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Research Note

Techno-economic feasibility of manually operated maize (*Zea Mays L.)* sheller

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Abstract
Traditionally, shelling was done by removing kernels with the help of fingers or with any tool like sickle which is very time consuming and tedious. Maize shelling technique is practiced since long time for various purposes like seed, poultry and human consumption. Thus, on industrial scale, large shelling machines are used which may cost more to be used by small and marginal farmers. For farmers having average cultivated land only 3 to 5 acres of land for cultivation, industrial maize sheller is not beneficial for them to use. Also, the rural area faces some electricity problems till today. Maize in Indian economy also has a good representation as maize cultivation, value addition and marketing in the country involves 1000-million-man days and contributes more than 9% to Indian food basket. The hand operated maize sheller was tested for its performance and economics feasibilities in term of machine capacity (%) shelling efficiency (%), damaged grain (%), unshelled grains (%), operational cost of machine, BC ratio and payback period. The capacity of machine when manually operated was 47.03 kg/h. The shelling efficiency, damaged grain and unshelled grain were 94.20%, 0.11% and 5.30% respectively. The operational cost of machine was 53.22 Rs/h. The benefit cost ratio and payback period were 6.11 and the break-even point was 155.53 kg as term of shelling and 0.163 year. Hand operated rotary maize sheller has been found suitable for small and marginal farmers for shelling maize, especially for seed purposes.

Keywords: Shelling, efficiency, damaged grain, unshelled grains, BC ratio, payback period

Introduction
Maize (*Zea mays L.)* also known as "Corn" said to be originated from Mexico is one of the most important cereal crops in the world agricultural economy has its footprints several thousand years back, even before Columbus landed in South America. It is the world's third most important cereal crop after wheat and rice. The yield potential of maize is very high and in general it is also known as "queen of cereals". Maize contains about 70% carbohydrates, 10.4% albuminoidal, 10% proteins, 2.3% crude fiber, 4% oil and 1.4% ash content. Maize contains adequate quantity of Vitamin E, Vitamin A, Riboflavin and Nicotinic acid. (Anon. 2024a) [2] As per 2022-23, total production of maize in world was about 1214.17 million MT, whereas in India it was about 35.91 million MT (Anon. 2024b) [3]. U.S.A. is the leading corn producer in the world with an estimated production of 389.7 million MT for the season 2023 – 2024. (Anon. 2024c) [4] It is grown over an area of 18.59 lakh hectares in Uttar Pradesh with total production of 19.52 lakh MT. For further processing maize kernels are removed from cobs and are used as fodder, seed, oil extraction and to develop various value-added products. Therefore, Shelling is one of the important post-harvest technology operations for maintaining the quality of maize product. Singh and Singh (2010) [10].
Traditionally, Shelling was done by removing kernels with the help of fingers or with any tool like sickle which is very time consuming and tedious. The maize sheller which are manually, or power operated, are used to remove the corn kernels from the cobs. There are several hand-held devices of various designs and outputs such as, small rotary hand sheller, free standing hand sheller, small/large hand operated sheller with 2 cleaning and grading

facilities. Various types of manually and power operated maize sheller have thus been developed and evaluated. Ali *et al*. (1986) [1] Hand operated rotary maize sheller has been found suitable for small and marginal farmers for shelling maize, especially for seed purposes. The large power operated sheller is provided with loading, cleaning, grading and bagging facilities, but they are not affordable for small and medium farmers. Kumar and Begum (2014) [7] conducted a study to design, build, and assess a corn sheller that is operated manually. The concave measured 91 cm in length and had a 30.3 cm by 2.5 cm slotted entrance. Verma *et al*., (2024) [12] evaluated techno economic feasibility of sugarcane (*Saccharum officinarum* L.) peeling machine.

Materials and Methods

The performance evaluation of manually operated maize sheeling machine was done to calculate the capacity of the machine before the economic evaluation. The hand operated maize sheller was tested for its performance and economics feasibility in term of machine capacity (%) shelling efficiency (%), damaged grain (%), unshelled grains (%), operational cost of machine, BC ratio and payback period.

The performance of the manually operated maize shelling machine was evaluated by operating machine for 8 h/day by a single worker. The average daily wages of India (₹500) were considered in economic analysis as per the data provided by the labor commissioner U.P. in year 2023-24 (Anon., 2024d) [5]. The machine was operated by unskilled workers for 8 hours. Similarly, to compare the machine with the manual process, an unskilled worker performed the hand operation for shelling the maize for 8 hours. Both hand operation and machine work were conducted in similar environmental conditions.

Fixed cost per annum

The fixed annual cost is a summation of the interest cost, depreciation cost, insurance cost and housing tax per year of the machine. The annual charges of interest were calculated as 10% average investment on the machine (BIS: 9164-1979). The useful life of the power-operated chaff cutter was described to be 10 years (Sunil *et al*. 2016) [11]; on this behalf, the useful life of the machine was taken 10 years. The salvage value of the machine was taken 10% of the purchase price (Mishra *et al*., 2017) [8]. The formula for interest rate, depreciation cost, insurance cost and house tax is given in Eq. 1, 2, 3 and 4, respectively.

$$\text{Interest rate} = \frac{\text{Machine cost+Salvage value}}{2} \times 0.10 \quad (1)$$

$$\text{Depreciation cost} = \frac{\text{Machine cost-Salvage value}}{\text{Useful life of machine (year)}} \quad (2)$$

$$\text{Insurance} = 2\% \times \text{cost of machine} \quad (3)$$

$$\text{House tax (H)} = 1\% \times \text{cost of machine} \quad (4)$$

Variable cost per annum

The variable cost of the machine involves repair and maintenance cost of the machine which was considered 5% of the machine cost (Singh and Mehta, 2015) [9], operator cost and the electricity charges are also included in the variable cost of the machine. The formula for calculation of operator cost of the workers and total variable cost is given in Eq. 5 and 6, respectively.

$$\text{Operator cost} = \text{Daily charge} \times \text{Working hours of the machine in a year} \quad (5)$$

$$\text{Total variable cost per annum} = \text{Repair and maintenance cost} + \text{Operator cost} + \text{Electricity cost} \quad (6)$$

Total operational cost of machine per annum

The total operational cost of the machine per annum was the summation of the fixed cost and variable cost of the machine. (Eq. 7)

$$\text{Total operational cost of machine per annum} = \text{Total fixed cost} + \text{Total variable cost} \quad (7)$$

Machine productivity per year

The machine productivity was calculated as the multiplication of the hourly capacity of the machine multiplied by the annual working hour of the machine (Eq. 8).

$$\text{Machine productivity per annum} = \text{Total working hour/year} \times \text{actual capacity} \quad (8)$$

Benefit cost ratio

The benefit cost ratio of the machine was calculated by dividing the annual profit of the machine by operational cost of the machine (Eq. 9).

$$\text{Benefit cost ratio} = \frac{\text{Annual profit}}{\text{Operational cost of the machine}} \quad (9)$$

Payback period

The payback period of the machine was calculated by dividing the operational cost of the machine by the annual profit of the machine (Eq. 10).

$$\text{Payback period} = \frac{\text{Operational cost of the machine}}{\text{Annual profit}} \quad (10)$$

Break-even point (per quintal)

The break-even point (per Kilogram) of the manually operated maize shelling machine was calculated using the formula given in Eq. 11.

$$\text{Break-even point (per quintal)} = \frac{\text{Fixed cost}}{\text{Profit}\left(\frac{\text{Rs}}{\text{quintal}}\right) - \text{Variable cost}\left(\frac{\text{Rs}}{\text{quintal}}\right)} \quad (11)$$

Results and Discussion

The average capacity of the hand operation shelling of maize used traditionally resulted in 6.208 kg in an hour per person. The capacity of the machine at optimized conditions was 47.02 kg/ hour.

Assumptions

- Average annual use = 500 hours (8 h/day)
- Life of machine = 10 years
- Salvage value = 10% of initial cost of machine
- Labor charge = 400 Rs/day (50 Rs/h)
- Interest rate = 10%
- Insurance = 2%
- House tax = 1%

Table 1: Economic parameters of the machine and manual operation

S. No.	Parameters	Values
1.	Cost of Machine	= ₹ 7156
2.	Fixed Cost Depreciation Cost per year @10% (₹) Interest cost per year @10% (₹) Insurance cost per year@2% of machine cost (₹) Housing tax per year@1% of machine cost (₹) Total fixed cost per annum (₹)	= {(7156 − 715.6)/10} = ₹ 644.64 = {(7156+715.6)/2} ×0.10 = ₹ 393.58 = 0.02×7156 = ₹ 143.12 = 0.01×7156 = ₹ 71.56 = ₹ 1252.30
3.	Variable cost per annum (₹) Repair and maintenance @ 5% of machine cost (₹) Wages (₹) of one worker per annum Total variable cost per annum (₹)	= 0.05×7156 = ₹ 357.80 = ₹ 25000 = ₹ 25357.80
4.	Total operational cost of machine per annum (₹)	= ₹ 26610.10
5.	Machine's productivity per annum Shelling cost of the machine (V/kg)	= 500×47.02 = 23510 kg = ₹ 1.132/Kg
6.	Wages of one worker for hand operation shelling of maize Capacity of hand operation shelling of one worker (Kg/h) Cost of hand operation shelling of maize (₹/Kg)	= ₹ 400 = 6.208 Kg/h = 8.05/ Kg
7.	Saving/profit per Kilogram (₹/Kg)	= ₹ 8.05 – ₹ 1.132 = ₹ 6.92
8.	Saving/profit per year (₹/year)	= 23510 × 6.922 = ₹ 162736.22
9.	Benefit cost-ratio	= 6.11
10.	Payback period (year)	= 0.16 year or 1.95 months
11.	Break-even point	= 155.53 Kg

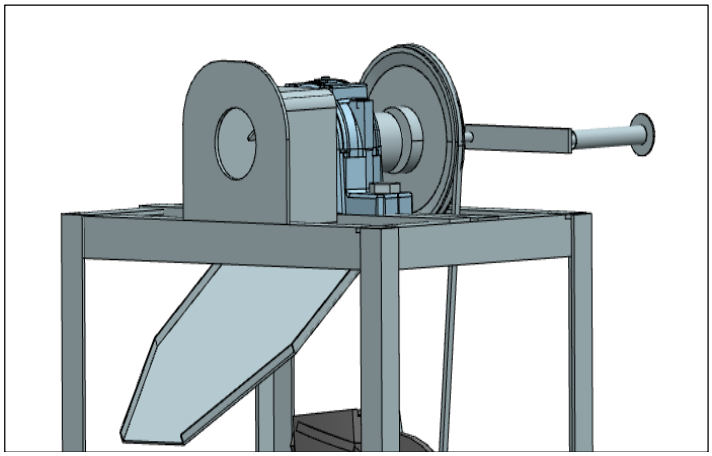

Fig. 1: 3D Diagram of Manually Operated Maize Shelling machine

Fig. 2: Developed Manually Operated Maize Shelling machine

Based on necessary assumptions made, the total fixed and variable annual cost for the operating machine was calculated as ₹ 1252.30 and ₹ 26610.10 respectively. The total operational cost of the machine was found ₹ 26610.10. The productivity of the machine per year was calculated 23510 Kg which was very high compared to hand operation used for shelling the maize. The shelling cost of the machine and hand operation resulted in ₹ 1.132/Kg and ₹ 8.05/Kg, respectively. It was observed that the machine operator has a profit of ₹ 6.92 per Kilogram of maize shelled which can result in an annual profit of ₹ 162736.22 if the machine is operated all the annual working hours. Based on the annual profit, the payback period of the machine was 0.16 years. To achieve profit from the machine, the information regarding the breakeven quantity i.e. the minimum quantity to be processed by the machine to avoid any losses must be known. The breakeven quantity was calculated using the equation given in Eq.8. The total fixed cost of the machine was calculated as ₹ 1252.30 and the variable cost per kilogram of shelled maize was ₹ 1.078/Kilogram. The breakeven analysis showed that to generate profit from the machine, a quantity of 155.53 Kilogram must be processed using the machine. The breakeven analysis graph is shown in Fig. 3.

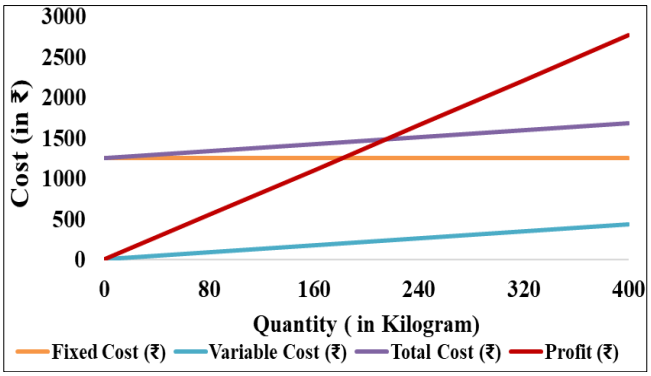

Fig. 3: Break-even point of Manually Operated Maize Sheller

Conclusion

The Manually operated Maize shelling machine was developed by viewing high labor cost and lower efficiency of the traditional operations. The capacity of the machine was evaluated 47.02 kg/h. On comparing traditional method and machine operation it was observed that the capacity of the machine was 6.11 times that compared of hand operation used traditionally. The processing cost of the machine and manual was ₹ 1.132/Kg and ₹ 8.05/Kg, respectively which results in a profit of ₹ 6.92/Kg. The payback period and benefit cost ratio of the machine was 0.16 years and 6.11 respectively. The breakeven analysis revealed that to avoid losses machine should process a minimum of 155.53 Kg/year. It was concluded that the machine can benefit small farmers which cannot afford the high-capacity machines as the breakeven quantity was low. The machine can be adopted by the small land holding farmers. The machine had a high capacity which solves the problem faced in traditional operation and reduced the risk of operation which occurs in the traditional hand operation.

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