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Performance evaluation and business model analysis of the modified jute fiber extraction machineRejaul M. Karim^{1,*}, Arshadul M. Hoque^{1,2}, Alamgir Chawdhury^{1,2} and Faruk U. Islam²¹Farm Machinery & Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh²Business Development and Quality Assurance, Practical Action, Bangladesh Country Office, Dhaka, Bangladesh*Corresponding author: rejaulkarim@bari.gov.bd

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Abstract

Karupannya (KP) Rangpur Ltd has imported a jute fiber extraction machine from Zhengzhou Shuliy Machinery Company Ltd, China, and it was not working properly in Bangladeshi condition. We redesigned and fabricated the machine at local metal workshops in Bangladesh and evaluated its performance following three business models after modification and also branded with the name “Aashkol.” in four districts of North-west Bangladesh during the jute harvesting time of 2017-19. Forty Aashkol were evaluated using three types of jute, such as Deshi, Tossa, and Kenaf and 10 Aashkols were selected for machine performance evaluation and performance compared with the Imported KP model machine. The jute stem input capacity (4.99 ton/h) of the redesigned Aashkol was 48% higher than the capacity (3.38 ton/h) of the KP imported machine where the ribbon out-put capacity was significantly higher than the KP model. The highest jute stem input capacity of Aashkol was found for Kenaf (5.94 ton/h). The highest ribbon out-put was 1.69 ton/h for Kenaf followed by Tossa and Deshi variety of jute. The highest fiber yield was found at 3.21 ton/ha for using Aashkol based extraction and retting method, which produced a 9% higher yield than the traditional retting method. Extraction and improved retting method with Aashkol required 91% less labor compared with the conventional method. Significantly lowest retting time was found from Aashkol based retting and saved 45% retting time. Among the three business models for Aashkol, the multipurpose use model was the most profitable and recommended to demonstrate the machine widely.

Keywords: Jute, Fiber, Extraction machine, Capacity, Aashkol

1. Introduction

Jute is one of the natural fibers proposed broadly to utilize for its eco-friendly properties [1]. This is a vegetable origin glossy natural best fiber containing cellulose fibrils and non-fibrous ground constituents like lignin and hemicelluloses. Vegetable fibers are biodegradable, annually renewable, and not carcinogenic, resulting from health-friendly fiber. Jute shows numerous inherent benefits like lustre, high tensile strength, moderate heat and fire resistance, and long-staple lengths [2]. Jute is the golden fiber of Bangladesh, an internationally traded commodity and one of the most popular cash crops to Bangladeshi farmers. Jute covers about 3.58% of the total cropped area [3]. There is a big call of 0.75 metric tons jute goods in the international market [4]. In 2016-17, the total jute production in Bangladesh was 8247000 bales from 738,057 ha land [5].

The primary use of jute produced in Bangladesh is to obtain fibre as textile materials and make ropes, mattresses, bags, and diversified handicrafts. In addition, jute fiber and jute sticks are used mainly for different domestic purposes such as cooking fuel and fencing of homestead areas [6,7].

The fibers in their original state are usually tightly bound in the stems of plants with the gummy substances that bind them together. Therefore, fiber separation has to be carried out with much care to obtain the best yield and quality of fiber. This fiber could be extracted by the traditional retting method.

Traditionally jute is retted following a biological process. In this process, the whole jute fresh plants are submerged under the water. After a few days, the plants started to decompose with the combined action of water

and aquatic microorganisms as like bacteria. After fully decomposed, the fibers are separated from the stem and finally dried in the sunlight. The retting process plays an essential role in some important quality indicators of fiber like strength, color, luster, and texture [8]. In some jute-growing areas of Bangladesh, water scarcity is found during jute retting time. Farmers go for retting their jute in small ditches, canals, ponds, etc., where water is stagnant for few days. In general process of jute retting in those jute growing areas is to submerge the jute plant bundles in slowly flowing clean water bodies like canals, tanks, ponds, or ditches. For excellence in retting plant material, the water ratio in stagnant water should be a minimum of 1:20 [8]. To maintain this process, jute plant bundles have to keep underwater into 2-3 layers for about 15-20 days. Thus, the retting is completed, and after that, retted fibers are extracted and washed manually as well as finally dried for sale [9]. The traditional retting process is comparatively a long-time consuming process to pull out fibers from jute stem.

Sometimes the traditional retting process fades the quality of jute fiber, and the environment is polluted due to the decomposition of biomass [10]. Moreover, due to the climate changes, the river and ponds/canals trend during jute harvesting period found to be dried earlier. Therefore, it has become difficult for the farmers to ret their jute timely and free of hazard [11].

In recent years' competitively higher production of jute is found but a massive problem is also found in retting process. Finally, water scarcity and low fiber quality are found simultaneously in some jute growing areas. It is a positive sign of increasing jute production but a negative sign of benefit due to poor quality fiber [12]. Low quality and darkness of color found into fiber due to black spot on the jute fiber. Fiber quality might not be the same all around due to a lack of control over the traditional retting process. Since farmers usually use the lower quality, black and dark colored water as well as muddy mixed insufficient from the lower level in the traditional retting process, and it becomes impossible to get assurance of good quality jute fiber. They are sometimes stacked by bundles of 20-30 plants in each bundle, and fiber strength declines due to over retting or retting.

It was also found that 16.9 to 20% cost involved in fiber extraction and 16.33 to 20% in weeding out of the total production cost of jute [6,7]. Thus, a cost-effective technology has to develop in the jute production and processing aspect for depressing the production cost and growing the profit margin [6].

So, there is an urgent need to develop a machinery technology for the extraction of jute fibre, which requires very little water, lesser time than the conventional method, improves fiber quality, and above all, which is user-friendly and eco-friendly. The improved technology involves mechanical extraction of ribbon/ bark from jute stems immediately after harvest with the help of machine followed by retting of ribbon in water, which is termed as Mechanic-microbial retting or mechanical-cum-retting method of fiber extraction. In this method, extraction of fiber is carried out in two steps - first, separation ribbon/bark from the wood by machine and later from the gummy substances of the ribbon by retting. Machines were developed to extract the ribbon of the harvested plants and retting ribbon in a small volume of water by steeping ribbon vertically. The fiber is then washed in clean water and dried.

Ribbon retting is particularly a mechanical pre-treatment of plant stalks that allowed a shorter length of retting time, less water requirement, and almost one-fourth of environmental pollution compared to other methods where the whole plant is processed. But, in the manual ribbon retting process; more labor is required to separate the fiber from the stem and other processing [13].

In Bangladesh, the Fibers Quality Improvement Division of Bangladesh Jute Research Institute (BJRI) invented a power-operated jute auto ribbon at its premises and demonstrate the machine in separating jute fiber, ribbon rating in 2016 [13].

NIRJAFT (National Institute of Research on Jute and Allied Fibre Technology-is a premier institute under Indian Council of Agricultural Research, Government of India and dedicated to the research of jute and allied fibers leading to the diversified use and industrial growth) has developed a Power Ribboner which is useful for extraction of ribbon from jute and Mesta/Kenaf plants. It is designed and developed considering the need for a low-cost, lightweight and portable machine for use for jute. It is powered by a (1 hp)s electric motor or an engine of equivalent capacity. The machine works on stripping green ribbon/barks from the harvested stem/canes without breaking the inner woody stick. The green bark/ribbon peeled off from the whole jute plants can be conveniently retted in much less water to yield quality fiber of high grade than the conventional method [14]. Jute fiber extraction machine has played an important role in producing quality jute fibers [15].

The Central Research Institute for Jute and Allied Fibers (CRIJAF) -a premier institute on jute & allied fiber crops of Indian Council of Agricultural Research (ICAR) under Crop Science is situated at Nilganj, Barrackpore, India has developed a power decorticator that strikes the stems by rotating blades and removes the green ribbon by breaking the stick into pieces, while the manual one produces whole stick [16].

Kenaf decorticator was developed, which had a chute to feed the kenaf stem into the machine. The stem passes through beaters that break the stem's unwanted core material and pushes out the fiber and the unwanted core through the delivery plate. The fiber is separated from the unwanted broken core material manually. The beaters that break the kenaf stem are of different sizes. The three sets of beaters are connected to a set of gear

meshed together. The machine is driven by a 2000 rpm diesel engine power unit with 9.48 kW maximum power [17,18].

Karupannya Rangpur Ltd has imported a jute fiber extraction machine and developed a retting process and extracting fiber from jute in Rangpur [19]. Some problems were found during the use of the imported extraction machine in the experimented field of Bangladesh. There was no availability of full satisfaction of farmers while operating that power-driven jute fiber extraction machine. Due to having some problems like unavailability of some spare parts of the engine attached with this machine and lower power of the engine for a long time and frequently to be operated. There were some common mechanical troubles during field operation and movement from one field to another due to the pull-type movement system, which is so drudgeries to operators particularly in muddy roads.

Moreover, the users faced another problem like low feeding capacity, lower output capacity, comparatively high purchase price, lack of options for multiple or alternative uses like rice wheat threshing and maize shelling for extra earnings after season of jute extraction, lack of it's easy availability in local machinery market of Bangladesh and after-sale services from seller's side, etc. In order to minimize and overcome these problems, the modified jute fiber extraction machine prototype was developed and fabricated locally in indigenous metal workshops under the project. This study was undertaken to evaluate the performance of the modified jute fiber extraction machine "Aashkol" over KP imported machine prototype, identifying the modifications of Aashkol over KP imported machine, and three business models analysis.

2. Materials and methods

Numbers of modifications were done in Aashkol to improve the performance of jute fiber extraction. Improvements done in Aashkol over KP model are shown in Table 1. In the KP model, the power source was a (10 hp) diesel engine, but the Aashkol (16 hp) diesel engine was used. Spare parts of the engine supplied with the KP model were not available in the local machinery market or machinery dealer points. Moreover, the engine power (10 hp) was insufficient for farmer's expected feeding rate of jute plants. To meet up the farmer's expectations and to get higher capacity, the machine was redesigned.

In the KP machine, power was transferred to the extraction machine only, and power was not transmitted to the wheels. But, a mechanical brake could be developed in Aashkol for differential mechanism. The forward speed was possible to keep in reasonable speed, and it was done by attachment of appropriately sized pulley with engine flywheel to line shaft and in the differential shaft. The forward speed of Aashkol was 29 km/h for transportation from one field to another field. Continuous, long time and long-distance transport became possible with this modification. The differential mechanism performed smoothly with fewer troubles.

An accelerator pedal was developed in footrest which was connected to the engine throttle lever with a wire/cable. The cable was attached with an especially designed tie rod to up down the throttle lever. It was designed such that the operator can control the rpm seating on the operator seat. It was developed such as if the operators press to downward the pedal, the throttle lever moves to downward for rpm increases and vice versa. But there was no such a rpm control system in the KP machine.

In the KP machine, a lot of energy was needed for the operators to shift the machine from one place to another and felt hazard during the long run. But in the Aashkol, such modification was done to operate the machine as a self-propelled machine and move easily from one field to another. For attachment of two grooves tension pulley with the lead pipe of the main clutch, it acted as media for engaging or disengaging the engine pulley with the differential pulley.

There was no headlight in the KP machine. But in Aashkol, a headlight was set up in front of the handle. It was basically separated from the engine head and shifted in front of the handle. Due to the absence of headlight in the KP machine, it was tough to come back from long distance field after evening or at night. In order to address this problem, that modification was done.

In Aashkol, the operator's seat was separable, which had 20 cm clearance from the side protection cover. Due to a plug and play system in the operator's seat, safety issues were addressed, and some essential tools could be kept under the seat.

The fork used in Aashkol was readymade which was being used in a two-wheel tractor's rear wheel. It was stronger and comparatively safer. Thus, wheel setting became easier and safer.

In the KP machine, the sprocket attached with the lower secondary extraction roller was of dual grooves- 15 teeth, and the lower grabs roller was of dual grooves-60 teeth. In order to matching with these two sprockets, the chain size was 16mm, which was easily available in the local market. But, in Aashkol, the sprocket attached with the lower secondary extraction roller was of double grooves 13 teeth, and the lower grabs roller was of double grooves 52 teeth. Therefore, to Matching with these two sprockets, the chain size used here was 20 mm was available in the local market even in rural areas as it is similar to the chain of two-wheel tractor rotavator chain.

The chain was being dismantled or worn out in the KP model when overfeeding was being done and was not easily available in the local market. To address these problems, the chain strength was increased and ensured easy availability in the local market as it was the same size as the two-wheel tractor's rotavator chain. In KP developed machine, sometimes found hammering injury in jute ribbons and it deteriorated the fiber's tensile strength. Taking into consideration this problem, the primary and secondary rollers were redesigned. The rollers were made with 6mm thickness pipe and barriers made with 50 x 50 mm angle bar with 4 mm thickness, which reduced hammering injury.

When greater diameter jute plants were passing through the gap between two grab rollers, some jute sticks were not being fully broken and separated from the ribbon in the KP model due to the deformed rod's diameter. Therefore, the grab rollers could not exert uniform pressure on all jute plants and found some non-separated broken jute sticks. In Aashkol, 10 mm diameter MS solid shaft was used, and I-hole was done to set the UCP bearing and grab roller with base frame for precision setting (increasing or decreasing the clearance), which was impossible in the KP model. Thus, the clearance maintaining between two grab rollers can be done accordingly, and a complete breakdown of jute sticks with complete separation could be possible.

According to plant height, the fiber receives stand had to adjust from time to time. But, in the case of the KP imported machine, it was a fixed type. The stand or rake was made adjustable in Aashkol. Moreover, the size of the feeding tray in Aashkol was bigger than KP model, which reduced the risk.

The rear wheels in KP imported machine were the same as the rear wheel of battery-operated three-wheeler easy bikes (Tire Size: 4-00-8), which did not skid-free. However, in Aashkol, the wheels of a two-wheel tractor (Tire size: 6-00-12) were used as rear wheels. Thus, the longevity of the wheel was increased, reduced tire punctured, and comparatively less slip/skid was found during movement from one field to another.

Numbers of modifications were done in Aashkol to improve the performance of fiber extraction from three types of jutes. Major changes done in Aashkol over the first prototype (KP Model) are shown in Table 1.

Table 1 Major modifications in Aashkol over a prototype (KP Model) of jute extraction machine.

Sl.No.	Parameters	KP prototype	Aashkol (Modified prototype)
01	Engine power	10.5 hp	16 hp
02	Power transmission systems	One way	Differential
03	Accelerator	Nil	Pedal operated
04	Main clutch	Nil	Incorporated
05	Head light	Nil	Incorporated
06	Operator's seat cum tools box	Nil	Incorporated
07	Front Wheel	Nil	Incorporated
08	Primary & secondary extraction roller	3mm sheet bended pipe	6 mm pipe
09	Grabs Roller	Made with MS rod	Made with MS shaft
10	Fiber Receive Stand	Fixed	Adjustable
11	Feeding tray	Length was 300mm	Length was 762mm
12	Rear wheels	Tire size: 4008	Tire size: 60012

Nil: Was not included.

The schematic diagram or model sketch of redesigned Aashkol (Figure 1) is shown below, which was done through modification over the imported KP Model shown in (Figure 1B). The developed Aashkol (Figure 1B) was tested as a laboratory test in the Rangpur Regional Office premises of Practical Action Bangladesh. A laboratory test was done comparing with the imported KP Model (Figure 1C) jute fiber extraction machine.

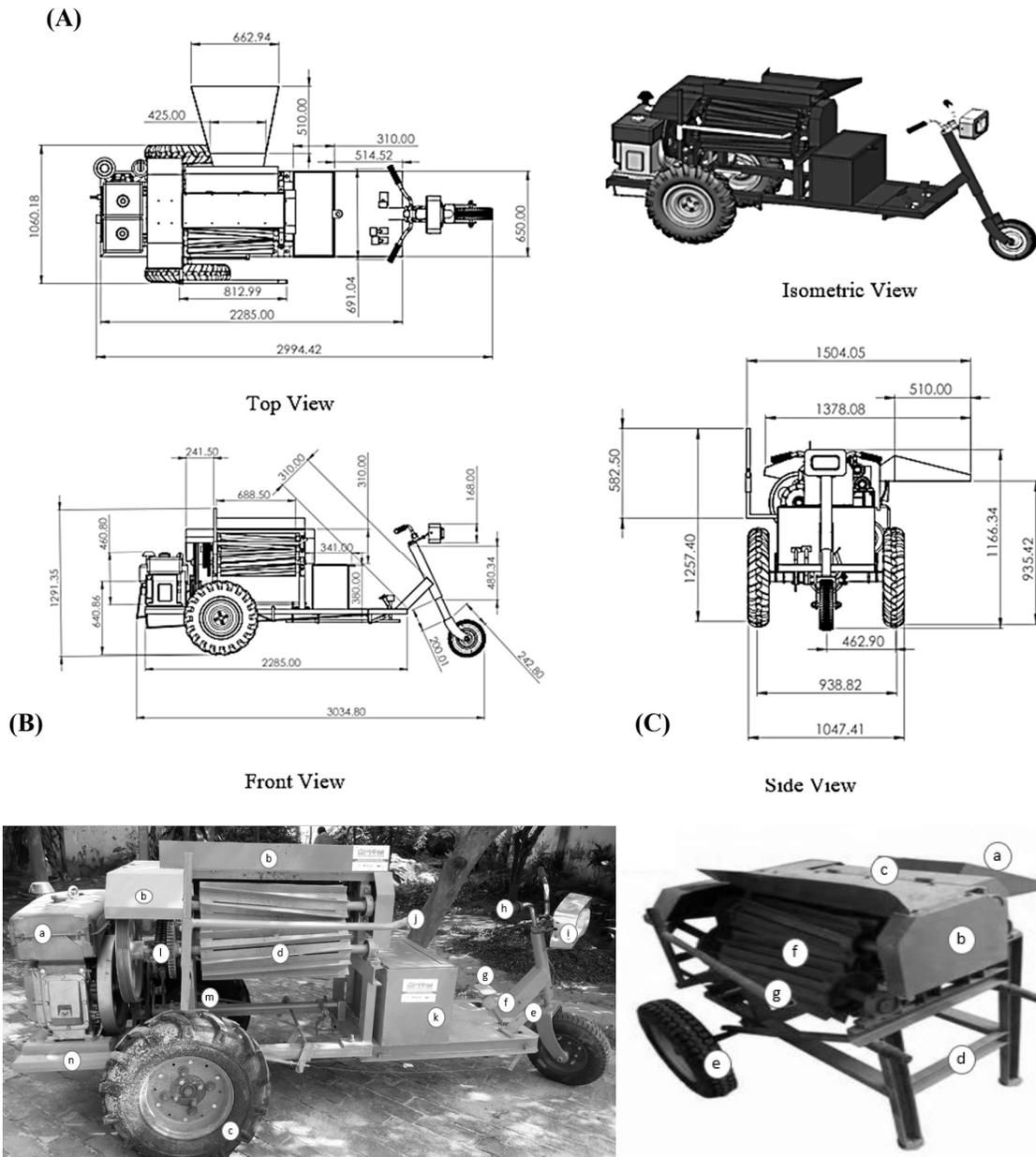


Figure 1 (A) a schematic diagram of Aashkol, (B) the developed Aashkol; a. Engine; b. Protection Cover; c. Wheel-Two Types; d. Extraction Roller; e. Throttle Lever/Accelerator; f. Brake; g. Main Clutch; h. Handle; i. Head Light; j. Fiber receive stand; k. Seat cum toolbox; l. Sprocket; m. Differential gearbox; n. Base Frame , and (C) imported KP model jute extraction machine (C); a. Feeding tray, b. Side protection cover, c. Top protection cover, d. Base frame, e. Wheel, f. Secondary extraction roller, g. Fiber receive stand.

2.1 Working principle of the Aashkol and improved retting method

The machine works on the principle of stripping green ribbon/barks from the harvested stem. The green bark/ribbon peeled off from the whole jute plants can be conveniently retted in much less water (Figure 2) to yield quality fiber of high grade compared to the conventional method (Figure 3). The machine extracts ribbons in full length from the stick while the jute sticks are broken down into smaller pieces (3-6 cm on average).



Figure 2 Extraction of green ribbon/barks from the harvested stem and retting (A) Aashkol base extraction, (B) KP machine base extraction, and (C) Improved retting.

2.2 Traditional retting method

In the traditional method (Figure 3), harvested jute plants were made up into bundles to steep in water. For steeping, the bundles are carried out immediately after harvest. Before steeping, the bundles were left for 3-7 days for the leaves to shed. Then the bundles are steeped in water at least 60 cm to 100 cm water depth, loaded with mud and banana tree. After decomposition, the jute fibers were separated manually from the sticks. Then, fibers were removed from the stalk by the method where single plants were taken, and their fibers were taken off [14].



Figure 3 Traditional retting method of jute.

2.3 Comparison between traditional and Aashkol based improved retting

The traditional retting method is more time-consuming, hazardous, too much laborious, and requires high-cost involvement. On the other hand, the Aashkol based jute fiber extraction and improved retting process are less time-consuming. It can reduce the drudgery, minimize hazardous labor involvement, reduce extraction and retting costs, and upgrade the fiber quality. The traditional method requires more quantity of water for retting comparatively than Aashkol based improved retting.

2.4 Determination of capacity of the Aashkol

A weighted sample of jute stem was fed into the machine at different speeds, size ranges, and maturity stages. The time taken to complete the decortication was recorded. The capacity of the machine was calculated by using the equation (1) below [20]:

$$\text{Jute input capacity of Aashkol} \quad \text{kg/h} = \frac{W_t}{T_t} \quad (1)$$

where, W_t = weight of total jute stem fed, kg; T_t = time taken to feed, h.

The ribbon out-put capacity of the machine was calculated by using the following equation (2) [20]:

$$\text{Ribbon out-put capacity of Aashkol} \quad \text{kg/h} = \frac{W_r}{T_t} \quad (2)$$

where, W_r = weight of ribbon, kg; T_t = time taken, h.

2.5 Field performance evaluation of Aashkol

The developed model of jute fiber extraction machine called Aashkol was multiplied. Total 144 units were fabricated and distributed through a local NGO named Rangpur Dinajpur Rural Service (RDRS), Bangladesh, which was one of the co-applicants of this project who worked for field-level activities implementation in four different districts in the north-west of Bangladesh during 2016-19. The said Aashkols were first time handed over to the working committee member of farmer's federation and jute farmer's groups formed by RDRS, and then they have leased the machines to their members who applied willingly for being the new jute processing local entrepreneurs (NJPLEs). Thirty-six Nos. of machines were distributed as lease in each district out of four districts, namely Rangpur, Gaibandha, Lalmonirhat, and Kurigram, under the said project. The machine was distributed among the selected NJPLEs through arranging a machine distribution ceremony in the presence of some high officials of the Department of Agricultural Extension and local government district level personnel. During jute harvesting time of 2017-19, only forty Aashkols were evaluated in four districts: Rangpur, Gaibandha, Lalmonirhat, and Kurigram; in each district, 10 (ten) Aashkols along with their users were selected. The NJPLEs were selected following some particular selection criteria. One male and one female member (a pair of male & female members) applied for each machine. Through a face-to-face interview and verifying their eligibility, their final selection was conducted by the technical team of Practical Action, Regional Office, along with RDRS Bangladesh. After getting final selection, every pair of selected NJPLE paid 235.85 USD as leasing money to the bank account of Farmer's Federation and Jute Farmer's Group (where federation was not available), of which they were the member for taking the machine as a lease for three years (project period). In each district, 10 Aashkols, along with their users, were selected. Selected Aashkols were operated with three types of jute varieties (Tossa, Deshi, and Kenaf). The time required for extracting green fiber/ribbon of 1336 m² (33 Decimal) land was calculated. Extracted green jute fiber was evaluated for retting comparing with the traditional retting system. Labor requirement and cost of retting the jute fiber were calculated during the experimentation. The dry yield of the jute varieties for different extraction methods were also recorded. All data has been analyzed using the analytical software "Statistix 10" (Source: Statistix 10. 1998. Analytical software. Tallahassee, Fla, USA).

2.6 Financial and business model analysis

The total cost of the Aashkol operations has consisted of fixed cost (FC) and variable cost (VC). Fixed cost included depreciation, interest on investment, shelter, taxes, insurance, and housing costs, etc. A resource is called a variable resource when its quantity is varied at the start of or during the production period. Variable costs comprise with the fuel cost, lubricant, operator's salary, labor cost, repair, maintenance, and miscellaneous expenses.

2.6.1 Fixed costs (FC)

A resource, investment cost, or input is called a fixed resource or fixed cost if its quantity is not varied during the producing period, and thereby, fixed costs are fixed costs. Fixed costs contain the depreciation cost (D) of the machine whether the machine is operated or not, interest on the value of machinery (I), lease value of the machine, shelter, taxes and insurance (STI), and depreciation on tools & equipment. Fixed costs normally remain fixed in total, but if the annual use of the machine is increased it may decline according to the unit over time [21]. To calculate the fixed cost, the following equation was used and assumed [22]

$$\text{Total fixed cost per year} \quad FC_{\text{yr}} = D + I + \text{STI} \quad (3)$$

where, FC_{yr} = Total fixed cost, USD/yr.; D = depreciation cost, USD/yr.; I = interest on investment (bank interest rate on agricultural loans), USD/yr.; STI = shelter, tax and insurance, USD/yr.

$$\text{Fixed cost per h} \quad FC_{\text{h}} = \frac{FC}{\text{EWH}} \quad (4)$$

where, fixed cost per h, FC_{h} EWH = Effective working hour, h

2.6.2 Depreciation

The actual decrease of the fair value of an asset, such as the decrease in the value of a machine or equipment each year due to its use, wear, and tears, and obsolescence when a newer and better model is available. In other words, the depreciated cost is the value of a fixed asset minus all of the accumulated depreciation that has been recorded against it. To calculate the fixed cost, the equation was followed for calculation [22]

$$D = \left[(P - S) \left\{ \frac{(1+i)^L - (1+i)^n}{(1+i)^L - 1} \right\} + S \right] - \left[(P - S) \left\{ \frac{(1+i)^L - (1+i)^{n-1}}{(1+i)^L - 1} \right\} + S \right] \quad (5)$$

where, D = depreciation cost, USD/yr.; P = purchase price, USD; S = salvage value (10% of P), USD; L = Effective working life of machine, yr.; n = Machine age in years at the starting of the year, yr.; i = Yearly bank interest rate in decimal.

2.6.3 Interest on investment (I_i)

The investment interest is included in fixed cost estimation. The charge for using the money invested on the machine irrespective of whether the money was borrowed or not, is known as interest on investment. The interest rate is set to 14% as representing a current average rate for capital interest calculation. For the calculation of interest on invest, the following equation was followed [22]

$$I_i = \frac{P+S}{2} \times i \quad (6)$$

where, I_i = Interest on investment, P = purchase price, USD; S = salvage value (10% of P), i = Yearly bank interest rate in decimal

2.6.4 Taxes, Shelter, and Insurance (STI)

Shelter, tax, and insurance were considered for calculating the fixed cost of the extraction machine [22]

$$STI = 2.5\% \text{ of } P \quad (7)$$

$$R\&M = \text{Annual cost of repair and maintenance} = 3.5\% \text{ of } P \quad (8)$$

2.6.5 Variable cost

A cost is a variable cost if its quantity is varied at the start of or during the production period. Variable costs are the expenditures (power costs, labor, and other inputs) gained on account of machine operation. Variable costs depend on hourly labor or operator cost and fuel, the required working hours for each operation. The cost of operator/labor was calculated as the labor cost in USD per day. The fuel costs were computed from the rate of consumption and multiplying by their respective prices. The following equation was used in the calculation of variable cost [22].

$$VC = L_o + F \quad (9)$$

where, VC = Variable Cost, USD/h; L_o = Operator/labour cost, USD/h

$$F = \text{Fuel cost, USD/h}$$

2.6.6 Annual cost of operation

Annual cost of operation is the regular costs necessary to operate and maintain a machine during its workable life [23]. The total cost of operations of Aashkol was divided into fixed costs and variable costs

$$\text{Annual cost (USD/yr), } AC = FC + VC \quad (10)$$

2.6.7 Payback period

The length of time it takes to recover the cost of an invested capital is called the payback period. This is the time until the net benefits equal the investment cost. More extended payback periods are typically not desirable for investment positions. Shorter paybacks mean more attractive investments. Depreciation is avoided in calculating cost to circumvent double accounting since the initial capital is included in the computation. The payback period of the machine was calculated according to the following equation

$$\text{Payback Period} = \frac{\text{Initial investment (USD)}}{\text{Annual profit}} \quad (11)$$

The investor's required payback period (RPP) is determined by comparison with the acceptability of the investment. When, $PBP < RPP$, the investment can be done; otherwise, investment has to be rejected.

2.7 Multiple operations of “Aashkol.”

For “Aashkol,” the machine is used for jute fiber extraction for around 40 days in a year. Both the financial parameters may achieve earlier by increasing the annual use of the machine. “Aashkol” is designed to use for multipurpose use by shifting the jute extractor with a proper machine and, thus increase the annual operating hours to make it more profitable. “Aashkol” can be utilized as: Closed-drum power thresher: The machine can be utilized as a thresher for about two to three paddy/wheat seasons for threshing paddy/wheat.

- Open-drum thresher: This machine may also be used as an open-drum thresher for long varieties of paddy for threshing.
- Maize Sheller: A maize Sheller may be operated with the replacement of “Aashkol” for corn shelling.

Multi-purposed use of the “Aashkol” is illustrated in (Figure 4). An increase in the operating hour usage intensify the payback period, and it is possible to get back the whole investment within one year.



Figure 4 Multipurpose use of (A) the Aashkol closed drum paddy/wheat thresher: the machine can be utilized as a thresher for about two to three paddy/wheat seasons for threshing paddy/wheat, (B) Open-drum paddy thresher: this machine may also be used as an open-drum thresher for long varieties of paddy for threshing, and (C) Maize sheller: a maize Sheller may be operated with the replacement of Aashkol for corn shelling. Source: Practical action.

2.8 Sensitivity analysis for redesigned Aashkol machine

The sensitivity analysis of the redesigned Aashkol was done following the two-way data sensitivity analysis method. It was a direct method of sensitivity analysis and took into consideration two parameters (annual use of Aashkol in hour and extraction service cost USD) used in the three types of business model. The sensitivity data analyzed using Microsoft Excel. The sensitivity analysis was done increasing and decreasing the service cost 5%, 10%, and 15% on a base cost for three types of the business model as well as increasing and decreasing the annual use of the machine as 80 h, 160 h, and 240 h for both the LSP model and Ownership model. On the other hand, it was done increasing and decreasing the annual use as 100 h, 200 h, and 300 h from the base time of annual use for the multipurpose use model.

3. Results and discussion

3.1 Performance evaluation of the modified jute fiber extraction machine “Aashkol” compared with KP imported machine prototype

The developed jute extraction machine Aashkol was evaluated comparing with the first prototype with green raw jute. Performance of the developed Aashkol and prototype in the laboratory are shown in Table 2. The jute stem input capacity of first prototype was only 3.38 ton/h. Significantly higher stem input capacity (4.99 ton/h) was found in Aashkol, which is 47.63% higher than the first prototype. Output capacity of Aashkol was also significantly higher than the first prototype.

Table 2 Jute fiber extraction performance of the modified Aashkol and KP imported prototype in the laboratory.

Basic features	Karnupannya		Aashkol	
	Jute stem input capacity (ton/h)	Ribbon output capacity (ton/h)	Jute stem input capacity (ton/h)	Ribbon output capacity (ton/h)
Jute extraction capacity of machine	3.38 ^b	0.96 ^b	4.99 ^a	1.43 ^a

Means followed by a common letter are not significantly different by the HSD-test at the 5% level of significance.

3.2 Performance of Aashkol in different location for three types of jute extraction

The Aashkol machine performance was also evaluated for three types of jute in four districts of Bangladesh, and the following results were found. Input and out-put capacities of Aashkol for three types of jute at different locations of Bangladesh are shown in Table 3. The interaction effect of three types of jute and locations of the experimentations on input and out-put capacity of Aashkol were not varied. The single effect of locations on capacity of Aashkol was also non-significant. But input and out-put capacity of Aashkol was significantly varied with the tested three types of jute. The highest jute stem input capacity of Aashkol was found for Kenaf (5.94 ton/h) followed by Tossa (4.59 ton/h) and Deshi (4.00 ton/h) types of jute. The machine could extract ribbon in out-put stand with all tested three types of jute. The highest ribbon output was 1.69 ton/h for Kenaf, followed by Tossa and Deshi jute.

Table 3 Input and out-put capacity of Aashkol for three types of jute at different locations of Bangladesh.

Row Labels	Jute input capacity (ton/h)	Ribbon output (ton/h)
Jute type		
Deshi (D)	4.00 ^c	1.16 ^c
Tossa (To)	4.59 ^b	1.40 ^b
Kenaf (K)	5.94 ^a	1.69 ^a
Location		
Gaibandha	4.85	2.11
Kurigram	4.81	2.09
Lalmonirhat	4.86	2.11
Rampur	4.86	2.06
Analysis of Variance (Probability F Value)		
Three types of Jute	0.00	0.00
Location	0.98	0.94
Three types of Jute * Location	1.00	1.00

a,b,c indicate Means followed by a common letter are not significantly different by the HSD-test at the 5% level of significance

3.3 Effect of Aashkol based extraction on the outcome of different jute stem parts

The effect of Aashkol extraction on the outcome of stem parts for three types of jute is shown in (Figure 5). The highest percentage of ribbon and stick was found in Kenaf, followed by Tossa and Deshi jute. There was no effect of location on ribbon recovery. The highest ribbon out-put was also found in Kenaf, followed by Tossa and Deshi jute.

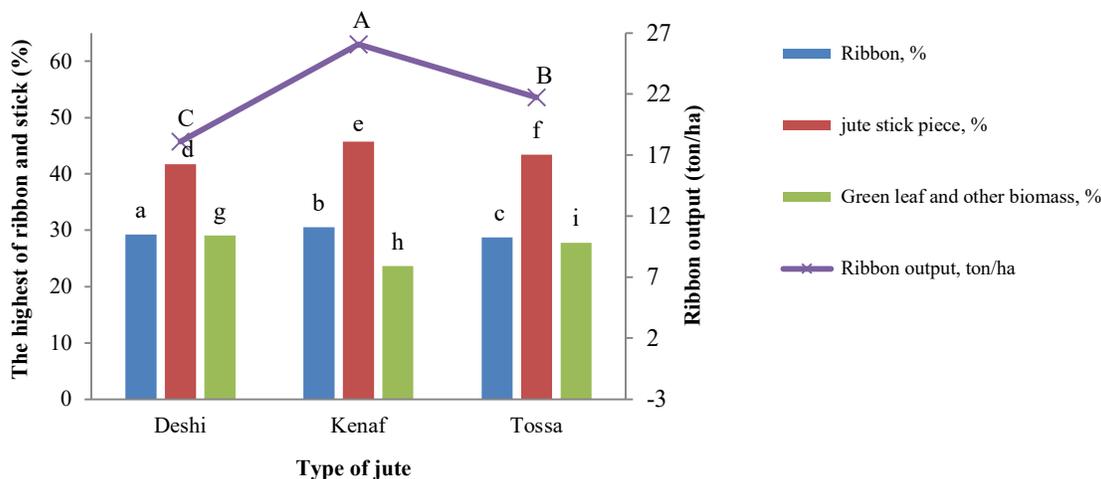


Figure 5 Effect of Aashkol based extraction on outcome of different jute stem parts for three types of jute. a,b,c indicate the data level of Ribbon (%); d,e,f indicate the data level of jute stick piece (%); g,h,i indicate the data level of green leaf and other biomass (%) and A, B, C indicate the data level of ribbon out-put (ton/ha) of Deshi, Kenaf and Tossa jute respectively.]

Dry jute fiber yield was significantly varied with extraction methods, variety, and locations. The highest fiber yield (3.21 ton/ha) was found for using Aashkol based improved extraction and retting method, which produces a 9% higher yield than the traditional retting method. Kenaf produced the highest fiber yield, followed by Tossa and Deshi jute. The fiber yield was, most elevated at Lalmonirhat, which was statistically similar to that at Gaibandha. Again, the fibre yield of Gaibandha and Kurigram was similar.

The lowest fiber yield was found at Rangpur. The interaction effect of extraction methods and the variety on fiber yield were significantly varied (Figure 6 A). The significant highest fiber yield was found for the interaction effect of using Aashkol with Kenaf, followed by Kenaf extracted with a traditional method. The lowest jute fiber yield was found for Deshi jute extracted with a traditional method.

3.4 Labour requirement for fiber extraction and retting

The highest labor requirement (1324 man-h/ha) for fiber extraction and retting was found for the traditional method. Labour requirement was also varied with different varieties. Significantly, the lowest labor requirement (109 man-h/ha) was recorded for Kenaf jute extraction with Aashkol and retting. Deshi and Kenaf jute required a similar amount of labor for traditional retting and extraction of fiber. Extraction with Aashkol and retting with an improved method required 91% less labor than the conventional method. The interaction effect of jute extraction methods and three types of jute on labor requirements and retting was significantly varied (Figure 6B). The lowest labor requirement was recorded for using Aashkol irrespective of three types of jute.

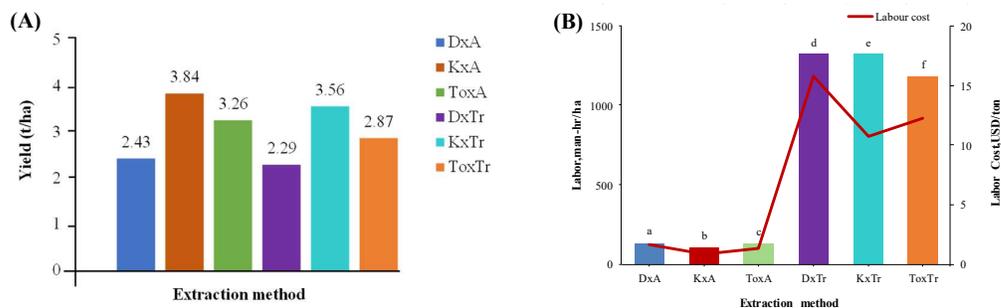


Figure 6 (A) Interaction effect of three types of jute extraction methods as well as the three types of jute fiber yield, and (B) Interaction effects of three types of jute extraction methods, labor requirement as well as the three types of jute fiber yield on labor cost. Dx:A, Kx:A and Tox:A indicate Aashkol based extraction method of Deshi, Kenaf and Tossa jute respectively whereas Dx:Tr, Kx:Tr and Tox:Tr indicate traditional extraction method of Deshi, Kenaf and Tossa jute respectively. On the other hand, a,b,c indicate the data level of labor using Aashkol based extraction of Deshi, Kenaf and Tossa jute respectively whereas d,e,f indicate the data level of labor using traditional extraction method of Deshi, Kenaf and Tossa jute respectively.]

3.5 Effects of fiber extraction methods on labor cost

The highest labor cost for extraction and retting was found in traditional method (Table 4). Labour cost of Aashkol based improved method was 90% less than the traditional method. Labor cost was also significantly varied with three types of jute. The lowest labor requirement was recorded for Kenaf. The interaction effect of jute extraction methods and the three types of jute on labor costs was also significantly varied (Figure 7A). The highest labor cost was required in a traditional method with Deshi jute, and the lowest labor cost was required in the improved method with Aashkol for Kenaf.

3.6 Interaction between fiber extraction methods and fiber price

The highest price of jute fiber was 614.68 USD/ton, which was found in Aashkol based improved processing method. The jute fiber price was significantly varied with three types of jute. The highest fiber price was found in Kenaf. The fiber price of Deshi and Tossa jute were statistically similar. The interaction effect of jute extraction methods and the three types of jute fiber price was significantly varied.

The highest jute fiber price was found in the interaction of Kenaf with improved Aashkol based extraction method followed by that of Kenaf with the traditional method (Figure 7 B). The lowest fiber price was found in jute with traditional extraction, which was also similar to that of Deshi jute fiber produced by the traditional method.

3.7 Interaction between fiber extraction methods and jute stick price

The highest price of jute stick was found for traditional methods. The jute sticks were broken by Aashkol, which reduced the price. Though the price of whole jute stick produced with the traditional method was higher it required more time and some extra investment for drying and handling. Jute stick price was also varied with three types of jute. The highest price of jute stick was found for Deshi jute followed by Tossa jute. The lowest price of jute stick was found in Kenaf jute. The interaction effect of jute extraction method and three types of jute on the price of jute stick was significantly varied (Figure 7 C). The highest jute stick price was found in Deshi jute stick produced by traditional method followed by Tossa jute stick extracted by traditional method. The lowest jute stick price was found for using Aashkol in three types of jute.

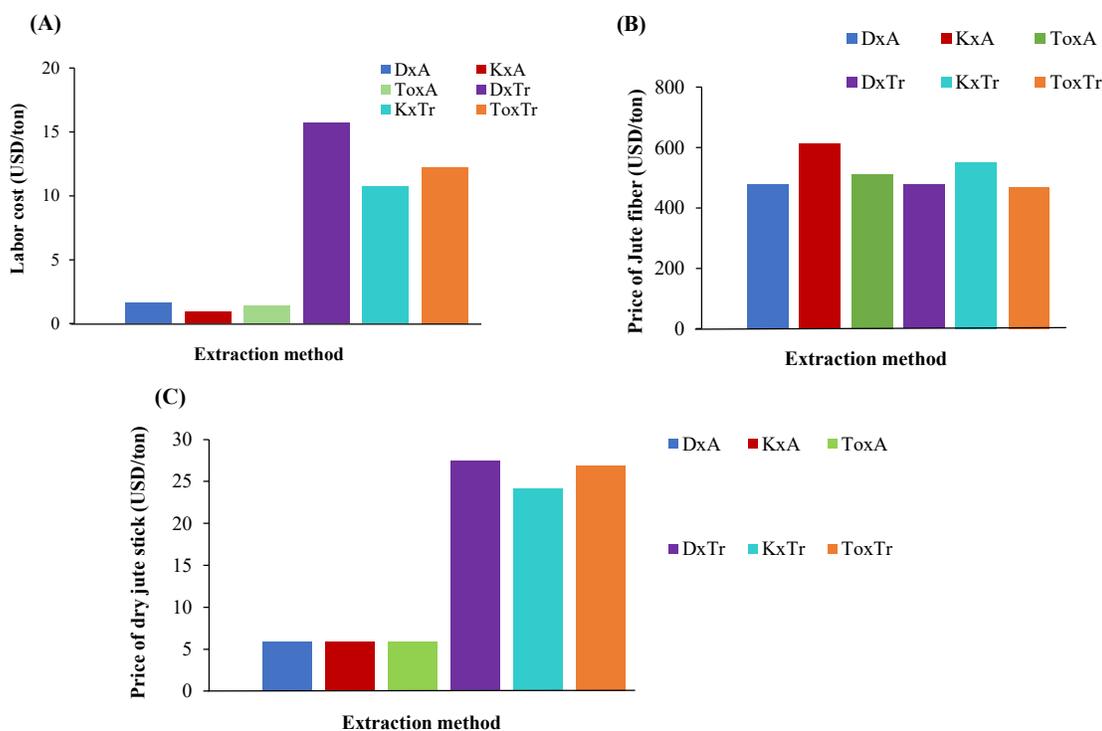


Figure 7 (A) Interaction effect of fiber extraction methods and the variety on labor cost for fiber, (B) Interaction effect of jute extraction methods and the types of jute on price of fiber, and (C) Interaction effect of fiber extraction methods and jute types on price of stick. DxA, KxA and ToxA indicate Aashkol based extraction method of Desi, Kenaf and Tossa jute respectively whereas DxTr, KxTr and ToxTr indicate traditional extraction method of Desi, Kenaf and Tossa jute respectively.]

3.8 Effect of jute extraction methods on retting time

The retting time of three types of jute was significantly varied with jute extraction methods and the jute types (Table 4). But retting time was not varied with locations and interaction effects. The highest retting time (27.11 days) was found for traditional whole stem stepping and manual retting systems. Whereas significantly lowest retting time was found for improve retting systems by extracting ribbon using Aashkol. This improved system can save 45% retting time. Retting time was also significantly varied with three types of jute. The highest retting time was required for Deshi jute followed by Tossa jute. The lowest retting time was required for Kenaf.

Table 4 Effect of jute extraction methods, three types of jute and locations on jute fiber yield, retting time, labor requirement, and price.

Row labels	Retting time, Day	Dry fiber yield (ton/ha)	Labor for extraction and retting (man h/ha)	Labor cost for extraction and retting (USD/ton)	Price of jute fiber (USD/ton)	Price of jute stick (USD/ton)
Jute extraction methods (EM)						
Aashkol (A)	14.78 ^b	3.21 ^a	125.70 ^b	1.30 ^b	537.96 ^a	5.90 ^b
Traditional (Tr)	27.11 ^a	2.94 ^b	1276.00 ^a	12.93 ^a	498.92 ^b	26.15 ^a
Jute types						
Deshi (D)	21.71 ^a	2.41 ^c	729.34 ^a	8.70 ^a	481.10 ^b	16.68 ^a
Tossa (To)	20.99 ^b	3.08 ^b	657.00 ^b	6.83 ^b	491.23 ^b	16.39 ^b
Kenaf (K)	20.13 ^c	3.73 ^a	716.21 ^a	5.82 ^c	582.99 ^a	15.00 ^c
Locations						
Gaibandha	20.80	3.09 ^{ab}	700.85	603.61	43872.92	1358.71
Kurigram	20.78	3.05 ^{bc}	700.85	603.61	44168.75	1358.71
Lalmonirhat	21.20	3.12 ^a	700.85	603.67	43939.58	1358.71
Rangpur	20.98	3.04 ^c	700.85	601.99	43872.92	1358.71
Analysis of Variance (Probability F Value)						
EM	0	0	0	0	0	0
Three types of jute	0	0.0043	0	0	0	0
Location	0.4885	0	1	0.9996	0.9388	1
EM * Three types of jute	0.3436	0.9654	0	0	0	0
EM * Location	0.9732	0.0001	1	0.9998	0.8784	1
Three types of jute * Location	0.9955	0.9212	1	1	0.9861	1
EM * Three types of jute * Location	0.9941	0.9381	1	1	0.9829	1

Aashkol (A): The redesigned and fabricated jute extraction machine at local metal workshops in Bangladesh branded with the name "Aashkol". Traditional (Tr): The conventional method of jute extraction where machine is not used. Deshi (D), Tossa (To) and Kenaf (K) are the types of jute used in this study. Gaibandha, Kurigram, Lalmonirhat, Rangpur are the name of four districts of Bangladesh which are situated in north west region of Bangladesh and selected as the study areas of this study. EM indicates the extraction methods of fiber followed in this study. Three types of jute indicate the types of jute Deshi, Tossa and Kenaf respectively. Location is the study areas that indicate the four districts Gaibandha, Kurigram, Lalmonirhat, Rangpur situated in north west region of Bangladesh. EM*Three types of jute mean the interaction between extraction methods and types of jute. EM* Location defines the interaction between extraction methods and locations (study areas). Three types of jute * Location defines the interaction between types of jute and locations (study areas). EM* Three types of jute * Location indicate the interaction among extraction methods of fiber, types of jute and locations (study areas).]

3.9 Financial analysis of different business models

The developed Aashkol was utilized in different country locations with project support of Practical Action, Bangladesh. After completion of the project, farmers will not get project support. Thus, different business models were evaluated for the profitable utilization of Aashkol. The main three models are the local service provider (LSP) model, ownership model, and multipurpose use of Aashkol model. The financial analysis of Aashkol used as the local service provider (LSP) model is shown in Table 5. The extraction cost of ribbon from the green jute stem was 0.99 USD per ton. Local Service Providers delivered the extraction service with 2.06 USD per ton which gave him 1.07 USD profit per ton. Using the Aashkol with LSP model, 5.35 USD profit can be found per h. The payback period of the Aashkol will be only 1.24 years with the LSP model.

The ownership model is shown in Table 5. In this model, the owner of the machine is considered the user. Big farmers who have produced jute or Kenaf in around 5 hectares of land could use the Aashkol with ownership model to get a best economic return. The extraction rate (0.99 USD/ton) was the same as the LSP model. The cost of traditional jute extraction methods is more than 11.79 USD per ton. If the owner of Aashkol considers the service rate as only 7.08 USD per ton, the profit will be 30.41 USD per h. Thus, the payback period in the ownership model will be only 70 h or 0.22 years.

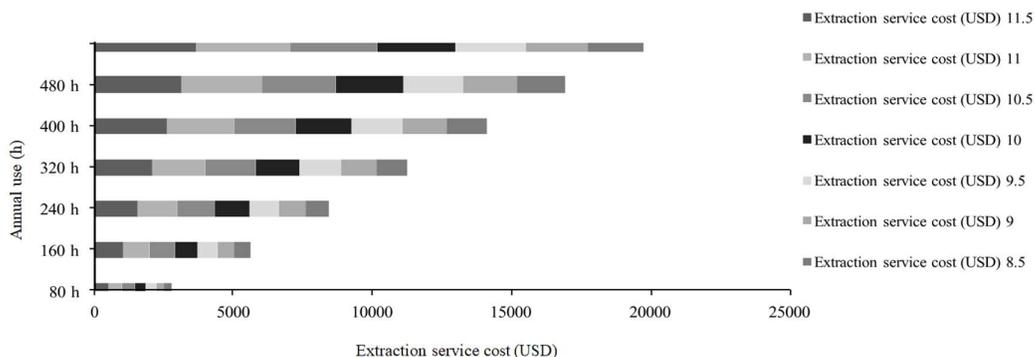
The financial analysis of Aashkol used as a multipurpose use model is shown in Table 6. In this model, the chassis and engine of the Aashkol were used for operating the BARI multi-crop thresher and BARI maize sheller as alternate use during the off-season of Aashkol. In this model, the initial investment cost (USD 3125) was higher than that of others models (USD 2122.64). But due to more annual use of the machines in this model, operation cost (USD 3.92) was less than the operation cost of other models (USD 4.97). Therefore, with the full operation of the expected operating hours, this model can produce 9603.15 USD per year. Thus, the payback period will be 0.33 years only in the multipurpose use model.

Table 5 Financial analysis of Aashkol used as Local service provider (LSP) model, Ownership model, and multipurpose use model.

Parameters	Unit	Local service provider (LSP) model	Ownership model	Multipurpose use model
Purchase price of engine	USD	412.74	412.74	412.74
Purchase price of chassis	USD	648.58	648.58	648.58
Purchase price of Aashkol	USD	1061.32	1061.32	1061.32
Purchase price of BARI multicroop thresher	USD	0	0	471.70
Purchase price of BARI maize sheller	USD	0	0	530.66
Total purchase price	USD	2122.64	2122.64	3125.00
Annual use				
Annual use of thresher	H	0	0	400
Annual use of maize sheller	H	0	0	320
Annual use of Aashkol	H	320	320	320
Total annual use	H	320	320	1040
Effective operation time	h/day	8	8	8
Economic life, L				
Economic life of chassis	Yr	7	7	7
Economic life of Engine	Yr	7	7	7
Economic life of Aashkol	Yr	7	7	7
Machine capacity	ton/h	5	5	-
Fixed cost				
Salvage value (10% P)	USD/yr	212.26	212.26	312.50
Depreciation, D	USD/yr	272.91	272.91	272.91
Interest on Investment, I, (12%)	USD/yr	140.09	140.09	206.25
STI (Tax, Shelter and Insurance), (2.5%)	USD/yr	53.07	53.07	78.13
Repair and Maintenance (3.5% P)	USD/yr	74.29	74.29	109.38
Total Fixed cost, (FC)	USD/yr	540.36	540.36	666.66
Total Fixed cost	USD/h	1.69	1.69	0.64
Variable cost				
Labour cost	USD/h	2.36	2.36	2.36
Fuel cost	USD/h	0.92	0.92	0.92
Total variable cost, (VC)	USD/h	3.28	3.28	3.28
Total cost, (FC+VC)	USD/h	4.97	4.97	3.92
Extraction cost	USD/ton	0.99	0.99	
Service rate				
Aashkol Service rate	USD/h	154.78	530.66	10.32
Aashkol Service rate	(USD/ton)	2.06	7.08	
Thresher Service rate	USD/h			11.79
Maize sheller Service rate	USD/h			17.69
Aashkol Service income	USD/yr			3301.89
Thresher Service income	USD/yr			4716.98
Maize sheller Service income	USD/yr			5660.38
Annual service income	USD/yr			13679.25
Annual service cost	USD/yr			4076.10
Profit	USD/ton	1.07	6.08	
Profit	USD/h	5.35	30.41	
Annual profit	USD/yr			9603.15
Payback period	yr.	1.24	0.22	0.33

3.10 Sensitivity analysis for redesigned Aashkol machine

The machine purchase price was 2123 USD, and annual base use of Aashkol was 320 h, service cost was 5 USD for the LSP and Ownership business model. The extraction service cost was 10 USD and 35 USD for LSP model and Ownership model, respectively. In the multipurpose use model, the total investment cost (machine purchase cost) was 3125 USD, and the total annual use of a machine (as multipurpose use) was 1040 h, multipurpose use cost was 4 USD where the average multipurpose service cost was 13 USD. The following tables have shown how sensitive the profit is to changes in some of the input variables like annual use and service cost.

**Figure 11** Profit changes with the change of annual use of time and service cost in LSP business model of Aashkol.

From figure 11, it is found that if the machine can be used for annual use of 560 (h), it seems to optimize total profits at all extraction service costs. When due to some difficulties or odd situations, it will be got comparatively low profit. When the annual use is gradually decreased, the profit will be reduced gradually. The entrepreneurs will reach the losses when the annual use will be less than or equal to zero hours of use. The service cost reaches from maximum service cost to minimum service cost, or the machine will face troubles or out of operation. The minimum profit (282.6 USD) will be got when the service cost will be 8.5 USD, and the annual use will be 80 h.

Similarly, trends of profit sensitivity for the ownership business model are also observed. It has also shown that the entrepreneur will get maximum profit from the annual used time and extraction service cost, which will be greater than the base service cost (USD 35) and vice versa.

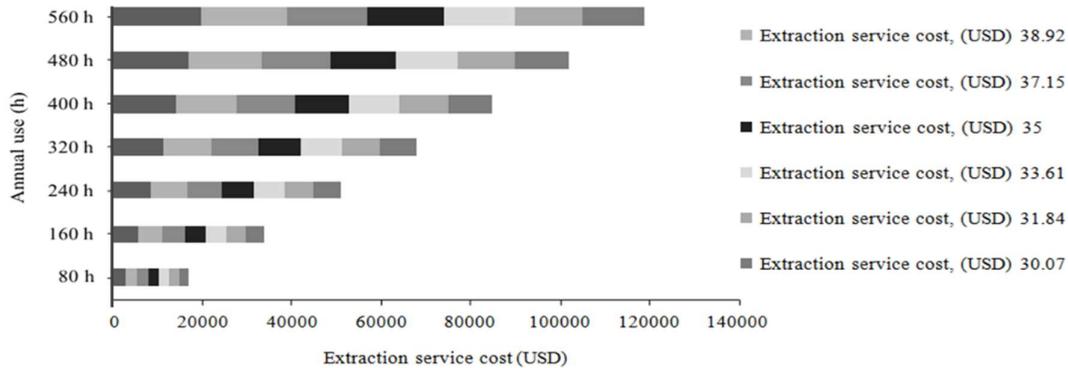


Figure 12 Profit changes with the change of annual use of time and service cost in ownership model of Aashkol.

When the machine use time is decreased, and the service cost will also gradually decrease, the profit will also reduces gradually (Figure 12). If the machine use time reaches to zero hours, no profit will come, and the entrepreneur will be looser. But it will never happen normally. So, the machine will not be a loss item for business without operation and may decide to disseminate.

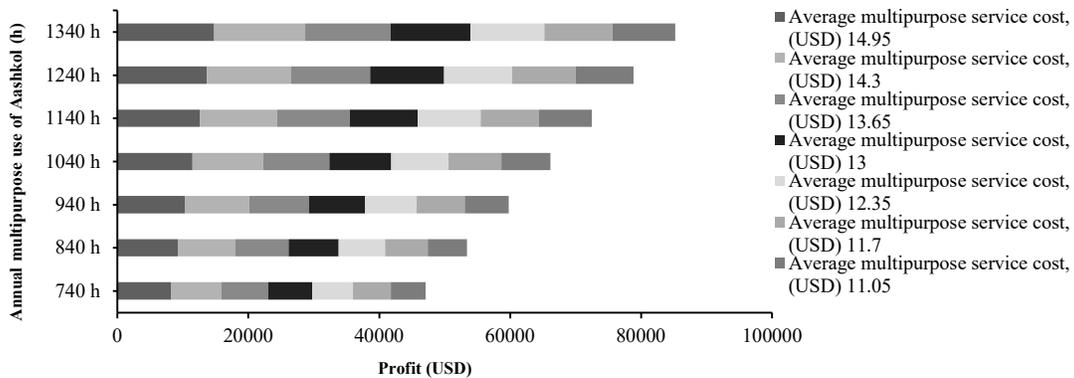


Figure 13 Profit changes in Multipurpose business model of Aashkol with respect to the change of different level of annual use of time and service cost.

Figure 13 shows that the maximum profit will gain for the combination of 1340 h annual uses with the service cost of 14.95 USD. Minimum profit will be got for 740 h use in respect to 11.05 USD service cost or both are when less than that.

3.11 Partial budget analysis of Aashkol

Partial budget analysis between three business models was done and showed the following results (Table 11 and Table 12)

Table 11 Partial budget analysis between LSP business model Vs. Multipurpose business model of Aashkol.

LSP business model of Aashkol (machine purchase price USD 2122.64 & Total annual use=320 h) Vs Multipurpose business model of Aashkol (Including Thresher & maize sheller machine purchase price USD 3125 & Total annual use=1040 h)

Section I – Costs

Additional Costs

Multipurpose business model of Aashkol:

Fixed cost = 0.64 USD /h
(where considered depreciation for 7 years economic year of machine, Interest on Investment 12%, Tax, Shelter and Insurance 2.5%, Repair and Maintenance 3.5% of purchase price)

Variable cost = 3.28 USD /h

Total cost (Fixed plus Variable) per h= 3.92 USD Total cost for annual use of 1040 h = 4076.8 USD

Reduced Returns

LSP business model of Aashkol: Total Service cost for 320 h annual use of Aashkol= 5* 320*52.06 USD = 3296 USD

Total Costs (A + B) = 7372 USD

Additional Costs

Multipurpose business model of Aashkol:

Fixed cost = 0.64 USD /h
(where considered depreciation for 7 years economic year of machine, Interest on Investment 12%, Tax, Shelter and Insurance 2.5%, Repair and Maintenance 3.5% of purchase price)

Variable cost = 3.28 USD /h

Total cost (Fixed plus Variable) per h= 3.92 USD Total cost for annual use of 1040 h = 4076.8 USD

Reduced Returns

LSP business model of Aashkol: Total Service cost for 320 h annual use of Aashkol= 5* 320*52.06 USD = 3296 USD

Total Costs (A + B) = 7372 USD

Section II – Benefits

Additional Returns

Multipurpose business model of Aashkol:

Aashkol Service income for 320 h uses =3301.89 USD

Thresher Service income for 400 h uses =4716.98 USD

Maize sheller Service income for 320 h uses =5660.38 USD

Total Annual service income for total 1040 h uses of above three machines = 13679.25 USD

Reduced Costs

LSP business model of Aashkol:

Fixed cost=1.69 USD /h
(Where considered depreciation for 7 years economic life of machine, Interest on Investment 12%, Tax, Shelter and Insurance 2.5%, Repair and Maintenance 3.5% of purchase price)

Variable cost = 3.28 USD /h
(where considered labor cost and fuel cost)

Total cost (Fixed plus Variable) per h= 4.97 USD

Total cost for annual use of 320 h = 1590.4 USD

Total Benefit= (D+ E) = USD 15269.65

Section III – Analysis

G. Net Change in Profits (F – C) = 7897 USD

H. Benefit/Cost Ratio (F ÷ C) = 2.07

From this partial budget analysis (Table 11), it is to be found that, for every 1 USD spent on following the alternative of Multipurpose business model of Aashkol to LSP business model of Aashkol, the entrepreneur will generate 2.07 USD in returns, or a profit of 1.07 USD on every dollar spent. But there is no option of multipurpose use in KP machine because it is not a separable machine. Moreover, the engine attached with the KP machine is a low powered engine (which is not sufficient for operating the multi-crop Thresher and maize sheller. So, this machine can be used only for jute fiber extraction and can be replaced with the Aashkol.

Table 12 Partial budget analysis between LSP business model Vs. Ownership business model of Aashkol.

Partial budget analysis of three business models: LSP Vs. Ownership business model of Aashkol (machine purchase price USD 2122.64 & Total annual use=320 h)

Section I – Costs
Additional Costs
LSP business model of Aashkol:
Total Service cost for 320 hs annual use of Aashkol= 5* 320*52.06 USD = 3296 USD
Additional Costs
LSP business model of Aashkol:
Total Service cost for 320 hs annual use of Aashkol= 5* 320*52.06 USD = 3296 USD
Reduced Returns
Ownership business model of Aashkol: Total Service cost for 320 hs annual use of Aashkol= 5* 320*52.06 USD = 3296 USD
Total Costs (A + B) = 6592 USD
Section II – Benefits
Additional Returns
LSP business model of Aashkol:
Fixed cost=1.69 USD /h
(where considered depreciation for 7 years economic life of the machine, Interest on Investment 12%, Tax, Shelter and Insurance 2.5%, Repair, and Maintenance 3.5% of purchase price)Variable cost = 3.28 USD /h
(where considered labor cost and fuel cost)
Total cost (Fixed plus Variable) per h= 4.97 USD
Total cost for annual use of 320 h = 1590.4 USD
Additional Returns
LSP business model of Aashkol:
Fixed cost=1.69 USD /h
(where considered depreciation for 7 years economic life of the machine, Interest on Investment 12%, Tax, Shelter and Insurance 2.5%, Repair, and Maintenance 3.5% of purchase price)Variable cost = 3.28 USD /h
(where considered labor cost and fuel cost)
Total cost (Fixed plus Variable) per h= 4.97 USD
Total cost for annual use of 320 h = 1590.4 USD
Reduced Costs
Ownership business model of Aashkol:
Fixed cost=1.69 USD /h
(where considered depreciation for 7 years economic life of the machine, Interest on Investment 12%, Tax, Shelter and Insurance 2.5%, Repair, and Maintenance 3.5% of purchase price)
Variable cost = 3.28 USD /h
(where considered labor cost and fuel cost)
Total cost (Fixed plus Variable) per h= 4.97 USD
Total cost for annual use of 320 h = 1590.4 USD
Total Benefit= (D+ E) = 3180.8 USD
Section III – Analysis
G. Net Change in Profits (F – C) = -3411.2 USD
H. Benefit/Cost Ratio (F ÷ C) =0.48

We know, if the answer is greater than zero, adopting the alternative will increase the business overall profit; if the answer is negative, the current practice is more profitable than the alternative. So, LSP model is profitable model than the ownership model because in the ownership model, the owner only extracts his own jute fiber and will not income or get any cash profit; he will get an equivalent kind of profit here.

4. Conclusion

The developed jute extraction machine “Aashkol” performed better than the KP model as it was modified and redesigned to overcome or address the problems or limitations found in KP machine. Now, farmers expectation is to much fulfilled with the satisfactory performance of the modified redesigned machine. The capacity of the Aashkol is 48% higher than the KP prototype and helps the farmers to adopt improved retting techniques which can reduce almost half the time required for the traditional retting system. The performance evaluation and the three types of the business model of Aashkol were successfully done and tested from the study. Even from sensitivity analysis, it is found that the Aashkol is an economically viable technology for dissemination. From this study, it is seen that the Aashkol based retting system can increase the dry fiber yield. This machine can also reduce labor requirement and the cost of labour compared with the traditional method and improve the jute fibre quality, which is being reflected in higher jute fiber price. Among the tested business models, the ownership model and the multipurpose use model of Aashkol are giving better financial options. Though the initial investment is high in multipurpose use model, but most profitable, which can ensure efficient use of the technology and the investment. Some limitations of the study like the KP model imported machine were collected from KP for a definite or limited time and for that, and some kinds of data could not completely collect from field. It would be better if such a machine could be collected permanently through the project. So, it is recommended to further study through long-term project designing and test the adaptability, and suitability of the Aashkol machine comparing with the imported machine and traditional practice. From sensitivity and partial budget analysis, it is revealed that the developed Aashkol could be widely adopted as an economically viable and technologically efficient machine over KP machine and traditional jute retting.

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