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Performance evaluation of banana fiber production unit

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Abstract
This study evaluates the performance and economic feasibility of a banana fiber production unit established at the village Rakhi, district Bemetara, Chhattisgarh and operated by a Women Self-Help Group to extract fiber from banana pseudo stems. India, being one of the largest banana producers, particularly in regions like Chhattisgarh, generates substantial banana stem waste after harvest (January to June), which can be effectively utilized for fiber production. The performance analysis of the fiber extraction unit focused on machine specifications, input capacity, and efficiency. The fiber extracting machine demonstrated an efficiency of 10.65% to 13.00%, with an input capacity of 107.66-110.00 kg/h and an output of 11.47-12.50 kg/h for fresh fiber and 1.60-2.00 kg/h for dry fiber. The hydraulic press and manual screw press showed water-based efficiencies of 65.49% and 46.01%, fiber-based efficiencies of 28.58% and 45.19%, and input capacities of 205 kg/h and 175 kg/h respectively. The waste fiber-recovery machine operated at 80% efficiency with a 60 kg/h input capacity, while the 7-stage filtration machine showed 71.67% efficiency at 67 kg/h, equivalent to approximately 63.81 L/h based on an assumed density of 1.05 kg/L. The processing unit incurred a total operational cost of ₹ 838.73 per hour. The fiber extraction machine accounted for ₹168.23 per hour (₹14.67 per kilogram) and exhibited a payback period of 41.23 days. The complete unit achieved a breakeven point at 720 (approximately) operating hours per year, with a payback period of 108.5 days. These results demonstrate that banana fiber extraction is not only technically feasible but also economically viable, presenting a sustainable livelihood opportunity particularly for rural, women-led enterprises.

Keywords: Banana fiber extraction, hydrualic press, banana fiber production unit

Introduction
Banana is an edible (*Musa* sp.), elongated fruit available worldwide throughout the year. The banana plant is a large herb that grows from an underground stem to create a false trunk, reaching heights of 3 to 6 meters. The lowest leaf sheath sections comprise this stem, which is capped by a cluster of 10 to 20 oblong to elliptical leaves that occasionally reach lengths of 3 to 3.5 meters and widths of 650 mm. Since each trunk can only hold one bunch of bananas, the plant is chopped down to the ground once it has finished bearing fruit. Then, around every six months, shoots that develop from the rhizome give rise to new trunks.

High-quality textile fibers, known as banana fiber, are produced from the banana plant. The banana plant's pseudo-stem is the source of these fibers. An appropriate extractor may process two banana plants' fibers at once. Known for its remarkable sustainability, banana fiber is categorised as a natural fiber.

Plant fibers are widely used in industries for a wide range of purposes. Nevertheless, natural fibers' market shares significantly decreased as synthetic fibers gained popularity in the middle of the 20th century. 2009 was declared the International Year of Natural Fibers (IYNF) to increase awareness of natural fibers and their advantages.

In banana plantations, after the fruits are harvested, the trunks or stems will be wasted. A billion tons of pseudo-stems are thrown away annually. The extraction of banana stem fiber is not a common practice and much of the stems are not used for the production of fiber. The banana harvesting period is almost around the year. Banana fiber is obtained from the superimposed leaves forming the pseudo-stem of the plant, which currently has no use, apart from a low percentage dedicated to cattle feed.

History of the Fiber

The use of natural fibers for textile materials began before recorded history. The oldest indication of fiber use is probably the discovery of flax and wool fabrics at excavation sites of the Swiss lake dwellers (7th and 6th centuries BCE). Several vegetable fibers were also used by prehistoric people. Reports of the spinning of cotton in India date back to 3000 BCE. The invention and development of sericulture silk and the method to spin silk date from 2640 BCE. New fiber plants were also discovered and their use was explored. In the 18th and 19th centuries, the Industrial Revolution encouraged the further invention of machines for use in processing various natural fibers, resulting in a tremendous upsurge in fiber production. The considerable improvement achieved has permitted increased total production, although natural fibers' actual share of the market has decreased with the influx of the cheaper, synthetic fibers requiring fewer man-hours for production.

Justification

A banana fiber production unit performance assessment is important as a means to assess the unit's efficiency and economic viability. Banana fiber has been considered a crop with eco-friendly properties that can be applied to textiles, paper, and handicrafts. Hence, as it obtains large acceptance, its evaluation in processing, costs, and products is essential to increase its production unit's performance. Natural fibers are low-cost, bio-degradable and easily available. Hence there has been a steep rise in their demands in recent times.

In Chhattisgarh, the production of natural fibers is mainly localized to traditional approaches followed by the rural community and it is not considered as a means of livelihood. Hence mechanization of the fiber extraction process to increase output for commercial applications is a viable option for rural development. Therefore, a study was undertaken to evaluate a banana fiber production unit comprising three different machines for three different operations installed in the village Rakhi, district Bemetara, which is run by women workers of a self-help group under KVK Bemetara. In the past, a tough, time-consuming extraction process of banana fiber resulted in limited use of it. But now, the mechanical method of extraction has made it easier, which may enhance the use of banana fiber widely. The study was carried out to evaluate the production process entitled “Performance Evaluation of Banana Fiber Production Unit”.

The benefits of the proposed fiber extractor machine are as follows:

1. Unused banana stem can be effectively converted into fiber.
2. It helps reduce agricultural waste by reusing, thus minimizing environmental pollution.
3. The machine is easy to operate and requires minimal maintenance, lowering overall costs.
4. Farmers may experience an increase in their income due to the added value of fiber production.

Flow Chart of Banana Fiber Production Unit Process

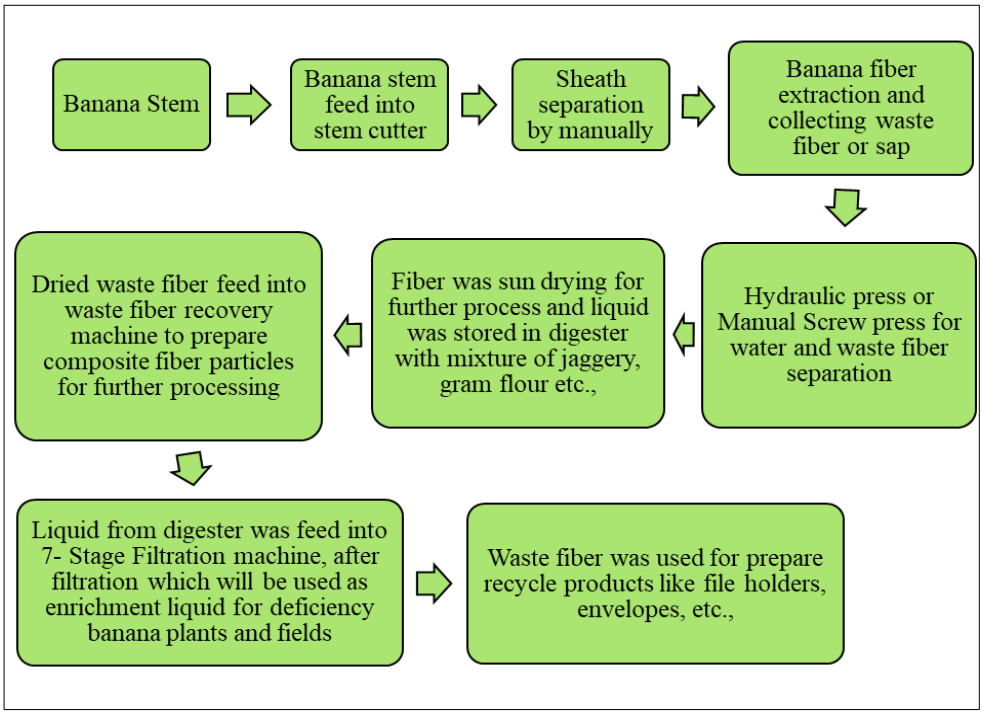


Fig 1: Flow Chart of Banana Fiber Production Unit Process

Materials and method

The experiment was carried out with the already manufactured banana fiber production unit installed at the gouthan, village Rakhi, district Bemetara Chhattisgarh, which is located 21º 42′ 50.4900″ N and 81º 32′ 8.2104″ E. The machine is installed by zila panchayat and runs by panchayat self-help groups women with the help of Krishi Vigyan Kendra, Jhal, Bemetara.

Bemetara is located near the centre of a large plain. The Shivnath river flows to the east of the city of Bemetara and the southern side has dense forest. The Maikal hills rise on the Deccan Plateau. Bemetara has a tropical wet and dry climate, temperatures remain moderate throughout the year, except from March to June, which can be extremely hot. The city receives about 51 inches (1300 mm) of rain.

Table 1: Details of Banana Fiber making machine and its attachments

Banana Fiber Extraction Machine	Hydraulic Press for Removal of Banana Stem Pulp Water	Waste Fiber Recovery Machine	Liquid Filter
• Fixed Foundation Stand • Power Consumption 1 hp 3phase Motor • Operating speed 530 rpm	• 2hp Power Pack with Motor • Heavy-Duty Structure • Dry Suture Outlet with lever • Easy to handle with hydraulic lever-operated • High Efficiency	• Fixed Foundation Stand • Power consumption 3hp 3phase Motor • Operating speed 640 rpm • MOC: Mild Steel and Powder Coating • Electrical Motor Hindustan	• 7 Stage • MOC: Stainless Steel • 10 to 32 microns

Performance Evaluation of Banana Fiber Production Unit

The performance evaluation of the banana fiber production unit includes the banana fiber extraction machine, hydraulic press for removing water from the pulp, waste banana fiber recovery machine, and a 7-stage filtration system for organic liquid nutrient derived from banana liquid.

Cost Analysis of Banana Fiber Production Unit

Cost economics of banana fiber production unit was determined by labour charges, material cost, electricity, repair, and maintenance. The machine cost was computed using the code IS: 9164. The current input and manufacturing costs for the machinery, equipment, and operator rental pay were used to calculate the operational cost. The overall operating expenses were separated into two groups: variable costs, which rise in direct proportion to the amount of use, and fixed costs, which stay the same regardless of consumption.

Depreciation, interest on capital costs, insurance, and taxes are all included in the fixed cost. Lubricant costs, labour charges, and maintenance and repair fees are all included in the operational cost. The banana fiber extractor machine's running costs were calculated in rupees per hour.

Results and Discussion

Experiments were conducted with the developed banana fiber extracting machine, hydraulic press for water removal from banana fiber, waste fiber recovery machine, and 7-stages filtration machine. The performance of the machines was studied.

Performance Evaluation of Banana Fiber Production Unit

The performance evaluation of the banana fiber extraction machine has been carried out considering the following indicators

Efficiency of Banana Fiber Extraction Machine

From the test procedure, it was found that the efficiency of banana fiber extraction machine was 10.65% at 530 RPM of the drum blade shaft.

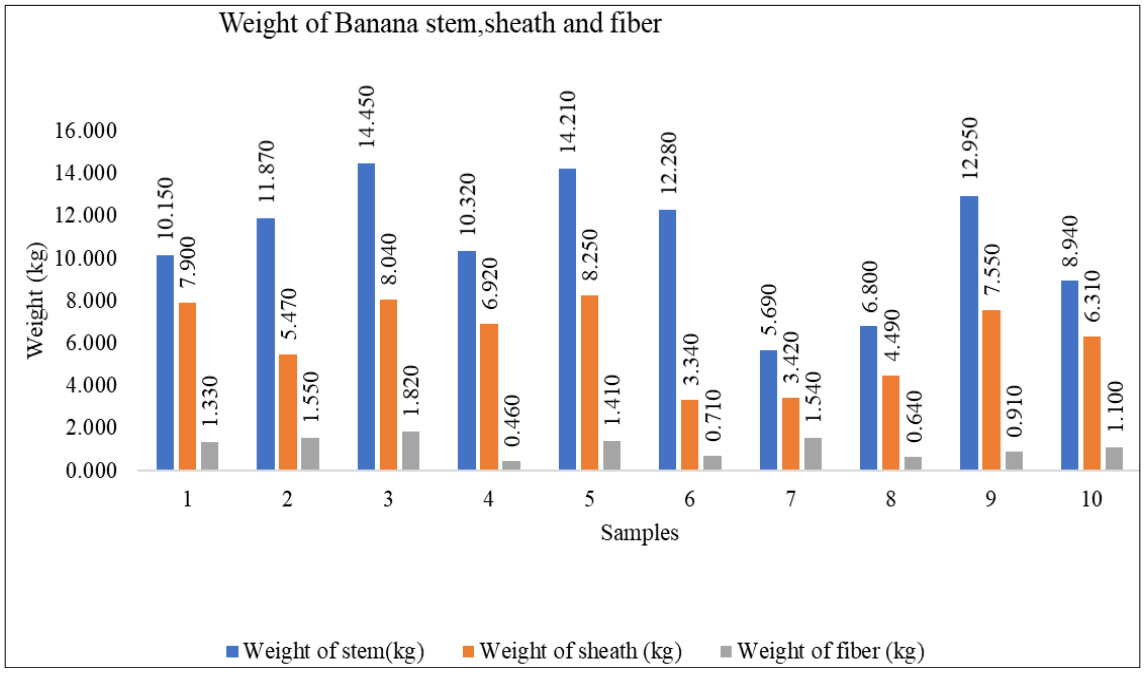


Fig 2: Weight of Banana stem, Sheath and Fiber

For this test, the machine was continuously run for an hour. The total amount of banana stem fed into the machine was 107.66 kg. Output from the machine was 11.47 kg of fiber in wet conditions. After sun drying weight of the fiber was reduced to 1.60 kg. Weight of the pulp was 31.63 kg after removing of water with the help of a hydraulic press and manually screw press, then the weight of the pulp was found to be 11.46 kg

$$\text{Machine efficiency} = \frac{\text{Wout}}{\text{Win}} \times 100$$

$$\text{Machine efficiency} = \frac{11.47}{107.66} \times 100$$

$$\text{Machine efficiency} = 10.65\%$$

Capacity of Machine

- Input capacity: Mass of banana pseudo stem input to the machine (kg/h).
- Input capacity of banana fiber extracting machine was: 107-120 kg/h.
- Fiber productivity: It is the rate of fiber productivity in the time unit (kg/h)
- Banana fiber productivity: 1.6-2.0 kg/h.

Table 2: Properties of banana stem

S. No	Weight of stem(kg)	Diameter (cm)	Height of stem (cm)	No. Of sheath in one stem	Weight of sheath (kg)	Weight of fiber (kg)
1	10.150	13	150	9	7.900	1.330
2	11.870	11	110	7	5.470	1.550
3	14.450	14	160	13	8.040	1.820
4	10.320	11	140	10	6.920	0.460
5	14.210	10	120	9	8.250	1.410
6	12.280	9	110	6	3.340	0.710
7	5.690	9	110	6	3.420	1.540
8	6.800	8	100	5	4.490	0.640
9	12.950	6	120	9	7.550	0.910
10	8.940	7	130	8	6.310	1.100
Total	107.660	98.000	1250.000		61.690	11.470

Table 3: Statistical analysis of properties of banana stem

S. No.	Particular	Mean Value	Standard Deviation	CV (coefficient of variance)
1.	Weight of stem(kg)	10.766	2.965	27.540
2.	Diameter (cm)	9.8	2.529	25.806
3.	Height of stem (cm)	125	19.578	15.662
4.	No. Of sheath	8.2	2.347	28.622

Fiber Recovery

The following formula is used to calculate fiber recovery

Fiber recovery (%) = F_w/F_p x 100

Fiber recovery = 11.47/61.69 x 100

Fiber recovery = 18.59%

The fiber recovery rate is the amount of fiber recovered or extracted from fiber extracting machine. Fiber recovery rate of the machine was 18.59%. The speed of blade drum was 530RPM.

Efficiency of Hydraulic Press for Water Removal from Banana Fiber

For Hydraulic based on fiber,

Machine efficiency = $\frac{\text{Wout}}{\text{Win}} \times 100$

Machine efficiency = $\frac{4.88}{17.07} \times 100$

Machine efficiency = 28.58%

For manual screw press based on fiber,

Machine efficiency = $\frac{\text{Wout}}{\text{Win}} \times 100$

Machine efficiency = $\frac{6.580}{14.560} \times 100$

Machine efficiency = 45.19%

For Hydraulic based on water,

Machine efficiency = $\frac{\text{Wout}}{\text{Win}} \times 100$

Machine efficiency = $\frac{11.180}{17.07} \times 100$

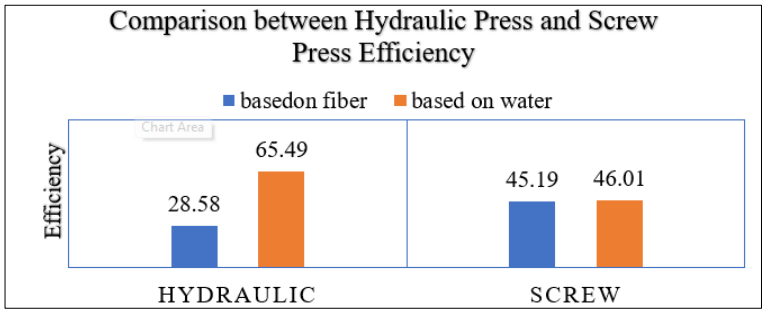
Machine efficiency = 65.49%

For manual screw press based on water,

Machine efficiency = $\frac{\text{Wout}}{\text{Win}} \times 100$

Machine efficiency = $\frac{6.700}{14.560} \times 100$

Machine efficiency = 46.01%



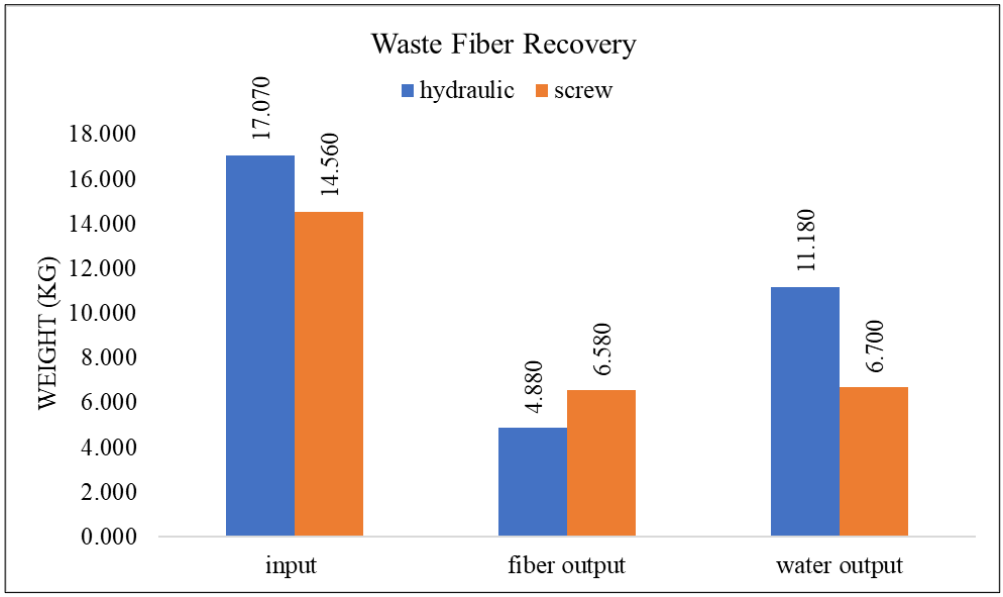


Fig 3: Comparison between Hydraulic Press and Screw Press

Capacity of Machine

- Input capacity: Mass of waste fiber with water (pulp) input to the machine (kg/h).
- Input capacity: For Hydraulic Press 205 kg/h

For Screw Press 175 kg/h

Efficiency of Composite fiber-making Machine/Waste fiber recovery machine

$$\text{Machine efficiency} = \frac{\text{Wout}}{\text{Win}} \times 100$$

$$\text{Machine efficiency} = \frac{2.85}{3.54} \times 100$$

Machine efficiency = 80%

Capacity of Machine

- Input capacity: It is the mass of dried waste fiber input to the machine per hour(kg/h)
- Input capacity: 60 (kg/h).

Efficiency of 7-Stages Filtration Machine

$$\text{Machine efficiency} = \frac{\text{Wout}}{\text{Win}} \times 100$$

$$\text{Machine efficiency} = \frac{64.510}{90.000} \times 100$$

Machine efficiency = 71.67%

Capacity of Machine

- Input capacity: It is the mass of liquid nutrient input to the machine per hour (kg/h)
- Input capacity: 67(kg/h).

Cost Analysis of Banana Fiber Production Unit

The cost of banana fiber production unit was Rs. 8,95,000. Cost analysis was done by straight line method. It is the sum of total fixed cost and total variable cost. Cost of extracting banana fiber per hour from banana pseudo stem, sap and water separation, waste fiber recovery, and liquid filtration by using installed machines was calculated. It was found that cost of extracting banana fiber production unit per hour was Rs.838.733. Table 2 show the Cost Economics of the Banana Fiber Production Unit.

The table presents detailed cost breakdowns for four machines: Hydraulic Press, Liquid Filtration, Waste Fiber, and Fiber Extraction. For each machine, the fixed costs per hour are calculated based on the cost of the machine, its life expectancy, annual usage, salvage value, depreciation, interest investment, and housing costs.

For example, the fixed cost per hour for the Hydraulic Press is Rs. 106.75, while for the Liquid Filtration, it is Rs. 129.63, and for the Waste Fiber, it is Rs. 170.29, with Fiber Extraction having the lowest fixed cost at Rs. 58.90. When combined with the operating costs, such as repair and maintenance, wages, transport, and electricity, the total operational cost per hour for Hydraulic Press is Rs. 185.25, for Liquid Filtration it is Rs. 215.63, and for Waste Fiber, it is Rs. 269.63. Fiber Extraction has a total operational cost of Rs. 168.23 per hour. The custom hiring costs and break-even points are also calculated for each machine, showing the price per hour for outsourcing each machine's use. The break-even point for the Hydraulic Press is Rs. 186.64, while the payback period for these machines varies significantly, with the Hydraulic Press having the shortest payback period of 8.54 days, and Fiber Extraction taking 41.23 days. The total payback period for all four machines combined is 108.45 days.

Because these machines allow rural women to make items from banana stems and fiber, they are essential in giving them opportunities for a living. Women may turn banana trash into useful products like fabrics, ropes, and mats by using these machines. In addition to giving people financial power, this encourages sustainable behaviors in rural areas. These women contribute to local economies and improve their quality of life by working in the banana fiber processing industry, which also preserves the environment by using agricultural byproducts.

Table 2: Cost Economics of the Banana Fiber Production Unit

S. No.	Particulars	Hydraulic Press	Liquid Filtration	Waste fiber	Fiber Extraction	Total
Fixed cost Rs./h						
1.	Cost of machine(P), Rs.	210000.00	255000.00	335000.00	95000.00	895000.00
2.	Life of the machine (year)	10.00	10.00	10.00	8.00	
3.	Annual use (Working hour per year)	300.00	300.00	300.00	300.00	
4.	Salvage value(S), @10%	21000.00	25500.00	33500.00	9500.00	
5.	Depreciation, Rs./h	63.00	76.50	100.50	35.63	
6	Interest investment (I)@12% per annum	38.50	46.75	61.42	20.90	
7	Housing cost @1% of cost of machine	5.25	6.38	8.38	2.38	
Total (A)	Fixed cost Rs./h	106.75	129.63	170.29	58.90	465.57
Operating cost Rs./h						
1	Repair and maintenance cost @ 5% of initial cost, Rs./h	35.00	42.50	55.83	15.83	
2	Wage of 1 operator (300 Rs./8 h)	37.50	37.50	37.50	37.50	
3	transport + raw material, Rs. 400/day	0.00	0.00	0.00	50.00	
4	Electric cost, Rs. 48/8h	6.00	6.00	6.00	6.00	
Total (B)	Operational cost, Rs./h	78.50	86.00	99.33	109.33	373.17
(A+B)	Total cost of operation, (Rs./h)	185.25	215.63	269.63	168.23	838.73
	Custom hiring cost	250.09	291.09	363.99	227.12	1132.29
	Break-even point	186.64	189.61	193.03	150.02	720 (approximately)
	Payback period	8.54	23.79	34.90	41.23	108.45

Conclusions

The fiber extracting machine demonstrated an efficiency of 10.65% to 13%, with an input capacity of 107.66-110 kg/h and an output of 11.47-12.50 kg/h for fresh fiber and 1.6-2.0 kg/h for dry fiber. The hydraulic press and manual screw press showed water-based efficiencies of 65.49% and 46.01%, fiber-based efficiencies of 28.58% and 45.19%, and input capacities of 205 kg/h and 175 kg/h respectively. The waste fiber-recovery machine operated at 80% efficiency with a 60 kg/h input capacity, while the 7-stage filtration machine showed 71.67% efficiency at 67 kg/h, equivalent to approximately 63.81 L/h based on an assumed density of 1.05 kg/L. The processing unit incurred a total operational cost of ₹ 838.73 per hour. The fiber extraction machine accounted for ₹ 168.23 per hour (₹ 14.67 per kilogram) and exhibited a payback period of 41.23 days. The complete unit achieved a breakeven point at 720 (approximately) operating hours per year, with a payback period of 108.5 days. These results demonstrate that banana fiber extraction is not only technically feasible but also economically viable, presenting a sustainable livelihood opportunity particularly for rural, women-led enterprises.

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