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Development of fermented cassava wet sieving equipment for rural settings

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DISCOVERY
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ABSTRACT
The concern of this paper is the development of rural wet sieving equipment for fermented cassava pulp to reduce the arduous task associated with the traditional process practised in most consumption areas. The fabricated equipment consists of a bucket with a cover and a collection pipe underneath, the stirrer rod with attached blades, the sieve, the sieve hanger or support, the sitting with bearings and the stand. The cassava pulp, when sufficiently softened by fermentation, can easily be disintegrated into microparticles by the application of minimal force in the presence of water. The fermented cassava is fed into the bucket and stirred manually through the crank handle, the blades/beaters break the pulp and the fine particles pass through the sieve where it is collected underneath while the coarse fibre is discharged through a chaff outlet. The production rate was determined using a mass input of 3kg and a mass output of 2.7kg. The sieving efficiency of the machine was, therefore, evaluated to be 90%. The time taken for the collection of the fine particle sediment mass was found to be 40 seconds. The fabricated simple but rugged wet sieving equipment is cheap, easy to install, easy to operate and easy to maintain.

Keywords: wet sieving, fermented cassava, traditional process, fabricated equipment, sieving efficiency

1. INTRODUCTION
The numerous products from cassava (Manihot esculenta) tubers undergo a series of processing stages to obtain the edible form. The processing technique that would be adopted is highly dependent on the desired end product. Some of the palatable end products include gari, dry fufu, wet fufu, tapioca and African salad ("abacha"). If cassava is processed into pounded fufu ("utara" "akpu") it provides a major staple food consumed in Southeast Nigeria and beyond. This form of cassava product is the most popular due to its close resemblance to the highest acknowledged traditional pounded yam which is only affordable by the affluent members of society. The mature cassava tubers are harvested from farms for processing after 10 to 18 months of cultivation, depending on the variety. The peels of the tubers are removed with a knife and the tubers cut into short lengths of about 10cm. The cuts are then washed and put in containers and filled with water. Some processors who have

streams and rivers around them prefer steeping the cuts by a secured corner in a bank of a flowing stream. The cassava is kept there for about 4 to 5 days to ferment. Fermentation enables the cassava to soften and reduce the cyanide content. It is also believed that the flowing stream washes away the smell in the cassava thereby making some pot-soaked processors replace the water once or twice before the completion of fermentation. The sieving of the softened fermented cassava is traditionally done manually by crushing, and simultaneously stirring and pressing with fingers against the inside of a truncated cylindrical basket made of palm fond or a fabricated sieve from a perforated aluminium sheet partly immersed in water in a container. The sedimented fine pulp mash is collected after decanting excess water and then put in small baskets and bags ready to be cooked. The sieved cassava is first moulded into balls and parboiled or simply heated for about 10 minutes in an open pan while stirring, and then pounded. It is moulded into balls again for final boiling and subsequently pounded till acceptable texture is obtained and ready to be swallowed or eaten with vegetable non-draw ("esusu") soup or draw ("ihe" "eha") soup.

However, most of the mechanizations carried out in the area of cassava processing in the recent past have focussed on gari production with little done in the area of wet fermented cassava for wet fufu ("akpu") production. This may be due to the higher storage value of gari, easy transportability and faster preparation into food which makes it the preferred choice for most urban dwellers. Nonetheless, the palatability of gari and other cassava products when compared to "akpu" are disadvantaged as some claim that akpu gives more sustainable fullness which earned it the name "six to six" meaning that if you eat akpu by 6.00 am it could sustain you till 6.00 pm. This characteristic behaviour endeared it to many low-income earners and artisans even in the urban areas. The processing of cassava into akpu relies largely on traditional methods with attendant inefficiencies and negative impacts. The fermented pulp sieving process is one of the tiring, tedious and demeaning activity in the preparation of akpu. The sedentary manual process of stirring the acidified fermented cassava pulp not only wears down the fingers/hand but also painful to the neck, shoulder and back as well as been unhygienic. The wet fermented cassava pulp carries a characteristic odour and the processor tends to smell cassava long after the sieving process. This is demeaning to the processor and offensive to passers-by. Because the kitchen place is the primary responsibility of women, they and their female offspring mainly are saddled with this part of the cassava processing job (Davies et al., 2008, Onyemauwa, 2012; Nwaobiala et al., 2019; Okorji et al., 2003). Yidana et al. (2013) stated that even though cassava processing is profitable and contributes significantly to the standards of living of women, the challenges encountered drastically reduce productivity and economic returns. Many young girls have also lost appropriate suitors based on the fermented cassava smell which follows them long after the sieving activity. Hahn (1997), however, advocated to improve or modify the presently used simple mostly manual processing equipment or systems which are labour intensive with very low productivity, rather than changing to entirely new, sophisticated and expensive equipment that might pose some challenges to the end-users. These and many more make the wet-sieving of fermented cassava pulp mechanization imperative for immediate action.

Ironically, many developed cassava sieving machines were specially designed for processing dewatered grated cassava for gari productions (Ikechukwu and Agu, 2018; Ikejiofor and Oti, 2012; Kolawole et al., 2010; Kudabo et al., 2012; Mohammed et al., 2015) and dried cassava pulp for flour and fufu ("alibo") production (Nwaigwe et al., 2012). Fermented cassava pulp wet sieving entails the separation of fine pulp particles from the coarse fibres using meshed or perforated container partly immersed in or supplied with water. The machine developed by Fayose (2008) uses mechanical shaking operation of a sieve to extract starch from milled wet cassava and other crops while Saengchana et al. (2015) applied centrifugation and filtration actions to separate free starch granules from milled cassava mash. This paper, therefore, focused on the development of wet sieving equipment for fermented cassava pulp processing which hitherto has received little attention.

2. METHODOLOGY

Many factors were considered in the design of the fermented cassava wet sieving equipment and these include the characteristics of the input working materials (fermented cassava and water). Materials that can withstand corrosion in moisture and the acidic environment was therefore selected. Also considered is the near non-availability of mains electricity and the high initial and running cost of prime movers. Affordable simple but rugged manual operated equipment was therefore considered for the target rural environment. The limited amount of continuous human effort vis-a-vis the endurance limit of the human hand was considered along with the desired output. Based on experience, a four days requirement of the sieved cassava pulp for an average family size of 6 was designed to avoid product deterioration. The machine will, therefore, operate under batch production. Consideration was given to the expected load on the equipment and the consequent load distributions on the components especially the shaft and the attached beaters. The equipment is required to be portable to enable it to serve several families in their homes and their preferred product processing locations. The manufacturability of the equipment was considered, involving majorly cutting, forming and welding operations using available common workshop tools. The sieving equipment was designed for easy maintainability by both less educated and low skilled persons.

2.1. Materials

Many materials were desired during the design of the equipment but few were chosen based on their mechanical and physio-chemical properties as shown in Table 1. The properties along with their availability and affordability informed the choice of the following: The aluminium sheet was chosen for the digestion chamber due to its corrosion resistance and its availability locally. The aluminium mesh was used for the sieve material due to its corrosion resistance, availability and less work input associated with manual perforation of aluminium sheet. Stainless steel rod and pipe were used for the stirrer shaft and the beaters respectively due to their high strength, corrosion resistance and low contamination of the product. Angle iron and reinforced steel sheet were used for the stand and bearing support respectively due to their strength, weldability and affordability. An anti-friction ball bearing was used to mount the shaft for reduced resistance during cranking. Plastic (PVC) was used as a discharge pipe due to its corrosion resistance, affordability and ease of replacement.

2.2. Methods

The simple production processes and techniques used to produce the equipment depends on the shape, material composition and the required quality of the component involved. Cutting, forming and welding were methods mostly applied. The main units of the wet sieving equipment are as shown in Fig. 1.

1. The stand: the stand supports the bucket which carries the other parts of the equipment. The stand is a table frame constructed by welding measured cut lengths of 38 by 38 mm angle iron and have a 465 mm square top and a height of 480 mm. The two sides of the base are braced with stabilising support rails made from the same angle iron.
2. Bucket with attached product discharge pipe: the bucket was produced using an aluminium sheet which is rolled and formed into a cylindrical chamber of diameter 400 mm and a height of 430 mm. Two lifting handles were riveted at opposite sides near the top of the bucket. It has an opening below attached with a PVC control tap and extension pipe where the sieved cassava product is collected. The bucket encloses the digestion chamber for the cassava pulp.
3. The sieve: the sieve is a cylindrical container made from aluminium gauze by forming process. The aluminium gauze sheet was folded to produce a container with a height of 230 mm and a diameter of 240 mm closed at one end. The size of the sieve which matches the expected product output forms the base for the sizing of other components of the equipment. The action of the stirrer on the fermented cassava wet pulp inside the sieve produces the fine cassava mash product.
4. The sieve hanger/bracket: the sieve is centrally suspended inside the bucket with the help of the hanger and brackets. The hanger was made from a cut metal plate formed into a circular ring with tripod extensions and then attached to the bucket with brackets using bolts and nuts.
5. The stirrer: the stirring shaft attached with the beaters was designed to withstand the stress caused by the resisting torque generated by the cassava mash and the ease to which it can be overcome by human power. The resisting torque also depends on the number of attached beaters. However, the number of beaters determines the effectiveness of the sieving operation. Hence, 5 beaters of length 100 mm and 20 mm diameter each were welded at predetermined positions unto a 435 mm long shaft of diameter 20 mm
6. The crossbar/bearing housing support: the stirring shaft is centrally located inside the sieve through the 2 anti-friction ball bearings housed in the centre of a crossbar attached to the bucket. The crossbar length of 390 mm by 80 mm wide is cut from a 1 mm thick steel sheet and reinforced along the length. A centrally cut through-hole was made on the bar to install the ball bearings of diameters of 52 mm and lengths of 14 mm. The bearing is permanently joined to the bar by tack-welding. The bearing ensures reduced effort from the operator by replacing sliding contact with rolling contact.
7. The bucket cover: the bucket cover was designed to match the bucket top opening. It is a top flanged cylindrical cover with a diameter of 408 mm and depth of 50 mm. The flange has a diameter of 430 mm. It protects the product from contamination and also prevents spattering during operation.
8. The crank: the crank was designed to an average human arm's length of about 550 mm and at an obtuse bent arm operation internal angle. Based on sampling measurements of potential operators, the average height at shoulder level was taken to be about 1400 mm when standing, hence, the crank handle grip point was located at a height of 1150 mm for convenience during operation. Keeping the crank length at a convenient distance reduces the stress on the arms and other cumulative trauma disorders while locating the handle at a maximum reasonable distance ensures reduced human effort during cranking as

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increased distance reduces the force required to achieve the same torque. A spherical-head screw is attached to the crank to fix it with the stirring shaft.

3. RESULTS AND DISCUSSION

Figure 1 shows the exploded view of the major units of the manufactured fermented cassava wet sieving equipment. The display also indicates the sequence involved in the assembly process. To sieve fermented cassava pulp, the equipment is partly assembled as shown in Fig. 2 with the tap below in close position. The fermented cassava pulp is placed in the sieve. Water is then poured into the bucket to reach a quarter height of the sieve. The bucket cover is put in place and the crank installed, ensuring the stirrer has a clearance from the bottom of the sieve, and then the crank tightened unto the shaft using the spherical head screw stopper (see Fig. 3). The stirrer rod is turned in a clockwise direction until the cassava pulp in the sieve is all sieved out remaining the chaff. The beaters crush and disintegrate the fermented cassava pulp with the bottom beater additionally clears the sieve bottom openings to enable the easy flow of fine cassava particles/water mixture. Additional water could be sprinkled into the digesting pulp to fasten the sieving operation. A receiving container is placed below the bucket to collect the sieved cassava slurry. The discharge control tap attached to the bottom of the bucket is then opened and the cassava slurry allowed to flow into the collection container for sedimentation, decantation and other further processing. The process can be repeated until the required fermented cassava is sieved while extracting the chaff after four to five cycles of operation. Wash the equipment after the day's operation.

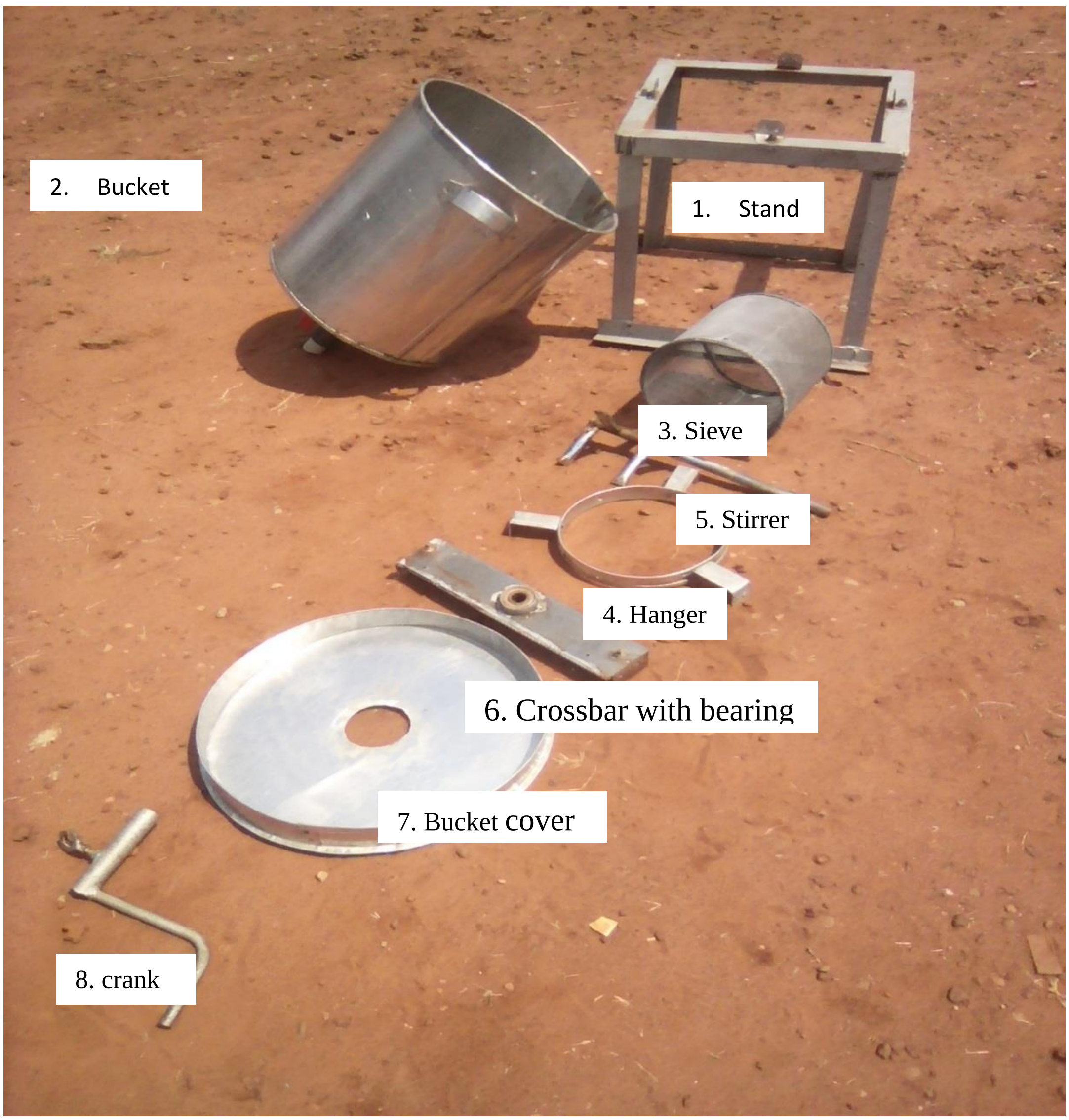

Fig. 1 Exploded view of the wet sieve equipment (numbered according to installation order)

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Fig. 2 shows the wet sieving equipment in a ready position to receive fermented cassava pulps

A test run of the machine was carried out to determine the effectiveness. The pilot test parameters include the fermented cassava mass input, mass output, time taken to complete sieving and discharge, the discharge rate of the mixture, the efficiency of the machine. The mass input was obtained by weighing the fermented cassava before sieving using an electronic weighing balance, the mass output was gotten by weighing the mixture after it has been sieved and decanted.

The discharge rate = $\frac{distance\ travelled\ by\ mixture}{time\ taken}$ or $\frac{mass\ output}{time\ taken}$

The efficiency of the machine, $\eta = \frac{mass\ output}{mass\ input}\ x\ 100\%$

The equipment was evaluated based on the following averaged sample values after 3 acceptable test runs:

Fermented cassava mass input	=	3.0 kg
Sieved cassava mass output collected	=	2.7kg
Sieving time	=	80s
Discharge rate calculated	=	0.034kg/s
The efficiency of the machine	=	90%

The efficiency of the equipment also took into consideration that the tested samples were from a four days fermentation period which is generally accepted as the normal time for proper softening of the cassava with good quality. The rate of sieving reduces the contact time between the operator and the fermented cassava, hence given the needed hygiene.

Fig. 3 The wet sieving equipment in a full set up position for a sieving operation

4. CONCLUSION

A piece of wet sieving equipment for fermented cassava has been developed to cater for the rural setting where sophisticated machines may not be very appropriate due to lack of adequate mains electricity power supply and the high operating costs of modular prime movers. The machine is simple as it mimics the hand-stirred sieving which it strives to replace. The machine will not only reduce the stress and sedentary burden involved in the traditional sieving method but improve greatly the hygienic conditions during sieving. Since the fabricated sieving equipment is rugged and portable, it is amenable to borrowing and lending especially in rural settings where the extended family system predominates. For future studies, it is desired to modify the bottom shape of the bucket to have a tapered or conical outlet for easier sliding of the slurry to the collecting container. A parametric test will be carried out to determine the effects of varying some of the controlling factors on the machine's effectiveness and impact on the operator.

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Conflict of Interest:

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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