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Techno economic feasibility of sugarcane (*Saccharum officinarum* L.) peeling machine

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Abstract
Sugarcane (*Saccharum officinarum* L.) is a tall, tropical grass cultivated for its sweet sap, which is the primary source of sugar production worldwide. It thrives in warm climates with abundant rainfall and fertile soil. The plant's thick stalks contain sucrose-rich juice that is extracted, processed, and refined into various sugar products. The manual peeling of sugarcane is labour intensive and unexciting work. To reduce the labour cost and increase the benefits to farmers, a sugarcane peeling machine was developed. The capacity of the garlic stalk cum grader was 109.4 kg/h. To check the profitability of the machine to farmers, an economic analysis of the machine was conducted. The comparison of manual and machine operation revealed that the capacity of the machine was 6.73 times the manual operation. The peeling cost of the machine was ₹ 54.87/q compared to the ₹ 307.69/q of manual operation. The annual profit and payback period of the machine, if operated for the whole working hours of the machine was ₹ 199141.25 and 0.217 years. The benefit-cost ratio of the machine was calculated 4.60 indicates that the projected benefits are 4.60 times higher than the associated costs. The break-even quantity analysis revealed that to avoid any losses 19.40 quintal sugarcane must be processed annually using the machine.

Keywords: Sugarcane peeling machine, profitability, break-even quantity, techno-economic feasibility etc.

Introduction
Sugarcane (*Saccharum officinarum* L.) is originated in New Guinea, and is now cultivated in tropical and subtropical countries worldwide for the production of sugar, ethanol and other products (Anonymous, 2023a). [1] It is a member of the Andropogoneae tribe of the Poaceae (grass) family (Anonymous, 2023b) [2] India is the second largest sugarcane producer and in Asia number one sugarcane producer country. In India, total area covered for cultivation of sugarcane is almost 4.851 million ha in which production rate is 397.657 million tonnes with productivity of 81.98 tonnes/ha (Anonymous, 2023c) [3]. Sugarcane juice is sweet in taste and is full of natural sweetness, which have a low glycaemic index (GI) hence it works very well for diabetic patients. It also prevents heart diseases as it helps decrease the levels of unhealthy or cholesterol and triglycerides (Pandaraju *et al*. 2021) [7]. Sugarcane juice is used as a natural alternative over synthetic beverages and providing refreshing relief during the summer season. Songsermpong and Jittanit (2010) [10] compared various methods of peeling, squeezing and concentration methods for the sugarcane juice production. The main objective of the research was to determine the appropriate peeling, squeezing and juice concentration procedures for the sugarcane juice production. The outcomes demonstrated that due to their high product yields and quick processing times, the abrasive machine and the roller should be used to peel and squeeze the sugarcane stem. The vacuum evaporator should be used with hot water at a temperature of 70 °C and a vacuum pressure of 70 cm Hg to create the concentrated juice to a level of about 60°Brix. A sugarcane peeling machine designed as sugar cane passes through the rotating hollow shaft, the blades and brushes inside the shaft work to remove the outer surface of the sugar cane. This process results in peeled sugar cane being pulled forward by rollers (Tagare *et al*. 2013) [12].

Keeping all these factors in view, a sugarcane peeling machine has been developed in Mahamaya College of Agricultural Engineering and Technology, Ambedkar Nagar (Verma, 2023) [13]. The techno-economic analysis of the machine in comparison to manual labour is important to determine its profitability and acceptance. This analysis contains various cost parameters, including maintenance, wear and tear, energy consumption, and labour required to operate the machine. The primary objective of the current study is to evaluate the economic feasibility of the sugarcane peeling machine. To achieve an accurate measurement of its techno-economic feasibility, a break-even point analysis, payback period and cost-benefit ratio was conducted (Singh *et al*. 2023) [8]. The main purpose of this paper were to analyse total cost of the machine and to determine the feasibility and economic viability of the sugarcane peeling machine for local sugarcane juice vendors in India.

Description of sugarcane peeling machine

The developed sugarcane peeling machine has three major units namely feeding unit, peeling unit and power transmission system. The major components of this machine are namely blade section, wire wheel brush section, main frame, pulleys, gear assembly, motor and pillow block bearing. The machine requires one labour to operate this machine. During the operation, the operator should have to feed the sugarcane into feed roller and ensuring that cane should move forward in the right direction to avoid any damage to the sugarcane. The roller was designed in such a way that the feeding of different sizes (diameter) of sugarcane was possible with the help of spring arrangement. The peeling process for sugarcane was carried out in two stages; at the first stage, shoots that presented over the nodes of the sugarcane was carefully removed using an adjusTable blade section. Moving on to the second stage, a wire wheel brush section was employed to uniformly peel the sugarcane through the abrasive action of its brushes. This method ensures a uniform peeling of the sugarcane and effectively removes its outer skin, resulting in a clean and consistent appearance. A motor of 0.5 HP was used to provide the necessary motion to the machine. The machine consumes 0.375 kWh of electrical energy. The total cost of the sugarcane peeling machine was ₹ 22500.

Materials and Methods

The working parameters of the developed sugarcane peeling machine were first optimized using SPSS (Statistical Package for the Social Sciences) before economic evaluation. The working parameters of the machine were the motor rom and length of sugarcane. The machine was optimized considering several dependent parameters such as peeling efficiency (%), through put capacity (cane/day (8h)) and microbial load (CFU/ml). At optimized conditions, the machine had a capacity of 109.4 kg/h.

The performance of the sugarcane peeling machine was evaluated by an operating machine for 8 h/day by three workers. The average daily wages of India (₹400) were considered in economic analysis as per the data provided by the labour commissioner of U.P. in year 2022-23 (Anon., 2023d) [4]. The machine was operated by unskilled workers for 8 hours. The average per unit electric charge (₹ 8/ kWh) of India in 2022-2023 was used in calculations. Similarly, to compare the machine with the manual process, nine unskilled workers performed the manual peeling of sugarcane for 8 hours. Both manual and machine work was 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) [5]. 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) [6]. The formula for interest rate, depreciation cost, insurance cost and house tax is given in Eq. 1, 2, 3 and 4, respectively.

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

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

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

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

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.

Operator cost = Daily charge × Working hours of the machine in a year .... (5)

Total variable cost per annum = Repair and maintenance cost + Operator cost + Electricity cost .... (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).

Total operational cost of machine per annum = Total fixed cost + Total variable cost .... (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).

Machine productivity per annum = Total working hour/year × actual capacity ... (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).

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

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).

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

Break-even point (per quintal)

The break-even point (per quintal) of the sugarcane peeling machine was calculated using the formula given in Eq. 11.

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

Results and Discussion

Economic aspect

The average capacity of the manual peeling of sugarcane resulted in 130 kg in 8 hours per person. The capacity of the machine at optimized conditions was 109.4 kg/ hour. As the machine was operated by one person, the machine's productivity was compared with the combined capacity of three workers. The capacity of the machine was 6.73 times more than the manual operation.

Breakeven quantity for sugarcane peeling machine

The important parameters related to economic analysis are given in Table 1.

Table 1: Economic parameters of the machine and manual operation

S. No.	Parameters	Values
1.	Cost of Machine	= ₹ 22500
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 (₹)	= {(22500 – 2250)/10} = ₹ 2025 = {(22500+2250)/2}×0.10 = ₹ 1237.5 = 0.02×22500 = ₹ 450 = 0.01×22500 = ₹ 225 = ₹ 3937.5
3.	Variable cost per annum (₹) Repair and maintenance @ 5% of machine cost (₹) Wages (₹) of one worker per annum Electric charges per annum Total variable cost per annum (₹)	= 0.05×22500 = ₹ 1125 = ₹ 36000 = ₹ 2160 = ₹ 39285
4.	Total operational cost of machine per annum (₹)	= ₹ 43222.5
5.	Machine's productivity per annum Peeling cost of the machine (V/q)	= 720×109.4 = 787.68 q = ₹ 54.87/q
6.	Wages of three workers for manual peeling of sugarcane Capacity of manual peeling of three workers (q/day) Cost of manual peeling of sugarcane (₹/q)	= ₹ 1200 = 3.9 = 307.69/q
7.	Saving/profit per quintal (₹/q)	= ₹307.69 – ₹54.87 = ₹ 252.82
8.	Saving/profit per year (₹/year)	= 787.68 × 252.82 = ₹ 199141.25
9.	Benefit cost-ratio	= 4.60
10.	Payback period (year)	= 0.217 year or 2.6 months
11.	Break-even point	19.40 q

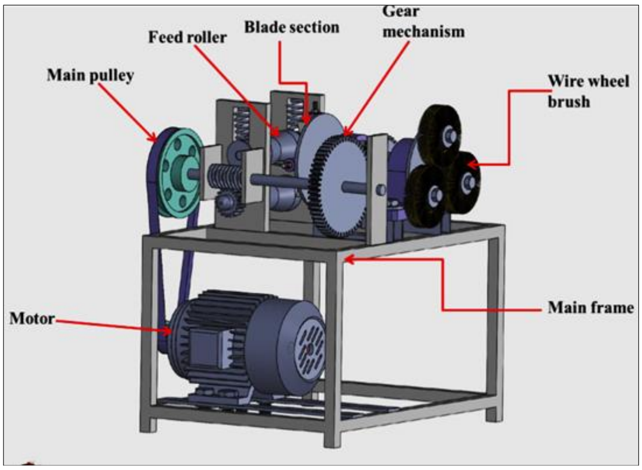

Fig. 1: 3D Diagram of sugarcane peeling machine

Fig 2: Developed sugarcane peeling machine

Based on necessary assumptions made, the total fixed and variable annual cost for the operating machine was calculated as ₹ 3937.5 and ₹ 39285 respectively. The total operational cost of the machine including electricity charges was ₹ 43222.5. The productivity of the machine per year was calculated 787.68 q which was very high compared to manual operations. The peeling cost of the machine and manual labour resulted in ₹ 54.87/q and ₹ 307.69/q, respectively. It was observed that the machine operator has a profit of ₹ 252.82 per quintal of sugarcane peeled which can result in an annual profit of ₹ 199141.25 if the machine is operated all the annual working hours. Based on the annual profit, the payback period of the machine was 0.217 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 ₹ 3937.5 and the variable cost per quintal of peeled sugarcane was ₹ 49.87/quintal. The breakeven analysis showed that to generate profit from the machine, a quantity of 19.40 quintal must be processed using the machine. The breakeven analysis graph is shown in Fig. 3.

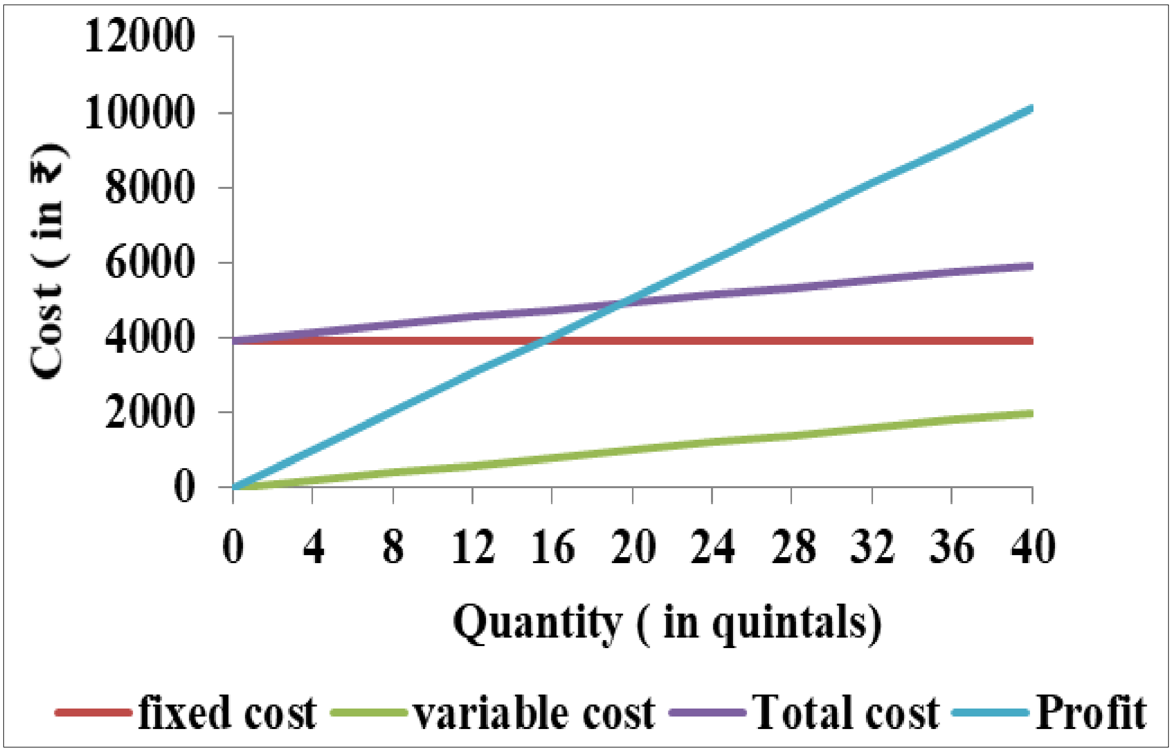

Fig. 3: Break-even point of sugarcane peeling machine

Conclusion

The sugarcane peeling machine was developed by viewing high labour cost and lower efficiency of the manual operation. The capacity of the machine was evaluated 109.4 kg/h. On comparing manual and machine operation it was observed that the capacity of the machine was 6.73 times that compared of manual operation. The processing cost of the machine and manual was ₹ 54.87/q and ₹ 307.69/q, respectively which results in a profit of ₹ 252.82/q. The payback period and benefit cost ratio of the machine was 0.217 years and 4.60 respectively. The breakeven analysis revealed that to avoid losses machine should process a minimum of 19.40 q/year. It was concluded that the machine can benefit both small and big farmers as the breakeven quantity was low. The machine can be adopted by the farmer as well by the local vendors. The machine requires less labour and had a high capacity which solves the problem faced in manual operation.

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