



Screen cleaner for on farm processing of grains

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ABSTRACT

Cleaning is the first unit operation performed on threshed grain to remove field impurities. Presently, cleaning machines are operated using conventional energy sources which are either uncertain or non-affordable to farmers. A solar powered multi-crop screen cleaner was developed (2014), modified and tested at ICAR-Indian Agricultural Research Institute, New Delhi (2016). The modified unit consists of the frame, feed hopper and discharge chutes, adjustable screen cradle assembly, slope adjustment mechanism for screen and screen cradle and a variable drive unit. Developed machine was tested for soybean, lentil and chickpea and evaluated in terms of cleaning efficiency at different feed rate, speed and screen slope. The optimum performance was achieved at a screen slope of 5°, 200 rpm, and feed rate of 150 kg/h. Cleaning efficiency in the range of 74-79 % was observed. Multi-grain processing ability, better cleaning efficiency and green energy utilisation assures that the developed machine is an appropriate techno-economic solution for on farm grain processing.

Keywords: Cleaning efficiency, Feed rate, Green energy, Screen slope, Seed/Grain cleaner

Presently post-harvest losses in food grains are to the tune of 10% (Jha *et al.* 2015), which can be minimized significantly with proper primary processing. Field crops, after harvesting and threshing, contain impurities like weed seeds, straw, chaff, stones and other crop seeds. Presence of these impurities increases the deterioration in quality, cost of storage, handling and transportation as well as threat of infestation. Material with such impurities fetch lower market price. Hence, removal of impurities is of utmost importance (Jha *et al.* 2015). Cleaning and grading are basically separating material in different homogenous groups according to its specific characteristics. In design and development of cleaning machines for particular cleaning operations affected by a number of factors, including physical properties of the material, physical purity (Aradwad *et al.* 2018), range of work parameters and energy requirement (Schmidt 2007). Commercially available cleaning machines are of higher capacity, high-power requirement and operated by grid power. Many researchers have developed cleaning and grading machine powered by electric motors (Tabatabaeefar *et al.* 2003, Akinoso *et al.* 2010, Muhammad *et al.* 2013, Jethva and Varshney 2016). The rising cost and unavailability of electricity-based farming inputs has

put farmers under pressure (Shyam and Kanakasabapathy 2017). In addition, manual and animal powered cleaning systems have also been tried by different researchers (Kachru and Sahay 1990, Chandrakar *et al.* 2014, Subudhi *et al.* 2014). But this system induces fatigue and in turn cleaning efficiency reduces significantly. The availability of energy is a key factor for farmers to expand their agricultural activities, which are not dependent on electricity only, but get their energy from renewable sources. Considering the specifics, the present research work on development of solar powered multicrop cleaner of medium capacity, adjustable screen mechanism, low operating cost, easy maintenance and usage, and technology appropriate solution for small and marginal farmers were key considerations.

MATERIALS AND METHODS

Prototype was developed in 2014 and modifications were done in 2016 at the Division of Agricultural Engineering, IARI, New Delhi. In order to assess the suitability of modified unit for different crops, three crops, viz. soybean, lentil and chickpea were selected. Soybean, lentil and chickpea grains were procured from the Seed Production Unit, IARI. A physical property of the material has close linkage with cleaning operation performance. Hence, important physical properties related with cleaning were measured and calculated for selection of screen assembly.

Design considerations: The basic considerations in the modification and development of screen cleaner were stroke length, uniform flow of material, screen cradle assembly and ease of operation in field. Particle movement on a screen surface is by vibration and the resultant force on a particle

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must be higher than the friction force between the grain and the surface. Particle velocity on the screen surface must not be too high, or the grain material will pass by the screen openings instead of falling through. Screen must be placed at an angle less than the angle of friction of the grain on the surface. This machine must be capable of producing 100-200 kg/h of cleaned material.

Step-wise development and modification process: The cleaning machine consists of a feed hopper, screen assembly, eccentric unit and motor. The main frame was 930 mm in length, 620 mm in width and 900 mm in height. In modification vibration stability was increased by reducing height of the machine and well-bracing provide with 2 inch angles cross connected to four legs. The feed hopper of rectangular shape tapered at base providing slope of 45° is fitted above scalping screen. Hopper gate is provided to change the feed rate and smooth and uninterrupted flow of material. Screen cradle (780 mm × 520 mm) was suspended by four bearings with adjustable flat mechanism connected to the frame to give mechanical strength and oscillating motion to screen cradle and screen unit. The adjustable mechanism was provided to change slope of whole screen cradle assembly and slope adjustment mechanism for each screen (Fig 1).

Power transmission and drive: The driving system consisted of belt, pulley, camshaft and DC motor, which were used for driving the cleaning unit. The DC motor has voltage, power, current and rpm of 24 V, 0.25 kW, 10.4 A, 3000 rpm. Speed regulator was used to vary the speed of motor. The setup consisted of a solar photovoltaic panel, dc motor and a screen cleaner. Three solar panels were connected in parallel to provide power of 250 W.

Performance evaluation of modified prototype: A known mass (5 kg) of each variety were mixed with known mass of impurities. The impurities used were chaff, immature seeds, broken seeds, weed seed, other crop seed and stone particles. Six screens of round hole of diameter 10 mm, 8 mm, 6 mm, 5 mm, 4 mm and one slot opening of 2.1 mm were selected. To determine cleaning efficiencies, products from clean seed and impurities discharge chute were separately collected. The weight of each raw seed fed into screen cleaner was taken. The machine was operated under normal working condition keeping constant feed rate.

The following variables were selected for carrying out the performance analysis

Variables	Levels
Feed rate, kg/h	100, 150 and 200
Speed, rpm	100, 200 and 300
Screen slope, °	0, 3, 5 and 8
Performance indicators	Cleaning efficiency (%)

Cleaning efficiency: The different fractions of grains were collected. The collected fractions were weighed and recorded. Cleaning efficiency was calculated by using the formula suggested by bureau of Indian standard (BIS) (IS 5187:1980)



Fig 1 Modified unit of solar powered screen cleaner.

$$\text{Cleaning of efficiency (\%)} = \frac{F(F - G)(E - F)(I - G)}{F(E - G)^2(I - F)}$$

where, E, Fraction of clean grain at clean seed outlet; F, Fraction of clean grain in feed; G, Fraction of clean grain at foreign matter outlet.

Statistical analysis: Three-factor completely randomized design was followed to determine the effect of feed rate, screen tilt angle and screen oscillation on the depended parameter. Analysis of variance was performed using SAS Version 9.3.

RESULTS AND DISCUSSION

Solar powered multicrop screen cleaner was tested for its performance at 3 feed rates, 4 slopes and 3 speed. Tests were carried out to determine the operational parameters and performances and analysed by using ANOVA.

Effect of feed rate on cleaning efficiency: Cleaning efficiency of three types of grains (soybean, chickpea and lentil) were studied under three levels of feed rate (100, 150 and 200 kg/h) (Fig 2). For soybean grain the average cleaning efficiency at 100, 150 and 200 kg/h feed rates were 69.72%, 71.21%, and 69.64% respectively. Similarly, for chickpea the average cleaning efficiency observed were 68.51, 70.34 and 66.99% at three feed rates respectively. For lentil seeds average cleaning efficiency were 66.41%, 69.13% and 64.93 % at three feed rates respectively. Similar influence of feed rate was reported for cumin cleaner (Jethva and Varshney 2016) and beniseed (Akinoso *et al.* 2010). It is clear (Fig 2) that as the feed rate increases from 100 to 150 kg/h the cleaning efficiency also increases and decreases with further increase in feed rates, i.e. 200 kg/h. Segregation and separation take place along the entire width and length of screen and divided into increasing, peak and decreasing sections as mixture of grain and other impurities transported over screen. Increase in feed rate decreases the cleaning efficiency and higher separation loss could be due to the thick layer of grain and chaff matting and longer travel path,

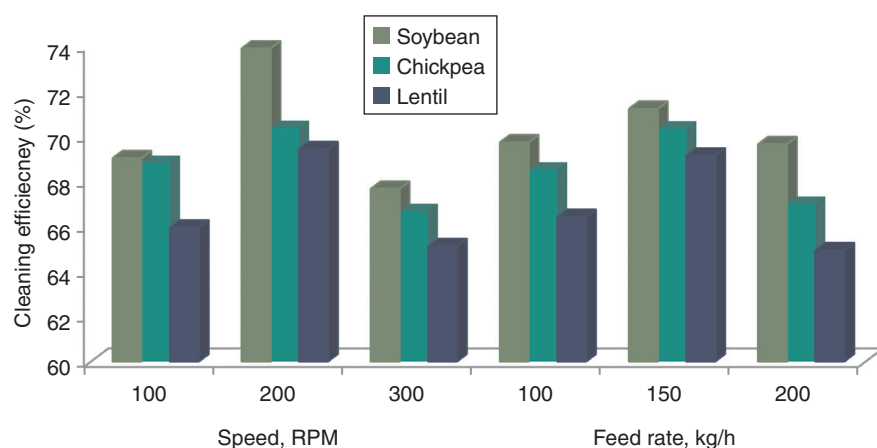


Fig 2 Effect of speed and feed rate on cleaning efficiency.

which constrained the penetration of grain through screen. Results observed in this study shows similar pattern with observation of Hanna and El Ashmawy (2010) and Jethva and Varshney (2016).

Effect of speed on cleaning efficiency: Cleaning efficiency of three types of grains (soybean, chickpea and lentil) were studied under three levels of speed (100, 200 and 300 rpm) (Fig 2). For soybean average cleaning efficiency were 69.02%, 73.89%, 67.66 at 100, 200 and 300 rpm respectively. Similarly, average cleaning efficiency for chickpea (68.81%, 70.36%, and 66.67%) and lentil (65.94%, 69.42%, and 65.11%) were observed at 100, 200 and 300 rpm respectively. The average maximum cleaning efficiency for soybean, chickpea and lentil was 73.89%, 70.36%, 69.42% found at 200 rpm, whereas the minimum cleaning efficiency 67.66%, 66.67%, and 65.11% at 100 rpm (Fig 2). The Maximum cleaning efficiency for soybean, chickpea and lentil were 75.33%, 72.67%, 71.97% found at 150 kg/h feed rate and 200 rpm and minimum cleaning efficiency was 66.22%, 65.35%, 63.43% found at 200 kg/h and 300 rpm. The lower cleaning efficiency at higher speed may be due to the reason that seeds are not getting sufficient time on the screen and also seeds may be overflowing over the screens and not passing through the holes of the screen. Higher speed leads to faster movement of grains over the screen and act as conveyor rather than separation. Analysis of variance shows that the feed rate and speed have significant effect

on cleaning efficiency at 5% level of significance. The interactions among the variables are non-significant at same level of significance (Table 1).

Effect of screen slope on cleaning efficiency: Cleaning efficiency of three types of seeds (soybean, chickpea and lentil) were studied under four levels of screen slope (0, 3, 5 and 8°) (Fig 3). The mean values of cleaning efficiency for soybean, chickpea and lentil at 0, 3, 5 and 8° were 68.54%, 71.05%, 73.21% and 70.39% respectively. It is clear from the Fig 3 that, as the slope increases the cleaning efficiency increases but

decrease as screen slope reaches to 8°. Similar influence was reported for cumin cleaner (Jethva and Varshney 2016). The maximum cleaning efficiency for soybean, chickpea and lentil were 75.12%, 74.67%, and 70.97% found at 5° screen slope and 150 kg/h feed rate and the minimum cleaning efficiency 67.21%, 66.22%, 62.74% at 0-degree screen slope and 200 kg/h feed rate. The cleaning efficiency at higher slope due to seeds were easily slide over the screen and give chances to every seed pass through screen holes giving better cleaning efficiency but at 8° screen slope bulk seeds are slide fast and move towards outlet without giving chances to seed.

Plugging effect was observed at low slopes, which resulted in straw and immature seeds in main seeds. The individual effect and interaction among feed rate and slope was found to be significant at 1% or 5 % level of significance. The slope is most effective parameter, which influence the cleaning efficiency (Table 1). The combined effect of various speed and screen slope for soybean, chickpea and lentil were studied. The average cleaning efficiency for soybean were observed 65.87%, 72.99%, 77.22%, and 72.72% at 0, 3, 5 and 8° respectively. Similarly, for chickpea (64.88%, 69.11%, 75.39%, and 71.10%) and lentil (60.77%, 66.74%, 73.05%, and 69.88%) average cleaning efficiency was observed at 0, 3, 5 and 8°. Similar influences were reported by Hanna and El Ashmawy (2010) and Jethva and Varshney (2016). Maximum cleaning efficiency was for soybean, chickpea and lentil were observed 79.12%, 77.67%, and 74.97% at 5° screen slope and 200 rpm speed. The individual effect and interaction among speed and slope was found to be significant at 1% or 5 % level of significance. The combined effect of screen slope, speed and feed rate was found to be highly significant for cleaning efficiency (Table 1).

Cost economics: The total cost of machine was ₹47100 and its estimated cost of operation ₹0.269/kg. This cost of operation is much lower than cost of manual and electricity operated cleaning ₹12.73 and 0.31/kg (Jethva and Varshney 2016), respectively, which saves up to 98.2 % operational cost as compared to manual cleaning. The solar powered screen cleaner had a breakeven point at 393.33 h/yr with a payback period of 2.48 years.

Table 1 ANOVA of feed rate, speed and screen slope on cleaning efficiency

Source of variation	F-ratio
Feed rate (F)	180.788**
Speed (N)	156.517**
Screen slope (S)	191.092**
F × N	NS
F × S	61.341**
N × S	71.055**
F × N × S	74.786**

*Significant at 5 % level

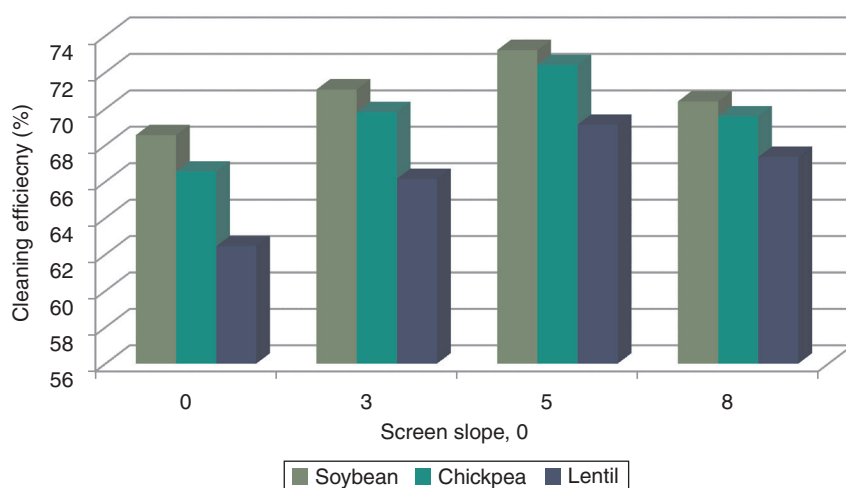


Fig 3 Effect of screen slope on cleaning efficiency.

Solar powered multi-crop cleaner was modified and tested. Feed rate, speed and screen slope affected the cleaning efficiency and shows significant difference on the performance parameters. The optimized operating parameters were 150 kg/h feed rate, 200 rpm and 5° screen slope. Under these conditions cleaning efficiency for soybean, chickpea and lentil were observed 79.12%, 77.67%, and 74.97% respectively. Multi-grain processibility, higher cleaning efficiency, lower losses and solar energy consumption makes this machine techno appropriate solution to farmer's field. This machine assures good quality seed and grains at affordable energy cost to small and marginal farmers in rural India. Solar powered cleaner has a tremendous potential to minimize post-harvest losses in rural areas.

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