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Ergonomical and Performance Study of Pedal Operated Maize Shellers

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ABSTRACT
Maize (Zea mays L.) is one of the most important cereal next to wheat and rice . It contributes to its economy and food security. Despite its importance, the process of maize shelling has remained laborious and inefficient, particularly for small and marginal farmers. Traditional methods, predominantly manual, have led to high labour costs, energy expenditure, and poor ergonomic conditions. In response, this study evaluates the performance of pedal-operated maize shellers, emphasizing their throughput rate, shelling efficiency, and ergonomic considerations. This research is conducted at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Godhra with taking three samples (A,B,and C), the research scrutinizes internally designed pedal-operated maize shellers. Results demonstrate the superiority of pedal-operated shellers, exhibiting maximum throughput rates (50.17 kg/h), shelling rates (39.74 kg/h), and shelling efficiency (98.09%). Furthermore, the sheller minimize scattered maize kernels (1.08%), unshelled kernels (1.95%), and broken maize kernels (0.63%) With a maximum collection efficiency of 98.8% and a minimal shelling cost of 82.98 Rs/h, they prove cost-effective and efficient for small-scale farmers, the study underscores the pedal-operated maize sheller effectiveness in achieving high throughput and shelling rates, while reducing costs and waste.Ergonomics assessment is also involved which shows the mean heart rates(126bpm)of operator of during shelling operations. These findings offer practical solutions for small-scale farmers, enhancing agricultural productivity and livelihoods and most suitable not only increasing efficiency of shelling but also reduced physical pain occurred during manual maize shelling methods.It makes maize shelling operation easy ,efficient and with low cost.

Index terms: Ergonomic ,Pedal operated sheller ,Shelling Efficiency, Throughput rate .

I. INTRODUCTION

India is an agriculture based country. Maize (Zea mays L.) is one of the most important cereal crops in the world. It is cultivated in about 170 countries having wider diversity of soil, climate, biodiversity and management practices. The crop is less water demanding than other cereal crops as well as day neutral plants. Globally, maize is known as “queen of cereals” because it has the highest genetic yield potential among the cereals. It is popularly known as "corn”. Maize approximately contains 4% fat, 10% protein, 72% starch supplying an energy density of 365 Kcal/100g. In India, major maize growing states are; Andhra Pradesh (20.9%), Karnataka (16.5%), Madhya Pradesh (5.7%), Maharashtra (9.1%), Rajasthan (9.9%), Bihar (8.9%), Uttar Pradesh (6.1%) and Himanchal Pradesh (4.4%).In Gujarat, 2.51 lakh hectares area is under maize cultivation with a production of 57.42 thousand tonnes in 2020-21. Panchmahal district is an important district in middle Gujarat region . It is second largest district in Gujarat state

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having 0.11million hectares area under maize cultivation with 0.16 million tonnes production in 2019-20. Maize Shelling is a process to separate the 'Kernels' from the Cobs". Maize Shelling requires sufficient force for detaching the kernel from the cobs because the kernels are firmly attached to the body of the cobs. Most of the low acreage maize growers encounter several difficulties in shelling as it involves relatively high labour, expenditure and human energy, Maize shelling generally performed by (1) fingers, (2) beating process with by wooden beater, (3) Hand shelling using tubular maize sheller (4) Pedal operated maize sheller, (5) Electric motor operated maize sheller, (6) Thresher. Percentage saving in cost of per quintal of grain shelling by using developed electric motor operated maize sheller was about 96.87% as compared to hand operated maize sheller and 92.66 % as compares to pedal operated maize sheller (Dabhi et al. ,2020). Small & marginal farmers with a very low maize cultivation carried out the shelling either by rubbing the maize cobs of one another by hand or by fingers. The electric motor is not affordable by the small and marginal farmers , so the pedal operated maize sheller is feasible for them.

Ergonomics considerations in the design of farm tools and equipment are essential for better health and safety of farmworkers and more productivity. (PK Nag, LP Gite ,2020). Traditionally farmer accomplish shelling of maize cob manually through finger nails, sickle or beating of cob by wooden sticks. They perform this activity either in sitting cum bending or in squatting posture for long time which leads to fatigue and drudgery. (T Lohani, S Rana - 2024). These traditional methods of separating the kernels from cobs are time consuming and tedious therefore researchers carried out some innovative and low-cost technologies which hand operated maize sheller, pedal operated maize sheller, electric motor operated maize sheller are used for shelling maize kernels from the cobs.

Therefore, the primary objective of this study is to assess the performance of pedal-operated maize shellers of three samples (A,B,and C). Pedal operated sheller is currently accessible within the Department of Farm Machinery and Power Engineering at the College of Agricultural Engineering and Technology, Godhra, specifically those that have been internally designed. Furthermore, our central focus lies in scrutinizing the ergonomic factor associated with the operation of pedal-operated maize shellers toto increase human machine systemefficiency and improve the operator health and ability to operate with great efficiency, accuracy, and safety.

II. MATERIALSAND METHODS

1. Physical properties of the maize cobs
2. Dimension and mechanism of pedal operated maize sheller
3. Instruments used for evaluation of maize sheller.
4. Performance evaluation of pedal operated maize sheller
5. Ergonomics consideration
6. Cost estimation

1. PHYSICAL PROPERTIES OF THE MAIZE COBS

Moisture Content of Maize Cobs

Moisture content significantly affects shelling operations, influencing the force required to detach maize kernels. We evaluated three samples with varying moisture levels: Sample A (1-day sun-dried), Sample B (1-week-old), and Sample C (1-day shed-dried). Moisture content, determined via the oven method and got average moisture content - 13.4 %,10.1%and ,17.4% on dry basis of respective sample A,B,and C.

Bulk density of maize cobs

Bulk density=Mass of the maize cobs in kg /Volume of the container in m3

Bulk density of maize cobs are determined by the above formula and got 406.01kg/m^3

Diameter and Length of Cob

Evaluation utilized the Gurjari maize variety. Cob size potentially impacts pedal sheller performance. We measured diameter and length of 30 randomly chosen cobs using Vernier callipers, providing insights into sheller-cob compatibility and got average length (163.22 mm)and average diameter of sample maize cobs(44.08 mm).

2.DIMENSION AND MECHANISM OF PEDAL OPERATED MAIZE SHELLER

The Department of Farm Machinery and Power Engineering at the College of Agricultural Engineering & Technology, Anand Agricultural University, Godhra, developed a pedal-operated maize sheller. Comprising a frame, power transmission system, shelling unit, extension, kernel collection tray, and seating for the operator, it employs a simple bicycle chain for power transfer. The sheller features a chain and sprocket transmission system, with two pedals driving equal-sized small sprockets on the shelling unit's 20mm diameter shafts. The operator easily pedals while seated, transferring power to the shelling unit.

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Evaluated on three cob samples—Sample A (1-day sun-dried), Sample B (approximately 1-week-old), and Sample C (1-day shed-dried)—the sheller demonstrated its efficiency.

Figure 1 : Pedal operated maize sheller

Table no. 1 :Overall dimension of pedal operated maize sheller

Sr. No.	Name of the part	Material	Dimension
1	Seat	Rubber	24x23x6
2	Frame for seat	M.S. Pipe	54x4.2
3	Octagonal shelling unit	M.S.	6x7
4	Additional support to shelling unit	M.S. Plate	2x0.5
5	Collection tray	G.I. Sheet	85x38x0.1
6	Pinion with shaft	M.S	3.5: No of teeth:15
7	Bush	M.S Pipe	5.5x5
8	Bearing	Forged steel	No. 6303
9	Bevel gear	M.S.	3.7: No of teeth:16
10	Main frame	M.S Square	4x4x0.2
11	Pedal	S.S.	19.5x4.2
12	Foot rest	S.S & Rubber	14x5.2
All dimensions are in cm			

3.INSTRUMENTS/EQUIPMENT USED FOR EVALUATION OF MAIZE SHELLER

1. Measuring tape
2. Digital weighing balance
3. Digital stop watch
4. Digital oven
5. Digital vernier callipers
6. Garmin vivo sport 3(Fitness band)

4. PERFORMANCE EVALUATION OF PEDAL OPERATED MAIZE SHELLER

4.1 Rate of throughput of the shelling machine:It is the mass of the maize cobs attempted by the machine in unit time and it was measured in kg/h. It was calculated as:

$$\textbf{Rateof throughput}(\textbf{kg/h}) = \frac{[\textbf{Ws}(\textbf{g}) + \textbf{Wu}(\textbf{g}) + \textbf{Wsc}\ (\textbf{g})]}{\textbf{Time t}\ (\textbf{s}) \times \textbf{1000}}$$

Where,
Wsc = Mass of shelled cobs (g)
Ws = Mass of whole kernel scattered outside the machine (g)
Wu = Mass of unshelled kernels (g)
t = Time duration for each trial (s)

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4.2 Percentage of scattered grain: Scattered shelled grains, excluding those from the main outlet, were collected from the ground during operation to calculate the percentage of scattered grain for each batch.

$$\textbf{Percentage of scattered grain} = \frac{[\textbf{Qty. of scattered grain Ws(g)}] \textbf{ x 100}}{\textbf{Total kernels input Wt (g)}}$$

Where,
Ws = Mass of whole kernel scattered outside the machine (g)
Wt = Wc +Ws + Wb = Mass of shelled grain (g)

4.3 Percentage of unshelled grain: It was calculated as, quantity of unshelled grains per total mass of input grains. Total grain input was found by adding the total mass of shelled grains and mass of unshelled grains.

$$\textbf{Percentage of scattered grain} = \frac{[\textbf{Qty. of unshelled grain Wu(g)}] \textbf{ x 100}}{\textbf{Total kernels input Wt (g)}}$$

Where,
Wu = Mass of unshelled kernels (g)
Wt = Wc +Ws + Wb = Mass of shelled grain (g)

4.4 Percentage of broken grains : It was calculated as,

$$\textbf{Percentage of broken grain} = \frac{[\textbf{Wb(g)} \times \textbf{100}]}{\textbf{Wt (g)}}$$

Where,
Wt = Wc +Ws + Wb = Mass of shelled grain (g)
Wb =Total mass of broken kernel collected from bucket, scattered outside of Machine (g)

4.5 Shelling rate: It was calculated by the quantity of the maize kernels (whole + broken) detached from the cobs in unit time.

$$\textbf{Shelling rate} = \frac{[\textbf{Wt(g)} \times \textbf{3600}(\frac{kg}{h})]}{\textbf{t(s)} \times \textbf{1000}}$$

Where,
Wt = Wc +Ws + Wb = Mass of shelled grain (g)
t = Time duration for each trial (s)

4.6 Shelling efficiency: It is the percentage by mass of shelled kernels from all outlets of the sheller with respect to total kernel input mass.

Shelling efficiency (%) = 100 – Percentage of unshelled grain

4.7 Collection efficiency : Percentage of kernels collected at main outlet (in tray and bucket) from the total kernels shelled detached from the cobs. It was calculated as:

$$\textbf{Collection efficiency (\%)} = \frac{[\textbf{Wc(g)}]}{\textbf{Ws(g)} \times \textbf{Wc(g)}}$$

Where,
Wc = Mass of whole kernels collected in bucket (g)
Ws = Mass of whole kernel scattered outside the machine (g)

1. ERGONOMICS CONSIDERATION

Ergonomics assessment was carried out by monitoring the heart rate of the subjects who are performing the shelling operations. The heart rate has been referred to as the primary indicator of strain or physiological reaction of a specific person to the stress of the environment (Brouho, 1967).The subjects were given a rest of 15 minutes

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prior to start of the experiment. Using Garmin vivo sport 3 fitness bands, heart rates were continuously recorded for 10-minute trials .Subjects were instructed to remain calm during recording to ensure accuracy. Heart rate stability was achieved within 3 to 5 minutes. The increase (ΔHR) from resting heart rate was computed to gauge strain levels. This method provided a non-intrusive means of evaluating physiological response to different shelling methods and samples, facilitating effective ergonomic analysis

ΔHR (bpm) = (Heart rate during work) – (Heart rate during rest)

Table no. 2 :Classification of different jobs based on physiological response of subjects

Grading	Heart rate (bpm)
Very light	<75
Light	75-110
Moderately heavy	110-125
Heavy	125-150
Very heavy	150-175
Extremely heavy	>175

6.COST OF OPERATION

The cost of operation on the basis of per hour and per 100 kg kernels was calculated by using straight line method of depreciation. The cost was estimateconsidering 10 year of life period maize sheller with 300-hour annual use of maize sheller. The cost of analysis was divided under the fixed cost and variable cost as follows:

A. Fixed cost

1. Depreciation (D): It is the loss of value of machine with the passing time.

$$\mathbf{D} = \frac{[\mathbf{C} - \mathbf{S}]}{\mathbf{L}}$$

Where,

D= Depreciation per hour C= Capital investment

S= Salvage value, 10% of capital L= Life of machine in years

2. Interest (i): Interest is calculated on the average investment of the machine taking into the considering the value of the machine in the first and the last year.

$$\mathbf{I} = \frac{[\mathbf{C} - \mathbf{S}]}{\mathbf{L}} \times \frac{\mathbf{i}}{\mathbf{100}}$$

Where, I = interest per hour

3. Housing: Housing cost : It is taken as 1% of the initial cost of the machine per year.

4.Taxes and Insurance: It may be taken as the 2% of the initial cost of the machine per year

B. Variable cost

1. Repair & Maintenance: Cost of repair and maintenance varies between the 8 to 10% of the initial cost of machine.

2. Wages: Wages are calculated on the basis of actual wages of the worker for one day (8 working hours Rs 300/day)

4.10 Germination test : Seed germination was assessed using the ISTA standard method with twenty seeds per sample. Tests were conducted for three operations and three maize samples. Germination counts on the fourth and seventh days determined normal seedlings, enabling total germination percentage calculation (Yaklich, 1985).

$$\textbf{Germination percentage} = \frac{\mathbf{J}}{\mathbf{K}} \times \mathbf{100}$$

Where, J = Number of seeds germinated

K = Total number of seeds used in test

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III. RESULTS AND DISCUSSION

Given tables no. 3,4,5 show the performance of all the three samples A,B,and C .

Table no. 3 :Performance of pedal operated maize sheller for sample A (m.c-13.4%)

S.NO	Weight of sample in grams	Time(s)	Visible damage (%)	Unshelled grain (%)	Shelling Efficiency (%)	Throughput rate (kg/h)	Shelling rate (kg/h)
1	3000	218	0.054	2.40	97.60	49.54	48.35
2	3000	211	0.047	1.55	98.45	51.18	50.39
3	3000	208	0.068	1.78	98.22	51.92	51.00
4	3000	216	0.074	1.38	98.62	50.00	49.31
5	3000	213	0.085	2.30	97.70	50.70	49.54
MEAN	**3000**	**150.2**	**0.065**	**1.88**	**98.09**	**50.67**	**40.14**

Table no. 4 Performance of pedal operated maize sheller for sample B (m.c-10.1%)

S.NO	Weight of sample in grams	Time(sec)	Visible damage (%)	Unshelled grain (%)	Shelling Efficiency (%)	Throughput rate (kg/h)	Shelling rate (kg/h)
1	3000	210	0.041	0.38	99.62	51.43	41.86
2	3000	205	0.036	2.30	97.7	52.68	41.95
3	3000	218	0.065	1.88	98.12	49.54	39.52
4	3000	213	0.045	1.70	98.3	50.70	40.42
5	3000	219	0.071	1.77	98.23	49.32	39.53
MEAN	**3000**	**213**	**0.051**	**1.61**	**98.39**	**50.73**	**40.65**

Table no. 5 :Performance of pedal operated maize sheller for sample C (m.c-17.4%)

S.NO	Weight of sample in grams	Time (sec)	Visible damage (%)	Unshelled grain (%)	Shelling Efficiency (%)	Throughput rate (kg/h)	Shelling rate (kg/h)
1	3000	220	0.078	2.7	97.3	49.09	38.45
2	3000	228	0.085	2.2	97.8	47.37	37.25
3	3000	239	0.091	1.9	98.1	45.19	35.55
4	3000	200	0.063	2.6	97.4	54.00	41.55
5	3000	216	0.094	2.4	97.6	50.00	39.43
MEAN	**3000**	**220.6**	**0.082**	**2.36**	**97.8**	**49.13**	**38.44**

Given table no 6 shows the Ergonomics evaluation.

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Table no. 6 :The ergonomics evaluation of pedal operated maize sheller

	Restingheartrate(bpm) Range (74to 80)	Working heart rate (bpm) Range (103 to 142)	Increase in Heart rate (ΔHR)
SAMPLE A	78	126	48
SAMPLE B	78	118	40
SAMPLE C	76	134	58
AVERAGE	**77.33**	**126**	**48.67**

From the results it was observed that the mean working HR of all subjects for pedal operated maize sheller was more than the acceptable limit of heart rate for Indian worker on 8 h work day, i.e110 bpm. So, it was suggested that the pedal operated maize sheller should not be operated continuously for 8 hours without frequent rest-pauses.

COST OF OPERATION

It was found that fixed cost ,variable cost, total cost were Rs.5.58 /h ,Rs. 77.40/h, Rs.82.98/h respectively.Shelling cost was Rs. 204.13/100kg

IV. CONCLUSION

Maize stands as a pivotal cereal crop globally, holding paramount significance in agricultural economies. Effectively detaching kernels from cobs poses a critical task, particularly for small-scale and marginal farmers, necessitating the development of satisfactory and efficient methods to accomplish this task. Therefore , performance study was carried out with pedal operated maize sheller , along with ergonomics factor of it.

On the basis of the results obtained for the performance of pedal operated maize shelling machines under study, following conclusions were drawn:

- The maximum throughput rate was obtained in the pedal operated (50.17 kg/h) in which for sample B throughput rate is maximum as compared to other two maize sample.
- The maximum shelling rate was obtained in the pedal operated (39.74 kg/h) in which for sample B shelling rate is maximum as compared to other two maize sample.
- The maximum shelling efficiency was obtained in pedal operated maize sheller (98.09 %). The shelling efficiency of hand operated maize sheller (98 %) in which for sample B shelling efficiency is maximum as compared to other two maize sample.
- The minimum value of scattered maize kernels was obtained in pedal operated (1.08 %)
- The minimum value of unshelled kernels was found in pedal operated maize sheller (1.95 %) in which for sample C unshelled grain % is maximum as compared to other two maize sample.
- The minimum value of broken maize kernels was obtained in the pedal operated maize sheller (0.63 %) in which for sample C broken grain % is maximum as compared to other two maize sample because kernels with high moisture content have low compressive strength and they deformed easily during shelling operation and did not detach from cobs easily.
- The maximum collection efficiency was obtained in the pedal operated maize sheller (98.8%)
- The minimum cost of shelling was obtained in the pedal operated maize sheller (82.98 Rs/h) .
- The pedal operated maize sheller should not be operated continuously for 8 hours without frequent rest-pauses.
- For better shelling performance, the moisture content of maize cobs 10% to 13% is recommended

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