Evaluation of Solar Photovoltaic (SPV) Operated Paddy Winnower

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Abstract

The paddy winnowing is the major time consuming post-harvest operation which required large man-power and depend on natural wind velocity when carried out manually. It required uninterrupted and costly power supply when carried out using electrical winnowers. The Solar photovoltaic (SPV) powered paddy winnower was developed and evaluated to overcome the above problems in the field. The power characteristic of the solar photovoltaic panel used for the winnower was evaluated. The SPV operated winnower was evaluated for no load and load conditions as the standard testing procedures. It was observed that, newly developed portable solar photovoltaic (SPV) operated paddy winnower is technoeconomicaly suitable for the winnowing of paddy at the feed rate of 120 kg h^{-1}. The overall output capacity at 30 cm distance was found to be maximum (119.77 kg h^{-1}), as compared to output capacity at 20 cm (119.30 kg h^{-1}) and 10 cm (118.74 kg h^{-1}) respectively. The weighted average cleaning efficiency at 30 cm distance (93.00%) was found to be maximum as compared to cleaning efficiency at 20 cm (89.13%) and 10 cm (62.24 %), respectively. The average cleaning efficiency of SPV operated paddy winnower is more than 90% with low operating cost of 0.25 Rs kg^{-1}. The developed SPV operated paddy winnower provided the solution for on farm paddy winnowing without dependency on natural wind velocity and secure electricity supply.

Keywords: Solar photovoltaic, cleaning efficiency, output capacity, energy consumption.

Introduction

India is one of the world's largest producers of paddy after China, accounting 20% world's production. India has the largest area under rice (42.95 million ha) and with the production of about 108.32 million tonnes, it ranks second only to china with the productivity of about 2424 kg ha^{-1} during the year 2016-17. Maharashtra has 1.60 million ha land under rice cultivation with rice production of about 3.31 million tons and productivity is 1970 kg ha^{-1} during the year 2016-17. In Konkan region, it is grown on 0.50 million ha with the production of 1.14 million tones and productivity is 2768 kg ha^{-1} (Anonymous 2016).

The harvesting of paddy is usually carried at quite high moisture content (25%) to avoid loss of grains during harvesting. After harvesting, the crop is allowed to dry in the field and then tied in small bundles and carried to threshing yard (Anonymous 2015).

Winnowing is the process of separating grain from a mixture of grain and chaff in an air stream created artificially or naturally. Separation is achieved by allowing the air stream to pass through the mixture falling vertically down. The grain being heavier material gets deposited almost at the place of dropping, whereas lighter material (chaff) is blown away to a greater distance. The winnowing operation which is very common in India is done on threshing floor where all harvested crops are stacked in bundles.

Traditionally, winnowing is carried out to separate straw or bhusa from the paddy by creating air draft or natural wind by dropping the grain from pan or scoop from a certain height in a blowing wind. This is very simple and effective method, but output is very low, i.e., 40-45 kg h^{-1} (Singh and Gite 2007). There are problem in traditional winnower and hand operated winnower like low output capacity, cleaning efficiency is less also labours get tiered within short period of time. Considering all these limitations, the solar photovolitaic (SPV) operated paddy winnower was developed and evaluated at Department of Electrical and Other Energy Sources, CAET, DBSKKV, Dapoli.

Materials and Methods

An attempt has been made to develop and evaluate the solar photovoltaic (SPV) operated paddy winnower to provide the on-farm source of power for cleaning of threshed paddy as well as to reduce the drudgery of la-

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bour.

The physical properties, namely terminal velocity (Ayman 2009), angle of repose and bulk density (Varnmakasti *et al*. 2007) were determined using standard test procedures before the development of SPV operated paddy winnower.

Development of SPV operated paddy winnower

A solar photovoltaic operated paddy winnower consist of different components viz; photovoltaic panel, motor, centrifugal blower, hopper, stand etc.The technical specification of SPV operated paddy winnower is depicted in Table 1. The cost of developed SPV operated paddy winnower as per the prevailing rate was found to be ₹ 8320.00. The isometric and pictorial views of SPV operated paddy winnower is shown in Figure1 and Figure 2.

Evaluation of SPV operated paddy winnower

The performance evaluation of developed SPV operated paddy winnower was carried out through laboratory and field evaluation.

Laboratory Testing

Table 1. Technical specifications of SPV operated Paddy winnower

Sr. No.	Component	Specification	Material used
1.	Solar Photovoltaic Panel	Power : 37 W, Voltage : 12 V Size: 83cm x 45cm	-
2.	D.C. Motor	Power :18 W, Voltage :12 volt	-
3.	Centrifugal Blower	RPM : 2800	Mild steel
4.	Hopper	Capacity: 10 kg, Size = 40 x 40 x 20 cm	G. I. Sheet
5.	Speed regulator	12 v	-
6.	Castor wheel	4 No.	-
7.	Switch	1 No. on/off	-
8.	Frame	Height : 100 cm Breath : 70 cm Width: 40cm	Mild Steel

The laboratory testing of SPV operated paddy winnower was conducted to test power characteristics of the solar photovoltaic panel and no load performance of developed SPV operated paddy winnower.

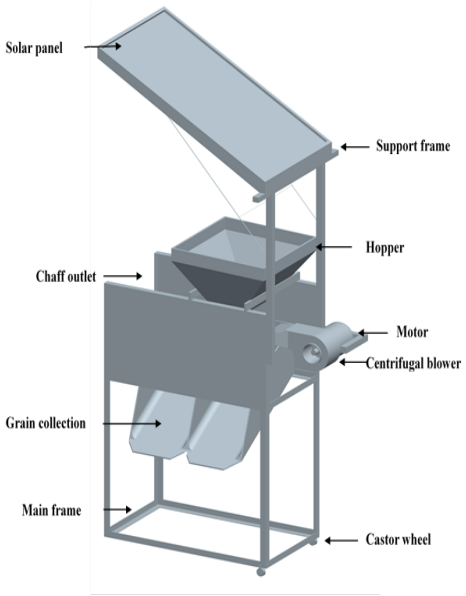

Figure 1. Schematic view of Solar photovoltaic operated paddy winnower

Figure 2. Pictorial view of Solar photovoltaic operated paddy winnower

The selected 37 watt solar photovoltaic panel was tested for I-V characteristics. As per standard procedure, solar panel was tested under clear skies, within two hours of solar noon (Gilbert 2004). The the solar panel was tested from 8:00 to 18:00 h. The parameters were measured are Short circuit current (Isc), Open circuit voltage (Voc), Current at maximum power (Im), Voltage at maximum power (Vm), Maximum power point (Pm), Solar intensity.

The developed solar photovoltaic system for paddy winnower was tested from 8:00 to 18:00 h. The output of centrifugal blower in terms of RPM and air velocity was recorded with corresponding solar intensity during winter season. The parameters were measured are solar intensity, wind velocity, RPM of blower, Voltage, Current, Ambient temp, Air velocity at 10, 20, 30 cm distance from the blower.

Field Testing of SPV operated paddy winnower

The field testing of SPV operated paddy winnower was conducted at Department of Agronomy, DBSKKV, Dapoli. The different operating parameters were recorded as per RNAM test code for field testing of winnower. The results obtained are described on the basis of cleaning efficiency and output capacity.

The SPV operated paddy winnower was evaluated using following test parameters.

Name of crop: Paddy
Operating time: 15 min

Variety of crop: Ratnagiri-1

Moisture content: 12.87%

Grain ratio: 0.89

Grain input: 30 kg

Results and Discussion

The Physical properties of paddy i.e, terminal velocity (tv), angle of repose (ar) and bulk density (bd) were determined for six varieties of paddy and a straw. The result obtained are summarised in Table 2.

It was observed that, terminal velocity and angle repose for Ratnagiri-1 variety was found to be 9.56 m s^{-1} and 33.22º, respectively. The terminal velocity of straw was found to be 2.26 m s^{-1} whereas the average bulk density of Ratnagiri-1 variety was 172.2 kg m^{-3}. Ratnagiri-1 variety was selected for the further study.

I-V and power characteristics of SPV panel

The I-V and power characteristics of the selected 37 watt solar panel were carried out at normal condition on a clear sunny day to determine the maximum current, maximum voltage and maximum power developed by solar panel. The typical I-V characteristic's and power curve of solar panel is shown in Figure 3 and Figure 4, respectively.

It was observed that, the solar intensity was varied from 88 W m^{-2} to 478 W m^{-2}. The peak value of solar intensity was achieved at 13:00 h (478 W m^{-2}). Also the power developed by selected 37 Watt solar panel varies from 29.7 Watt to 35.1 Watt. The peak value of power was achieved at 13:00 h (35.1 Watt). It was revealed that, the power generated by the selected solar panel was suitable to operate the selected DC motor coupled with a blower of paddy winnower.

No load performance of developed SPV operated paddy winnower

The effect of time of day on solar intensity and the RPM of the blower was studied to determine the change in RPM of blower changed with time and solar intensity. The variation of the RPM of blower with respect to time and solar intensity is shown in Figure 5.

It was observed that the solar intensity directly affects the RPM of the blower. The maximum solar intensity (483.5 W m^{-2}) was achieved at 13:00 h of the day. The

Table 2. Average of Physical properties of paddy and straw

Sr. No.	Property	Variety of paddy						Straw
		Sahydri-4	Ratnagiri 1	Sahydri-2	Ratnagiri 73-1	Ratnagiri-4	Palghar-1	
1.	Terminal velocity, m s^{-1}	9.15	9.56	7.49	8.26	7.41	7.14	2.26
2.	Angle of repose,º	32.73	33.22	29.88	27.08	30.20	31.27	-
3.	Bulk density, kg m^{-3}				172.2			

maximum RPM of blower (2824.5) was achieved at maximum solar intensity. The RPM of blower varied from 2095.5 to 2824.5 with respect to time and solar intensity. The RPM of blower increased with the increase in solar intensity due to production of higher voltage and current through the solar panel. The suitable time of operation for SPV operated paddy winnower was found 9:00 to 15:00 hrs with RPM of blower more than 2240 which is 80% of rated RPM of blower (i.e. 2800 RPM). It was revealed that, the suitable operating period of SPV operated paddy winnower was 9:00 to 15:00 hrs with available solar intensity.

The effects of time of day and solar intensity on air velocity were studied to determine operating span, within which, air velocity required for winnowing was created. The air velocity of blower changed with time and solar intensity. The variation of air velocity with respect to time and solar intensity is shown in Figure 6.

It was observed that, the solar intensity goes on increasing up to 13:00 and gradually decrease after it. The maximum solar intensity was observed at 13:00 h (483.5 W m^{-2}). Air velocity varied with respect to time and solar intensity. To achieve proper winnowing operation the air velocity must be greater than the terminal velocity of straw (i.e. 2.26 m s^{-1}) and less than terminal velocity of paddy i.e. Ratnagri-1 variety (9.56 m s^{-1}).It was observed that, the air velocity at a distance 10 cm from the outlet of blower ranged from 6.2 m s^{-1} to 8.8 m s^{-1}. Similarly, air velocity at 20 cm distance from the outlet of blower ranged from 5.4 m s^{-1} to 7.3 m s^{-1} and for 30 cm values ranged from 3.8 m s^{-1} to 5.3 m s^{-1}. As the distance increases the air velocity decreases.

It was revealed that, air velocity, which is required for winnowing operation was obtained throughout the day i.e. from 8:00 to 17:00 hrs. To increase the life of blower, it is better to operate the winnower at 80% of rated rpm (2240). The suitable operating period of SPV operated paddy winnower was 9:00 to 15:00 hrs with available solar intensity as it developed rpm more than 2240 (i.e. 80% of rated RPM).

Field Performance of SPV operated paddy winnower

The comparative cleaning efficiency of SPV operated paddy winnower at different distance from blower with respect to time and solar intensity were studied. The variation of cleaning efficiency at outlet 1 and outlet 2 is shown in Figure 7 and Figure 8 respectively.

It was observed that the cleaning efficiency of SPV paddy winnower at outlet-1 varied from 94.55% to 96.99%

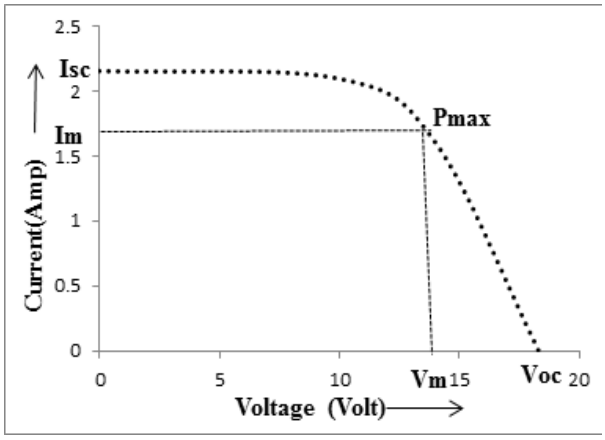

Figure 3. I-V characteristics of solar panel at NTC

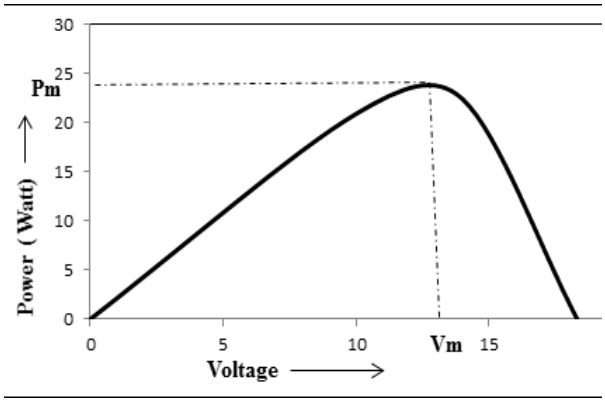

Figure 4. P-V characteristics of solar panel at NTC

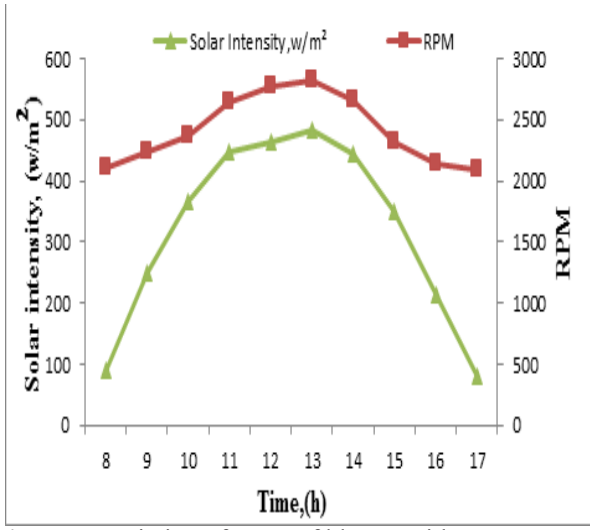

Figure 5. Variation of RPM of blower with respect to time and solar intensity

for 10 cm distance from the blower whereas for 20 cm distance from blower it varied from 86.45% to 89.51% and for 30 cm distance it varied from 95.4% to 98.40%. The solar intensity varied from 130 W m^{-2} to 438.50 W m^{-2}. Similarly, at outlet-2, the cleaning efficiency at a distance of 10 cm, 20 cm and 30 cm from the blower ranged between 13.31% to 45.14%, 89.25% to 91.31% and 89.04% to 89.19%, respectively.

It was revealed that cleaning efficiency at outlet-2 at a distance 10 cm was very low as compared to other distance may be due to higher output capacity at outlet-1 and most of the straw was collected in outlet-2 during operation.

The comparative output capacity of SPV operated paddy winnower at different distance from blower with respect to time and solar intensity were studied. The variation of output capacity at outlet-1 and outlet-2 is shown in Figure 9 and Figure10 respectively.

It was observed that, the output capacity at a distance 10 cm from blower for outlet-1varied from 107.56 kg h^{-1} to 109.06 kg h^{-1} as compared to 39.79 kg h^{-1} to 46.12 kg h^{-1} at 20 cm and 0.8 kg h^{-1} to 1.49 kg h^{-1} at 30 cm distance from blower respectively. Similarly, at outlet-2, the output capacity at a distance of 10 cm, 20 cm and 30 cm from blower ranged from 9.54 kg h^{-1} to 11.32 kg h^{-1}, 72.95 kg h^{-1} to 79.75 kg h^{-1} and 118.24 kg h^{-1} to 119.03 kg h^{-1}.

It was revealed that the highest output capacity was observed for 30 cm distance from blower for outlet-2 because feed was dropped directly above the outlet-2. The lowest output capacity was observed at 10 cm distance because the only straw was collected at outlet-2.

The results of SPV operated paddy winnower at different distances from the blower in term of cleaning efficiency and output capacity are summarised in Table 3.

It was revealed that, the output capacity of SPV operated paddy winnower obtained at 30 cm distance from blower was maximum at oulet-2 however, the cleaning efficiency was less. The maximum cleaning efficiency of paddy winnowing was obtained at outlet-1 when feed was dropped at 30 cm distance from blower. However, the output capacity is very low at same condition. Based on comparative field performance it was recommended to operate the newly developed SPV operated paddy winnower at a distance 30 cm from blower to obtain the better cleaning efficiency (93.00%) and output capacity (119.78 kg h^{-1}).

It was observed that, the operating cost of SPV operated

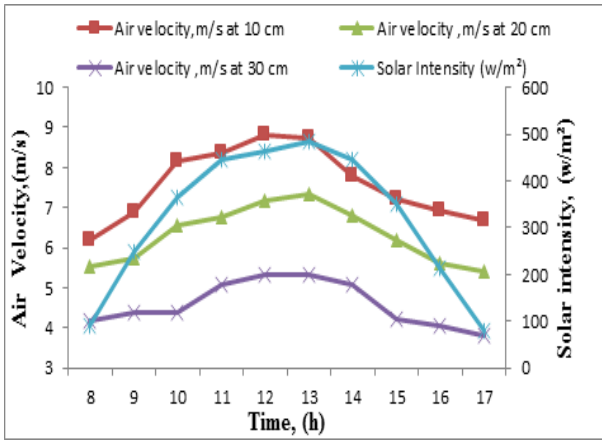

Figure 6. Variation of air velocity with respect to time and solar intensity.

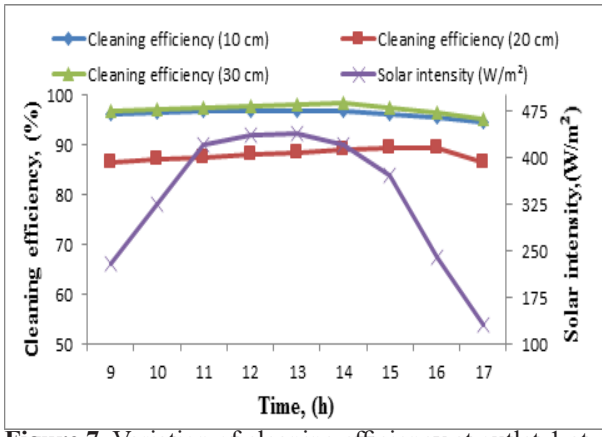

Figure 7. Variation of cleaning efficiency at outlet-1 at different distances from blower.

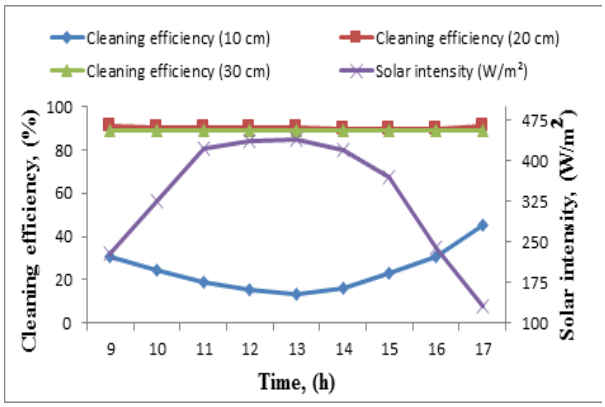

Figure 8. Variation of cleaning efficiency at outlet-2 at different distances.

paddy winnower was found to be 0.25 ₹ kg^{-1} for the feed rate 120 kg h^{-1} which is less than power operated paddy winnower 0.30 ₹ kg^{-1} (Kadam 2013), power operated fan 0.58 ₹ kg^{-1} (Anonymous 2014), manual operated fan 0.82 ₹ kg^{-1} (Anonymous 2014), manual winnowing operation 1.5 ₹ kg^{-1}. Thus the performance of SPV operated paddy winnower (for feed rate 120 kg h^{-1}) is economically feasible than other winnowing operation.

Conclusions

The newly developed portable solar photovoltaic operated paddy winnower is technoeconomicaly suitable for the winnowing of paddy at feed rate of 120 kg h^{-1}.

The average cleaning efficiency of paddy winnowing is more than 93% and low operating cost of 0.25 ₹ kg^{-1}.

The developed SPV operated paddy winnower provided the solution for on farm paddy winnowing without dependency on natural wind velocity and secure electric supply.

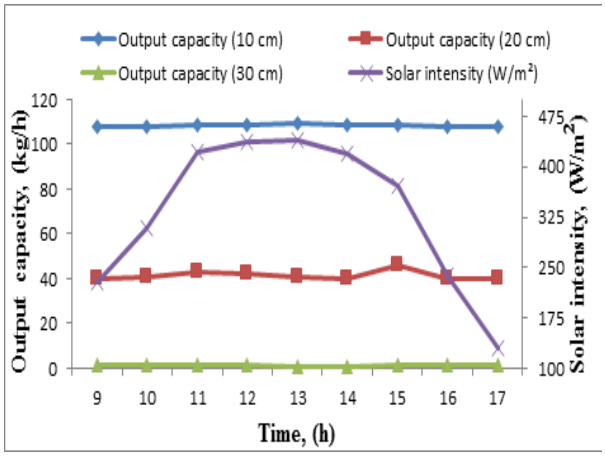

Figure 9. Variation of output capacity at outlet-1at different distances from blower

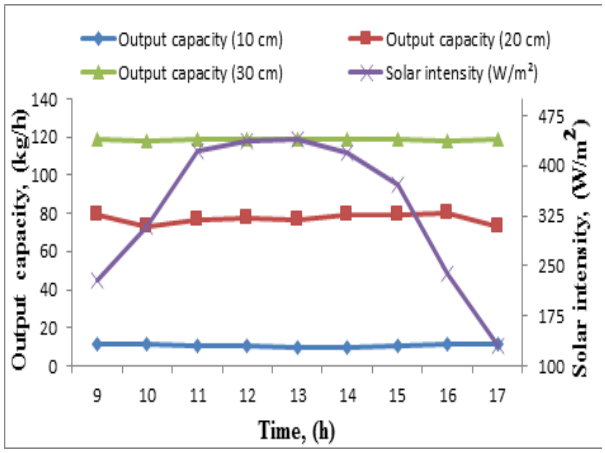

Figure 10. Variation of output capacity at outlet-2 at different distances from blower

Table 3. Summarized results of SPV operated paddy winnower

Particulars	Outlet-1			Outlet-2		
	10 cm	20 cm	30 cm	10 cm	20 cm	30 cm
Average Cleaning efficiency (%)	95.77	87.98	96.9	28.72	90.28	89.11
Average output Capacity (kg h^{-1})	108.31	42.95	1.145	10.43	76.35	118.63

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Received 22 June 2017; revised accepted 19 July 2017