

Design and Performance Evaluation of Cassava Fibre Removal Machine for Fufu Production

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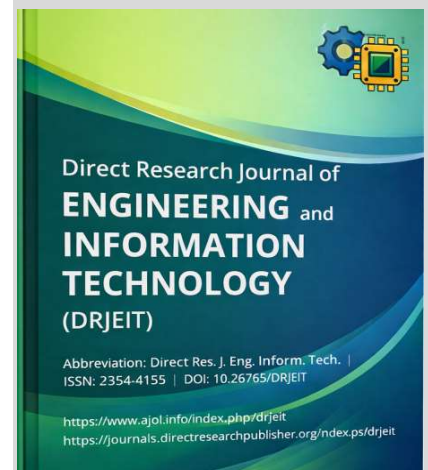
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ABSTRACT

This research work was carried out to design and evaluate the performance of a cassava fibre removal machine capable of efficiently removing insoluble fibres from fermented cassava and retaining the starch slurry used for the production of a fufu or akpu (cassava dough) a common staple food in West and Central Africa. Traditional cassava processing methods is labour-intensive, time-consuming, inefficient and often leave residual fibers in the cassava slurry, reducing product quality and increasing processing time. Processing of cassava is necessary for several reasons: it reduces or removes the potentially dangerous cyanogenic glucosides found in raw cassava and provide more options for consumer's diets. Materials of right strength and sizes for the machine parts were determined and selected based on the design analysis and calculations carried out. Drum, conical water chamber, frustum screen, gear box, stirrer shaft, frame and discharge chute are the main components of the machine. Several cassava processing machines and method of removing insoluble fibre from cassava have been developed globally; however, some are not cost-effective for use in small-scale operations but rather for large industrial scale; others have negligible efficiency, low throughput capacity, high percentage of loss, and contamination of the food due to mild steel's propensity to rust over time and subsequently degrade processed product quality. In this research, the developed machine performance evaluation was based on the effect of the insoluble cassava fiber removal in the drum, and retention of the cassava slurry in the conical chamber, encompassing different fermented cassava mash variation (5, 10, 21, 30 and 35kg) and residence time on key performance indicators (proportioned by weight of fermented mash, separation efficiency and throughput capacity). The machine operated at a reduced speed achieved by a 2.6Hp prime mover through a reduction gear mechanism, exhibited commendable performance, resulting in an average fiber separation efficiency of 89.4% and average throughput capacity of 191.4kg/h under the tested operating conditions (5 – 35kg feed loads). The inclusion of a conical water chamber into the design facilitated efficient fractionation and creating of slurry that washes the fine starch granules down through the sieve mesh, ensuring a smooth, lump-free texture for fufu/akpu production, leaving the insoluble fiber, bran and chaff out. The results also unveiled that the developed machine is efficient, economical, user friendly, reduce drudgery and fatigue than the traditional methods commonly used by Nigerian fufu/akpu processors in the removal of insoluble fiber from fermented cassava.

Keywords: Cassava, Insoluble fibre removal, Fermentation, Machine efficiency, Food processing



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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial woody shrub with an edible root and fan-shaped leaves. Cassava occupies a pivotal role in the agricultural landscape of Africa, where it is the second most crucial staple crop after maize, with the highest per capita consumption occurring in Sub-Saharan Africa (SSA) (Hood *et al.*, 2023). In 2019, approximately 63.3% of the 304 million metric tons of cassava produced came from Africa. With Nigeria accounting for 21% of the roughly 278 million tons of the world's total production of cassava root in 2018 (Amanuel Erchafo. 2025). *Fufu/akpu*, *Garri* and *Lafun* are fermented foods made from cassava (Fatoye, M.N. *et al.*, 2026). According to (Kumar *et al.*, 2022), the fiber content of fermented cassava is substantially higher than that of non-fermented cassava. From Journal of Food Science and Technology, Ayenew, Lemma, & Yemer (2023) reported that there is a considerable amount of soluble fiber in fermented cassava. The removal insoluble fiber from fermented cassava enhances the smoothness of *fufu/akpu*. Starch is used as food in most part of Nigeria and to produce diverse products like textiles, adhesives, pharmaceuticals etc. (Etim *et al.*, 2024). Wet sieving is instrumental in washing starch granules and milk from other particles such as fibers and hulls, notably in processing cereal grains such as maize, millet, and cassava, used in local diets and beverages (Ayodeji *et al.*, 2026).

Ikechukwu and Agu (2018) designed and developed a motorized cassava mash sieving machine that comprises a 3hp electric motor, pulverization unit, sieving unit, collection unit, and fiber outlet. The machine breaks and sieves dewatered cassava mash, allowing the fiber to exit through the fiber outlet, thus reducing drudgery and time wastage. It also eliminates human contact with the cassava, unlike existing traditional or semi-mechanized sieving methods. Performance test analysis revealed that the developed machine achieved an average throughput of 174.46 kg/h at 25% moisture content, significantly outperforming the manual/traditional process. (Ovat *et al.*, 2021) developed a commercial-scaled motorized vibratory gari sieving machine featuring a 3-phase motor with one horsepower operating at 1500 rpm. This machine offers several advantages over traditional sieving methods, including increased output per time, improved hygiene, higher gari quality, and reduced processing time. Performance evaluation showed an efficiency of about 96%, surpassing existing machines with efficiencies ranging from 50% and above. The study suggests that the motorized vibratory gari sieving machine is a practical solution for enhancing gari production and processing, particularly in Nigeria and similar food processing contexts. Nwankwojike *et al.*, (2022) integrated a rotary vacuum drum filter into a milling and sieving machine for continuous slurry starch production. The machine operates with an average throughput of 70.44 kg/h and 98.48% extraction

efficiency, reducing moisture content to 31.52% in the processed slurry starch cake. This innovation saves over 5.39 hours and reduces water consumption by recycling drained water. It also improves hygiene and reduces drudgery by eliminating human contact during loading/discharging. Cereda & Branco (2024) designed and evaluated an equipment for starch extraction. The study developed a milling-extraction system and reported that the system offered a simple structure requiring only adjustments of the sieves and with basic advantage of cost reduction. Vilpoux (2024) compared industrial technologies obtainable in China, Thailand and Brazil. They described the various unit operations to involve the following: cleaning, peeling, stem grating, starch extraction and bran removal, starch milk concentration and refining, dewatering and drying, packaging and waste handling and treatment. Manual removal of insoluble cassava fiber is time-consuming, while mechanical sieving is faster and requires only operator oversight. The variance that exists in this cassava fiber removal machine, is that the sieving allows the pulping and sifting of the cassava mash while submerged in its starch slurry. According to (Gareth *et al.*, 2025) soaking reduces cyanide levels in cassava. The removal of insoluble cassava fiber after soaking (fermentation) in the production of *fufu/akpu*, is commonly done by hand in many parts of Nigeria and the key processors (often women), might suffer from spastic paralysis and goiter due to the effect of exposure to cyanide which may still be present in the soaked cassava tubers. (Forkum *et al.*, 2025) reported that cyanide exposure from cassava and cassava-related products is still prevalent in SSA. It is therefore imperative to develop an appropriate machine that will be easily available to access and affordable.

Therefore the objective of this review was to design and fabricate a small-scale cassava fibre removal machine. The performance of the machine was also compared to available traditional means of sifting cassava mash and removing the fibre in Bida, Niger State, Nigeria. The cassava fibre removal machine developed was economical, fitted with easy loading and discharge outlets, and excellent ergonomics. The machine was fabricated using locally available materials to promote local content, interchangeability and maintainability. Also, it is expected that the development of this machine will decrease complexities such as human drudgery and inform context-sensitive interventions that promote food safety, public health, and sustainable food systems.

MATERIALS AND METHODS

Materials

Stainless steel, iron screen, angle iron, U-channel, welding machine, hand shea-cutter, drilling machine, vice

and electric hand grinder are some of the equipment used during the fabrication.

Machine description

The cassava fibre removal machine is composed of the following component parts.

Machine frame

The machine frame is constructed with 2inch X 4mm, mild steel angle iron. The frame carries the whole machine and also provide extension for mounting the gear box and the prime mover as shown in (Figure 6).

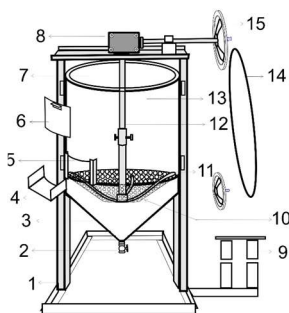


Figure 6. Exploded View of the Machine

PART NO.	PART NAME
1	Frame
2	Discharge Chute
3	Conical Chamber
4	Outlet Tray
5	Fiber Outlet
6	Slide Gate
7	Drum Aperture
8	Gear Box
9	Engine Seat
10	Frustum Screen
11	Stirrer Arms
12	Stirrer Shaft
13	Drum
14	Belt
15	Pulley

Separation Drum and Shaft Assembly

The cylindrical shape of this separation drum allow consistent material flow and consists of several components, including the sieve, shaft, speed reducer (bevel gears), pulley and key. To streamline the construction process and make the machine cost-efficient, bevel gears were assembled to form the speed reducer, which can be relatively expensive to buy a gear box. The entire drum is suspended in between two U-channel frame of the machine (Plate 1).



Plate 1. Coupling of the fibre removal machine

Gear box system

The gear box is seated above the entire machine. It comprises of big and small bevel gears and bearings arranged to form angle of 90° and enclosed with a 3mm thick plate. It increase speed and converts rotational motion of the prime mover into circular motion of the stirrer (Plates 2 and 3).



Plate 2. Bevel gears



Plate 3. Gear box

Frustum screen

This is a frustum shape metal screen of about 44.5cm diameter and a depth of 11cm, hanging in between the hopper and the conical water chamber where pulping and sifting operations takes place (Plate 4 and 5).



Plate 4. Screen



Plate 5. Frustum screen

Conical Base

This is designed to hold water and starch slurry throughout the whole process of the fibre removal from fermented cassava before the discharge of starch slurry. It is constructed with 1.5mm steel sheet, and carries the discharge chute at the apex of the conical bottom of the machine as seen in plate 1.

Slurry discharge chute

The slurry discharge chute is at the apex of the conical water jackets. It consist of a 2inch steel pipe, a union and

valve at the bottom of the machine for collecting starch slurry after insoluble fibres have been removed (Plates 6, 7).



Plate 6. Discharge Chute for cassava slurry collection



Plate 7. Discharge outlet for Insoluble Fibre

Insoluble Fiber Outlet

This is a continuation of the cylindrical flange at the bottom before the drum and conical chamber. It directs the flow of fibres after separation to a receptacle.

Design analysis of machine components

The intent of the design assessment is to evaluate the design parameters needed to be able to choose the various machine components that are suitable in achieving the required end product. This includes estimating numbers to guide the selection of materials. The machine primary expectation was to handle a capacity of 200kg cassava per day.

Assumptions

Acceleration due to gravity is 9.81m/s^2

Bulk density of cassava is 600kg/m^3 (FAO)

Density of stainless steel is 7880 kg/ (khurmi and Gupta, 2005)

Speed of the machine pulley is 1500 rpm. Expected machine output capacity is 2 tons per day Density of the shaft is 7850 kg/m^3

Production capacity: The machine is to handle a capacity of 2000kg/day

Operational hours: Daily operational hours is set to be 8 hours.

Operation mode: The machine works based on batch processing mode.

Batch cycle time: Each batch cycle including loading, processing and discharge takes 5 minutes

Cassava bulk density: 600kg/m^3 (FAO)

Separation Drum Dimensions

In the design of this drum, the human ergonomic factors was put into considerations for ease of loading the fermented cassava, and general maintenance. The diameter of the drum is (45cm) and the height is (35cm) as shown in (Figure 1) below:

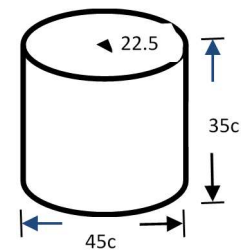


Figure 1. Drum

Volume of the Drum

To determine the volume or capacity of the drum, this cylinder formula was used: $V = \pi \times r^2 \times H$

Where: V is volume of the drum, r is radius of the drum, H is height of the drum, and π is 3.1416.

Substituting the values:

$$\begin{aligned} V_{\text{drum}} &= 3.1416 \times (22.5)^2 \times 35 \\ &= 3.1416 \times 506.25 \times 35 \\ &= 55,718.65\text{cm}^3 \end{aligned}$$

The drum has a conical base, which holds water and starch slurry during the fibre removal processes. Therefore, there is need to find the volume of the drum separately from the conical chamber and adding them together to know the total volume (Figure 2).

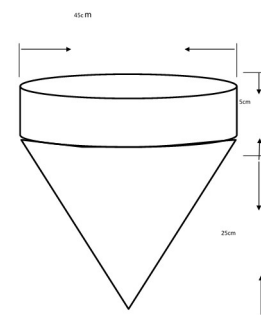


Figure 2. Cone

The volume of the cone is given by:

$$V_{\text{cone}} = \frac{1}{3} \pi r^2 H_{\text{cone}}$$

Substituting the values:

$$= \frac{1}{3} \times 3.1416 \times (22.5)^2 \times 25$$

$$= \frac{1}{3} \times 3.1416 \times 506.25 \times 25$$

$$= \frac{1}{3} \times 39,799.03$$

$$= 13,199.03 \text{cm}^3$$

$$\text{Total volume of the drum} = V_{\text{cylinder}} + V_{\text{cone}}$$

$$= 55,718.65 \text{cm}^3 + 13,199.03 \text{cm}^3$$

$$= 68,918.69 \text{cm}^3$$

$$= 68,918.69 \text{cm}^3$$

Mass of fermented cassava mash that the drum can hold at a time was deduced using the following:

$$\text{Total volume of drum} = 68,918.69 \text{cm}^3$$

$$\text{Bulk density of cassava } (\rho) = 600 \text{kg/m}^3$$

$$\text{Conversion factors used: } 1 \text{m}^3 = 1,000,000 \text{cm}^3$$

Converting the volume to cubic meters

$$\frac{68,918.69 \text{cm}^3}{1,000,000 \text{cm}^3}$$

$$= 0.06891869 \text{m}^3$$

$$V \text{m}^3 = 0.06891869 \text{m}^3$$

Using $m = v \times \rho$, where: m is mass of the fermented cassava the hopper can hold, v is volume of the hopper in cubic meters, and ρ is the bulk density of the cassava $m = 0.06891869 \text{m}^3 \times 600 \text{kg/m}^3 = 41.35 \text{kg}$. Therefore from the drum analysis, the mass of fermented cassava mash that this machine can hold at a time is 41.35kg. The drum was designed with a maximum holding capacity of 41.35kg. However, during the machine performance evaluation, the machine was tested at batch loads of up to 35kg, representing approximately 84.6% of the drum's total capacity. Operating below the maximum drum capacity was intended to prevent overloading, ensure smooth material flow, reduce spillage, clogging, and allow accurate assessment of the machine's performance under practical operating conditions. Therefore, the reported batch load of 35kg does not contradict the drum capacity of 41.35kg; rather, it reflects the maximum load condition adopted during testing.

Design of gear box

In the fabrication of the gear box, consideration was given to the gear type, number of gear teeth, gear ratio,

output speed, torque, size of the shaft and bearings (Figure 3). The bevel gears were enclosed in 12cm x 13.5cm rectangular steel case with a fitting for lubrication. The purpose of this casing is to give it strength, prevent dust, and moisture ingress.

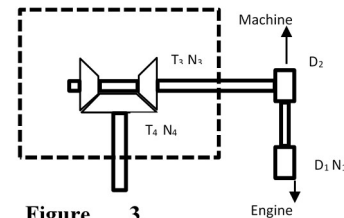


Figure 3.

Gear ratio: The gear ratio calculation was done using

$$\frac{\text{Driven Gear Teeth } 16}{\text{Driver Gear Teeth } 9}$$

$$\text{Gear ratio} = 1.78$$

Where the driver gear (pinion) is 9 teeth, and the driven gear is 16 teeth. The output speed is 1.78 times the input speed.

Output speed: the output speed calculation was done using $N_2 = N_1 \times \text{GR}$ Where: N_1 is input speed (1500rpm), N_2 is output speed, GR is the gear ratio.

$$N_2 = 1500 \text{rpm} \times 1.78 = 2670 \text{rpm}$$

Torque: The torque is related to power and speed, and is

$$\frac{P \times 60}{2 \pi N}$$

was calculated using $T =$

Where T is torque (Nm), P is power (W or KW), N is speed (rpm). Assume input power to be 1kw (1000W). $T =$

$$= \frac{1000 \times 60}{2 \pi 1500} = 6.37 \text{Nm}$$

Design of frustum screen

The frustum is the chamber made of screen, where the fibre is separated from the fermented cassava. The open diameter of the frustum is the same with that of the drum because it comes in between the drum and the conical chamber (Figure 4).

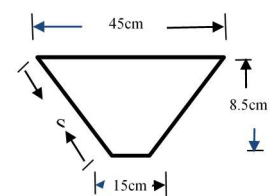


Figure 4. Frustum Screen

$$\text{Slant height of frustum (S)} = \sqrt{h^2 + (R - r)^2}$$

Where: **S** = slant height, **h** = height of frustum, **R** = radius of big diameter, **r** = radius of small diameter.

Determination of pulley diameter

It helped in selecting the right pulley size for speed, torque adjustment, ensured power transmission and belt efficiency.

The formula used was given by R.S Khurmi and J.K.

$$\frac{N_1}{N_2}$$

Gupta's: $D_2 = D_1 \times$

Where: **D₁** is diameter of the driver pulley (cm), **D₂** is diameter of the driven pulley (cm), **N₁** is speed of the driver pulley (rpm), and **N₂** is speed of the driven pulley (rpm).

Determination of belt length

The belt length of this machine was determined to ensure smooth operation, reduce downtime, and improve productivity

(Figure 5). Using the formula:
$$L_b = \frac{\pi}{2} (D_1 + D_2) + 2c + \frac{(D_1 - D_2)^2}{4c}$$

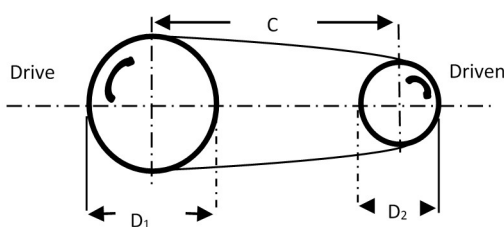


Figure 5. Belt

Where: **D₁** = Radius of drive pulley, **D₂** = Radius of driven pulley, **c** = Center-to-center distance.

Determination of mass of the horizontal shaft

The calculation of the mass of the horizontal shaft was done in order to determine its weight and to assess its impact on the overall design and performance of the machine (Tables 1 and 2). The mass of the horizontal shaft is crucial in determining the mechanical stresses

Table 1: A complete statistical analysis .

Fermented cassava mass (kg)	Fiber removed (kg)	Processing time (min)	Separation efficiency (%)	Throughput capacity (kg/h)
5	0.15	2	83.3	150.0
10	0.30	3	89.3	200.0
21	0.63	5	93.8	252.0
30	0.90	10	88.3	180.0
35	0.05	12	92.3	175.0

Table 2: Mean ± SD report.

Parameter	Mean ± SD
Separation Efficiency (%)	89.4 ± 4.1
Throughput Capacity (kg/h)	191.4 ± 38.3
Processing Time	6.4 ± 4.2
Feed Load (kg)	20.2 ± 13.2

and forces it will experience during operation. And it was

$$\rho \times v$$

carried using the formula: $M_s = \rho \times v$

$$M_s$$

$$\rho$$

$$v$$

Where; M_s = mass of shaft (kg), ρ = density of shaft, v = volume of shaft (m³).

Working procedure of the machine

The conical chamber was filled with water first, via the upper aperture of the drum and allowed to submerge the frustum screen. Power was provided by the 2.6 Hp prime mover which drove the stirrer arms inside the separation drum. Followed by introduction of the fermented cassava mash which was fed into the machine through the upper aperture under gravity.

The stirrer arms pulverizes and pulps the fermented cassava mash in the presence of water inside the frustum screen. The speed reducer helps increases the resident time the fermented cassava mash will spend in the separating drum to achieve better insoluble fiber and fine cassava slurry (Plate 9). The prime mover was connected to the speed reducer (axle) through belt and pulley system and the stirrer shaft was connected to the speed reducer with a knuckle joint, to enhance the connection alignment. The cassava slurry was separated through the frustum screen and flow downward into the conical chamber from where it is collected through the discharge chute at the bottom part of the machine into a bucket or decanting trough before sedimentation and decanting, while the insoluble fiber was expelled through an aperture situated on one side of the drum as the stirrer arms were in motion.

The product (cassava dough) was securely tied in a chiffon or cheese cloth, allowed to be drained of excess liquid until a firm, thick cassava dough is left.

Testing of the machine

The component parts of the machine were firmly assembled. With the machine belt properly tensioned to prevent excessive wear and tear on the belt, pulleys, bearings, and to ensure optimal power transmission. A sack of cassava was obtained from a local *fufu* producer in Bida, Niger State, Nigeria. And the cassava were peeled, washed, soaked and properly covered for 3 days for fermentation to take place. After which the fermented cassava were collected and divided into five part of 5kg, 10kg, 21kg, 30kg, and 35kg. This five set of experiment were carried out to investigate the machine performance. In the experiment, it took the machine 2minutes, 3minutes, 5minutes, 10minutes, and 12 minutes to remove insoluble fibre content from fermented cassava of 5kg, 10kg, 21kg, 30kg, and 35kg respectively. The time taken also include both loading and discharge. The experiment was carried out before the members of the Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna, Niger State, Nigeria (Plate 8).



Plate 9. Stirrer arms inside the separating drum

Machine performance determination

The performance of the machine was analyzed based on capacity, speed or time taken to remove fibre, and the efficiency of the separation.

RESULTS

Analysis of Machine Performance

Recent studies by *Adetunji et al., (2023)*; *Oladebeye et al., (2020)*; and *Uzoejinwa et al., (2025)* have demonstrated that mechanized wet sieving and sifting systems significantly improve processing efficiency, reduce processors fatigue, and enhance productivity in food processing. In line with these findings, the results obtained in this study are presented and discussed based on separation efficiency,

circle time, throughput capacity and material conditions (Tables 1 and 2). Each feed load represented a distinct operating condition. Since only one observation was obtained per condition, the reported standard deviation reflects variability among operating conditions rather than replicate experiment error. The machine achieved a separation efficiency of $89.4 \pm 4.1\%$ and a throughput capacity of 191.4 ± 38.3 kg/h (mean \pm standard deviation). Inferential statistical analysis such as Analysis of Variance (ANOVA) was not performed because each feed-load treatment (5 – 35kg) was evaluated using a single experimental run. Consequently, the within-treatment experimental error required for ANOVA could not be estimated. Future studies are recommended to employ replicated trials to permit more rigorous statistical evaluation.

DISCUSSION

The developed cassava fiber removal machine was evaluated using feed loads of 5, 10, 21, 30, 35kg of fermented cassava mash. The corresponding separation efficiencies obtained were 83.3, 89.3%, 93.8%, 88.3% and 92.3%, respectively, while the throughput capacities were 150.0, 200.0, 252.0, 180.0, and 175.0 kg/h, respectively. The mean separation efficiency of the machine was 89.4%, with a standard deviation of 4.1%, indicating relatively consistent performances across the tested feed loads. The coefficient of variation was 4.55%, suggesting low variability in separation efficiency.

Similarly, the mean throughput capacity was 191.4kg/h. the coefficient of variation for throughput capacity was 20.0%, indicating moderate variation in machine throughput under different feed loads. The highest separation efficiency (93.8%) and throughput capacity (252.0kg/h) were obtained at a feed load of 21kg, suggesting that this operating condition provided the most favorable balance between machine loading and separation performance. Because each feed-load treatment was evaluated once, inferential statistical tests requiring replicated observations could not be performed. Therefore, the results are presented using descriptive statistical measures only.

CONCLUSION

The cassava fiber removal machine demonstrated stable and efficient performance in removing insoluble fiber from fermented cassava in the production of cassava dough (*fufu/akpu*), achieving notable improvements in throughput capacity, fiber separation efficiency and retention of higher-viscos cassava slurry. The results indicate that mechanization of the insoluble fiber removal process significantly reduces processors' physical workload, as observed by improved physiological indicators compared with traditional removal methods,

thereby providing more hygienic and less strenuous processing conditions. The machine showed better capability in the cassava mash recovery, pulping and sifting speed of the fermented cassava mash compared to the regular use of plastic sieve and hand washing method to remove the insoluble fiber which is more tedious, time-consuming and labourious. The machine demonstrated an admirable average throughput capacity of 252.0 kg/h, and due to its efficiency, affordability, and user-friendly design, ergonomic conditions, the machine is deemed well-suited for small scale and industrial purposes. Nevertheless, future design should incorporate enhanced controllability of operational parameters, and the integration of intelligent monitoring systems to further expand its applicability and industrial acceptance.

Author's declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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