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Research Article

Design and Development of a Sunflower Thresher for Separating the Seeds

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ABSTRACT

The area under sunflower crops is now increasing, especially in the southern region of Bangladesh. Sunflowers are manually threshed by beating the sunflower heads with sticks. Though farm machinery significantly reduces the time required to complete farm tasks, efficient machinery for separating sunflower seeds is not available in farmers' fields in Bangladesh. The aim of the experiment was to design and fabricate a power-operated machine that would separate seeds from sunflower heads. The sunflower thresher was designed and fabricated in the FMPE Divisional workshop of Bangladesh Agricultural Research Institute (BARI) using locally available materials during 2020-22. The threshing was done by beating with the pegs of the rotating cylinder. The thresher was powered by a 2.98 kW diesel engine. The weight of the thresher was 125 kg (without engine). The capacity thresher ranged from 600 to 1000 kg/h, depending on the moisture content of the sunflower heads. Especial criteria for this machine is that it can be used for both fresh-harvested heads and dry heads. No broken seeds were found during the operation. The machine is operated at a 375-400 rpm speed of the threshing cylinder to avoid unshelled seeds. The threshing cost of the sunflower thresher was 494 BDT/ton. The benefit-cost ratio (BCR) for the machine's custom-hire service is 3.45. The sunflower thresher was also evaluated at farmer's field. Farmers expressed their satisfaction with sunflower threshing. The machine could be recommended for threshing of sunflower in Bangladesh.

Keywords: Sunflower, Thresher, Rotating Cylinder, Capacity, Threshing Cost and BCR

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1. Introduction

Sunflower is becoming an important oilseed crop in Bangladesh. The area under sunflower crop is now increasing especially in the southern region. Sunflower is a salinity-tolerant crop, and there is good scope to increase sunflower cultivation in the saline belt coastal areas of Bangladesh. It is expected to increase its production in the coming decade to meet the country's growing demand for vegetable oil. The present total area under sunflower cultivation in Bangladesh is 2576 ha with a production of 3622 tons during 2022-23 [1]. The area and production of sunflower increased 61% and 80% compared to 2020-21 year [1].

Sunflower cultivation is sometimes restricted by farmers due to a lack of appropriate machinery, especially a threshing machine [2]. Sunflower is one of the most important cash crops in the world's food and health industries, and it is beneficial to the human body [3]. Farm machinery is an important and fundamental element for agricultural development and crop production in Bangladesh. Farm machinery significantly reduces the time farmers spend on farm tasks. One of the problems in increasing sunflower production is the threshing of sunflower seeds from the heads. It is a tedious job to remove seeds from sunflower and takes long time and huge labour. If farmers want to reduce production costs, they must reduce harvest costs because this is the most expensive step in the entire production process [4, 5]. Either farmers use a manual method to remove the seeds, or they have to

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depend on industries that lend them large machines to remove the seeds [6]. In the manual method, they remove seeds by sliding the sunflower over a wire mesh or thrashing it with a metal weld, which is really problematic and involves a lot of labour, leading to wastage of time and energy. The output of traditional manual threshing is very low and depends on the workers' efficiency and experience. Due to the unavailability of suitable sunflower thresher, farmers are forced to follow traditional methods.

So, the above circumstances dictated undertaking the research to develop a suitable machine to address the problems farmers face in removing sunflower seeds. During the nineties, a pedal-operated manual single-head sunflower thresher was developed at BARI, which was then suitable for a very small amount of sunflower threshing [7]. Now, the machine has become obsolete with advancement of modern technology. A sunflower thresher was developed at Bangladesh Agricultural Research Institute for threshing only freshly harvested sunflower. The capacity of the thresher varied from 89 to 125 kg/h at the moisture content from 31 to 62% (wb) [8]. There were press rollers to separate the grains from the head of the harvested sunflower. That machine was design to feed sunflower head horizontally and manually for which the machine capacity was low. Farmers were urged higher capacity machine. Considering the above facts and the socio-economic conditions of farmers', this research was undertaken to design and fabricate a power-operated sunflower thresher and to evaluate its performance.

2. Materials and Methods

A sunflower thresher was designed and fabricated during 2020-21 at the Farm Machinery and Post-harvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. Some factors were considered in designing the power-operated sunflower thresher. An orthographic projection was drawn using SolidWorks 2016. The orthographic and isometric views of the sunflower thresher are shown in Figure 1 and Figure 2. All dimensions are in mm.

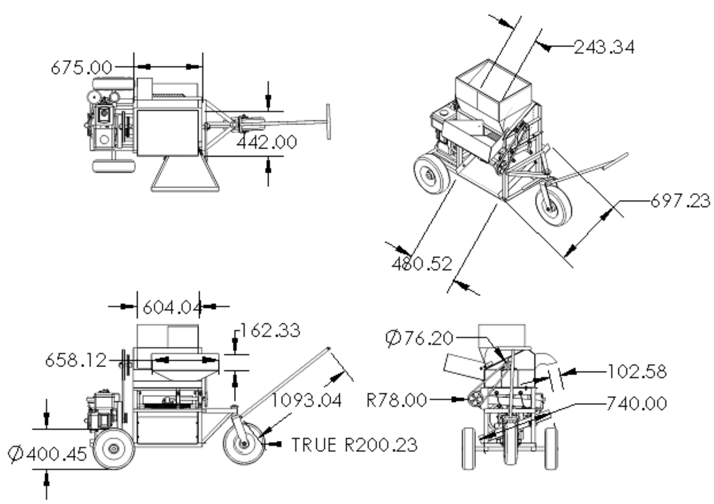

Figure 1. Orthographic views of the sunflower thresher

Figure 2. Orthographic views of the sunflower thresher

2.1 Description of the machine

The feeding system was developed for higher feeding capacity since the user was asking for a higher capacity machine. The design parameters considered were feed rate, power requirement, axial flow shaft speed, seed separation capacity and hopper capacity etc. The main components of the sunflower thresher were hopper, threshing cylinder, axial shaft with peg, output hopper, separation sieve, seed output hopper, wheel, engine etc. The feeding system was developed for higher feeding capacity since the user was asking for a higher capacity machine. The design parameters considered were feed rate, power requirement, axial flow shaft speed, seed separation capacity and hopper capacity etc. The main components of the sunflower thresher were hopper, threshing cylinder, axial shaft with peg, output hopper, separation sieve, seed output hopper, wheel, engine etc. Descriptions of different parts are given below:

Storage hopper: The storage hopper was made of MS angle, MS flat bar and MS Sheet. It is placed on the top of the threshing chamber. The operator initially put the sunflower heads on this hopper. The outlet of this storage hopper was connected to the inlet hopper. It was also inclined to the inlet hopper for easy feeding.

Inlet hopper: The inlet hopper was made of MS angle, MS flat bar and MS Sheet. It is placed on the top of the threshing chamber. The operator inserts the sunflower heads into the threshing chamber through it. It was also inclined to the threshing cylinder for easy feeding.

Threshing cylinder: The main working part of this machine. There is one rotating cylinder that was placed centrally. The rotating cylinder was attached to two self-centered bearings (Figure 3). The rotating cylinder had a diameter of 250 mm and a length of 600 mm. A total of 20 beating pegs were uniformly placed on five strips, with a screw shape. The peg diameter was selected to avoid seed injury. The diameter of the pegs was 20 mm, and the length was 55 mm. The inner cylinder was covered with an outer cover. The cover diameter was 780 mm and the number of threads in the screw conveyor was 5.

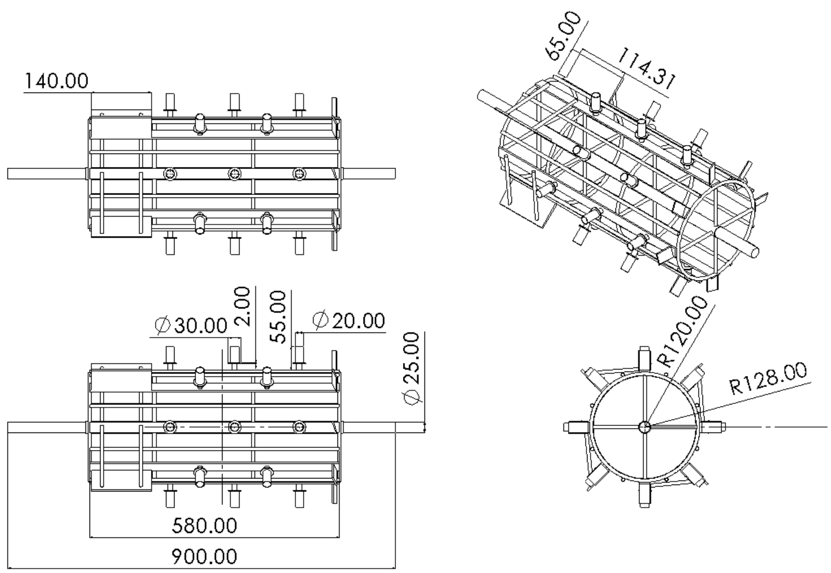

Figure 3. Orthographic views of the threshing cylinder

Head output hopper: This hopper allows the heads to discharge after separating the seeds. The hopper was made of MS sheet with a curved shape to keep the head at a fixed distance from the machine.

Separation sieve: After the action of the threshing chamber, the heads were thrown out, and the ed, along with broken parts of the heads, dropped down from the machine. A separation sieve was placed here to separate the garbage from the seed. The sieve was powered from the axle of the rotating cylinder. The cam connection imparted forward motion to the larger particle on top of the sieve, allowing the seed to dispense through the hole.

Wheel: Three wheels were used to facilitate the machine's easy movement. The front wheel was attached to a handle that allowed it to turn or rotate.

Engine: A small (4hp) single-cylinder diesel engine was used as the prime mover for this machine. This type of diesel engine is the smallest available in Bangladesh for operating small agricultural equipment.

A pictorial view of the improved sunflower thresher is shown in Fig. 4. The specification of the sunflower thresher is given in Table 1. The threshing was done by beating with the pegs of the rotating cylinder. The thresher was powered by a 2.98 kW (4 hp) diesel engine. The weight of the thresher was 125 kg (without engine).

Figure 4. Pictorial view of operation of the sunflower thresher at BARI, Gazipur

Table 1. The specification of the sunflower thresher

Parameters	Values
Overall dimension (mm)	1500 x 1300 x 1500
Dimension of feeding hopper (mm)	360 x 360 x 90
Dimension of sieve (mm)	600 x 600
Rotating cylinder dimension (mm)	600 x Ø 250
Number of peg	20
Peg dimension (mm)	50 x Ø 60
Speed of rotating cylinder (rpm)	375-400
Wheel diameter (mm)	100
Engine capacity, kW	2.98 (4 hp)
Weight of the machine excluding engine (kg)	125 kg

2.2 Testing and Performance Evaluation

The fabricated sunflower thresher was tested, and relevant data were collected at FMPE Division of BARI, Gazipur during 2020-21. The performance test was conducted, and the following parameters were calculated according to the Regional Network for Agricultural Machinery (RNAM) test codes [9].

Capacity of sunflower thresher: The capacity of the machine was evaluated as the quantity of sunflower heads that could be threshed to obtain seed within a recorded time. In this case, 10 kg of sunflowers was fed into the machine, and the time required for the threshing operation to complete was recorded. This was calculated using following equation as stated by [8].

$$C = Q/T \quad (1)$$

Where,

C = Capacity of the machine, ton/h
Q = Mass of processed sunflower head, ton

T = Time taken for processed, h

Injured seeds: The percentage of injured seeds was determined during the threshing process. The injured seeds were separated from the whole seeds by hand picking immediately after the threshing process was completed. This was computed using the equation as stated by [8]

$$P_2 = \frac{M_2}{M_a} \times 100 \quad (2)$$

Where,
P_2 = Percentage of injured seed, %
M_2 = Mass of injured seed, ton
M_a = Actual mass of seed fed into the machine, ton

Unshelled seeds: The percentage of unshelled seeds during the threshing process was calculated. This was computed using the following equation as stated by [8].

$$P_3 = \frac{M_3}{M_0} \times 100 \quad (3)$$

Where,
P_3 = Percentage of unshelled seeds, %
M_3 = Mass of seed unshelled, ton
M_o = Mass of seed unshelled + mass of seed shelled, ton

Separation efficiency: The percentage of separation during the threshing process was calculated. This was computed using the following equation as stated by [8].

$$P_4 = \frac{M_4}{M_4 + M_5} \quad (4)$$

Where,
P_4 = Percentage of separation, %
M_4 = Mass of separated seed, ton
M_5= Mass dust mixed seed with separated see, ton

2.2 Financial analysis

Financial analysis of the sunflower thresher was done. The cost analysis included the machine's operating costs. The operating cost of the machine included both fixed and variable costs. Fixed cost of the machine included capital consumption and shelter. Variable costs included labour, diesel, repair & maintenance. One labourer was required to operate the machine.

Fixed cost

The fixed cost of the machine included annual depreciation, interest on the investment, and rent. Capital consumption included depreciation and interest [8, 10].

(i) Capital consumption (CC)

$$CC = (P - S)CRF + S \times i \quad (5)$$

Where,
P=Purchase price, BDT
S=Salvage value, BDT
CRF= Capital recovery factor

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \quad (6)$$

Where,

i= Rate of interest

L=Life of machine, yr

(ii) Shelter, T=3.0% of purchase price of the machine, BDT

Total fixed cost per year

$$FC = CC + T \quad (7)$$

Variable Cost

In the calculation of variable cost, the following relations were assumed

i) Labour cost per hour, Lb=BDT man-h-1

ii) Fuel cost per hour, E=Lh-1

Total variable cost

$$VC = L_b + E \quad (8)$$

Annual cost/operating cost

$$AC = FC + VC \quad (9)$$

2.3 Field performance evaluation

The adaptive trial of the power sunflower thresher was conducted at four different locations in Subarnachar Upazilla, Noakhali district (Figure 5). Subarnachar is the important sunflower growing area of Noakhali district. A total of 120 farmers were observed to assess the performance of the machine for threshing sunflowers. The performance of the machine was evaluated during adaptive trials.

Figure 5. Operational view of the power sunflower thresher at Subarnachar Noakhali

3. Results and Discussion

3.1 Testing and Performance Evaluation

The design analysis results for the peg in threshing cylinder and thrower in threshing cylinder of sunflower thresher are shown in Figure 6 and Figure 7, respectively. The magnitudes that are represented by the colors red, green, and blue in the figures are the highest, medium, and lowest, respectively. The design analyses were carried out based on the load imposed on the specific parts of the sunflower thresher. To execute this, a 100 N force was applied to the selected parts which were constructed with ASTM A36 steel. It is important to keep in mind that a factor of safety value of 1.0 indicates that the material is starting to distort in a particular place. The factor of safety distribution in the peg shows that the lowest factor of safety (FOS) was 8.3×102. and in head thrower the lowest factor of safety was 1.3×103. This indicates that the material would start to yield if a force much higher than the considered force were applied. The sunflower seeds are tightly bound when the moisture content of the sunflower heads is more than 20%. In this case, several times more force is required to release them than usual. Moreover, the pressure on the pegs can reach several thousand newtons when many sunflower heads are fed into the machine at once. If hard stalks or weeds enter with the sunflower heads during threshing, a mechanical obstacle may be created which requires additional force. The results also showed that the peg yield strength was 2.5×108 N/m2, suggesting that the peg of the threshing cylinder will start to deflect in the other direction when the magnitude of the strength is greater than this amount (Figure. 6). It was observed that this material had begun to yield when the von Mises stress approached the yield strength of 2.5×108 N/m2. The highest stress, displacement and strain of the head thrower were 1.88×105 N/m2, 6.67×10-4 mm and 6.69×10-7, respectively. It revealed that the maximum stress and strain in the peg were at the connection point between the peg and the load-bearing bar. The maximum displacement of the peg may occur at the tip of the peg. The maximum displacement of the head thrower occurs due to the ring deformation.

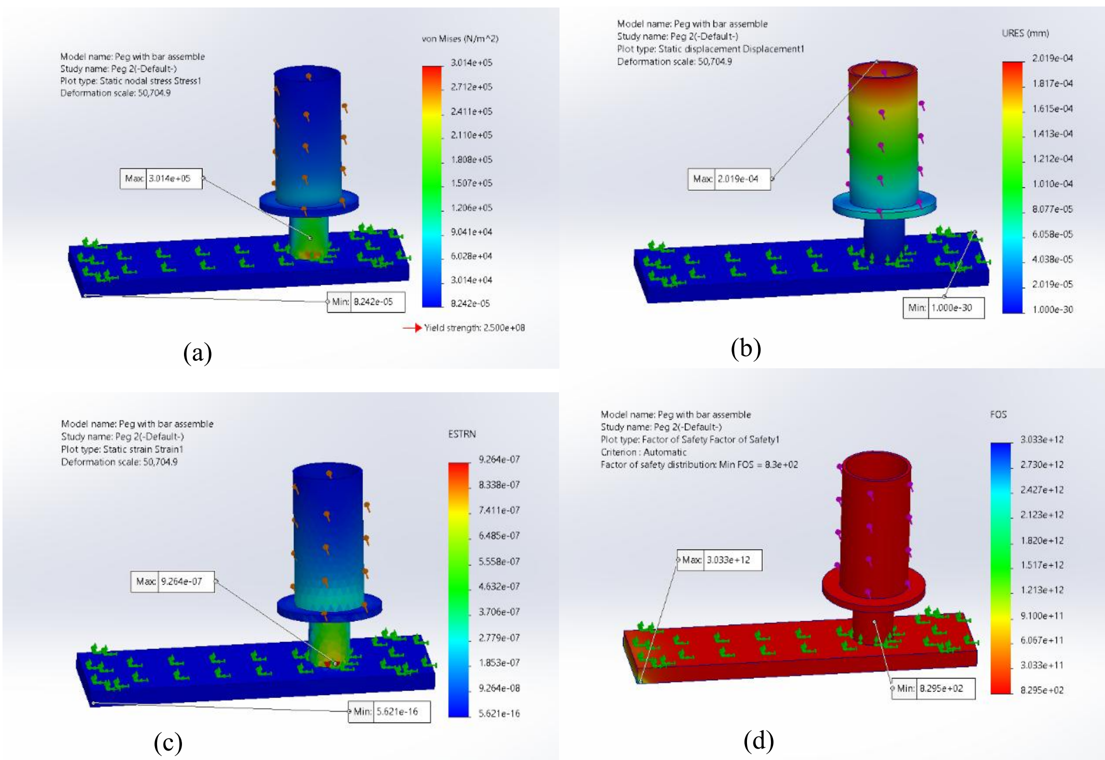

Figure 6. Peg analyses with application of 100 N force for: (a) stress; (b) displacement; (c) strain; and (d) factor of safety.

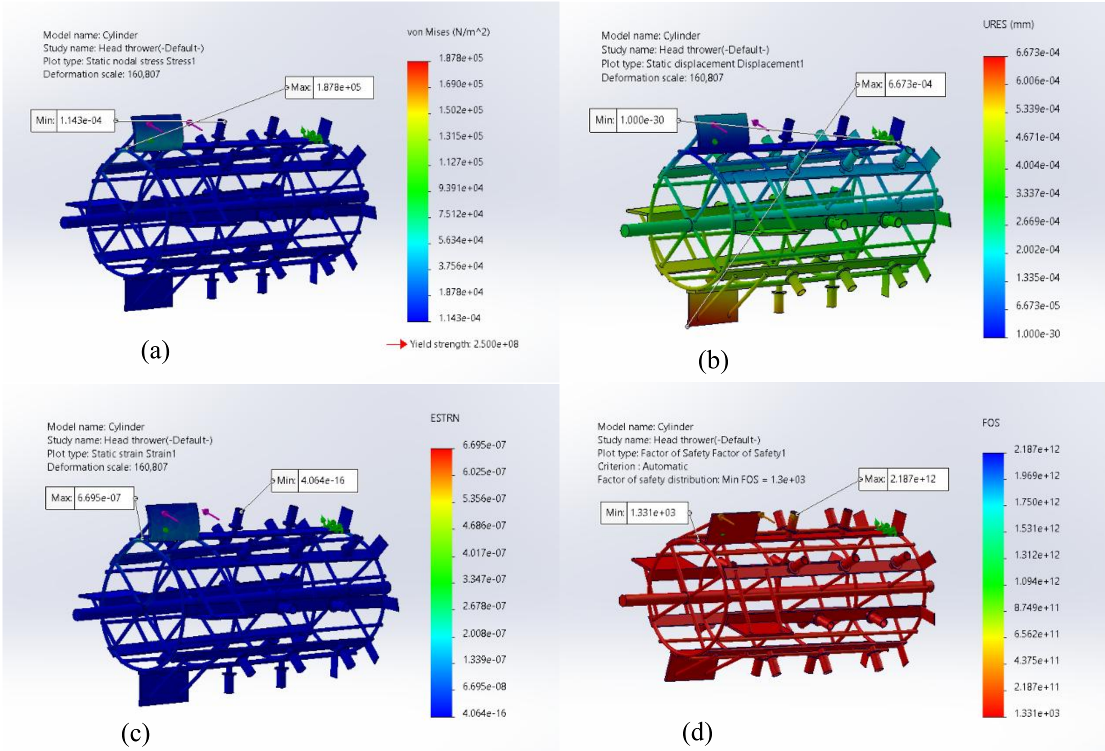

Figure 7. Head thrower analyses with application of 100 N force for: (a) stress; (b) displacement; (c) strain; and (d) factor of safety.

The performance of the power sunflower thresher was varied with the speed of the rotating threshing cylinder (Table 2). The effects of the speed of the threshing cylinder on the performance evaluation matrix of the sunflower thresher were demonstrated in Figure 8. When the speed was lowest (300 rpm), the capacity was lowest, and unshelled seed (7.94%) was found on the head. As the speed of the rotating cylinder increased, the machine's capacity increased, and unshelled grain decreased. On the other hand, the machine's seed separation efficiency from the husk, broken heads, and other garbage increased. However, the unshelled seeds on the heads were found to be negligible at speeds from 375 onward. The highest separation efficiency was found between 375 and 400 rpm. The broken grain was not found at all tested speeds, since the higher-diameter pegs were used to beat on the heads. Considering all performance parameters, the suitable rotating speed of the threshing cylinder was found to be within 375 to 400 rpm. The highest undamaged seeds, threshing efficiency, and machine productivity of 97.4, 94.15 %, and 306.12 kg/h were obtained at a drum speed of 600 rpm and a moisture content of 10.2 % [11]. The reported thresher was suitable for threshing only dried sunflower heads, but the present thresher was found suitable for threshing both freshly harvested and dried heads of sunflower.

Table 2. Effect of speed of the threshing cylinder on performance of the sunflower thresher

Speed (rpm)	Capacity (kg/h)	Separation efficiency (%)	Injury (%)	Unshelled (%)
300	716	92	0.16	7.94
325	720	93	0.17	5.56
350	735	93	0.82	2.06
375	916	95	0.73	0.73
400	938	95	0.63	0.02
425	958	75	0.84	0
450	960	63	2.14	0
500	982	58	3.33	0
700	1004	55	3.91	0

The 3D surface plots in Figure 8 illustrate the effects of speed (rpm) and capacity (kg/h) on sunflower threshing performance. Separation efficiency shown in Fig. 8a improves with increasing speed up to 375–400 rpm, beyond which it declines. Figure 8b showed that Seed injury increases with higher speeds and feed capacities, particularly above 400 rpm, indicating a trade-off between efficiency and seed quality. The unshelled percentage shown in Fig. 8c decreases with speed, reaching near zero at 400 rpm, ensuring complete threshing. Optimal performance such as high separation efficiency, minimal unshelled seeds, and low injury which occurs at 375–400 rpm and 938–960 kg/h, emphasizing the need to balance speed and capacity for efficient threshing with minimal seed damage. Ali et al. (2024) [12] developed a modified sunflower threshing machine incorporating angled rasp and tine bar rotors, compared to the conventional round bar rotor, and evaluated its performance. Performance evaluations at varying rotor speeds (150–300 rpm) and concave clearances (10–20 mm) revealed that the tine bar rotor achieved the lowest specific energy consumption, which decreased with increasing rotor speed and decreasing concave clearance. In their study, threshing efficiency improved with higher rotor speeds and reduced concave clearance, reaching a maximum of 97.93% at 300 rpm. The rotor design modifications significantly improved threshing performance, resulting in a notable increase in efficiency compared to the traditional setup. The efficiency of this study (95%) is also closer to the above study.

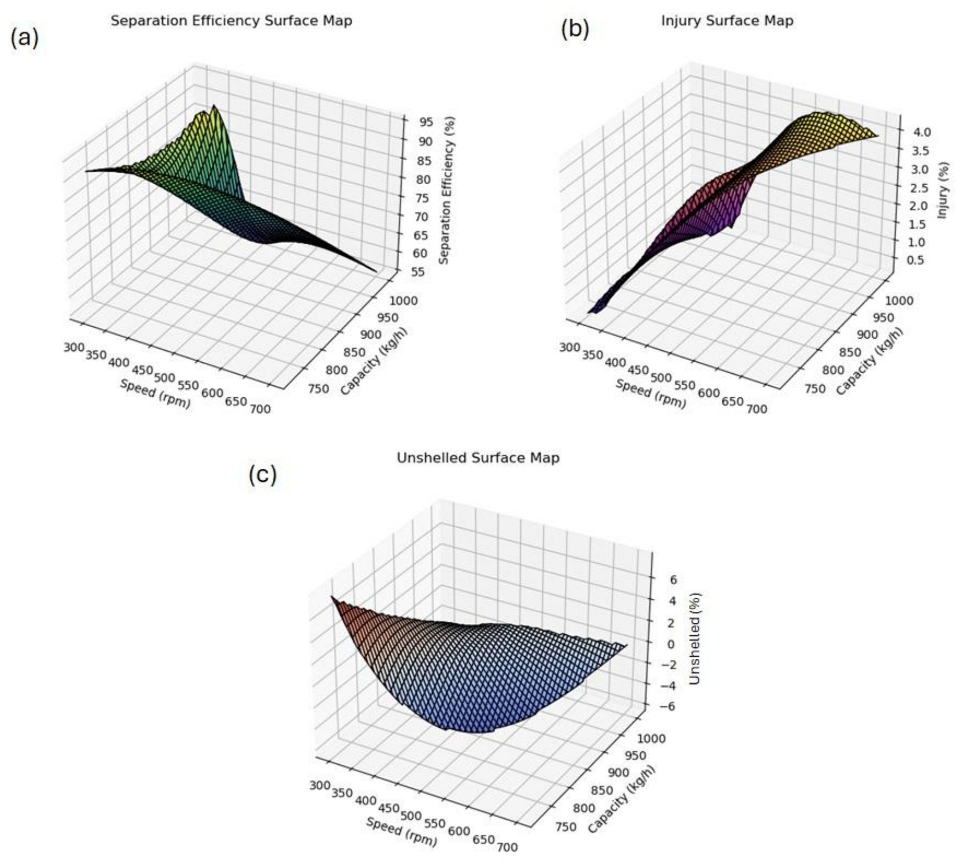

Figure. 8. Effect of speed of threshing cylinder on performance evaluation matrix of sunflower thresher (a) effect of speed on separation efficiency (%) concerning capacity, (b) effect of speed on grain injury (%) concerning capacity, (c) effect of speed on unshelled grain (%) concerning capacity.

The comparative capacity of sunflower threshing at Gazipur is shown in Table 3. Capacities of the pedal thresher and manual threshing were 51 and 34 kg/h, respectively. The capacities of the power-operated sunflower thresher, both the previous and improved models, were found to be 100 and 800 kg/h, respectively. The capacity of the improved power sunflower thresher was 8, 19 and 38 times higher compared to previous power thresher, pedal thresher and manual threshing, respectively. Ali et al. (2021) [13] designed and developed a sunflower threshing machine and tested its performance with a closed threshing box and a screw conveyor, which effectively distributed sunflower heads along the threshing roller, improving overall efficiency. In the study, they found that threshing efficiency increased with higher roller rotational speed and feed rate up to 800 kg/h, beyond which efficiency declined, while unthreshed seed percentage and seed damage increased. Machine productivity, power requirements, and seed damage rose with increasing roller speed and feed rate, highlighting the need for optimized operating conditions. In this study, the sunflower threshing capacity of the improved thresher also reached 800 kg/ha, which is almost equal to their results.

Table 3. Comparative capacity of the sunflower threshing in Gazipur during 2020-21

Types of thrashings	Capacity, kg/h
Improved thresher	800
Previous thresher	100
Pedal thresher	51
Manual beating	34

The performance of the improved power sunflower thresher at different moisture contents is shown in Table 4. The thresher's capacity varied with the moisture content of the heads. The freshly harvested heads, at maturity, usually have a higher moisture content. The thresher's capacity ranged from 606 to 1013 kg/h at 35 to 65% moisture content (wb). A similar feeding rate was also reported by Muenkaew et al. (2024) [14]. The results showed that with decreasing moisture content, separation efficiencies increased [15]. Unshelled sunflower seed were higher (1%) in heads with higher moisture content. Goel et al., 2009 [16] tested the performance of two low-cost sunflower threshers such as wire mesh type and perforated GI sheet type sunflower thresher, against a pedal-operated thresher and traditional methods at varying moisture contents. In their study, the wire-mesh type sunflower thresher exhibited the highest threshing capacity, the lowest cost, and minimal grain breakage (<2%) at an optimal seed moisture content of 10.50%, making it suitable for small and marginal farmers. Threshing efficiency increased while mechanical damage decreased with lower seed moisture content, but threshing capacity declined below 10.50%.

Table 4. Performance of the improved power sunflower thresher at different moisture content in Gazipur

Moisture content (%, wb)	Capacity (kg/h)	Separation efficiency (%)	Unshelled seed (%)
35	606	95	0.0
55	748	94	0.6
65	1013	80	1.0

3.2 Financial analysis

Financial analysis of the power sunflower thresher is shown in Table 5. The operating cost of the power sunflower thresher is 494 BDT/ton, respectively. Net profit of the power sunflower thresher is 245632 BDT/year. The BCR of the machine is 3.45.

Table 5. Financial analysis of the sunflower thresher for different models

Cost Items	Power sunflower thresher	Manual beating
Purchase Price, BDT	43000.00	
Working days per year, yr	30	
Working hours per year, h	240	
Machine life, yr	7	
Salvage value, BDT	4300.00	
Capital consumption cost (CC), BDT	8389.19	
Shelter cost, BDT	215.00	
Total fixed cost, BDT/year	8594.19	
Total fixed cost, BDT/h	35.81	
Labour cost per hour, BDT/h	187.50	62.5
Diesel cost , BDT/h	65	
Repairing cost, BDT/h	6.27	
Lubricating cost, BDT/h	1.95	

Total variable cost, BDT/h	260.72	62.5
Total operating cost, BDT/h	296.53	62.5
Capacity, kg/h	600	25
Operating cost, BDT/kg	0.49	2.5
Operating cost, BDT/ton	494	
Operating cost, BDT/yr	71167	2500.00
Custom hire-based income (@2200BDT/ton), BDT/yr	316800	
Net Profit, BDT/yr	245632	
BCR	3.45	

1 Dollar=115 BDT

3.3 Field performance evaluation

The power sunflower thresher was evaluated in Noakhali during 2020-21. The sunflower thresher was demonstrated at four different places in Subarnachar Upazila of Noakhali district and used by farmers (Figure 9). The capacity of the sunflower thresher was 625-750 kg/h (Table 6), which was similar to the capacity observed in Gazipur.

Figure 9. Field use of the sunflower thresher in Noakhali.

Table 6. Field Performance of the improved Sunflower thresher at different location of Noakhali district

Location	Amount, kg	Capacity, kg/h
Purba Badamtoli	1600	635
Alamin Bazar	1200	625
Uttar kocchopia	1200	625
Bhuiarhat	1000	750

4. Conclusions

A small power (4 hp) operated sunflower thresher was designed and developed. The machine's capacity ranged from 600 to 1000 kg/h at Gazipur, depending on moisture content. The machine could be used for both the freshly harvested head at maturity and dry head. The sunflower seed was not break due to use of the machine. The unshelled seed on the head could be avoided, and satisfactory seed separation could be achieved by operating the machine at 375-400 rpm. The machine was financially profitable. Performance of the sunflower thresher was satisfactory and farmers expressed their satisfaction. The machine could be recommended for the sunflower growers in Bangladesh.

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