UniversePG

Publisher homepage: www.universepg.com, ISSN: 2663-6913 (Online) & 2663-6905 (Print)

https://doi.org/10.34104/ajpab.023.01160123

American Journal of Pure and Applied Biosciences

Journal homepage: www.universepg.com/journal/ajpab

Development of a Power Tiller Operated Safe Grain Cleaner

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ABSTRACT

Threshed grain contains impurities which should be removed as soon as possible after harvesting and certainly before storage. A clean grain has esteem value, improves storability, reduces price penalties, and improves milling quality. Traditionally farmers use wind or fan to remove foreign matter from the grain. In mechanical grain cleaner, a fan and several superimposed reciprocating sieves or screens are now used. These can be operated manually or by electric motor. Traditional cleaning methods are laborious and mechanical cleaners are costlier for a farmer. An attempt was made to develop a power tiller-operated grain cleaner incorporating safety protection. Power tiller-operated (PTO) grain cleaner has been developed at BRRI research workshop and tested at farmers' yard. Two flat bars of 680x100 mm size were taken and both ends of the bars were curved in the same direction. Those were fixed with a pulley as a cross blade and fitted rigidly with the flywheel of a power tiller engine and a protection cage was made as safety measures to protect the operators/ users from accidents. The cage was made with mild steel (MS) wire (1/8th) and tightly attached to the chassis and oil tank by nut bolts. Air flow rate was found 7 m/s at a linear distance of 1 m and decreased to 3 m/s at 5 m from center of flywheel. No foreign matter was observed in cleaned grain during operation. Fuel consumption was found about 700 ml/hr. About 1200-1600 kg paddy can be cleaned in an hour. Males or females can use it easily without any accidental risk i.e. clogging dress with flywheel. However, the developed safe grain cleaner can significantly contribute to improving product quality by separating un-ambient materials especially foreign matter, insect bored, and diseased grain.

Keywords: Power tiller, Protection, Safe grain cleaner, Cage, PTO, BRRI, Development, and Cleaner.

INTRODUCTION:

Three forth of total world population consumes rice as staple food as major constituent of their daily diet. Rice production is a crucial area of the agro-technical complex; it has the biggest impact on the supply of food to the population (Bilde, 2015; Matveev *et al*., 2016). Harvesting, threshing, drying and bagging bears contaminants such as stones, sticks, chaff and dust (Usman *et al*., 2014) into grains, which needs to be cleaned. Materials separated through the concave and sieves are composed of grains, chaff and other small components of materials other than then grains (Miu, 2003). After manual threshing or by using hold on type threshers for threshing rice crop winnowing operation is necessary. Winnowing removes unwanted materials like straws, chaffs, weeds, soil particles and rubbish from grains. It progresses grain storability, diminishes dockage, amid processing, gives quality processed rice and improved yield. Moreover, it diminishes crawling, bothers, and disease (Usman *et al*., 2017). Seed comes from the field, contains different contaminants like weed seeds, other seeds, and such fabricated stems, broken seeds, and earth. These contaminants must be expelled, and the clean seed legitimately taken care of and put away to supply quality planting seed that will increment, cultivate generation and supply uniform crude fabric for industry (Al Mamun *et al*., 2021).

Winnowing has greater importance as clean seed maintains the genetic purity of seed. One of the most labor-intensive and important operations in grain production is seed cleaning (Bilde, 2015; Sheidler *et al*., 2014; Stan & Linde, 2014). After manual threshing or mechanical threshing, winnowing operation is necessary (Hossain *et al*., 2023; BRKB, 2020). Winnowing is process of separating grain from a mixture of grain and chaff in an air stream created artificially or naturally. Separation is accomplished by allowing the air flow to pass through the mixture declining vertically down. The grain being heavier material gets deposited almost at the place of falling, whereas lighter material (chaff) is blown away to a larger distance. The winnowing operation which is very common in Bangladesh is done by kula on threshing yard where all harvested crops are stacked. This is very trouble-free method but output is very low down, i.e., 40-45 kg/hr (Ali, 1997). For that, one has to wait for wind currents. But this method is time consuming, uncomfortable and laborious and totally depends on wind conditions. Labor is essential to put at higher platform and pour grains from higher to lower elevation with unsuitable body conditions which increases labor toil. Air is generated by natural or mechanical fan. However, the inadequacy of natural wind for cleaning is its erratic direction, speed and stability, high labor requirement and rather imprecise degree of partition (Aguirre and Garray, 1999). Considering these restrictions in winnowing, now-a-days small fans are used but it also involves same hard work, labor has to set in front of fan and pour grains in customary direction of wind. This method has also one drawback that percentage of blown grain was high due to indecent pose of operator. Also these operations are carried out in open yard and subjected to the stormy weather. Hollatz and Quick, (2003) reported that a combination of aerodynamic-mechanical process is used for grain cleaning and that it would be a simple mechanical sieving process without fan.

Miu, (2003) designed vibratory clean-up sieve stochastically and divided overall movement of grain within chaff layer as segregation movement to the top of the sieve (diffusion created by the sieve vibration), transport movement along the sieve and passing through sieve openings. Transport of particles along an oscillating sieve influences the effectiveness of the process and also affects metering of the particulate materials along an oscillating pan (Elfverson and Regner, 2015) and particles caught in the opening reduce the sieving efficiency (Picket and West, 1988). No important progress has been made in the design of new efficient grain cleaners of local manufacture or the development of improved grain cleaning techniques (Liang *et al*., 2016; Mingjie *et al*., 2012). One of the crucial problems facing manufacturers of competitive grain cleaners is the substantiation of rational designs and equipment for current technologies of cleaning and separation of grain seeds, which would achieve good results at minimum cost (Bischoff, 2015; Clearout, 2015). It needs to improve postharvest cleaning and separation of grain without implementing advanced technologies (Eskhozhin and Bayshugulova, 2015; Capov & Shepelev, 2010). These types of winnower use in Bangladesh are sophisticated and costly. Only 23% farmers are large and medium category in the country. Therefore, it is crucial to develop low cost and efficient grain cleaning mechanism. In Bangladesh, Power tiller is a key agricultural element used in diverse operations i.e. tillage, planting, harvesting, milling and goods transportation. It would be better to design and develop effective grain cleaning mechanism useable in existing Power tiller at farmer's level. Thus, the study was carried out to develop an effective cleaning mechanism and incorporate in available power tillers in Bangladesh.

MATERIALS AND METHODS:

The study was conducted at BRRI research workshop; and tested at BRRI threshing yard and a farm house holder at Harinakundu, Jhenadah.

Components of PTO grain cleaner

Power tiller operated grain cleaner is consisted of the components: Power tiller, cleaning unit and safety cage. Fourteen horse power (hp) power tillers was used to develop the power tiller operated grain cleaner. SS flat bar, SS rod, Wheel plate, Nut, Bolt were used in cleaning unit and safety cage.

Design considerations

1) The machine should fulfill its basic task of cleaning the grain.
2) It should be economical.
3) There should not be a need for repeat of process
4) It should be portable to ease transportation.
5) The design should be optimized to reduce fatigue of farmers, and
6) The attachments should employ low cost materials, methods and standard parts that are locally available.

Determination of moisture content

Moisture content of grain and straw was determined by Riceter L moisture meter.

Measurement of speed

Digital Tachometer DT2234C+ was used which displaces the revolutions per minute on digital screen. MS6252A Digital Anemometer was used to measure the wind speed during the experiment.

Working procedure

The followings are the steps which were followed to evaluate the performance of a solar power operated paddy winnower:

1) At first, 50kg of paddy sample were taken.
2) After checking the winnower was started and then paddy was put into the hopper
3) Stopwatch was started at the beginning of winnowing and it was stopped at the time of winnowing finished completely.
4) The air speed was taken by using anemometer.
5) After finishing the winnowing, original paddy was weighted, chaff, the immature paddy, dust weight was taken by a weight machine.

Performance evaluation of solar power operated paddy winnower

Measurement of performance was primary importance and was carried under controlled conditions to obtain reliable data on machine, such that work capacity, quality of work, adaptability to different kinds of crop in comparison with local methods. The feed rates on different parameters like cleaning efficiency, output capacity of winnower was also determined.

Determination of grain ratio

Weight of sample of paddy grain, weight of clean grain and impurities was measured and the grain ratio was calculated using the following equation (Kadam, 2016).

$$\text{Grain ratio} = \frac{\text{weight of grain in sample}}{\text{total weight of sample}} \times 100$$

Blown grain percentage

The sound grain carried away along with the straw and chaff was calculated (Kadam, 2016).

$$\text{Blown grain (\%)} = \frac{F}{A} \times 100$$

Where,

F= Amount of whole grain collected at chaff outlet per unit time, kg.

A= Weight of total grain input per unit time, kg.

Cleaning efficiency

Cleaning efficiency of the winnower is defined as the ability to separate the sound grains from a mixture of grain, dust, straw and chaff (Kadam, 2016).

$$\text{Cleaning efficiency } (\eta) = \frac{I}{J} \times 100$$

Where,

I =Weight of whole grain per unit time at main grain outlet, kg.

J= Weight of whole material per unit time at the main outlet, kg.

Theoretical considerations

The following theories and equations were considered in the study.

Optimal fan wind speed and the corresponding required rpm

It was found that the optimal wind speed for this application was 4.57-7.11m/s. In order to achieve this wind velocity, a specific rotational speed (rpm) would be required of the shaft of the fan. This was calculated using the fan affinity law (Ngadi, 2013).

$$\frac{n_1}{Q_1} = \frac{n_2}{Q_2}$$

Where,

Q_1 = first air flow rate (m^3/min)

n_1 = rotational speed corresponding to Q_1 (rpm)
Q_2 = second air flow rate (m^3/min)
n_2 = rotational speed corresponding to Q_2 (rpm)

Due to the equal diameter of two pulleys, the optimal fan wind speed and corresponding required rpm is the same.

Pulley diameter

To size the correct dimensions of the pulley, a ratio between rpm and pulley diameter was used (Ngadi, 2013).

$$n_1 d_1 = n_2 d_2$$

Where,
d_1 = diameter of driver pulley, cm
n_1 = rotational speed corresponding to d_1, rpm
d_2 = diameter of driven pulley, cm
n_2 = rotational speed corresponding to d_2, rpm

Performance evaluation

The performance evaluation involves collecting samples from the grain outlet and the non-grain or unwanted outlet. The weight of grains and other materials in each sample was recorded. The procedure was replicated for each throughput.

The following equations were used to determine the percentage cleaning efficiency and percentage grain loss.

$$\text{Cleaning Efficiency, Ec (\%)} = \frac{\text{Initial Weight of Sample } (W_1) - \text{Final Weight of Sample } (W_2)}{\text{Initial Weight of Sample} (W_1)} x\ 100$$

$$\text{Grain Loss, GL (\%)} = \frac{\text{Weight of Total Material in Clean Grain Sample } (W_{tg})}{\text{Weight of Grain Material Non Grain Sample } (W_{gn})} x\ 100$$

Where,
Ec = Cleaning efficiency (%)
GL = Grain loss (%)
W_1= Initial weight of sample (kg)
W_2= Final weight of sample (Kg)
W_{tg} = Weight of total material in clean grain sample (Kg)
W_{gn} = Weight of grain material in non-grain sample (Kg)

Cost analysis of winnowing

Fixed cost

$$\text{Depreciation(Tk./hr)} = \frac{\text{Initial Cost} - \text{Salvage Value}}{\text{Useful Life}} x\ 100$$

Interest (Tk./hr) = Principal×Interest Rate×Time
Insurance and taxes (Tk./hr) = 2 per cent of initial cost
Housing (Tk./hr) = 1.5 per cent of initial cost
Total fixed cost = Sum of all cost

Variable cost

Electricity cost= Electricity consumed (KWh) X Electricity charge (Tk. /kWh).
Operators cost= Wage of operator/ working hours
Repair and maintenance = 10 per cent of initial cost.
Total variable cost = Electricity cost + Operators cost + Repair and maintenance
Operating cost= Fixed cost + Variable cost

Where,
C = Initial cost of machine, Tk.
H = Annual use of machine, hr.
I = Interest rate, per cent.
L = Total life of machine, yr.
S = Salvage value, Tk.

RESULTS AND DISCUSSION:

PT operated safe grain cleaner was developed using locally available material at WMMD research wok-shop.

Single blade

Two flat bar of each was taken 680X100 mm and 1/8th thickness. Width of each blade was made curve 45 degree angle at inner direction to zero degree angles at center of the blade. Each single blade thickness was 100 mm. This airflow helps separate lighter impurities like chaff and dust from the grains. The single blade was shown in the **Fig. 1**.

Cross blade

Cross blade was fixed with the flywheel of the power tiller engine before use. Two curved and inner bended blade was perpendicularly fixed as cross sign as shown in **Fig. 2**. A linear distance of 1 m from the flywheel revealed the air flow rate, which fell at a rate of 3 m/s at that distance.

Safety cage

Safety cage was prepared using stain less steel (SS wire) (**Fig. 4**). The cage length and width were 747 mm and 723 mm respectively. As a safety precaution, a cover was created to shield the users or operators from any mishaps. The cover was composed of stainless steel wire and was firmly fastened to the chassis and oil tank with nut bolts. Farmers are safe in using PTO safe grain cleaner due to the safety cage. The safety cage can protect the user to avoid cloth cling to the PTO safe grain cleaner. PTO grain cleaner is safe for both men and women to use and won't cause any accidents among farmers.

Cleaning unit

Cross blade with safety cage was fixed with a wheel plate. Diameter of the wheel plate was 180 mm. Then it was fixed with flywheel of the power tiller. That is termed as cleaning unit as shown in **Fig. 6**. It is the core of the grain cleaner and composed of cross blade, fly wheel and cage.

Fig. 1: Single Blade.

Fig. 2: Cross Blade.

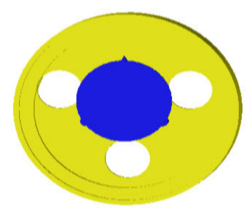

Fig. 3: Wheel Plate Attached with Flywheel.

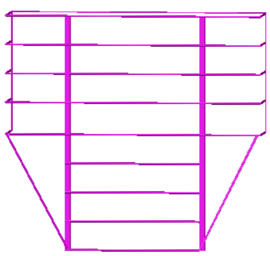

Fig. 4: Safety Cage.

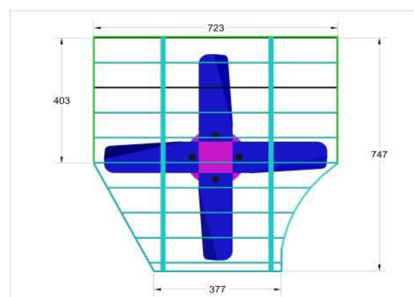

Fig. 5: Cleaning Unit Attached with Flywheel.

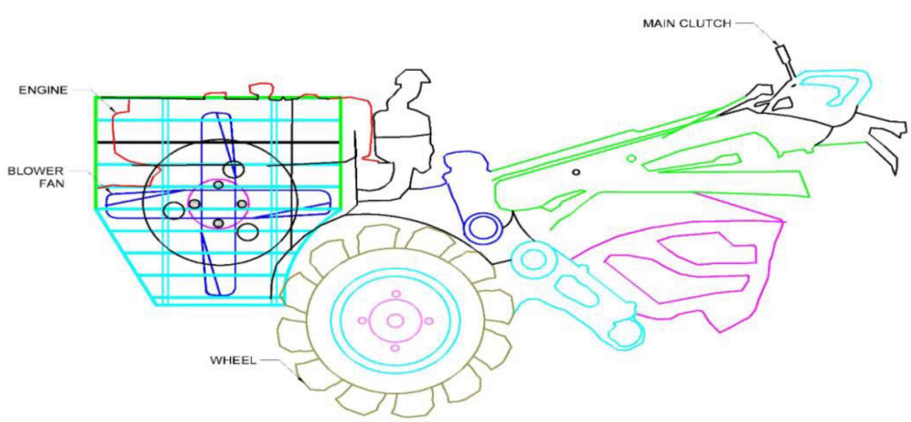

Fig. 6: Power tiller Operated Safe Grain Cleaner.

Fig. 7: PT operated grain cleaner without safety cover tested in farmer's yard.

Performance evaluation

In this system, the grain is cleaned removing unexpected materials. The air flow rate was found 7 m/s at a linear distance of 1 m and it is decreased at 3 m/s at the distance of 5m from the flywheel. Threshed paddy was fallen from man height and linear distance 5 m from the flywheel. When grain was fallen at this height, the forein materilas are gone away for air flow and no foreign materials are observed in the cleaned grain (**Fig. 7**).

Capacity of PT operated grain cleaner

About 1200-1600 kg paddy can be cleaned in an hour. Male or female can use this easily. Fuel consumption of it is 700-800 ml/hr. Safety cage gave safe guard for the user. Farmers can use this cleaner as safe one without accident.

Cost analysis

Cost of cleaning per kg in PT operated grain cleaner and manual is Tk. 0.07 and 0.31, respectively. This finding coincides with (Kadam, 2011 and Manisha, 2017). Cost of cleaning can be saved by 77% using PT operated grain cleaner over manual method. The system was found economically feasible on the basis of the cost of operation of solar photo voltaic (SPV) operated paddy winnower 0.30 Tk./kg for the feed rate 120 kg/hr. It is less than that of power operated paddy winnower 0.40 Tk./kg (Kadam, 2011), power operated fan 0.80 Tk./kg (M/s. Benson Agro Engineering), manual operated fan 1.1 Tk./kg (M/s. Benson Agro Engineering) and manual winnowing operation 2 Tk./kg. The result obtained is summarized in **Table 1**. The economics of different paddy winnowing machine like power operated paddy winnower, power operated fan, manual operated fan and manually winnowing operation was calculated.

Table 1: Economic analysis of power tiller operated safe grain cleaner.

Sl. No.	Economical parameters	Particulars
1	Cost of the grain cleaner (Tk.)	10973
2	Total fixed cost (Tk./hr)	7.9
3	Total variable cost (Tk./hr)	31.9
4	Capacity of winnower (kg/hr)	120
5	Operational cost (Tk./kg)	0.30

CONCLUSION:

PTO safe grain cleaner was found satisfactory in paddy cleaning. It decreased time required to clean the rice grain, while cost also saved. Its' materials could be sourced locally. The machine is suitable and fulfills the need of the farmers. PTO grain cleaner is much faster in grain cleaning than that of manual cleaners. It can also be used any time of the harvest. This is a great adventage in hot climate. An operator can do the cleaning operation with ease. The machine has a limited number of moving parts that requires less maintenance. The machine is cheap and easily affordable by the farmers. About 1200-1600 kg paddy can be cleaned in an hour. Male or female can use it easily without any accidental risk i.e. clogging dress with flywheel. However, the developed safe grain cleaner can significantly contribute to improving product quality separating un-ambient materials especially foreign matter, insect bored and diseased grain.

ACKNOWLEDGEMENT:

This research was performed as part of annual research program of farm mechanization and postharvest technology program area of Bangladesh Rice Research Institute, Gazipur. Thanks to all specially Dr. M A Zami, Former Head of Workshop Machinery and Maintenance Division of BRRI for enormous support.

CONFLICTS OF INTEREST:

The authors have no conflict of interest about the manuscript publication.

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Citation: Hossain MA, Rahaman H, Ahmmed MM, Khan AU, Hossen MA, Nath BC, Huda MD, Bhuiyan MGK, and Hossain M. (2023). Development of a power tiller operated safe grain cleaner. *Am. J. Pure Appl. Sci.*, **5**(5), 116-123. https://doi.org/10.34104/ajpab.023.01160123