

INNOVATION OF STARCH FIBER SEPARATOR IN THE PULPER AND FIBER SEPARATOR MACHINE FOR ARROWROOT TUBERS (*Maranta Arundinacea* L) TO IMPROVE MACHINE CAPACITY AND PERFORMANCE

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Abstract. Innovation is needed to improve the performance of the arrowroot (*Maranta arundinacea* L.) grinding machine and arrowroot pulp pressing in the production of arrowroot flour at the An-Nur MSMEs. Until now, arrowroot grinding using a rotary crusher and pressing using a centrifugal separator has not been optimal. The objective of this study is to innovate the rotary crusher machine with a pulper machine, the centrifugal separator with a starch-fiber separator, and to combine these two machines into a single unit. The innovation is aimed at increasing production capacity, pulping efficiency, and the efficiency of fiber and slurry separation in arrowroot pulp. The innovation stages include discussions with partners, designing the machine in accordance with the results of discussions with partners, preparing materials and tools, assembling machine components based on technical drawings, assembling and testing the machine (production capacity, pulping efficiency, and separating efficiency). The machine innovation resulted in the following specifications: the pulper machine uses a 1/2 HP electric motor, a 65 mm pulley diameter, and an ADV 125 V-belt. The starch fiber separator machine uses a 1 HP drive motor, a 200 mm pulley, and an A65 belt. UCP 25 bearings are mounted on a 130×130×8 mm angle iron frame with a low carbon steel cover. Dimensions (Length × Width × Height) = 700×350×1300 mm. This machine has a production capacity of 53.33 kg/hour, an average pulping efficiency of 94.45% and an average fiber separation efficiency of 68%. The machine's performance can increase production capacity by 77.76% compared to the previous machine used by the partner.

Key Words: efficiency, innovation, capacity, starch-fiber separator, arrowroot flour

1 INTRODUCTION

Arrowroot (*Maranta arundinacea* L.) is a local starch source with the potential to be developed as a raw material for the food industry. Arrowroot starch is usually available in flour form and is often referred to as arrowroot flour. According to (1), arrowroot starch source with potential for use in the food industry based on its functional properties. Arrowroot starch has the advantages of relatively high amylose content, stable viscosity, and easily digestible gel properties, making it very suitable for special food products such as baby food and food for people with digestive disorder (2)(3).

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Double-modified arrowroot flour has great potential for food applications requiring enhanced thermal and emulsification performance (4). Arrowroot starch flour has the potential to be developed and diversified into various processed products (5).

The nutritional content of arrowroot starch flour consists of low crude protein ($0.72 \pm 0.02\%$), crude fat ($0.26 \pm 0.19\%$), and crude fiber ($1.00 \pm 0.09\%$), which indicates the purity of the flour. The contents of sodium, potassium, calcium, iron, and zinc are 52.6 mg/kg, 4,312.95 mg/kg, 382.67 mg/kg, 9.07 mg/kg, and 2.59 mg/kg, respectively. The low water content indicates a longer shelf life for stored arrowroot flour.(6)(7). Arrowroot tubers, a source of starch, are fibrous and resilient, so producing arrowroot flour requires several stages, including crushing the tubers, separating the fibers, settling, and drying. Problems often occur during the processing of arrowroot tubers, particularly during the crushing and separating stages. These challenges result in suboptimal flour production (7).

This problem was also experienced by the An-Nur MSME (Micro Small and Medium Enterprises) in Polokarto Village, Central Java. Polokarto Village is one of the arrowroot-producing villages in Sukoharjo Regency. Arrowroot tuber production reaches 13 tons per hectare per year. The area planted with arrowroot covers approximately 7,798 hectares (8). The area used for arrowroot cultivation includes home gardens (Figure 1).



Fig 1. Cultivation of arrowroot tubers at An-Nur MSMEs, Polokarto, Sukoharjo

The An-Nur MSMEs produces processed foods from arrowroot tubers, in the form of arrowroot chips and arrowroot flour (Figure 2). The arrowroot chips and flour are marketed primarily in the Soloraya region. To date, arrowroot chip production has faced relatively few significant challenges. However, problems have arisen with arrowroot flour production, particularly related to low production capacity, which has prevented it from meeting consumer demand. This low production capacity is caused by the arrowroot tubers pulping machine and fiber separator not working optimally and efficiently. The pulping process produces arrowroot tubers pulp, which must then be separated from the fiber and slurry. This slurry is then processed into arrowroot flour.

The arrowroot pulping process carried out by the An-Nur MSMEs has been using a rotary crusher to produce arrowroot pulp. This machine is known to produce arrowroot pulp that is partially incomplete crushed and not smooth. Furthermore, the machine's capacity is only around 30 kg/hour. The arrowroot pulp is then squeezed using a centrifugal separator to separate the slurry and fiber. The use of the centrifugal separator is known to be suboptimal due to the imperfect squeezing process. The fiber still contains arrowroot starch, which should be included in the slurry. Therefore, innovation is needed to solve this problem.



Fig 2. Production of arrowroot chips and arrowroot flour at An-Nur MSME

According to research results (9) it was stated that the rotary system crusher made was able to grind arrowroot tubers optimally at 30 kg/hour or 2 kg/4 minutes with the selected pulley diameter and screen hole diameter of 4 inches and 2 mm. Under these conditions, the yield of arrowroot starch flour obtained was 11.79%. It was further stated that the centrifugal separator made was able to squeeze the crushed arrowroot tubers with a higher percentage of arrowroot starch obtained than the manual method. Squeezing the crushed arrowroot tubers carried out with a centrifugal separator provided a higher percentage of starch obtained (13.5%) compared to the manual method (11.87%). Improvements to the tool still need to be done because in its operation, the tool still requires pressure to prevent shaking when the tool is working. The shaking will be greater if the tool is operated for a longer time. Therefore, it is necessary to improve the tool to be more efficient and produce better quality flour, hygienic, and fast production time with the innovation of the arrowroot tubers pulping and separating machine, with the innovation of starch fiber separator.

Innovation is needed to replace the rotary crusher with a pulper and the centrifugal separator with a fiber starch separator. Furthermore, the two units need to be combined into a single unit. This integration will streamline the transfer of power. Previous research suggests that starch separation efficiency can be improved through better machine design, optimal fiber and starch separation, and the selection of machine materials that meet food standards (10)(11)(12).

An arrowroot grinding machine was developed and evaluated in terms of functional performance by Pascua in 2018. The evaluation results revealed that the model was capable of grinding arrowroot tubers with an average power consumption of 0.85 kW, a processing time of 7.85 minutes, a capacity of 46.6 kilograms per hour, and an efficiency (starch recovery) of 16.6%. These results still require innovation for development in MSMEs in Sukoharjo Regency. Meanwhile, (10) stated that starch separation efficiency depends on the total mass of free and semi-bound starch separated from cassava pulp by rasping and extraction units, respectively. The starch fiber separator innovation shows promise for application in MSMEs.

Before the machine is implemented in real conditions, trials are necessary to cover production capacity and efficiency. The purpose of this research is to innovate a rotary crusher with a pulper, a centrifugal separator with a starch-fiber separator, and then combine the pulper and starch-fiber separator into a single unit. The application of this machine is expected to increase production capacity, folding efficiency, and efficiency of fiber separation from slurry.

2 Materials and Methods

2.1 Materials

The materials used for the innovation of the pulper and fiber separator machine for arrowroot tubers consist of raw materials and materials for making the machine.

2.1.1 Raw Materials

The raw material used in this innovation was fresh arrowroot tubers taken from Polokarto village, Sukoharjo regency.

2.1.2 Materials used for the pulper and fiber separator machine

Materials used for the pulper and fiber separator machine innovation for arrowroot tubers include: 3 mm plate for the hopper, hollow iron for the body, carbon steel for the frame (130×130×8 mm angle iron), a 1 HP drive motor with 65 mm and 200 mm pulleys, ADV 125 V-belt, and UCP 25 bearings and SS304 stainless steel for all materials that come into direct contact with food.

2.2 Methods

The stages of innovation for the pulper and fiber separator machines and performance testing in the manufacture of arrowroot flour include:

- a) Discussion with partners to reach an agreement that suits their needs. The partner needs a machine to pulp arrowroot tubers and to separate the fibers from the arrowroot pulp. In addition, that machine needs to be combined into a single unit.
- b) Design and design simulation using SolidWorks 2018 design software, which is already licensed.
- c) Calculation of production capacity using indicators: loading, processing, unloading, and idle/cleaning times. Next, the results of the production capacity calculations obtained are compared with the previous machine production capacity.
- d) Material preparation includes:
Cutting plates, making porous grinding cylinders, screw cylinders, shafts, hoppers, screens, bearings, frames, outlets for slurry and fiber residue.
- e) Assembly of 1 HP drive motor components with 65 mm and 200 mm pulleys, ADV 125 V-belt, and UCP 25 bearings, frames, and other components in point d). The motor power required to drive the pulper machine is ½ HP or 373 Watts, while the fiber separator machine requires 1 HP or 746 Watts.
- f) Finishing includes painting the frame and installing protective covers.
- g) Performance testing
The parameters tested include production capacity (kg/hour), arrowroot tubers pulping efficiency, and the efficiency of separating fiber and starch from arrowroot pulp. The experiment to calculate the efficiency was carried out 4 times each; the data obtained was calculated as the average and standard deviation.

The stages of innovation for the pulper and fiber separator machine for arrowroot tubers were carried out through the stages shown in Figure 3.

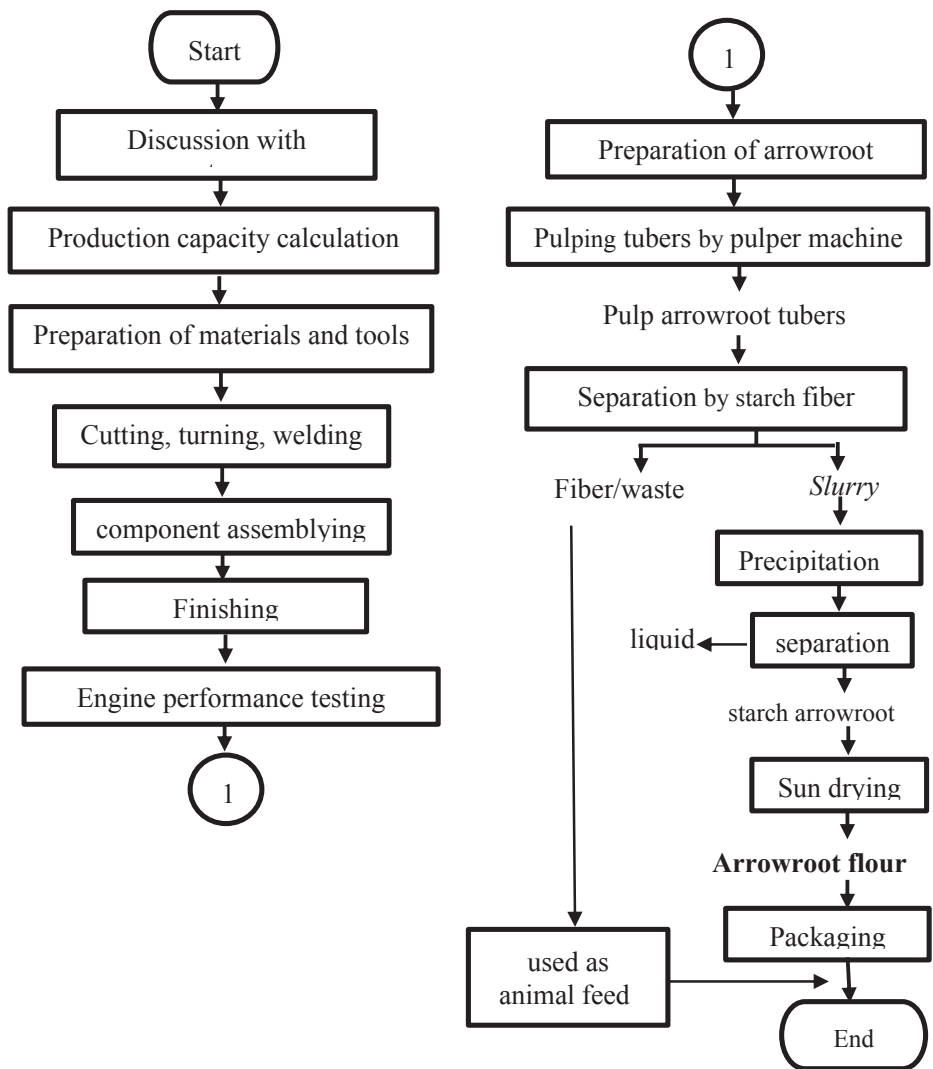


Fig 3. Stages of innovation in pulper and fiber separator machines and performance testing in the manufacture of arrowroot flour

3 Results and Discussion

3.1 Innovation Results

Based on discussions with partners, an agreement was reached on the partner’s needs in arrowroot flour production, including an arrowroot tubers pulping and a fiber separator from an arrowroot pulp. In addition, each machine needs to be combined into a single unit. The result of combining the two machines into a single unit and the design are shown in Figure 4.

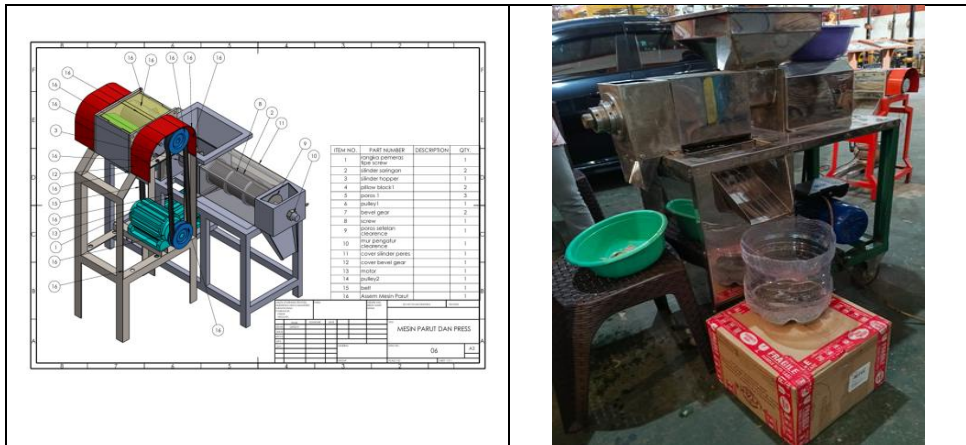


Fig 4. Results of pulper and fiber separator machine innovations

The innovative machine has the following specifications:

- The pulper machine uses a 1/2 HP electric motor and a 1 HP fiber separator machine drive motor.
- The pulley diameter is 65 mm for the pulper machine and 200 mm for the fiber separator machine.
- The V ADV 125 belt is used for the pulper machine, and the A65 belt is used for the fiber separator machine.
- UCP 25 bearings, mounted on a 130×130×8 mm angle iron frame with a low carbon steel cover.
- Dimensions=Length × Width × Height = 700×350×1300 mm.

The machine, which is a combination of a pulper and fiber separator, works as follows:

- The pulping process is carried out in the pulper to produce arrowroot pulp.
- The arrowroot is fed into the pulper inlet by pressing it down.
- The tubers are pulped by a rotating rotor or porous cylinder to produce arrowroot pulp.
- The arrowroot pulp is produced through the outlet and is collected in a container.
- The arrowroot pulp is then fed into the hopper of the fiber separator machine.
- The pulp that enters is pressed by a rotating screw and then separated by the fiber separator into fibers/pulp and slurry. The fibers exit through the fiber/pulp outlet, while the slurry exits through the slurry outlet and is collected in a container.
- The resulting slurry is settled, and the sediment is separated from the liquid. The sediment is dried to produce arrowroot flour.

3.2 Production capacity

The production capacity of the machine, which is a combination of a pulper and fiber separator, is calculated using the following formula:

$$\text{Production capacity} = 3600 / \text{Cycle time} \times \text{operating hours}$$

Note: 1 hour = 3600 seconds.

Cycle time is calculated as follows:

- Loading time is required from when the arrowroot tubers enter the pulper machine inlet to when they become arrowroot pulp. The experimental results for 1.5 kg of arrowroot tubers needed 5 minutes.

- 2) Processing time is required for the fiber separator machine to separate the fibers and slurry. The experimental results for 1.5 kg of arrowroot tubers required 3.5 minutes.
- 3) Unloading time is required to remove the fiber/residue and slurry.
The experimental results required 2 minutes.
- 4) Idle/cleaning time is the downtime or cleaning time before the next batch, lasting 3 minutes.

Total cycle time = Loading time + Processing time + Unloading time + Idle time
 = 5+3.5+2+3=13.5 minutes = 810 seconds

Production Capacity = (3600/810) x 8 operating hours
 = 4.44 cycles/hour x 8 operating hours
 = 35.5 cycles/hour
 = 1.5 x 35.5 = 53.33 kg/hour

This production capacity is higher than that reported in the 2014 study by (9), which was only 30 kg/hour. Therefore, this innovation has increased the capacity of (53.33-30)/30 x 100% = 77.76%. The integration of a pulper and starch–fiber separator machine for arrowroot tubers successfully improved machine performance especially of production capacity compared with the conventional rotary crusher and centrifugal separator. The innovated machine reached a production capacity of 53.33 kg/hour, which represents a 77.76% increase compared with the rotary crusher system that had only achieved 30 kg/hour (9).

3.2 Machine Performance

Machine performance was tested using the parameters of arrowroot tuber pulping efficiency and fiber and slurry separation efficiency.

3.2.1 Arrowroot tubers pulping efficiency

Arrowroot tubers pulping efficiency was tested by conducting four arrowroot tubers pulping experiments. Each experiment was measured based on tubers weight, arrowroot pulp weight, and efficiency. Pulping efficiency was calculated using (pulp arrowroot weight/arrowroot tubers weight) x 100%. The results are presented in Table 1.

Table 1. Efficiency of pulping arrowroot tubers

Weight of arrowroot tubers (g)	Weight of arrowroot pulp (g)	Pulping efficiency (%)
1845.75±161.46	1742.75±143,26	94.45±0.98

Table 1 shows that the average pulping efficiency is 94.45%. This achievement indicates that the innovated pulper machine performs well, as only 4.55% of the fiber remains in the pulping machine attached to the perforated/serrated cylinder. The results of this study are more efficient than those of (8), who stated that grinding arrowroot tubers with a rotary crusher has an efficiency of 63.39%. Thus, this innovation can increase efficiency by 31.06%. The pulping efficiency of 94.45% is substantially higher than the 63.39% reported by (9), confirming that the pulper system is more effective in breaking down arrowroot tubers into pulp, thereby maximizing starch release (9).

3.2.1 Efficiency of separating fiber/pulp and arrowroot tubers pulp slurry

The efficiency of separating fiber/pulp and slurry from arrowroot pulp was tested by conducting 4 experiments. Each experiment measured the slurry's weight, the pulp's weight, and the separation efficiency. The results of the experiments are presented in Table 2.

Table 2. Efficiency of fiber and slurry separation

Weight of arrowroot pulp (g)	Slurry weight (g)	waste weight (g)	Separation efficiency (%)	waste/slurry percentage (%)
1742.75±143.26	1187±142.55	481.75±88.27	68.00±4.56	27.72±5.14

In separating fiber/pulp and slurry, water must be added to facilitate the separation process. However, when weighing the slurry, a correction factor for the additional weight of water required has already been applied. Separation efficiency is calculated using (slurry weight/pulp weight) x 100%. Table 2 shows that the average separation efficiency of slurry and fiber is 68%. This indicates that the lower the percentage of pulp, the greater the slurry fraction.

The separation efficiency of fiber and slurry averaged 68%, which, although improved, still indicates that starch losses remain during separation. This finding is consistent with earlier studies showing that starch separation efficiency is influenced by particle size, root variety, and the separation method (10). The screw-based separator used in this study provided a more stable and effective process compared with centrifugal extractors, which were reported to cause incomplete separation and vibration during prolonged operation (9).

The separator is more effective at separating solid particles (fiber) from the liquid phase. The results of this study are in line with (13), which explains that grinding arrowroot tubers with an average power consumption of 0.85 kW, processing time of 7.85 minutes, capacity of 46.6 kilograms per hour, and efficiency (starch recovery) of 16.6%. The same research was conducted by (10), who explained that the efficiency of free starch separation increases as the particle size decreases in all varieties of cassava tubers.

In addition to improving technical performance, the machine design incorporated food-grade stainless steel (SS304) on all food-contact components, ensuring compliance with hygiene and food safety standards. Such material selection is important since arrowroot starch has wide applications in the food industry due to its functional properties, including high amylose content, digestible gel formation, and stable viscosity (1)(12)(2). Ensuring hygienic processing increases the value and marketability of the flour for functional food applications.

The innovation also has practical implications for micro, small, and medium enterprises (MSMEs). For example, the An-Nur MSMEs in Sukoharjo previously faced challenges of low production capacity and incomplete separation, resulting in limited flour output and unmet consumer demand. By adopting the new machine, these enterprises can enhance productivity, reduce raw material losses, and expand their markets. Similar efforts have been reported by (13), who developed an arrowroot grinding machine with a capacity of 46.6 kg/hour but only achieved a starch recovery of 16.6%, far lower than the efficiency achieved in this study (9).

The improvement of starch recovery efficiency is also critical in supporting the development of functional and modified arrowroot starches. Modified arrowroot starch has demonstrated enhanced thermal and emulsification properties (4), while porous starch prepared through enzymatic and microwave-assisted treatments has shown improved

functional characteristics for food and industrial applications (1)(7)(13). These developments highlight the need for efficient starch extraction at the raw material level, as improved machine efficiency directly supports downstream applications in advanced food formulations. Furthermore, the diversification of arrowroot flour into processed products such as noodles and bakery items (14)(11) depends on consistent flour supply. The improved production capacity and efficiency from this innovation therefore contribute not only to local food security but also to the expansion of arrowroot-based industries.

4 Conclusion

The pulper machine uses a 1/2 HP electric motor, a 65 mm pulley diameter, and an ADV 125 V-belt. The starch fiber separator machine uses a 1 HP drive motor, a 200 mm pulley, and an A65 belt. UCP 25 bearings are mounted on a 130×130×8 mm angle iron frame with a low carbon steel cover. Dimensions (Length × Width × Height) = 700×350×1300 mm. This machine has a capacity of 53.33 kg/hour and a capacity increase of ±77.76%. Average pulping efficiency is 94.45% and average fiber separation efficiency is 68%. The starch–fiber separator innovation significantly enhances production efficiency and starch recovery compared with earlier machines. It also provides MSMEs with a practical solution to increase competitiveness, while simultaneously strengthening the supply of high-quality arrowroot starch for functional food development and industrial applications.

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