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Performance Evaluation of a Mobile Solar Powered Maize Dehusker Cum Sheller

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Abstract

Maize (*Zea mays*) is grown throughout the year in India. Maize is one of the most widely cultivated crop grows in both tropical and warm temperate latitudes. Maize in India ranks third in total production and productivity and fifth in total area. Solar power is ideally used in India due to location factor and also gives the benefit to the environment as renewable energy. In present study, the small sized DC motor (0.5 hp) operated mobile maize dehusker cum sheller was developed for selected operational parameters, *viz*. moisture content (11.23, 13.07, 15.36%), feed rate (20, 40, 60 kg h^{-1}) and rotational speed (415,460,510 rpm). The machine performance parameters resulted that, the maximum dehusking (98.79%) and shelling (96.84%) was found to be at 20 kg h^{-1} feed rate, 510 rpm and 11.23% moisture content. The total losses of grains were found to be maximum (7.08%) while it was minimum (4.31%) on 11.23% of moisture content, 510 rpm of rotational speed & 40 kg h^{-1} of feed rate. The maximum output capacity (36.14 kg h^{-1}) was obtained for 60 kg h^{-1} feed rate. The total production cost of the mobile maize dehusker cum sheller was found to be Rs. 1, 78,000 and the operating cost per hour as 169.22 Rs h^{-1}.

Keywords: Renewable energy, mobile unit, maize, Dehusking, shelling

1. Introduction

The agricultural production system is the main source of livelihood for one third of population of an India. The dependency for food and fodder supplementing with main crops of cultivation rather than selling commercial crop produce for capital generation (Chaudhary *et al*. 2017) [5]. In rural areas according to the study of directorate of Maize Research, livestock production is contributing 7% to National GDP and a source of occupation and ultimate livelihood for 70% of the population. In India maize is grown in all the seasons and it is cultivated in all states of the country for various purposes. In addition, the climate change presents a major risk to long term food security as it may decline wheat and maize yields by 5 to 10% by 2050 (Anonymous 2016) [3]. In farming. Maize is called as “Queen of cereals” and “King of fodder” due to its highly importance in human and animal food. In farming, mechanization in harvesting and threshing is below 20% (Singh 2010) [18]. Traditionally, dehusking and shelling of maize are carried out by manually which involves a lot of drudgery (Mudgal *et al*. 1998, Singh 2010 [18], Naveenkumar 2011, Anonymous 2012) [2, 11]. The output of manual separation reported to be 30 kg h^{-1} with shelling efficiency of 80-100% and grain damage of 0 to 8.3% (Mudgal *et al*. 1998, Anonymous 2005) [1, 11]. The capacity of manually operated shellers is in between 27 to 150 kg h^{-1} which is fit for marginal farmers, whereas 1000 to 1800 kg h^{-1} capacity is suitable for engine operated and more than 2000 kg h^{-1} is for tractor operated machine are fit for large farmers.

It is predicted that India has source of solar power of 750 GW considering 3% of waste is land is available. Considering all the facets of energy in mind we cannot totally replace non-renewable sources of energy by renewable sources but we can use renewable sources for sustainable development and eco- friendly environment. There are several motor or engine and tractor operated maize dehusker shelling machines for dehusking and shelling purpose. Keeping the above factors in view, present study was under taken to survey the different threshing/shelling methods used for maize by farmers and different power operated maize dehusker cum shellers were evaluated for suitability in terms of social economic conditions that are prevailing. In this context present research study to complete the need of small sized farms the solar powered mobile maize dehusker cum sheller was developed, since 80.3% of farmers are marginal and small group cultivating 36% of the area (Naveenkumar 2011) [12] in the country. Hence, the objective has been taken for developing maize dehusker cum sheller with no concession in its performance to reach the prevailing maize dehusking cum/and shelling equipment (Sarma 2007, Singh and Singh 2010, Singh *et al*. 2011, Vyavahare and Kallurkar 2015) [17, 18-19, 24] with minimum damage to maize seeds and energy savings.

2. Materials and Methods

2.1 Raw material

The physical properties of maize variety of Odisha Maize Hybrid (OMH 14-27) were studied and considered in design of maize dehusker cum sheller (Mohsenin 1970, Jayan and Kumar 2004, El-Fawal *et al*. 2009, Coskun *et al*. 2006) [10, 9, 7, 4]. For the study 100 randomly picked cobs and 100 maize grains were selected from a selected variety of maize. The performance evaluation of developed mobile solar powered maize dehusker cum sheller was carried out (with OMH 14-27 maize variety) in CAET, Bhubaneswar (20.2961° N, 85.8245° E).

2.2 Development of mobile unit:

The designed and developed mobile unit has named as OMSPAM (OUAT Multipurpose Solar Powered Agri Machinery) as shown in fig.1. It was designed and developed by department of Farm Machinery and Power, CAET, OUAT, Bhubaneswar. This machine was developed in order to flourish farm machinery to the root level of farmers. Its price is also minimum so that a maximum farmers can also afford it. The developed OMSPAM is multipurpose mobile unit. Multipurpose means it can be used for different purposes, now mobile unit is using for maize dehusker cum sheller machine but in future it is also will be used for pulses threshing, millet threshing, paddy threshing, groundnut decorticator, juice maker machine and water pumping purposes. In a mobile unit machine is fitted at one side (rear side) of unit. Person will stand outside the unit and it will operate a machine. Only one person is required for operating a unit and machine so its saves labour cost. Two solar panels are fitted on a roof top of machine and manual tracking is also possible. One solar panel is fixed and other is moved by manually for getting of more solar radiations. Batteries and controller are situated inside a unit. Inside a unit seat, fan, light, mobile charging plug is also provided for operators comfort. It is a self-propelled mobile unit which can be moved to the field for use on site resulting reduction on transportation cost. Batteries are dual charged means it can be charged by solar energy also by electrical energy hence we can use this mobile unit any time. It uses renewable source of energy and saves a cost on fuel, electrical energy.

2.3 Development of maize dehusker cum sheller

Principles of machine working: Axial flow system was adopted in the present design by giving a two helical louverers (at the feeding side) on a middle shaft to pass dehusked maize cobs easily to the outlet side for shelling purpose. This feature with the axial flow threshing system helps in getting more retention time for undehusked cobs during continuous feeding. On a half-length of machine dehusking is done and other half part of machine is used for shelling purpose. Dehusking is done with the help of nitrile rubbers which was placed in zig-zag manner on two side shafts of a middle shaft. The dehusking is done by shearing and tearing force which is created in between cuts given on a rubbers and cobs. For the shelling of maize, arrangement is given inside a top cover. A section of top cover after dehusking part consist a half circular section (500 mm length) with a taper, consists of 9 number of cuts on both side of a section which helps in removing of a grains from cobs. The size of cut is 25 mm wide, 25 mm depth and spacing between the cut is 25 mm. In order to enhance the easy flow of the plant mass and create more abrasion, the top cover was made in hexagonal shape of MS sheet (1060mm length × 300 mm width × 200mm height) with feeding chute (trapezoidal shaped) to feed cobs by gravity flow. The overall dimensions (length × width × height) of developed machine were 1250 × 720 × 800 mm. There are three outlets were given *viz*. husk outlet, grain outlet, cob outlet. Husk was removed from the husk outlet.

It is evident from the literature that, power requirement increases with the increase in the Feed Rate (F) and rotational speed (S) (Olaoye 2002, Tastra 2009, Sachin 2008, Tiwari *et al*. 2010) [14, 21, 15, 22]. Since, the design of maize dehusker cum sheller was carried out suitable (for marginal) for the F of 20 to 60 kg h-1, 0.5 hp DC motor was selected as prime mover.

2.4 Performance evaluation of developed machine

Performance evaluation of developed maize dehusker cum sheller was carried out in accordance with procedure and guidelines prescribed by the Indian Standard Test Code IS: 7051-1973 and IS: 6284-1985 for cereals. The experiments at load condition were conducted at different levels of independent parameters and dependent parameters as shows in Table 1. The performance evaluation of maize dehusker cum sheller was carried out one hour duration at specified rotational speeds, moisture content and feed rates. During the evaluation, a sample was collected from main grain outlet, cob and husk outlet for further analysis. The view of the evaluation setup of maize dehusker cum sheller is shown in fig 2.

Fig 1: OMSPAM (OUAT Multipurpose Solar Powered Agri Machinery)

Fig 2: Performance evaluation of mobile solar powered maize dehusker cum sheller

Fig 3: Solar Irradiance meter

Fig 4: Measurement of solar radiations

2.4.1 Total grain input per unit time

The total grain input per unit time were calculated by summing the weight of clean grain, broken grain and unthreshed grain from all outlets per unit time. This was calculated by following formula.

A = B + C + D (1)

Where,
A = Total grain input per unit time, kg
B = weight of clean grain from all outlets per unit time, kg
C = weight of broken grain from all outlets per unit time, kg
D = weight of unthreshed grain from all outlets per unit time, kg

2.4.2 Dehusking efficiency

The dehusking efficiency was found by ratio of the number of dehusked cobs in test run to the total number of cobs used in test run.

$$\text{Dehusking efficiency} = \left(1 - \frac{G}{H}\right) \times 100\% \quad (2)$$

Where,
G = Number of un-dehusked cobs
H = Total number of cobs to be used

2.4.3 Shelling efficiency

The shelling efficiency is was found by the ratio of threshed grains collected in all the outlets per unit time to the total grain input per unit time. (IS: 6284-1985). This was calculated by using the following formula.

Shelling efficiency =(100 -% unthreshed grain),% (3)

Where,

$$\%\ \text{Unthreshed grain} = \left(\frac{H}{A}\right) \times 100 \quad (4)$$

Where,
H = weight of unthreshed grain per unit time obtained from all outlets, kg

2.4.4 Total losses

Total losses (T) were the sum of the percentage of broken grain, percent of unthreshed grains. This was expressed in terms of percentage.

T,% = Broken grain,% + Unthreshed grain,% (5)

The broken grain percentage is the ratio of the quantity of broken grain from all outlets per unit time to the total grain input per unit time. (IS: 6284-1985)

$$\text{Broken grain} = \left(\frac{E}{A}\right) \times 100,\% \quad (6)$$

Where,
E = quantity of broken grain from all outlets per unit time, kg
A = total grain input per unit time, kg

2.4.5 Output capacity

The output capacity was determined by weighing the total grain (whole and damaged) received per hour at main grain output of the thresher (IS: 6284 – 1985).

$$\text{Output capacity (kg h-1)} = \frac{\text{Weight of grain threshed,kg}}{\text{tame taken,h}} \quad (7)$$

To study the effect of different operational parameters on performance parameters, a 3 × 3 × 3 asymmetric factorial completely randomized design was considered and given in Table 1.

Table 1: Operational parameters studied for developed machine at load condition

Independent variables	Levels	Description	value	Dependent variables
Rotational speed (S), rpm	3	S1	415	Dehusking efficiency,% Shelling efficiency,% Total losses,% Output capacity, kg/h
		S2	460	
		S3	510	
Feed rate (F), kg/h	3	F1	20	
		F2	40	
		F3	60	
Moisture content (M),%	3	M1	11.23	
		M2	13.07	
		M3	15.36	

3. Result and Discussion

3.1 Performance evaluation of mobile unit

The various tests for the performance evaluation of the OMSPAM vehicle were conducted. The different tests performed were as follows:-

3.1.1 Measurement of solar radiations

The solar radiations and panel temperatures were measured by using an instrument as shown in fig 3. From changing the orientation of solar panel and by measuring of solar radiations incident on a solar photovoltaic panels concluded that when front wheel of OMSPAM vehicle remains towards the sun position then both the solar panels were getting the maximum and nearly same radiations. Measurement of solar radiation and panel temperature with instrument is shown in fig. 4. Average values of measured solar radiations, module temperature, and ambient temperature were given in following Table 2. Solar radiations are found to be maximum at 12 noon. The solar radiations were increasing from morning 9 A.M. to upto 12 noon and after that radiations are decreasing.

Table 2: Measurement of solar radiations

Time, h	Average values					
	Module temperature, °c		Ambient temperature, °c		Solar irradiations, wm^{-2}	
	Left side (English side) solar panel	Right side (Odia side) solar panel	Left side (English side) solar panel	Right side (Odia side) solar panel	Left side (English side) solar panel	Right side (Odia side) solar panel
9	38	37	35	34	506	478
10	40	39	37	36	658	612
11	42	41	39	38	745	697
12	44	43	40	39	871	852
13	45	44	39	38	820	763
14	43	42	37	36	639	611
15	41	40	36	35	543	495
16	39	39	35	34	437	390

3.1.2 Recording of time for full charging of battery system

Generally it takes 7 to 8 hours for full charging of battery. The full charge battery holds for 5-6 hours in working condition. The vehicle travels at a speed of 35 km h^{-1} (25 km h^{-1} fully laden). The range of distance travelled is 120-130 km with solar panel (on sunny day).The vehicle will only operate if the voltage is min 48 V as each battery rating is 12 V.

3.1.3 Performance evaluation of maize dehusker cum sheller

Prior to the actual performance evaluation of maize dehusker cum sheller, pre-test observations were recorded. The pre-test observations such as moisture content were found to be in the range of 11.23% to 15.36%. At no-load condition visual observations were presented. During one hour prototype run under no load conditions, no breakdown or loosening of parts were observed. The observations of machine during the operation were made on slippage of belts, presence of undue knocking or ratting sound, slackness of any components and presence of any oscillation. The results pertaining to the effect of operational parameters *viz*., rotational speed, moisture content and feed rate on the performance parameters of the maize dehusker cum sheller were presented below.

3.1.4 Dehusking efficiency

The dehusking efficiency was determined by using the equation no. 2. The effect of rotational speed (S) and moisture content (M) on dehusking efficiency (DE) of machine is presented in Figs 5, 6 and 7, which have mean DE of 97.95%, 96.91% and 96.24%, with respect to F1, F2 and F3 feed rate (F), respectively. The trend shows that dehusking efficiency increased with the increase in rotational speed for all the moisture content tested because of increased removing of the husk from cob with the increase in shearing and tearing force created in between the rotating shaft and nitrile rubber with increased rotational speed at all the feed rates and moisture content. The similar findings were reported by Singh, 2010 [18] and Chilur 2017. The maximum DE obtained at 11.23% moisture content for all the rotational speeds, while it was minimum for 15.36% moisture content. On other hand, all individual factors and interactions of all factors affected significantly different at both 1 per cent and 5 per cent level of significance whereas, the interaction of M and C were statistically significant at only 5 per cent level of significance (Table 3).

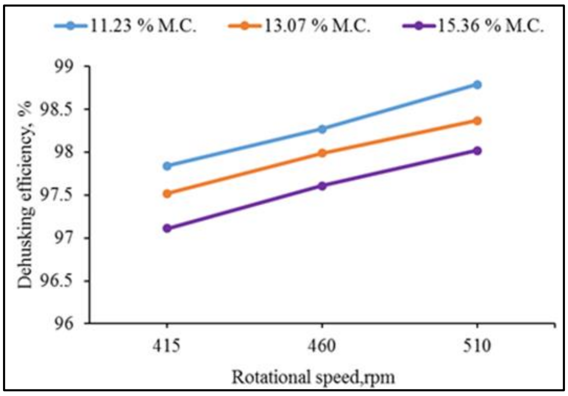

Fig 5: Effect of rotational speed and moisture content on dehusking efficiency at feed rate of 20 kg h^{-1}

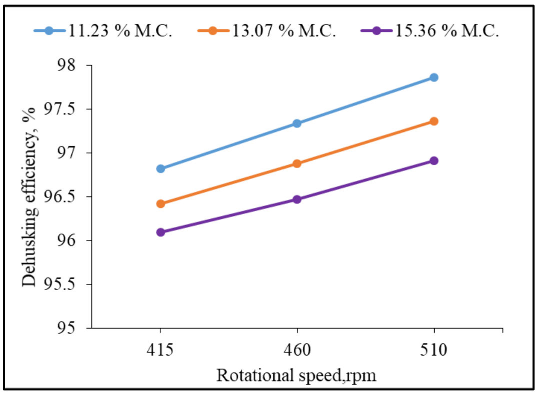

Fig 6: Effect of rotational speed and moisture content on dehusking efficiency at feed rate of 40 kg h^{-1}

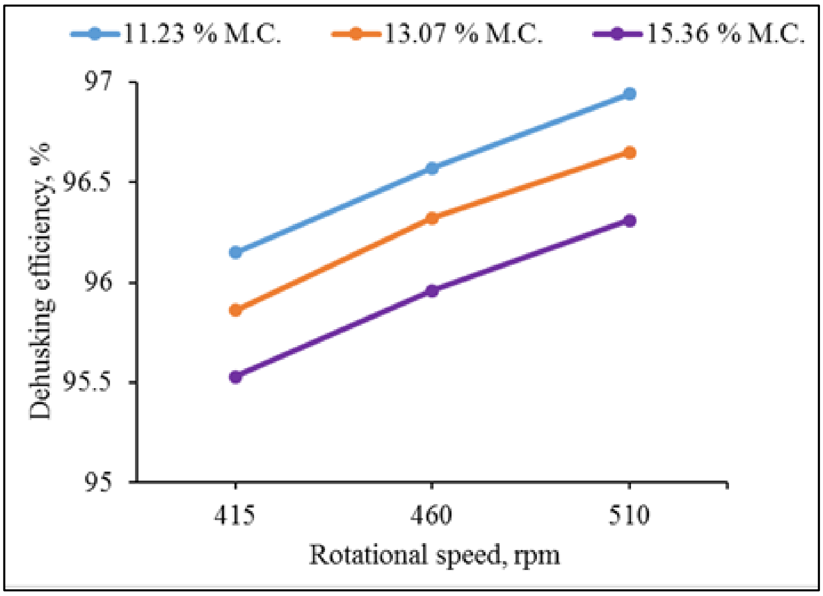

Fig 7: Effect of rotational speed and moisture content on dehusking efficiency at feed rate of 60 kg h^{-1}

Table 3: Analysis of variance of dehusking efficiency

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	P value
F	2	39.353	19.677	51.802	0.000
M	2	7.203	3.601	9.481	0.000
Int FX M	4	12.144	3.036	7.990	0.001
S	2	10.265	5.133	13.513	0.000
Int FX S	4	12.217	3.054	8.038	0.000
Int M X S	4	5.972	1.493	3.931	0.024
Int F X M X S	8	15.128	1.891	4.978	0.000
Error	54	20.534	0.380		
Total	80	122.816			

3.2.2 Shelling efficiency

The shelling efficiency was determined by using the equation no. 1, 3 and 4. From Figs 8,9 and 10, the data revels that, the shelling efficiency (SE) varied from 96.84%to 93.31%. An increased F resulted in the decreased SE due to less energy spent per cob in terms of less friction taken place on cobs for same length of shaft of sheller. While the "cushioning" effect at higher feed rates also caused to decrease in shelling efficiency of sheller (Sandhar and Panwar, 1975; Vas and Harrison, 1969) [16, 23]. Further, the increased rotational speed resulted in the increased shelling efficiency. This may be due to the increased detachment of the grains from cob with higher friction created between the rotating shaft with cobs and taper arrangement provided inside the top cover for shelling purpose, as the rotational speed increases. As for the increasing the grain moisture content leads to decreasing of the shelling efficiency. This is due to the increase in moisture content of grain also leads to obstruct the shelling process due to reducing of dry matter of grains so percentage of unshelled grains are increases hence decreasing of shelling efficiency. This is consistent with Wanjala (2014) [24]. The maximum shelling efficiency was observed at F1S3M1. On other hand, all individual factors and all other interaction affected each other significantly different at both 1 per cent and 5 per cent level of significance (Table 4).

Table 4: Analysis of variance of shelling efficiency

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	P value
Factor A	2	56.534	28.267	162.477	0.000
Factor B	2	10.442	5.221	30.008	0.000
Int A X B	4	13.428	3.357	19.296	0.000
Factor C	2	11.714	5.857	33.667	0.000
Int A X C	4	17.292	4.323	24.845	0.000
Int B X C	4	18.512	4.628	26.598	0.000
Int A X B X C	8	21.208	2.651	15.236	0.000
Error	54	9.411	0.174		
Total	80	158.541			

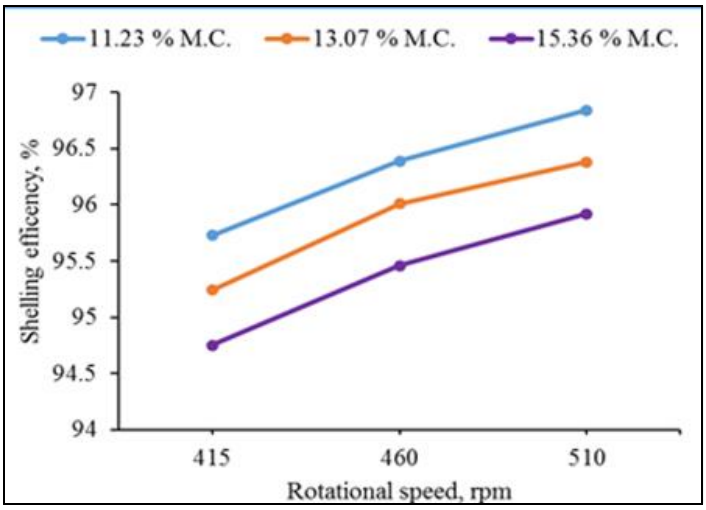

Fig 8: Effect of rotational speed and moisture content on shelling efficiency at feed rate of 20 kg h^{-1}

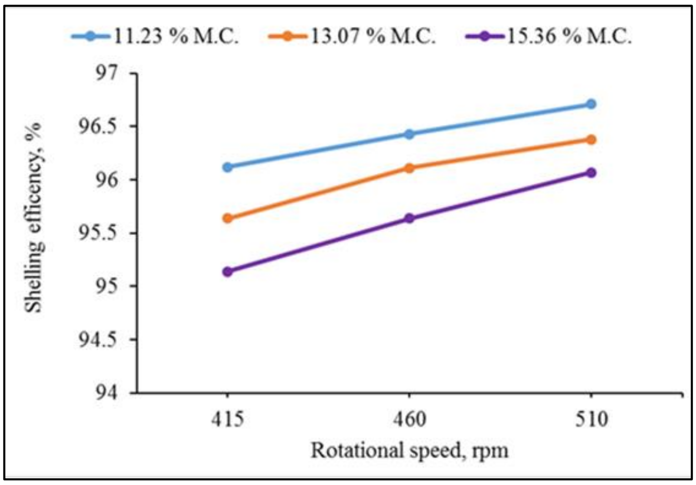

Fig 9: Effect of rotational speed and moisture content on shelling efficiency at feed rate of 40 kg h^{-1}

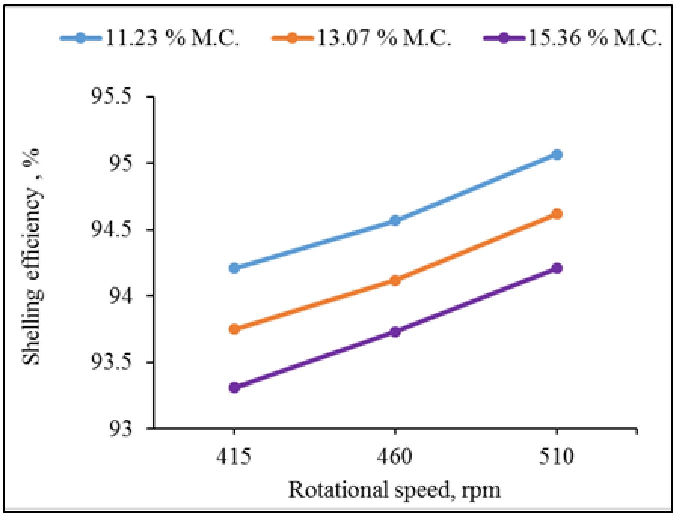

Fig 10: Effect of rotational speed and moisture content on shelling efficiency at feed rate of 60 kg h^{-1}

3.2.3 Total losses

The total losses was determined by using the equation no. 5and 6. The total losses consist of percentage of broken grain and percentage of unthreshed grain From Figs 11, 12 and 13, the data shows percentage of total loss (Lt) varied from 4.31% to 7.08%. The total losses, for all the moisture content, increased with the increase in M. The total losses decreased from rotational speed of 415 to 510 rpm in all the M. When F was increased it resulted in increasing total losses of maize dehusker cum sheller due to less energy spent per cob in terms of less friction taken place on cobs for same length shaft of sheller so the total losses were increased with increasing of percentage of unthreshed grains. The broken grains were reduced as increasing of feed rate but the percentage of broken grains is much less than the percentage of unthreshed grain so the total losses were increasing. The similar results were reported by Chilur and Sushilendra 2017.

On other hand, all individual factors and all other interaction affected each other significantly different at both 1 per cent and 5 per cent level of significance (Table 5).

Table 5: Analysis of variance of total losses

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	P value
Factor A	2	23.406	11.703	69.303	0.000
Factor B	2	4.982	2.491	14.751	0.000
Int. A X B	4	7.212	1.803	10.668	0.000
Factor C	2	9.062	4.531	26.835	0.000
Int. A X C	4	8.268	2.067	12.236	0.000
Int. B X C	4	11.32	2.830	16.749	0.000
Int. A X B X C	8	16.208	2.026	11.986	0.000
Error	54	9.143	0.169		
Total	80	89.601			

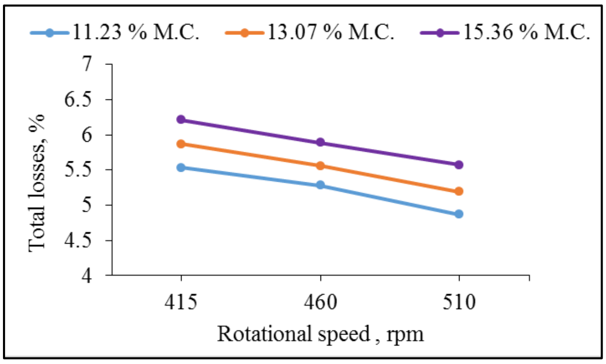

Fig 11: Effect of rotational speed and moisture content on total losses at feed rate of 20 kg h^{-1}

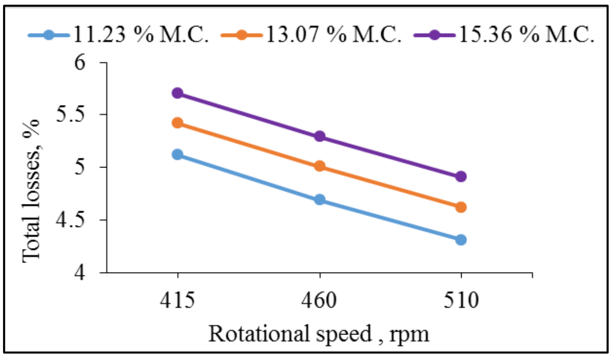

Fig 12: Effect of rotational speed and moisture content on total losses at feed rate of 40 kg h^{-1}

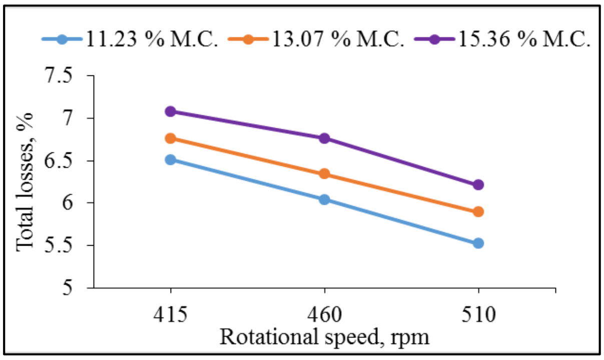

Fig 13: Effect of rotational speed and moisture content on total losses at feed rate of 60 kg h^{-1}

3.2.4 Output capacity

The output capacity was determined by using the equation no. 7. The effect of rotational speed (S) and moisture content (M) on output capacity (OC) of machine is presented in Figs 14,15 and 16, which have mean OC of 11.21, 23.08 and 35.15 kg h-1, with respect to F1, F2 and F3 feed rate (F), respectively. It was found that the output capacity increased with increase in the rotational speed for all the moisture content tested because of when the rotational speed is increases then the less time is required for shelling of grains due to input of higher energy, more friction is created so the shelling of cob is in a fast rate hence the output i.e. output capacity of maize dehusker cum sheller is increases. Highest output capacity was obtained at the moisture content of 11.23% and the lowest output capacity was obtained at the moisture content of 15.36%. As feed rate is increased output capacity is increases.On other hand, all individual factors and all other interaction affected each other significantly different at both 1 per cent and 5 per cent level of significance (Table 6).

Table 6: Analysis of variance of output capacity

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	P value
Factor A	2	7743.58	3,871.790	12,875.058	0.000
Factor B	2	11.328	5.664	18.836	0.000
Int. A X B	4	12.756	3.189	10.596	0.000
Factor C	2	24.01	12.005	39.922	0.000
Int. A X C	4	16.392	4.098	13.615	0.000
Int. B X C	4	11.872	2.968	9.862	0.000
Int. A X B X C	8	30.336	3.792	12.596	0.000
Error	54	16.304	0.301		
Total	80	7866.578			

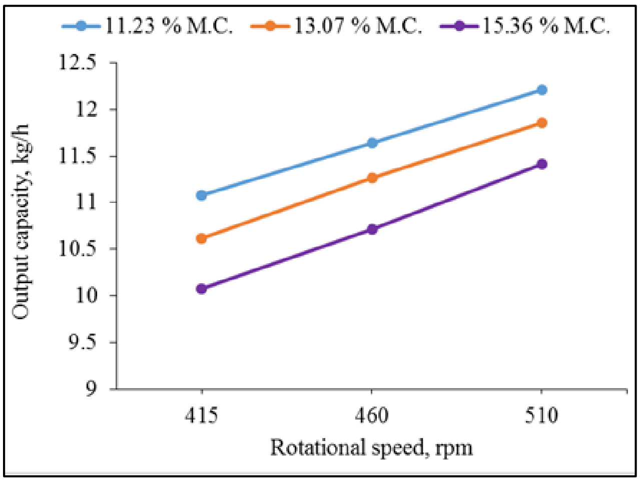

Fig 14: Effect of rotational speed and moisture content on output capacity at feed rate of 20 kg h^{-1}

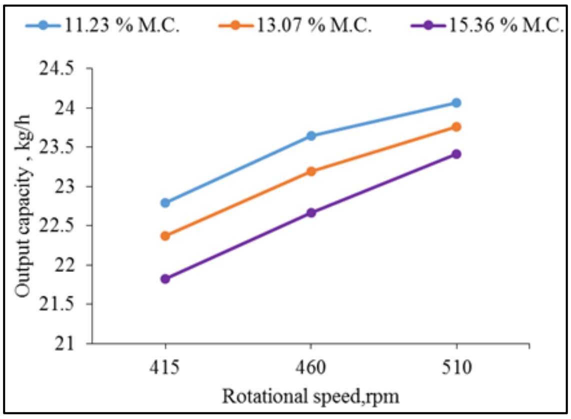

Fig 15: Effect of rotational speed and moisture content on output capacity at feed rate of 40 kg h^{-1}

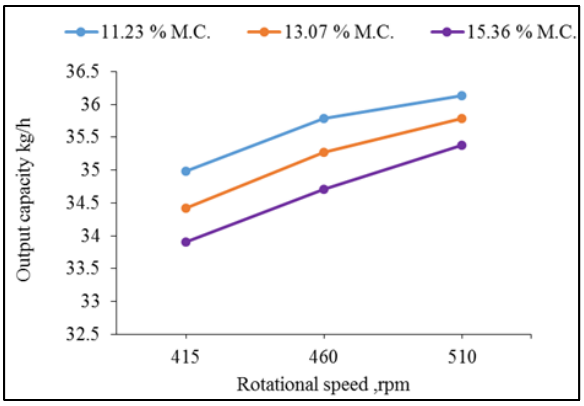

Fig 16: Effect of rotational speed and moisture content on output capacity at feed rate of 60 kg h^{-1}

3.3 Cost economics of mobile maize dehusker cum sheller

Cost economics consist of cost of mobile unit and cost of developed maize dehusker cum sheller. The cost involved in raw material, fabrication cost, labours were considered to the cost of machine. The fixed cost generally consist of depreciation, interest on investment, insurance, taxes and housing. The operating cost consist of cost of repairs and maintenance and labour wages (Ojha and Michael, 2009) [3]. The total production cost of mobile solar powered maize dehusker cum sheller was ` 1,78,000 (including cost of mobile unit, solar panels, batteries, machine, etc.) The total operating cost per hour was estimated as 169.22 Rs h^{-1}. and 468 Rs q^{-1}. Cost of manual dehusking and shelling by tubular sheller was found Rs 620 q^{-1} so there is net saving of 152 Rs $q^{-1}$with respect to manual threshing.

4. Conclusion

The dehusking efficiency increases with increase in rotational speed and decreases with increase in feed rate and moisture content among the different treatments. The maximum shelling efficiency of 96.84% was observed with 20kg h^{-1} feed rate for the 11.23% of moisture content and 510 rpm rotational speed where as it was minimum of 93.31% for 60 kg h^{-1} feed rate at 15.36% moisture content and 415 rpm rotational speed. The maximum mean shelling efficiency was found to at 40 kg h^{-1} of feed rate. The total losses were found to be decreases with an increase in rotational speed. The total losses were observed to be increases with increase in feed rate and moisture content. The maximum output capacity (36.14 kg h^{-1}) was obtained for 60 kg h^{-1} feed rate. The mobile unit (OMSPAM) performance revels that, by measuring of solar radiations incident on a solar photovoltaic panels, concluded that when front wheel of OMSPAM vehicle remains towards the sun position then both the solar panels were getting the maximum and nearly same radiations. Generally OMSPAM takes 7 to 8 hours for full charging of battery & the full charge battery holds for 5-6 hours in working condition. The vehicle travels at a speed of 35 km h^{-1} (25 km h^{-1} fully laden) & range of distance travelled is 120-130 km with solar panel (on sunny day).

5. References

1. Anonymous. Empowerment of farm women in agriculture. Final Report of MM NATP-20. College of Home Science, MPUAT. Udaipur. 2005, 63.
2. Anonymous. Maize dehusker cum sheller reduces drudgery in farm women. Success Stories, Directorate of Research on Women in Agric. (ICAR), Bhuvaneswar, Odisha. 2012.
3. Anonymous. ICAR Vision 2050. Published by Indian Council of Agricultural Research, Krishi Bhavan, New Delhi. 2016. (http:// www.icar.org.in/files/Vision-2050-ICAR.pdf)
4. Coskun Bulent M, Yalcin Ibrahim, Cengiz Ozarslan. Physical properties of sweet corn seed (Zea mays saccharata Sturt.). Journal of Food Engineering. 2006;74:523–8.
5. Chaudhary DP, Kumar A, Sapna SM, Srivastava P, Kumar RS. Maize As Fodder? An alternative approach. Technical Bulletin 2012/04. Directorate of Maize Research, Pusa Campus, New Delhi. 2012.
6. Chilur Sushilendra R. Performance assessment and optimization of maize dehusker cum sheller - A technology for Northern Transition Zone of Karnataka. Indian Journal of Agricultural Science. 2017;87(11):1535-42
7. El-Fawal YA, Tawfik MA, El Shal AM. Study on physical and engineering properties for grains of some field crops. Misr Journal of Agricultural Engineering. 2009;26(4):1933-51.
8. IS: 6284 Indian Standard. Test code for power thresher for cereals (Second Revision). Bureau of Indian Standard (Indian Standard Institution), New Delhi. 1985.
9. Jayan PR, Kumar VJF. Planter design in relation to the physical properties of seeds. Journal of Tropical Agriculture. 2004;42(1-2):69-71.
10. Mohsenin NN. Physical Properties of Plant and Animal Materials, 2nd Edn,. Gordon and Breach Science Publications, New York. 1970, 56-91.
11. Mudgal VD, Jain NK, Bordia JS, Seth P. Research Digest (1992-97). Udaipur Centre. AICRP on PHT, CTAE, Udaipur, 1998, 17–8.
12. Naveenkumar DB. Modification and evaluation of power operated maize (*Zea mays* L.) sheller. M. Tech. (Ag. Engg.) thesis, University of Agricultural Sciences, Bengaluru, Karnataka. 2011.
13. Ojha TP, Michael AM. Principles of Agricultural Engineering, Volume-I. Jain Brothers, New Delhi. 2009.
14. Olaoye JO. Performance modeling of a multipurpose crop threshing machine for assessment of grain loss. Senate Research Grant, University of Ilorin, Ilorin, Nigeria. 2002.
15. Sachin P. Design, development and evaluation of a power

operated maize sheller (Spiked disk type). International Journal of Agricultural Science. 2008;4:215-9.
16. Sandhar NS, Panwar JS. Force and energy requirements for detaching grains from cobs. Journal of Agricultural Engineering. 1975;10(5&6):29-32.
17. Sarma A. Studies on design and performance of maize dehusker-cum-sheller. Ph D thesis, Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur. 2007.
18. Singh SP, Singh P. Hand operated maize dehusker-sheller for farm women. Agricultural Engineering Today. 2010;34(1):152-4.
19. Singh SP, Pratap Singh, Surendra Singh. Status of maize threshing in India. Agril. Mechanization in Asia, Africa and Latin America. 2011;42(3):21-28.
20. Tajuddin Karunanithi T. Comparative performance evaluation of different hand operated maize shellers. J Agril. Engg. 1996;20:1-4.
21. Tastra IK. Designing and testing of improved maize sheller. Agricultural Mechanization in Asia, Africa and Latin America. 2009;40(1):12–7.
22. Tiwari PS, Pandey MM, Gite LP, Shrivastava AK. Effect of operating speed and cob size on performance of a rotary maize sheller. J. Agril. Engg. 2010;47(2):1-8.
23. Vas FM, Harrison HD. The effect of selected mechanical threshing parameters on kernel damage and threshability of Wheat. Canadian Agricultural Engineering. 1969;11(2):83-7.
24. Vyavahare RT, Kallurkar SP. Ergonomic evaluation of maize sheller cum dehusker. International Journal of Current Engineering and Technology. 2015;5(3):1881–6.
25. Wanjala NF. Design of a modified hand operated maize sheller. Engineering design project report submitted to the University of Nairobi. 2014.