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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Development and Performance Evaluation of Peanut Threshing Machine

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Abstract

Peanut also called groundnut (*Arachis hypogaea* L.) is an important oilseed and cash crop that is grown in tropical and subtropical regions of the world. Nowadays, tractor mounted peanut threshers without grading systems are commonly used to thresh the harvested groundnut plants, which results in the mixing of standard quality groundnut pods with immature/dead pods, mud/clods, and other impurities. To address this challenge, the conventional thresher was incorporated with a grader. The modified thresher was evaluated during the threshing season of 2023-24 in district Rawalpindi, *Pothwar* region of Punjab, Pakistan. The performance of the newly developed groundnut thresher (TH_1) was compared with conventional thresher (TH_2) based on threshing productivity (capacity) (kg h^{-1}), pod breakage percentage (%), cleaning efficiency (%), and threshing efficiency (%) at three different ranges of moisture contents viz. M_1 = 19-23%, M_2 = 14-17%, M_3 = 8-12%. Experimental data were collected and statistically analyzed at a 5% level of probability. The experimental results revealed that maximum cleaning efficiency in the improved (TH_1) and conventional (TH_2) threshers were 97.88% and 84.92% respectively at the minimum moisture content (8-12%) while the minimum pod damage percentage was observed 2.24% and 4.44% at higher moisture content (19-23%). The overall performance of improved groundnut thresher was more satisfactory than the conventional thresher based on cleaning efficiency and pod damage percentage while it performed equally for threshing productivity and threshing efficiency. From the experimental results, it reveals that the modified groundnut thresher performed better to clean and grade the groundnut pods in one operation.

Keywords: Groundnut grader, Standard-quality pod, Post-harvest technology, Cleaning efficiency, Pod-damage percentage

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1. Introduction

Peanut also called groundnut (*Arachis hypogaea* L.) is an important oilseed and cash crop. Its roasted form is used as dry fruit and its straw is an important animal feed during the slack period when fresh fodder is not available. Worldwide, it occupies sixth rank in oilseed crops, with developing countries contributing 97% of their cultivated area with 94% of the production (Yilmaz et al., 2023; Shubham et al., 2015; Onemli, 2005). In Pakistan, groundnut is grown approximately on an area of 94 thousand hectares including districts Attock, Chakwal, Jhelum, Rawalpindi, Karak, Swabi, and Sanghar with a total production of 101 thousand tonnes and a yield of 1.1 tons per hectare. In Pakistan, the major portion of total groundnut production (82.8%) is recorded in the Pothwar plateau of Punjab province, while Khyber Pakhtunkhwa and Sindh contribute 13% and 3% respectively (Saad et al., 2024; Hussain et al., 2020).

Traditional harvesting methods used in developing countries have several challenges such as prolonged harvesting periods and high harvesting costs. Due to the prolonged harvesting period, growers are unable to fulfill bulky orders from consumers in time. To overcome these challenges affordable and reliable mechanical harvesting techniques need to be designed (Dhliwayo and Mushiri, 2018). In threshing operation grain breakage is usually caused by the seed hitting the rigid surface of the thresher unit, the short distance between the thresher and the concave, the feeding rate, and the inadequate thresher speed (Nasir et al., 2023; Ali et al., 2021).

Cleaning efficiency is a measure of the presence of foreign materials within the pod outlet during the cleaning process. It was observed that as the moisture content of the plants increased, the cleaning efficiency decreased. This decrease in cleaning efficiency was found to be influenced by two key factors: the cohesion between the soil and the pod, and the densities of the attached soil and pod material at that particular moisture level. As moisture levels increased, the cohesion that held the soil and pod together decreased, and this reduction in cohesion led to a decrease in the densities of both the pod and soil. Therefore, the detachment of soil particles from the pod surface was more prominent at lower moisture levels. This, resulted in a reduction in the sliding velocity of the pods, ultimately leading to higher cleaning efficiency when the moisture content was lower (Makhliyo and Rustam, 2022).

Groundnut grading and handling practices originated in the 1960s through the U.S. marketing quota groundnut program. Grading involves categorizing a product according to specific criteria to maintain quality by removing harmful elements. It's essentially classifying products based on their commercial value and use, guided by grade standards. Farmers choose grading methods based on market specifications, considering physical, chemical, or biological properties. Physical properties include aspects like size, weight, moisture, texture, color, shape, and foreign matter (Fashina et al., 2015).

Keeping in view the above discussion, an experiment was performed to modify conventional thresher to overcome the challenges of the farming community. The objective of this study was set to document and describe the pod grades to meet the market demands for grain quality by separating defects and impurities from the sound grain to satisfy customer needs with exact specifications. Nevertheless, a grader was integrated at the pods delivery unit to separate the quality pods from defective, immature-sized, shrinkage, undesirable-sized pods, unwanted clods, and other impurities. It will not only affect the economic and social benefits of the farmers but also minimize the efforts and human power to make better-quality produce. The modified design of groundnut thresher will facilitate farmers with ease and safety of operation.

2. Materials and Methods

The performance evaluation of newly improved machine (with grader system) was compared with conventional thresher at three moisture content. Grading system was designed at AutoCAD software according to the requirements in the CAD/CAM Lab of the Faculty of Agricultural Engineering and Technology PMAS-Arid Agriculture University Rawalpindi, Pakistan. The proposed and designed system was fabricated with an existing thresher with the help of a local farm machinery manufacturer.

2.1. Description of study area

The experiment for the testing of the improved thresher was conducted during the harvesting season of 2023-24 in the district Rawalpindi, Pothwar region in the Punjab province of Pakistan as this region is the rich in production of groundnut (*Figure 1*). The testing location on the world globe is between 33˚ 1' to 33˚ 6' N and 73˚ 30' to 73˚ 45' E with highest temperature in summer is 38 ˚C and lowest in winter is 18 ˚C.

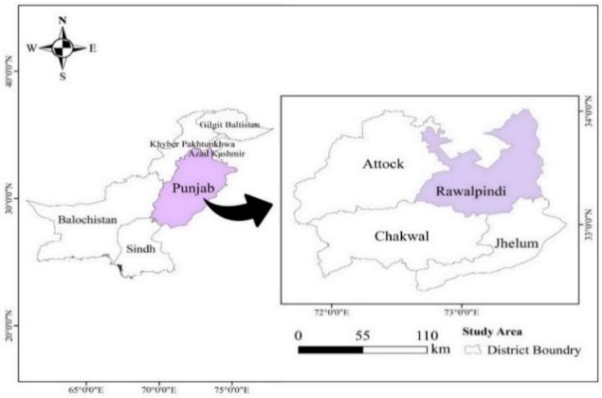
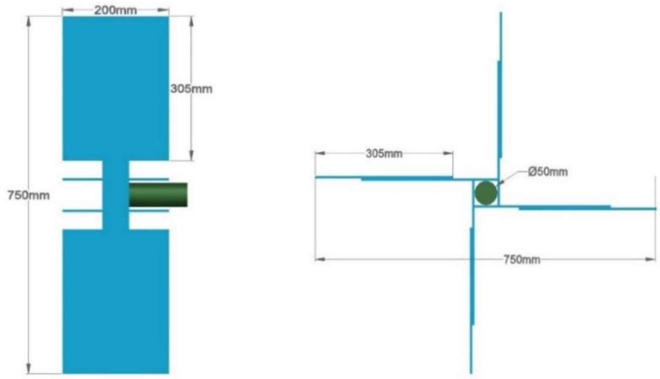


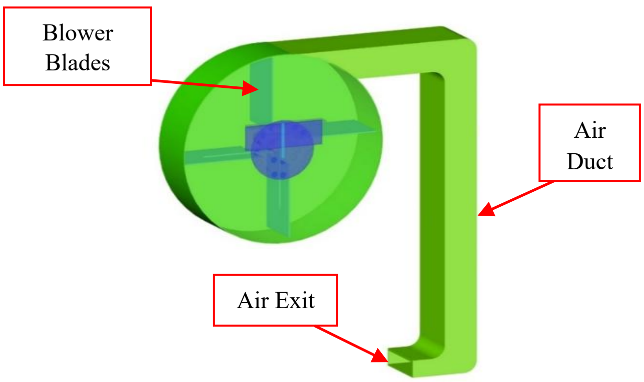
Figure 1. Location of the study site

2.2. Design of blower

It consists of a mild steel shaft of 50 mm in diameter which rests at rectangular stands on both sides. There are four flat steel blades of 200×305 mm was attached on the shaft periphery consecutively at a 90° angle along the shaft which is milled square at the center of the shaft to blow the wind by generating centrifugal force during operation (*Figure 2A&B*). The air is generated by the rotation of rotors at 898rpm which is pushed into the duct (*Figure 2C*).



(A) (B)



(C)

Figure. 2. Blower of the grader (A) Top view of blades (B) Side view of blades (C) 3D view

2.2.1. Determination of main shaft speed

Okonkwo et al. (2019) proposed an equation to calculate the speed of the shaft. The speed of both the blower and the eccentric mechanism shafts was calculated by using the relation given below (Eq. 1). The thresher was operated with the tractor (>35hp) at the speed of 540rpm.

$$\boldsymbol{NmDm = NvDv} \quad \text{(Eq. 1)}$$

Where Nm is the speed of the driving pulley (rpm); Nv is the speed of the driven pulley (rpm); Dm is the diameter of the driving pulley (m); and Dv is the diameter of the driven pulley (m).

$$\boldsymbol{540 \times 0.254 = Nv \times 0.340}$$

Nv = 403 rpm

Blower speed

403 × 0.457 = Nv × 0.205

Nv = 898 rpm

Velocity of belt drive

The velocity of the belt drive (V) for the blower and eccentric mechanism was derived by using the Eq. 2 (Adanu et al., 2015).

$$V = \frac{\pi DN}{60} \ (\text{m s}^{-1}) \quad \text{(Eq. 2)}$$

Where D is the diameter of the driven pulley (m) and N is the speed of the driven pulley (rpm).

For the eccentric drive

$$\boldsymbol{V = \frac{\pi(0.34)(403)}{60}}$$

V = 7.17 m s^{-1}

For the blower

$$\boldsymbol{V = \frac{\pi(0.205)(898)}{60}}$$

V= 9.63 m s^{-1}

2.2.2. Flow rate of the blower

The blower must be capable of providing the required air velocity necessary for the separation of the pods from clods and coco-melon (a small sized watermelon just bigger than peanut pod, it’s a type of weed in peanut crop). The flow rate was assumed using the Eq. 3 of continuity by Tertsegha et al. (2021) given below;

$$\boldsymbol{Q = AV} \ (\text{m}^3 \text{ s}^{-1}) \quad \text{(Eq. 3)}$$

$$\boldsymbol{Q = 0.062 \times 9.63}$$

Q = 0.597 (m3 s^{-1})

Where, A is the area of the blade, (m^2); V is the actual velocity of air produced from the

2.3. Design of sieve

In this unit, the pods are sifted and cleaned. It includes a sieve with holes of 10 mm in diameter (*Figure 3*). The normal inclination angle (calculated according to coefficient of friction) of the sieve was 5°. The quality pods were dragged and moved to collection chamber while the dead/immature pods fall through the sieve and moved toward bottom collection chamber (*Figure 3*).

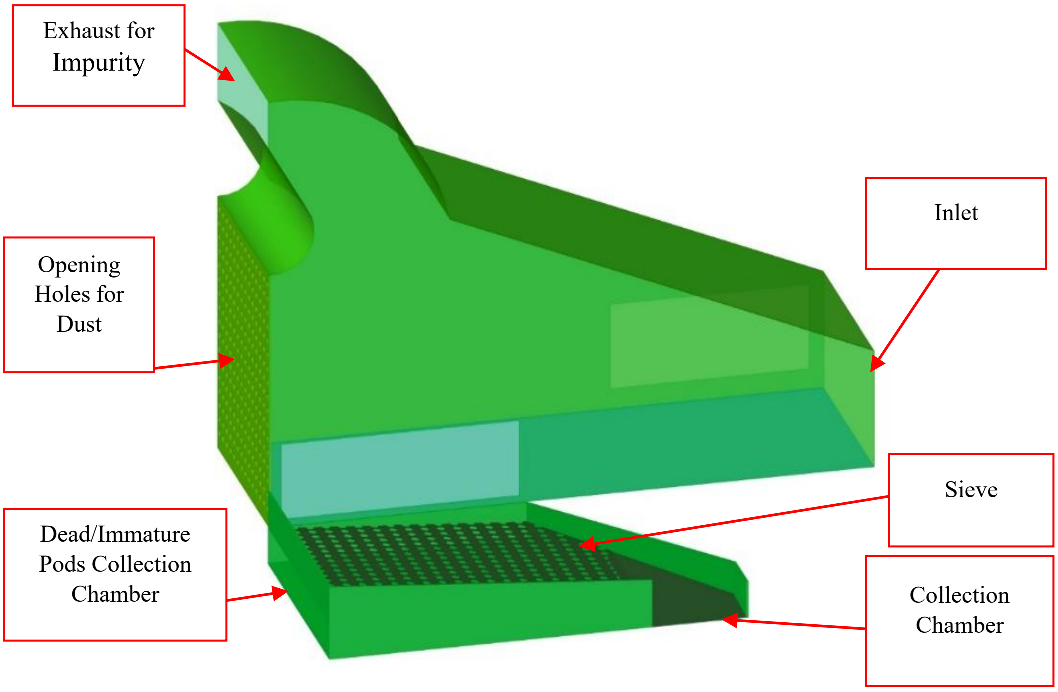


Figure. 3. Pod separating mechanism of the grader

Table 1. Some engineering properties of pod and other foreign materials to design sieve

Sr. No.	Engineering Property		Dead/Immature Pods Value		Standard Sized Pods Value	
			Min value (Avg)	Max value (Avg)	Min value (Avg)	Max value (Avg)
1	Size	Length mm	14.8	25.6	26.8	45.2
		Width mm	8.6	12.3	12	16
		Thickness mm	5.2	9.2	9.5	14.1
2	Equivalent diameter mm		8.7	14.2	14.51	21.68
3	Sphericity		0.58	0.55	0.54	0.47
4	Single pod weight, g		1.54	1.98	2.2	2.85
5	Terminal velocity (pod) m s^{-1}		8.25	10.11	10.25	12.55
6	Terminal velocity (clods)m s^{-1}		13.45 (Min)		18.75 (Max)	
7	Clod's weight, g		3.25 (Min)		28.75 (Max)	
8	Coco melon weight, g		4.48 (Min)		12.25 (Max)	
9	Angle of repose, °		20.25 (Min)		28.20 (Max)	
10	Bulk density, g cc^{-1}		0.280 (Min)		0.288 (Max)	
11	Coefficient of friction		0.031 (Min)		0.039 (Max)	

2.4. Development of grading system for groundnut thresher

Pod received from the grain outlets of conventional groundnut thresher contains unwanted materials as shown in *Figure 4*. This unwanted foreign material has adverse impacts on the quality of groundnut pods and hence reduces its market value. Proper cleaning and grading of groundnut pods are useful for both the farmer and the buyer. The pods and foreign materials differ in their physical properties. The difference in their physical properties permits their separation by attaching a suitable grader with a conventional groundnut thresher. The pod with impurities coming out from the grain outlet chamber was entered into the newly developed grading system as shown in *Figure 5*. The grading system consists of pneumatic and mechanical graders. In pneumatic graders, compressed air is used to create viable energy. Its working principle is to compact air within the blower reduce the volume and increase the air pressure because all the air molecules are condensed. They capture, compress, and transport air around a circuit, and accomplish designated tasks with the generated energy. The important part of a pneumatic grader is the air blower.

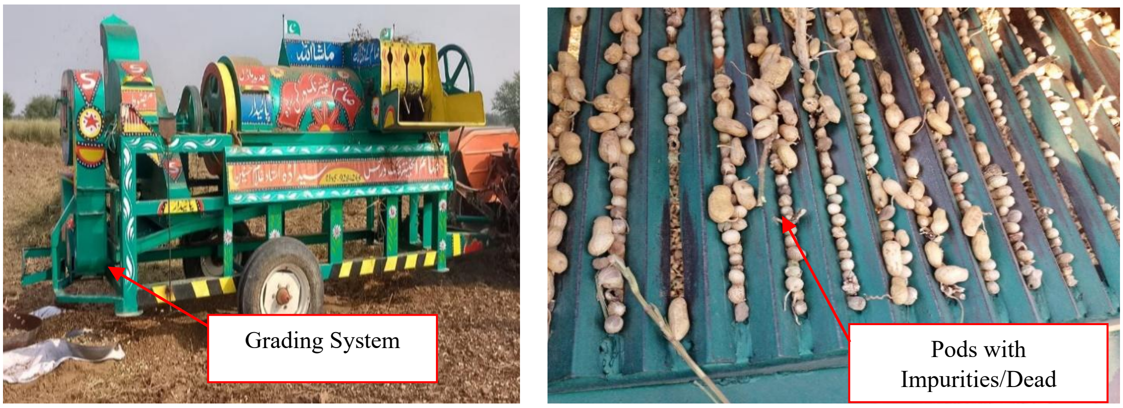


Figure. 4. Conventional groundnut thresher with impurities, broken, dead/immature pods

A pneumatic grader separates pods from coco-melon, leaves/straw, dry mud clods, and other unwanted material. Unwanted material was moved away from the grader while the groundnut pods were entered into the next integrated mechanical grading system as high-pressed air (at terminal velocity) blew the pods due to their lighter weight (*Figure 6*).

Figure 5. Improved (modified) groundnut thresher while separating standard-quality pods

In the current experiment, tractor NH-480 (55hp) was used to operate the groundnut thresher having enough power at PTO around 88% of engine hp (48 hp). This tractor was selected because it has sufficient horsepower to operate groundnut thresher and it is the most popular tractor among the farming community of the Pothwar region of Pakistan. Okonkwo et al. (2019) suggested that the groundnut thresher can be operated at HP >35.

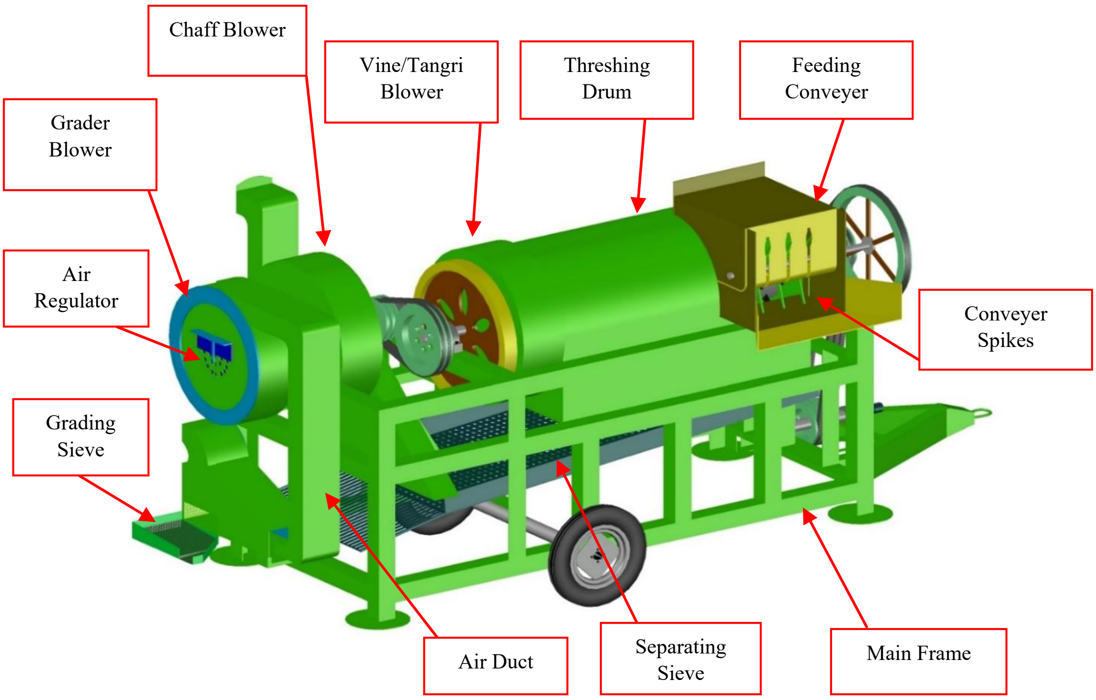


Figure 6. Isometric view of modified groundnut thresher with the grading system and feeding conveyor

2.5. Variables to be measured

The performance of the improved thresher machine at three moisture content was evaluated during the harvesting season of 2023-24. The data regarding threshing productivity, grain cleaning, gain breakage, and threshing efficiency was collected.

2.5.1. Threshing productivity

It is also called grain throughput capacity. To measure threshing productivity, five samples were taken from the pod's collection chamber per unit of time. The weight of the threshed pods was recorded with the help of weighing the balance five times to get the average value. Threshing productivity was calculated by using Eq. 4 (Aluko et al., 2020):

$$Pth = \frac{Wg}{t} \quad (\text{kg h}^{-1}) \qquad \text{(Eq. 4)}$$

Where:

Wg = Weight of total grain after threshing (g)

t= time consumed in threshing operation (sec)

2.5.2. Pod damaged percentage

The groundnut pod is a valuable source of protein, vitamins, and energy for both humans and animals. These are vulnerable to predators before and after harvesting. All the pods are required to be in their original form as the broken pods are more susceptible to the attack of insects or pests. To measure the pod damaged percentage in threshing five samples were taken from the pod's collection chamber. The weight of threshed and broken pods was recorded with the help of weighing the balance five times to get the average value. The pod damage was calculated using the equation Eq. 5 (Husain et al., 2024; Vennela et al., 2018):

$$PD(\%) = \frac{Wdg}{Wtg} \times 100 \qquad \text{(Eq. 5)}$$

Where:

PD = Damage pods, %

Wdg = Weight of damaged pods in the sample, g

Wtg = Weight of total pods of the sample, g.

2.5.3. Cleaning efficiency

Cleaning efficiency is a crucial aspect of machinery performance as it contributes to value addition. To assess this efficiency, five samples of threshed grains were collected and their weights were measured. These samples were then subjected to a separation process to remove all materials except the clean grains. The cleaning efficiency was calculated using the Eq. 6 (Alwagie, 2024).

$$CE\ (\%) = \frac{Ws - Wi}{Ws} \times 100 \qquad \text{(Eq. 6)}$$

Where:

C.E= Cleaning efficiency, %

Wi = Weight of unwanted/impurities material from sample, g

Ws = Total weight of sample, g

2.5.4. Threshing efficiency

Threshing efficiency was measured by weighing the weight of pods before threshing and the weight of threshed pods. It was calculated by the using the Eq. 7 (Ajmal et al., 2017):

$$TE\ (\%) = \frac{Wth}{Ws} \times 100 \qquad \text{(Eq. 7)}$$

Where:

Wth= Average weight of threshed pods (output), g

Ws= total weight of the sample (input), g

2.6. Statistical analysis

The collected data were statistically analyzed by applying the Two-way ANOVA method using the software "*Statistics 8.1*". The mean of treatments was compared at a 5% level of significance.

3. Results

The performance of improved (TH_1) & conventional (TH_2) groundnut thresher was evaluated at three ranges of moisture content (M_1 = 19-23 %, M_2 = 14-17%, M_3 = 8-12%). The threshing productivity, pod breakage percentage, cleaning efficiency, and threshing efficiency were calculated and statistically analyzed (*Figure 7-10*). These results were compared with previous research to retrieve useful information for end users/farmers.

3.1. Threshing productivity

The statistical analysis presented in *Figure 7* showed that the threshing productivity was significantly affected by changing three moisture contents (M_1 = 19-23%, M_2 = 14-17%, M_3 = 8-12%) while it was not significantly affected by employing the improved (TH_1) and conventional (TH_2) groundnut threshers. It reveals that by decreasing the moisture content of the groundnut crop (vine), the threshing productivity increased significantly. The maximum threshing productivity (277.55 kg h^{-1}) was observed at the lowest moisture content M_3 (8-12%) while the minimum threshing productivity (230.10 kg h^{-1}) at higher moisture content M_1 (19-23%). The mean threshing productivity for TH_1 (256.40 kg.h^{-1}) and TH_2 (256.25 kg h^{-1}) on the base of three moisture contents was not significant to each other at a 5% level of probability.

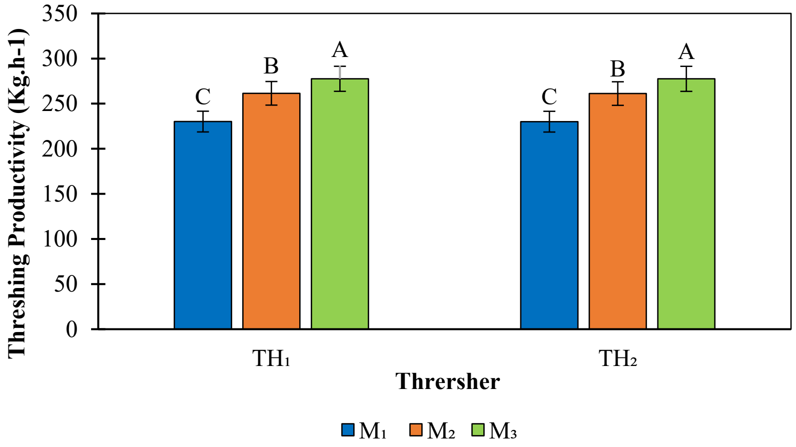


Figure 7. Effects of improved (TH_1) and conventional (TH_2) groundnut thresher on threshing productivity for three moisture contents (M_1=19-23 %, M_2=14-17% & M_3=8-12%)

3.2. Pod damage percentage

The effect of improved (TH_1) and conventional (TH_2) groundnut threshers on pod damage percentage (*Figure 8*) at three levels of moisture content (M_1 = 19-23 %, M_2 = 14-17%, M_3 = 8-12%). The mean maximum pod damage percentage (5.12%) showed at lowest moisture content M_3 (8-12%) while the minimum pod damage percentage (3.34%) at higher moisture content M_1 (19-23%). It reveals that the decrease in moisture content resulted in an increased pod damage percentage by employing the improved (TH_1) and conventional (TH_2) groundnut threshers. The statistical analysis showed that the pod damage percentages (3.34, 4.38, and 5.12%) under three moisture contents were significantly different from each other. Similarly, the mean pod damage percentage under TH_1 (3.04%) and TH_2 (5.52%) on the base of three moisture contents were also significantly different at a 5% probability level.

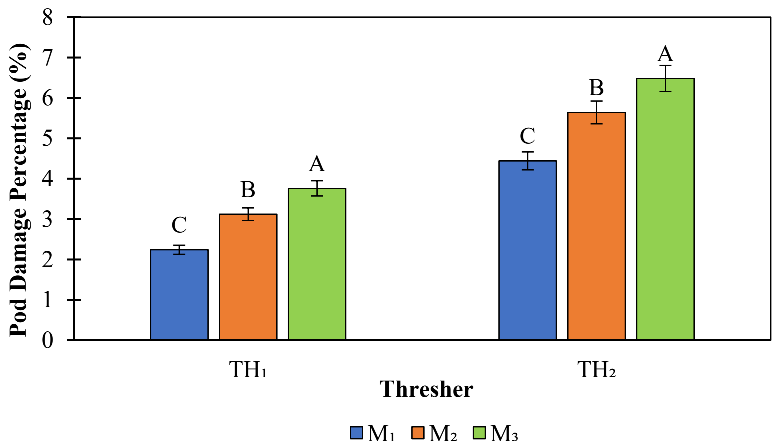


Figure 8. Effects of improved (TH_1) and conventional (TH_2) groundnut thresher on grain damage percentage for three moisture contents (M_1=19-23%, M_2=14-17% & M_3=8-12%)

3.3. Cleaning efficiency

The effects of improved (TH_1) and conventional (TH_2) groundnut threshers on cleaning efficiency at three levels of moisture content (M_1 = 19-23 %, M_2 = 14-17%, M_3 = 8-12%) is shown in *Figure 9*. The mean maximum cleaning efficiency (91.40%) showed at lower moisture content M_3 (8-12%) while the minimum cleaning efficiency (86.25%) at higher moisture content M_1 (19-23%). The statistical analysis showed that the cleaning efficiency of the improved and conventional thresher was significantly different at three levels of moisture. The average cleaning efficiency under TH_1 (96.12%) and TH_2 (81.59%) based on three moisture contents were significantly different at a 5% probability level.

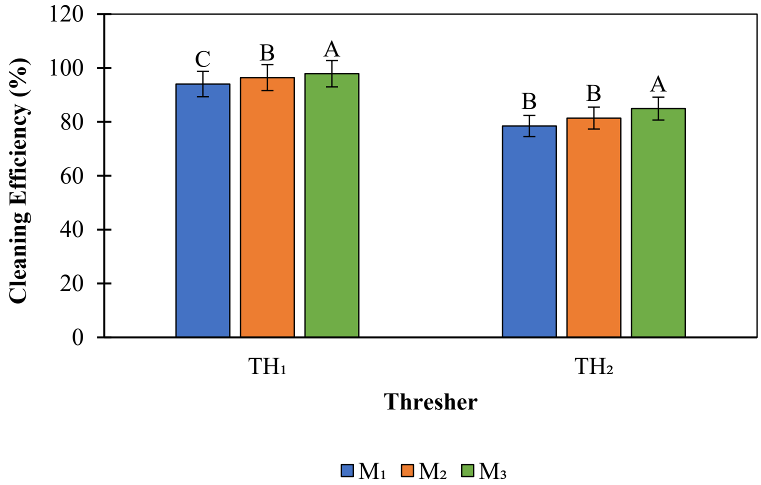


Figure 9. Effects of improved (TH_1) and conventional (TH_2) groundnut thresher on cleaning efficiency for three moisture contents (M_1=19-23%, M_2=14-17% & M_3=8-12%)

3.4. Threshing efficiency

Figure 10 showed the effects of improved (TH_1) and conventional (TH_2) groundnut threshers on threshing efficiency at three levels of moisture content (M_1 = 19-23 %, M_2 = 14-17%, M_3 = 8-12%). The mean maximum threshing efficiency (98.16%) showed at lower moisture content M_3 (8-12%) while the minimum threshing efficiency (93.26%) at higher moisture content M_1 (19-23%). The statistical analysis showed that the threshing efficiency of the groundnut thresher was significantly different at three levels of moisture content. The average threshing efficiency under TH_1 (95.60%) and TH_2 (95.48%) based on three moisture contents were not significantly different from each other at a 5% level of probability.

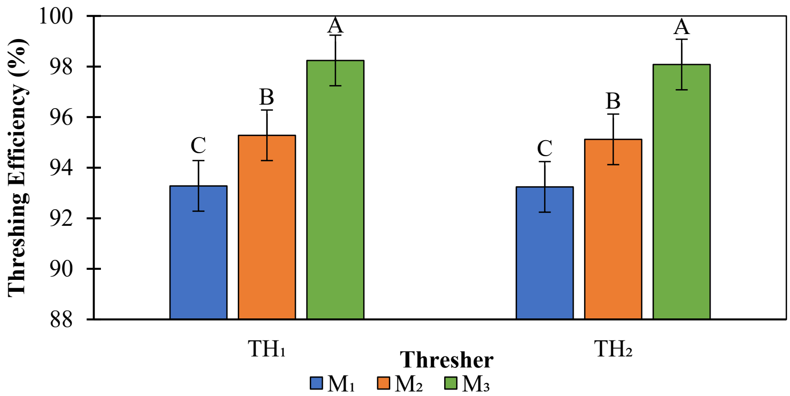


Figure 10. Effects of improved (TH_1) and conventional (TH_2) groundnut thresher on threshing efficiency for three moisture contents (M_1=19-23 %, M_2=14-17% & M_3=8-12%)

4. Discussion

The findings of *Figure 7* show that the threshing productivity (capacity) increased with the decrease in moisture content in both cases i.e., improved (TH_1) and conventional (TH_2) groundnut threshers. The results are in line with the findings of Belay and Fetene (2021) who concluded that the threshing productivity was significantly affected by the changing moisture content of the cop at ($P<0.05$). The results indicate that, by increasing the moisture content of the crop, the threshing productivity (capacity) decreased because the change in the moisture content of the crop affects the performance of the thresher. In another experiment by Vennela et al. (2018), the threshing productivity was 227.25 kg h^{-1} and it decreased with the increase in moisture content of the crop, which is also in line with the current experiment.

Figure 8 indicate that the improved thresher (TH_1) has less pod damage percentage than conventional thresher (TH_2) and in both cases, the pod damage percentage increased by decreasing the moisture content of the groundnut crop (vines). The results are in line with Magar et al. (2010) who reported that the pod damage percentage for square beater threshing drum and flat plate beater drum at three moisture content of groundnut i.e., 21.30, 18.40, and 16.10% was noted as 1.57, 2.5, and 3.12%, respectively. The results showed that the grain damage percentage was increased by decreasing the moisture content of groundnut. In another experiment, Sharifi et al. (2019) found that the lowest grain damage percentage (1.712%) was reported at 20% of moisture content while the highest grain damage percentage (2.606%) was recorded at 16% of moisture content, which is also in line with the current experiment. Chilur et al. (2014) also showed consistent results by adding that the pod cobs resulted in damage by adhesion at lower moisture content.

The analyzed results shown in *Figure 9* indicates that the cleaning efficiency of improved (TH_1) groundnut thresher showed better performance than conventional (TH_2) and by decreasing the moisture content, the cleaning efficiency increased in both threshers which is in line with Tertsegha et al. (2021) who found that the maximum cleaning efficiency (84.46%) was recorded at the moisture content (8%) of the groundnut crop (vine and pod) while the minimum cleaning efficiency (74.12%) was obtained at 12% moisture content. The ANOVA indicated that the moisture content highly affected the cleaning efficiency of groundnut pods. In another experiment by Belay and Fetene (2021), the results indicate that the cleaning efficiency of the thresher was significantly affected by the amount of moisture content of the crop (vines). Al-sharifi (2018) reported the maximum cleaning efficiency (94.824%) for vines at 14% moisture content whereas the minimum cleaning efficiency (89.246%) was observed at 22% moisture content. In general, cleaning efficiency decreases by increasing the moisture content, while it's increased with the decrease of moisture content. Magar et al. (2010) added that the cleaning efficiency indicates the presence of impurities in pods. It was seen that the cleaning efficiency increased with the decrease of moisture content. In another experiment by Sharifi et al. (2019) found that the highest cleaning efficiency (90.658%) was recorded at lower moisture content (16%) while the minimum cleaning efficiency (88.351%) was gained at higher moisture content (20%). Further Lupu et al. (2015) added the same statement that the increased in moisture content of plant and straw leads to decrease in the cleaning efficiency. All these studies showed in line results with the current experiment.

Figure 10 showed that the performance of improved (TH_1) and conventional (TH_2) groundnut threshers was shown the same for threshing efficiency while on the other side, the decrease in the moisture contents resulted to the increase in threshing efficiency and vice versa. The results are in line with the findings reported by Karthik et al. (2015). The threshing efficiency of the thresher was 98.6% when tested in the dry mixture of crop and 68.4% in the wet mixture. The results showed that the threshing efficiency was highly significant in a dry mixture of crop. In an experiment by Al-sharifi (2018), the maximum threshing efficiency (97.629%) of the thresher was observed at 14% moisture content while the minimum threshing efficiency (95.091%) was recorded at 22% moisture content. This shows that the threshing efficiency of the thresher significantly increased by decreasing the moisture content of the groundnut crop (vine and pod).

5. Conclusion

Tractor mounted groundnut thresher was improved by incorporating a grading system with the conventional thresher. The improved thresher (TH_1) was compared with conventional thresher (TH_2) at three ranges of moisture contents (M_1 = 19-23 %, M_2 = 14-17%, M_3 = 8-12%). It was concluded that threshing productivity (capacity) in both threshers (TH_1 = 256.40 kg h^{-1} and TH_2 = 256.25 kg h^{-1}), the pod damage percentage (TH_1 = 3.04% and TH_2 = 5.52%), the cleaning efficiency (TH_1 = 96.12% and TH_2 = 81.59%) and the threshing efficiency (TH_1 = 95.60% and TH_2 = 95.48%) increased with the increase of moisture content as shown in *Figure 7,8,9* and *10* respectively. This shows that the improved thresher with grader performed better to clean and grade the pods and both threshers performed satisfactorily at low moisture content in all aspects. Therefore, with this performance, the improved thresher will solve the problems of farmers to meet the market demand by cleaning and grading the groundnut pods.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Saad, A., Haq, Z. U., Iqbal, T., Ansar, M.; Design: Saad, A., Khan, A.A; Data Collection: Saad, A., Alam, T., Islam, M. A; Statistical Analysis: Ahmad, I; Literature Search: Saad, A.; Writing, Review and Editing: Saad, A., Haq, Z. U., Khan, A. A.

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