Effect of cob size and moisture content on shelling performance of lever operated maize cob sheller

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Abstract: The operating factors were studied for different maize shelling methods (lever operated maize sheller, octagonal tubular maize sheller and conventional beating method) that affected losses and capacity of shelling methods. The factors comprised two levels of moisture content (16%-20% and 12%-16%) and three levels of cob size (< 30 mm, 30-40 mm, and > 40 mm). The results of this study indicated that the shelling force required to detach maize grains from the unshelled cob was dependent on the grain moisture content and cob size. The highest shelling force of 173.5 N was found at moisture content of 16%-20% w.b. and cob diameter > 40 mm while the lowest shelling force of (133.0 N) was found at cob diameter <30 mm and moisture content of 12%-16% w.b. Both moisture content and cob size significantly affected shelling capacity, shelling efficiency, grain breakage and unshelled grain. Increasing the moisture content increased both the grain breakage and unshelled grain, but decreased shelling capacity and shalling efficiency, respectively. The cob size affected the shelling capacity, but did not affect shelling efficiency and grain breakage. The optimised shelling capacity and shelling efficiency of the lever operated maize cob sheller was 30.50 kg h^{-1} and 91.37% at 12%-16% moisture content and 30-40 mm size of cobs, respectively, which was better than the conventional beating method which has been found to have 17.56 kg h^{-1} average shelling capacity and 73.00% shelling efficiency.

Key words: cob moisture content, cob size, lever operated maize cob sheller, shelling capacity, shelling efficiency,grain breakage

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1 Introduction

Maize (*Zea mays L.*) is one of the major cereal crops having wider adaptability under varied agro-climatic conditions. In India, maize is the third most important food crops after rice and wheat. About 0.20 m ha area in Jammu and Kashmir is under maize cultivation with the production of 7116 MT (Anonymous, 2016). Most of the maize produced in the Jammu and Kashmir is consumed as poultry feed, human food like chapattis prepared out of maize flour and grain, roasted ears and popcorn by Dixit et al. (2012). In addition to large industries, several cottage industries are also flourishing on the by-products of maize. Shelling is one of the important post harvest operation where the kernels are to be separated from the cobs to use as seed, fodder, oil extraction and to prepare the value added products and also to maintain the quality of end product, as mentioned by Singh and Singh (2010). Maize harvested are traditionally shelled by hand or by beating sacks stuffed with maize cobs with wooden sticks according to Dixit et al. (2012). These traditional methods of shelling maize are time wasting, hazardous and associated with lots of drudgery by Dixit et al. (2012), Kumar and Begum (2014) and Oriaku et al. (2014). Shelling of the dried cobs by

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the majority of farmers in India and specifically in Jammu and Kashmir are carried out by the repeated beating of the cobs with a stick while helding inside Sacks, open barrels or spreading it over plastered ground floor in the house or outdoor by Dixit et al. (2014), and Patil et al. (2014). These methods cause damage to the kernels and are time consuming involving drudgery. The maize shellers which are manually or power operated, are used to remove the corn pearls from the cobs. There are hand-held devices of various designs and outputs like small rotary hand sheller, free standing hand shellers, small/large hand operated shellers with cleaning and grading facilities. Various types of manual and power operated maize shellers have thus been developed and evaluated by Ali et al. (1986). Hand operated rotary maize shellers have been found suitable for small and marginal farmers for shelling maize, especially for seed purposes, as damage grains are lower in comparison to power operated maize shellers. The large power operated shellers are provided with loading, cleaning, grading and bagging facilities, but they are not affordable by small and medium farmers. In view of this, a lever operated maize sheller was designed and developed for the benefit of small and marginal farmers, especially for seed purposes according to Bashir and Dixit (2018).

The appropriate hand maize sheller for shelling maize cobs requires the study of important factors that affect the performance of shelling and losses, namely, the cob size, and cob moisture content. Therefore, the aim of this research was to study the effects of cob size and cob moisture content on the shelling performance of lever operated maize cob sheller.

2 Material and methods

This study was conducted using lever operated maize cob sheller developed by College of Agricultural Engineering & Technology, SKUAST-K, Srinagar (India) as shown in Figure 1. The different components of lever operated maize sheller are framed, shelling unit, handle, depressor, push rod assembly and handle support.

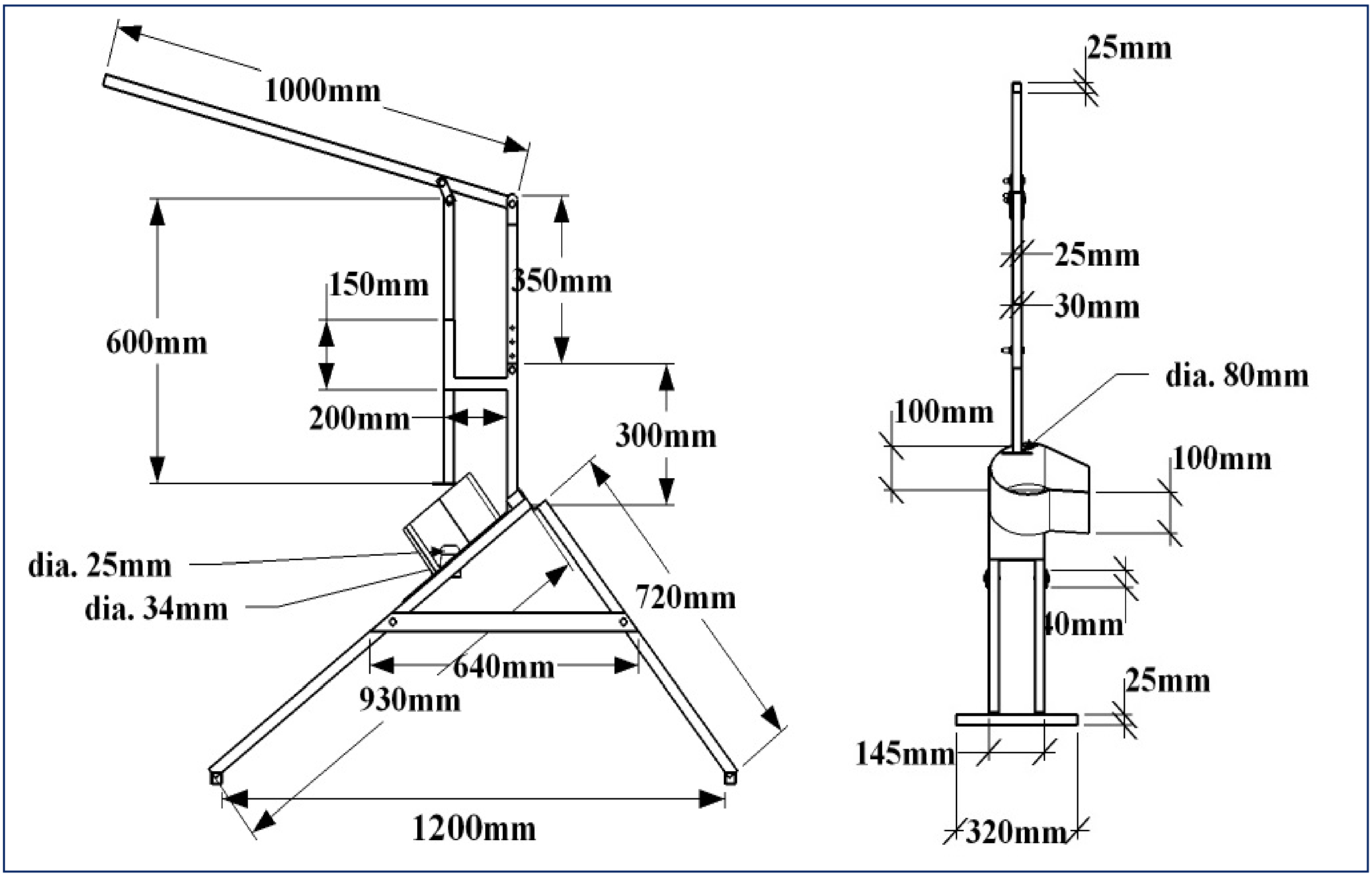

Figure 1 Dimensions of lever operated maize cob sheller

Figure 2 Lever operated maize cob sheller in operation

2.1 Working of the lever operated maize cob sheller

The main working principle of maize shelling in the lever operated maize sheller is the application of compressive force to remove the grains from maize cobs. The maize cobs are fed manually to the shelling unit between the depressor plate and the top end of shelling unit. By pressing the lever, the depressor and push rod comes down vertically and due to the downward stroke, a compressive force applies on the maize cob. The shelling unit is made hollow inside to allow the passage of cob through it. The top end of the shelling unit is made with sharpened edge which causes the maize grains to detach easily with the application of a little force and the cob passes through the unit freely. The whole shelling unit is tapered for easy passage of maize cob and to avoid any choking while feeding large sized cobs. A special arrangement in the form of adjustable diametrical sleeve is provided for smaller size cobs of < 30 mm diameter. The shelled grains are collected at the bottom of the sheller.

2.2 Factors studied and experimental design

The lever operated maize cob sheller was evaluated (Figure 2) as per the standard procedures (Indian Standard, 2018) for a combination of two moisture contents *i.e.*, 16%-20% w.b. and 12%-16% w.b. and three different cob sizes. The three cob sizes corresponded to <30 mm, 30-40 mm, and >40 mm, respectively. The performance evaluation of the developed prototype was carried out at two levels of moisture content and three levels of cob size, in comparison with hand maize sheller and traditional beating method of shelling.

2.3 Independent parameters

A. Methods of shelling (three methods)

1. Mechanical shelling using developed sheller
2. Hand shelling using octagonal maize sheller
3. Beating method

B. Moisture content (w.b) : 2 levels (16%-20% and 12%-16%)

C. Size of cob: 3 levels (<30 mm, 30-40 mm and >40 mm)

The weight of whole grains, broken grains and unshelled percentage of grain were recorded at the time of operation and shelling capacity, shelling efficiency and percentage of grain breakage were determined following standard procedures.

A multi response optimization technique was employed for the optimization of various independent parameters. Design Expert 10.0.0 software was used for optimization of responses.

3 Results and discussion

3.1 Effect of moisture content and cob size on shelling force

It was observed that the shelling force required to detach maize grains from the unshelled cob was dependent on the grain moisture content and cob size. For all the selected maize cobs, shelling force was recorded highest (173.5 N) for cob diameter >40mm at moisture content of 16%-20% w.b. While, it was recorded lowest (133.0 N) for cob diameter <30 mm at moisture content of 12%-16% w.b. (Table 1). A highest shelling force of 173.5 N was found at moisture content of 16%-20% w.b. and cob diameter >40mm. The lowest shelling force of (133.0 N) was found at cob diameter <30 mm and moisture content of 12%-16% w.b.

Table 1 Effect of moisture content and cob size on shelling force

Cob Size	Moisture Content (%w.b)		Mean
	C_1: 16-20%	C_2: 12-16%	
S_1:<30mm	168.6	133.0	150.8
S_2: 30-40mm	167.6	138.8	153.2
S_3: >40mm	173.5	147.7	160.6
Mean	169.9	139.8	

$CD_p \leq 0.05$
Cob Size = 6.146
Moisture Content=5.018
Cob size×Moisture Content=N.S

Note: C: Moisture content (w.b) S: Cob size (mm) C_1: 16-20% C_2: 12-16%
S_1 : <30 mm S_2: 30-40 mm S_3: >40 mm

3.2 Shelling capacity (kg h^{-1})

The mean shelling capacity for the lever operated maize cob sheller was found highest (32.21 kg h^{-1}) at >40 mm cob size and 12%-16% moisture content (w.b.) while the lowest shelling capacity (24.27 kg h^{-1}) was found at 30-40 mm cob size and 16%-20% moisture content (w.b.). The increased shelling capacity at a lower moisture content might be due to the weaker bond between the shell and maize grains, which facilitated easy detachment of grains and hence results in higher shelling capacity. The interaction effect of moisture content and cob size was also found significant on shelling capacity (Table 2). It was observed that shelling capacity increased with decrease in moisture content and increase in cob size for all the three methods of shelling, due to a strong bonding force between the cob and grains at higher moisture contents, the time involved in shelling or detaching the grains from the cob was higher, which lowered the shelling capacity at higher moisture content. At lower moisture content the resistance offered by the cob to detachment of grains was lower, thereby decreasing the amount of time involved for shelling of maize, which increased the shelling capacity. The results are in close agreement with the findings by Srivastava et al. (2003) and Tastra et al. (2006), who had found a combination of 14.2% d.b. cob moisture content (grain moisture content 15.7% d.b.) yielded maximum machine capacity, maximum shelling efficiency (99.88%) and minimum percent grain breakage (8.25%).

Table 2 Effect of moisture content (w.b.) and cob size (mm) on shelling capacity (kg h^{-1})

Method of shelling		Size of Cob	Moisture Content		Mean	Factor Mean
			C_1	C_2		
M_1		S_1	24.68	29.85	27.26	
		S_2	25.66	30.49	28.08	
		S_3	24.27	32.21	28.24	
	S.M		24.87	30.85		
					27.86	S_1=17.84
M_2		S_1	7.64	9.63	8.64	S_2=18.86
		S_2	11.11	11.13	11.12	S_3=19.16
		S_3	10.46	12.63	11.55	
	S.M		9.74	11.13	10.43	
		S_1	14.16	21.08	17.62	
M_3		S_2	13.88	20.86	17.37	
		S_3	12.25	23.13	17.69	
	S.M		13.43	21.69	17.56	
	Mean		16.01	21.22		

$CDp \leq 0.05$
M = 0.725 C = 0.592 S = 0.725
M×C = 1.025 M×S = NS C×S = 1.025 M×C×S = NS

Note: M: Shelling method; **M_1:** Lever operated maize sheller; **M_2:** Octagonal hand maize sheller; **M_3:** Beating method; **S:** Cob size; **S_1 :** <30 mm; **S_2:** 30-40 mm; **S_3:** >40 mm; **C:** Moisture content; **C_1:** 16%-20% **; C_2:** 12%-16%.

3.3 Shelling efficiency (%)

The mean shelling efficiency was found highest (87.12%) at 12%-16% w.b., moisture content and the lowest (80.60%) at 16%-20% w.b. ,moisture content. The mean shelling efficiency for lever operated maize cob sheller was observed highest (90.77%) at moisture content 12%-16% w.b., and lowest (86.56%) at moisture content 16%-20% w.b. For all the three shelling methods the shelling efficiency, increased with increase in cob size. The mean shelling efficiency was found lowest (83.19%) at < 30 mm cob size and highest (84.65%) at > 40 mm cob size Statistically, there was a significant difference of shelling efficiency at 5% level of significance (Table 3). The interaction effect of moisture content on shelling efficiency was also found significant. For all the shelling methods shelling efficiency, increased with decrease in moisture content. The results were in close agreement with the findings of Dixit et al. (2012) and Kunjara et al. (1998).

Table 3 Effect of moisture content (w.b.) and cob size (mm) on shelling efficiency (%)

Method of shelling		Size of Cob	Moisture Content		Mean	Factor
			C_1	C_2		Mean
M_1		S_1	85.83	90.5	88.16	
		S_2	86.50	91.37	88.93	
		S_3	87.36	90.45	88.91	
	S.M		86.56	90.77	88.67	
		S_1	85.00	92.95	88.97	S_1=83.19
M_2		S_2	86.96	92.18	89.57	S_2=83.74
		S_3	87.66	94.70	91.18	S_3=84.65
	S.M		86.54	93.27	89.91	
		S_1	68.60	76.28	72.44	
M_3		S_2	67.90	77.55	72.72	
		S_3	69.60	78.11	73.85	
	S.M		68.70	77.31	73.00	
	Mean		80.60	87.12		

$CD_p \leq 0.05$
M = 1.005 C = 0.821 S = 1.005
M×C = 1.422 C×S = NS M×S = NS
M×C×S= NS

Note:M: Shelling method; M_1: Developed prototype; M_2: Octagonal hand maize sheller; M_3: Beating method; S: Cob size; S_1 : <30 mm; S_2: 30-40 mm; S_3: >40 mm C: Moisture content; C_1: 16%-20% ; C_2: 12%-16%

3.4 Percentage of grain breakage

The average grain breakage percentage increased with an increase in moisture content, irrespective of cob size (Table 4). The higher grain breakage at higher moisture contents is attributed to the softness of the grain, which could not resist the compressive force applied due to shelling process. Because of that lower moisture content (12%-16%) facilitated better grain recovery and negligible damage percentage. The average grain breakage was found lowest for the octagonal hand maize sheller (4.05%) and it was highest for beating method (12.61%). For the lever operated maize cob sheller, average grain breakage was 5.86% and it was found highest (7.0%) at cob size <30 mm and moisture content 16%-20%, while it was lowest (5.0%) at cob size <30 mm and moisture content 12%-16%. The interaction effect of moisture content was found significant on grain breakage for different shelling methods. The average grain breakage was highest (8.77%) at 16%-20% w.b., grain moisture content and lowest (6.24) at 12%-16% w.b., grain moisture content. Lowest grain breakage of 2.78% was observed for the octagonal hand maize sheller at moisture content 12%-16% and highest grain breakage of 14.56% was observed for beating method at moisture content 12%-16%. Increasing cob moisture content resulted in a tendency for grain breakage to increase according to Chuan-Udom (2013), Mahmoud and Buchele (1975), because the high moisture content of the grain was more flexible, making the grain more prone to breaking when it was beaten.

Table 4 Effect of moisture content (w.b.) and cob size (mm) on grain breakage (%)

Method of shelling	Size of Cob	Moisture Content		Mean	Factor Mean
		C_1	C_2		

M_1	S_1	7.00	5.00	6.00	
	S_2	6.33	5.33	5.83	
	S_3	6.00	5.50	5.75	
S.M		6.44	5.27	5.86	
M_2	S_1	5.00	2.33	3.66	S_1=7.47
	S_2	5.00	3.66	4.33	S_2=7.58
	S_3	6.00	2.33	4.16	S_3=7.47
S.M		5.33	2.77	4.05	
	S_1	14.00	11.50	12.75	
M_3	S_2	15.00	10.16	12.58	
	S_3	14.66	10.33	12.50	
S.M		14.55	10.66	12.61	
Mean		8.77	6.24		

$CD_p \leq 0.05$

M = 0.554 C = 0.452 S = 0.554

M×C = 0.783 M×S = NS C×S = NS

M×C×S = NS

Note:M: Shelling method; M1: Developed prototype; M2: Octagonal hand maize sheller; M3: Beating method; S: Cob size; S1 : <30 mm; S2: 30-40 mm; S3: >40 mm C: Moisture content; C 1: 16%-20% ; C 2: 12%-16%

3.5 Unshelled grain percentage

The mean unshelled grain percentage was found lowest (3.94%) at a moisture content 12%-16% and highest (6.98%) at moisture content 16%-20% (Table 5). The unshelled grain percentage was found lowest (3.30%) at the combination of cob size >40 mm and 12%-16% moisture content. Statistically, there was a significant difference of cob size and moisture content on unshelled grain percentage. The mean unshelled grain percentage was found lowest for the lever operated maize cob sheller (5.46%) and highest for beating method (14.38%). The percentage of unshelled grain decreased with a decrease in grain moisture content. The low unshelled grain percentage at a lower moisture content can be attributed to the easy passage (at a lower moisture content) of maize cobs through the main shelling unit without getting choked. Because of that lower moisture content (12%-16%) facilitated better grain recovery and negligible damage percentage. Mean grain breakage was found lowest (6.63%) at 12%-16% w.b., moisture content and the highest (10.61%) at 16%-20% w.b., moisture content. The percentage of unshelled grain decreased with an increase in cob size. The unshelled grain percentage was found lowest (7.87%) at >40 mm cob size and highest (9.33%) at < 30 mm cob size.

Table 5 Effect of moisture content (w.b.) and cob size (mm) on unshelled grain percentage

Method	Size of Cob	Moisture Content		Mean	Factor
		C_1	C_2		Mean
M_1	S_1	7.16	4.50	5.83	
	S_2	7.17	3.30	5.23	
	S_3	6.63	4.04	5.38	
S.M		6.98	3.94	5.46	
	S_1	10.00	4.71	7.35	S_1=9.33
M_2	S_2	8.03	4.15	6.09	S_2=8.67
	S_3	6.33	2.96	4.65	S_3=7.87
S.M		8.12	3.94	6.03	
	S_1	17.40	12.21	14.80	
M_3	S_2	17.10	12.28	14.69	
	S_3	15.73	11.55	13.64	
S.M		16.74	12.01	14.38	
Mean		10.61	6.63		

$CD_p \leq 0.05$

M = 0.699 C = 0.571 S = 0.699

M×C = NS M×S = NS C×S = NS

M×C×S =NS

Note:M: Shelling method; M1: Developed prototype; M2: Octagonal hand maize sheller; M3: Beating method; S: Cob size; S1 : <30 mm; S2: 30-40 mm; S3: >40 mm C: Moisture content; C 1: 16%-20% ; C 2: 12%-16%

3.6 Optimization of grain moisture content and size of cob

The constraints to optimize the operating parameters of shelling unit which would have maximum acceptability are given in Table 6. The maximum value of desirability obtained was 0.914 for 12%-16% w.b moisture content and 30-40 mm cob size. Hence, these operating parameters were selected as optimum conditions for efficient operation of lever operated maize cob sheller. The grain moisture content and cob size were optimized keeping in consideration the higher shelling efficiency, higher shelling capacity, lowest grain breakage and low unshelled grain percentage. The shelling capacity was found highest (30.50 kg h^{-1}) at cob size 30-40 mm and moisture content 12%-16%. The shelling efficiency was observed highest (91.37%) at cob size 30-40 mm and moisture content 12%-16%. The grain breakage was lowest (5.33%) at cob size 30-40 mm and moisture content 12%-16% w.b. The unshelled grain percentage was the lowest (3.30%) at cob size 30-40 mm and grain moisture content 12%-16% w.b. Hence, the cob size of 30-40 mm and the grain moisture content of 12%-16% w.b., were selected as optimum parameters for the operation of a lever operated maize cob sheller. However the sheller was found suitable for shelling of maize cobs of any size.

Table 6 Numerical optimization of response parameters.

Variables	Goal	Optimum/Predicted value
	Input variable	
Method	In range	Lever operated maize cob sheller
Moisture content	In range	12%-16%
Size of cob	In range	30-40 mm
	Output variable/response	
Shelling efficiency (%)	Maximize	91.37
Shelling capacity (kg h^{-1})	Maximize	30.50
Unshelled grain (%)	Minimize	3.30
Grain breakage (%)	Minimize	5.33
Labour requirement (man-h t^{-1})	Minimize	32.83
	Desirability	0.914

4 Conclusions

The optimised shelling capacity and shelling efficiency of the lever operated maize cob sheller was 30.50 kg h^{-1} and 91.37% at 12%-16% moisture content and 30-40 mm size of cobs, respectively, which was better than the conventional beating method which has been found to have 17.56 kg h^{-1} average kernel shelling capacity and 73.00% shelling efficiency. The percentage of grain breakage to the detached kernels recorded was 5.33%. Thus the lever operated maize cob sheller seems to solve the problem that small and marginal scale farmers regarding maize shelling.

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