sesame threshing	Threshing with our sesame thresher
1	Threshing efficiency	82 %	94 %
2	Cleaning efficiency	87 %	93 %
3	Damaged sesame grains	2 %	1.03 %
4	Number of workers required for threshing (240 kg/hr)	Minimum 4 workers	Minimum 2 workers
5	Cost of operation of threshing sesame grains (240 kg)	Rs. 400	Rs. 118

4. Conclusion

The physical properties of TMV 7 sesame variety viz., The average plant height was 1195mm. The average length and thickness of the capsule were 28mm and 11mm. The average weight of 1000 grains was 3.4g. The average number of seeds in a capsule was 59. The average length, width, and thickness of sesame seed were 2.95mm, 1.85mm, and 0.7mm. Our sesame threshing unit was tested in the field and tests were conducted with different levels of variables. Its threshing efficiency was 94%, cleaning efficiency was 93% and seed damage was 1.02% could be achieved by the combination of 240 kg/h feed rate, 3mm clearance between two plates, 60 strokes per min, and 14% of moisture content. Our sesame thresher results in 71% and 75% saving cost and time compared to manual threshing.

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