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Modernizing Traditional Cuisine: The Design and Construction of a Mini PAP Processing Machine

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Abstract

The study presents a mini pap processing machine designed for small-scale producers, showcasing its efficiency across various grains like maize, guinea corn, and millet. It processes 1.2 kg of maize in 13 mins, 1.2 kg of guinea corn in 8 mins, and 1.5 kg of millet in 10 mins, highlighting its versatility and effectiveness. Material selection, including food-grade stainless steel and mild steel, ensures durability and affordability, while modular design aids in easy maintenance. The machine's adaptability to different grain types addresses the needs of small-scale producers, enhancing productivity and quality. Emphasis on locally sourced materials and simple manufacturing processes reduces costs and facilitates maintenance. Future improvements could focus on optimizing the grinding mechanism and integrating advanced features like automated feeding systems. Overall, the machine represents a significant advancement in small-scale pap production, aligning with the needs of local communities and contributing to food security and economic development.

Key words: Machine; efficiency; Pap; grains; maintenance; material selection

1. Introduction

Pap, known in various regions of Africa as ogi or akamu, is a beloved staple food, particularly in Nigeria, where it forms an integral part of the daily diet (Akinsola et al., 2021). This traditional fermented cereal porridge, made from maize, millet, or sorghum, is cherished for its nutritional value, affordability, and comforting texture. Despite its widespread popularity, the traditional methods of pap preparation are labour-intensive and time-consuming, posing significant challenges for households and small businesses seeking to produce large quantities of this essential food (Osungbaro, 2009).

The traditional process of pap making is a multi-step procedure that begins with washing and soaking the grains in water for extended periods. The soaked grains are then ground into a fine paste using a processing plant stone or millstone (Akingbala, Rooney, andFaubion, 2006). This paste is mixed with water and sieved to remove husks and other unwanted particles, resulting in a smooth slurry that is then fermented. The final stage involves cooking the slurry on a stove until it thickens into a smooth, porridge-like consistency.While these manual processes are deeply rooted in cultural traditions, they are also physically demanding and time-consuming. For households and small-scale producers, the need to perform each step manually can limit productivity, reduce the quality of the final product, and increase labour costs. This has led to a pressing demand for more efficient, hygienic, and affordable methods of pap production (Kumar, and Kalita, 2017; Dhanaraju et al., 2022).

In response to these challenges, recent years have seen a surge of interest in the design and construction of mini pap processing machines (Adetunji, and Omoruyi, 2016). These machines are engineered to streamline the pap-making process, reducing the time and effort required and ensuring a consistent, high-quality product. Typically, these machines consist of key components such as a hopper for grain loading, a processing plant unit for grinding, and a filtering unit for sieving. Some advanced models also feature motorized operations to further enhance efficiency (Raj et al., 2022).Despite the advancements in pap processing technology, the adoption of these machines by households and small businesses has been limited, primarily due to the high costs associated with these devices. This gap highlights the need for the development of more affordable, efficient, and user-friendly mini pap processing machines that can cater to the needs of small-scale producers and households.

2. Materials and method

2.1 Major Components and Material Selection Criteria for the Mini Pap Processing Machine

The design and construction of a mini pap processing machine involve various components that work together to streamline the production process. Each component plays a critical role in ensuring the machine's efficiency, durability, and overall performance. Below, we discuss the major components of the machine and outline the criteria for selecting appropriate materials for each part.

1. Standing Frame

Function

The standing frame provides structural support and stability for the entire machine. It ensures that the machine remains stable during operation and supports the weight of all the components.

Material Selection Criteria

- **Strength and Durability:** The frame must be made of a material that can support the weight of the machine and withstand mechanical stresses during operation. Steel is commonly used due to its high strength and durability.
- **Corrosion Resistance:** To prevent rusting and extend the machine's lifespan, the material should resist corrosion. Galvanized steel or stainless steel are excellent choices as they offer good resistance to corrosion.
- **Weight:** While the frame needs to be strong, it should not add excessive weight to the machine, making it difficult to move or transport. Hollow steel sections or aluminum alloys can provide a balance between strength and weight.

2. Hopper

Function

The hopper is the component where grains are loaded into the machine. It guides the grains towards the grinding and processing sections.

Material Selection Criteria

- **Food-Grade Quality:** Since the hopper comes into direct contact with food materials, it must be made from food-grade materials to ensure safety and hygiene. Stainless steel is ideal for this purpose as it is non-reactive and easy to clean.
- **Corrosion Resistance:** The hopper should be resistant to corrosion to prevent contamination and ensure longevity. Stainless steel or high-density polyethylene (HDPE) are suitable choices.
- **Ease of Cleaning:** The material should allow for easy cleaning to maintain hygiene standards. Smooth surfaces and non-porous materials are preferred.

3. Bearing

Function

Bearings facilitate the smooth rotation of components, such as the grinding disc and cutting disc, by reducing friction and wear.

Material Selection Criteria

- **Load Capacity:** Bearings must be capable of handling the loads generated by rotating components. High-quality steel or ceramic bearings are often used due to their ability to withstand significant loads.
- **Corrosion Resistance:** Bearings should resist corrosion to maintain performance and durability. Stainless steel or sealed bearings with appropriate lubrication are effective in preventing corrosion.
- **Durability and Wear Resistance:** Bearings should be durable and have low friction coefficients to minimize wear and extend their operational lifespan.

4. Belt

Function
The belt transfers rotational power from the electric motor to other components like the grinding disc or pulley, enabling them to operate.

Material Selection Criteria

- **Flexibility and Strength:** The belt needs to be flexible enough to accommodate movement but strong enough to transmit power efficiently. Materials like reinforced rubber or neoprene are commonly used.
- **Heat Resistance:** The belt should withstand the heat generated during operation to prevent degradation. High-temperature rubber compounds or synthetic materials are suitable.
- **Durability:** The material should resist wear and tear to ensure a long service life. Reinforced rubber with textile or steel reinforcements is often used for durability.

5. Electric Motor

Function
The electric motor provides the power required to operate the machine, driving components such as the grinding disc and cutting disc.

Material Selection Criteria

- **Power and Torque Output:** The motor must provide sufficient power and torque to handle the workload. Motors with adequate horsepower and torque ratings for the expected load are necessary.
- **Efficiency:** An energy-efficient motor will reduce operational costs and energy consumption. High-efficiency motors that meet or exceed regulatory standards are preferred.

- **Durability and Heat Resistance:** The motor should be robust and capable of operating in various conditions without overheating. Materials with good thermal management properties, such as copper windings and aluminum or steel casings, are ideal.

6. Grinding Disc

Function
The grinding disc is responsible for crushing and grinding the grains into a fine paste.

Material Selection Criteria

- **Hardness and Wear Resistance:** The grinding disc must be hard and wear-resistant to handle the abrasive nature of grains. Hardened steel or carbide-tipped discs are suitable due to their high hardness and wear resistance.

- **Corrosion Resistance:** The disc should resist corrosion to maintain hygiene and durability. Stainless steel or coated steel discs can provide good corrosion resistance.

- **Ease of Sharpening:** The disc material should allow for easy sharpening to maintain cutting efficiency. Materials that can be easily resharpened, like certain tool steels, are preferred.

7. Cutting Disc

Function
The cutting disc is used to cut or slice grains before they are ground, facilitating a more uniform grinding process.

Material Selection Criteria

- **Sharpness and Durability:** The cutting disc needs to be sharp and durable to cut through grains effectively. High-carbon steel or tungsten carbide are excellent choices due to their sharpness and durability.

- **Corrosion Resistance:** The disc should resist corrosion to ensure a long lifespan and maintain food safety standards. Stainless steel or coated cutting discs are appropriate.

- **Ease of Replacement:** The material should allow for easy replacement when the disc becomes dull or worn out. Standardized materials that are readily available are preferred.

8. Pulley

Function
The pulley system helps transmit power from the electric motor to the grinding and cutting discs through the belt.

Material Selection Criteria

- **Strength and Durability:** The pulley must be strong enough to handle the forces involved in power transmission. Cast iron or aluminum alloys are commonly used for their strength and durability.
- **Corrosion Resistance:** The pulley should resist corrosion to ensure long-term operation. Materials like aluminum alloys or coated steel can provide good resistance.
- **Smooth Operation:** The pulley should facilitate smooth operation, reducing vibration and noise. Precision-machined materials with smooth surfaces are preferred.

9. Mesh

Function

The mesh is used to sieve the ground grain paste, separating fine particles from coarser ones to ensure a smooth consistency in the final product.

Material Selection Criteria

- **Mesh Size and Precision:** The mesh must have the appropriate size and precision to effectively separate fine and coarse particles. Stainless steel or brass mesh with precise hole sizes is ideal.
- **Corrosion Resistance:** The mesh should be resistant to corrosion, especially when in contact with moisture and food materials. Stainless steel is the best choice for its corrosion resistance and durability.
- **Ease of Cleaning:** The material should be easy to clean to prevent clogging and maintain hygiene. Smooth, non-reactive materials like stainless steel are preferred.

2.2 Design Consideration for a High-Efficiency and Reliable Mini Pap Processing Machine

The design of the mini pap processing machine hinges on three critical considerations: minimizing production costs, achieving the desired product quality, and ensuring the use of locally sourced materials for ease of maintenance. Each of these factors is essential to creating a machine that is not only functional and efficient but also affordable and easy to maintain, ultimately making pap production more accessible and sustainable for small-scale producers and households.Designing a mini pap processing machine involves careful consideration of several factors to ensure its efficiency, reliability, and cost-effectiveness. The goal is to create a machine that not only meets the functional requirements of pap production but also addresses the practical needs of users. Here are the key design considerations:

Minimize the cost of production to make the machine affordable for small-scale producers and households.

Material Selection: Choose cost-effective materials that provide durability and functionality without significantly increasing the overall cost. Opt for materials that offer a good balance between quality and price.

- **Manufacturing Processes:** Use simple and efficient manufacturing processes that reduce labor and production costs. Avoid complex machining or fabrication techniques that increase expenses.
- **Component Standardization:** Utilize standard parts and components that are readily available and inexpensive. This reduces costs associated with custom parts and simplifies assembly.
- Use locally sourced materials that are both affordable and easy to procure.
- Design the machine with a modular approach, allowing for easy replacement of parts, which can reduce maintenance costs over time.
- Ensure the machine can produce pap with a smooth, consistent texture that meets consumer expectations.
- **Grinding Efficiency:** The machine should grind grains into a fine paste that, when sieved, results in a smooth and homogeneous texture suitable for pap.
- **Precision of Components:** Components like the grinding disc and mesh must be designed and calibrated to achieve the desired particle size and consistency.
- **Adjustability:** Include adjustable settings that allow users to control the texture and fineness of the ground paste, accommodating different preferences and grain types.
- Incorporate a high-quality grinding disc that can achieve a fine, consistent grind.
- Use a mesh with precise sizing to ensure proper separation of fine and coarse particles, resulting in a smooth end product.

Facilitate ease of maintenance and repairs by using materials and components that are locally available.

- **Availability of Materials:** Select materials that are commonly available in local markets to ensure easy access for repairs and replacements.
- **Simplicity of Design:** Design the machine with simplicity in mind to make maintenance straightforward, reducing the need for specialized tools or skills.
- **Compatibility with Local Conditions:** Choose materials that can withstand the local environmental conditions, such as humidity and temperature variations, ensuring long-term durability and reliability.

- Use locally available metals like mild steel or aluminum for structural components, which are easy to source and work with.
- Ensure that moving parts like bearings and belts are standard sizes available in local hardware stores, simplifying maintenance and replacement.

2.3 Components

2.3.1 Standing frame

This the stand that provides support for the whole machine and it is made up of rectangular mild steel pipe of 6.00mm and 4.00mm dimension and a mild steel angle iron of size 4.00mm by 4.00mm dimension. The pipe and angle bar are welded together by means of electric arc welding process which make the component

2.3.2 Hopper

The hopper is a pyramidal shape and pathway through which the soaked or wet grains were fed into the machine for grinding, inside the hopper, there is a stopper that regulate the flow of fed into grinding chamber of the of the pap making machine. The hopper is made of stainless steel and wrapped extremely with mild steel plate for rigidity and support in other to withstand vibration. The plate used was 2mm thick and the top opening has dimension of 410mm by 230mm, 150mm by 150mm lower opening and height of 420mm. the plate was marked cut to size and welded.

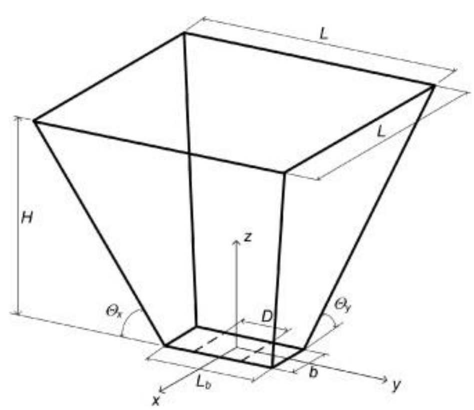


Fig 1 Hopper

2.3.3 The Grinding Disc

This unit consists of the shaft perforated mesh rolled sheet, circular discs and rivet pins. The drum is formed by the shaft passing through the rolled cylindrical sheet and welded in place by circular discs. This drum is then wimped with the perforated mesh. This unit house the rotor that hold the grinding disc and the mesh for sieving. The inner part of the chamber is made from stainless steel of size. The stainless steel was used for the inner chamber due to its non-corrosive properties of the stainless steel

2.3.4 Belt and pulley

Two pulley were used for the machine which were the driver and the driver pulley respectively. The driver pulley of the size is mounted on the electric motor while the driven pulley of was mounted on the main shaft that force the rotor of the pap grinding machine. The V belt passes through the pulley Easy transmission

2.3.5 Mesh

Mesh act as a sieve for the milled fermented dried cassava before it is finally discharged. It is made up of stainless steel with a 2mm mesh size and it is replaceable with other sizes

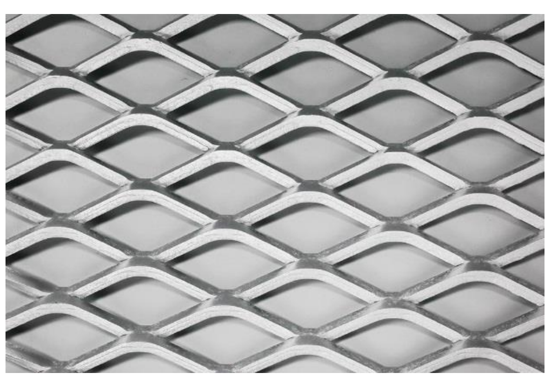


Fig 2 Mesh

2.3.6 Casing chamber

The casing chamber is a mild steel plate of 2mm thick, that cover the grinding chamber of the machine with chose end cover.it is folded to form hexangonal shape and a closed end cover perforated at the center that the main shaft will pass through it for transmission of the grinding disc.

2.3.7 Discharge Chute

This is the part of the machine that receives the milled or grinded material from the screen into a container. It is installed in the bottom and is designed in such a way that the angle of inclination of the discharge chute is a little greater than the angle of inclination of the material that the machine is designed to grind.

2.3.8 Pulley: Pulleys are used singly or in combination to transmit energy and motion.One or more independently rotating pulleys can be used to gain a mechanical advantage, especially for lifting weights

2.3.9 Filtration: Filtrationis a physical separation process that separates solid matter and fluid from a mixture using a filter medium that has a complex structure through which only the fluid can pass.It is used to separate particles and fluid in a suspension, where the fluid can be a liquid, gas, or supercritical fluid.The solid particles that cannot pass through the filter medium are described as oversize, while the fluid that passes through is called the filtrate.Filtration occurs both in nature and in engineered systems, and there are biological, geological, and industrial forms of filtration.

2.4 Design and Calculation

2.4.1 Design of the hopper volume

The volume of the hopper was determined using the volume of frustum pyramid.

Volume of hopper, $v_h = 1/3h(a^2+b^2+\text{ab})$ (1)

Where a is the lower base length (230mm) and b is the upper base length (410mm) and h is the height(420mm) substituting the values into Equation 1

$$v_h = {}^1/_3 \text{x } 420(230^2+410^2 + (230\text{x}410) = 44{,}14200mm^3 = 0.044m^3$$

2.4.2 Design of shaft speed.

The speed of the shaft used was determined using information obtained from the diameters of the driving and the driven pulley. The number of revolution of driven pulley N_2 achieved by using Equation 2

$$\frac{D_1}{D_2} = \frac{N_2}{N_1} \quad (2)$$

Where D_1 is the diameter of driving pulley (60mm)

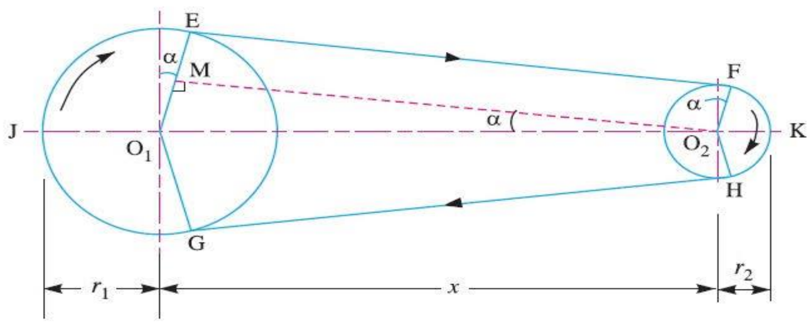
D_2 is the diameter of the driven pulley (90mm)

And N_1 is the number of revolution of the driving pulley (3500 rev/min) by the petrol engine

Substituting the values into the Equation 2

$60/90 = \frac{N_2}{N_1}$: N_2 =2400rev/min

2.4.3 Design for Belt



The length of the belt was calculated using Equation 3

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \left(\frac{D_1 - D_2}{4C}\right)^2 \quad (3)$$

Where, L is the length of the belt $\pi = 3.142$ and c is the center between the two shafts (390mm)

Substituting the values into Equation 3

$$L = \frac{3.142}{2}(60+90) + \left(\frac{60-90}{40\ x390}\right)^2 = 1015.65mm$$

The belt contact angle can be calculated using the formula as described by Mora King et al. (2014)

$$a = sin^{-1}\left(\frac{R-r}{C}\right) \quad (4)$$

Where R is the radius of the driven pulley (45mm) and r is the radius of the driving pulley

Putting the values into Equation 4

$$a = sin^{-1}\left(\frac{45-30}{390}\right) = 2.20^{\circ}$$

The angle of wrap around each of the pulley i.e. driving and driven can be calculated using Equations 5 and 6

$$Ø = 180 + 2a \quad (5)$$

From equation 3.4 angle of wrap a is 2.20

Therefore,

$Ø_1$ =180 + 2 x 2.20 = 184.4^o

Also, $Ø_2$ = 180 – 2a (6)

$Ø_2$ = 180 – 2x 2.20 = 175.6^o

Therefore, Øis the average angle of the wrap around each pulley (the motor and the shaft in radian

$$Ø= \left(184.4 + \frac{\pi}{180} + \left(175.6\ x\ \frac{\pi}{180}\right)\right) = 3.14^{\circ}$$

The coefficient of friction μ between belt pulleys was assumed to be 0.3

2.4.4 Velocity of the shaft

The velocity of the shaft V was calculated by Equation 7 (khurmi and Gupta,2005)

$$V = \frac{\pi N D}{60} \quad (7)$$

Where, N is the number of revolution 2400 rpm of driven pulley and D is the diameter of the driven pulley 0.09m

$$V = \frac{3.142 \times 2400 \times 0.09}{60} = 11.3\text{ms}^{-1}$$

2.4.5 Centrifugal Force Exerted By the Grinding Disc

The centrifugal force (fc) exerted by the Grinding Disc was calculated using Equation 8 Khurmi and Gupta (2005)

$$F_C = \frac{MV^2}{e} \quad (8)$$

Where, m is the total mass of the grinding disc 8.64kg r_s is the radius of the shaft 0.015 and v is the velocity of the shaft

Therefore,

$F_C = \frac{8.64\ x\ (11.3)^2}{0.015}$ = 73.55kN

2.4.6 Design of the tension on the belt

According to Khurmi and Gupta (2005), the density of the belt is assumed to be 1140kgm^{-3}

Therefore, the tension on each side of the belt was calculated by Equation 9Ezurike et al. (2018)

$$\frac{T_1 - T_C}{T_2 - T_C} = e^{\mu\theta} \quad (9)$$

Where T_1 is the tension on the tight side of the belt T_2 is the tension on the slacked side of the belt, T_c is the centrifugal tension on the belt,μ is the coefficient of friction between the belt and pulley and θ is the average angle of wrapped around each pulley as shown in Equation 10.

$$T_C = MV^2 \quad (10)$$

Where, is the mass of the belt per unit length and v is the velocity of the shaft

Also,the centrifugal tension can be calculated using Equation 11 Ezurike et al (2018)

$$T_C = \frac{T_1}{3} \quad (11)$$

The mass of the belt per unit length m was calculated Equation 12

Where w is the width 12mm, is the thickness 9mm × belt density, and p is density of the belt 1140 kgm^{-3}

$$M = w \times t \times p \quad (12)$$

Therefore,

M = 120 x 9 x 1140 = 0.123kgm^{-3}

Form Equation 10, the centrifugal tension

T_C =0.123 x 11.3 = 15.7N

3.12, T_1 =3T_c

Hence, T_1= 3 x 15.7 = 47.1N

Substituting the values into Equation 9

$$\frac{47\ .1 - 15.7}{T2 - 15.7} = e^{0.3x3.14^{3.14\ \times 0.3}}$$

$= 27.78 \times 1$ N

2.4.7 Determination of power and torque transmitted to the shaft

The power and torque transmitted to the shaft was calculated using Equation13 Khurmi and Gupta (2005)

Therefore,

$p_{s=(}T_{1-T_{2)}}$V (13)

$$P_{Belt}\ = (47.1 - 27.78) \times 11.3 = 218.32w$$

$T_{S=(}T_{1-T_{2)}}$R

Hence,

$T_{S=(47.1-15.7)45}$ =1413N

2.5 Construction Procedures

2.5.1 Material Purchasing

This step involved conducting a market survey to identify and purchase the necessary tools and materials required for constructing the machine. Key materials procured included:

- Metal steel plates
- Angle bars
- Paint

2.5.2 Marking out the Material

Accurate dimensioning was crucial for the construction process. This step utilized measuring tapes and scribers to mark the materials according to the project requirements. For example:

- A 2” × 4” rectangular bar was measured and marked to create components like the base, hopper, and frame of the machine.

2.5.3 Cutting the Materials to Various Sizes and Shapes

The marked materials were cut using a hacksaw, with the following steps:

- The material was securely clamped in a vice.
- A hacksaw with a frame and blade was used to cut the material to the required sizes.
- The cut edges were finished with a file to ensure smoothness and accuracy.

2.5.4 Forming the Parts

In this step, the cut materials were arranged into the desired shapes for the machine:

- Components were held together with a vice to ensure a secure fit before welding.
- The machine's frame, with dimensions of 7ft × 3ft, was assembled at a 45-degree angle.
- The hopper was welded together to achieve the required shape using permanent welding, which involves generating an electric arc to melt and fuse the metal.

2.5.5 Welding the Joints

Arc welding was used to permanently join the metal parts:

- The welding machine, which could be electric or engine-driven, was employed.
- Electrodes facilitated the welding process to ensure strong, durable joints.

2.5.6 Filing and Filling the Welded Joints

To finish the welded joints:

- Files and grinding discs were used to smooth and flatten the welded areas.

- Body filler was applied to ensure uniformity and a clean finish on the machine's surface.

2.5.7 Painting

The machine was painted in two layers:

1. **First Layer:** Anti-rust paint was applied to prevent corrosion and prolong the metal's life.
2. **Second Layer:** Oil-based paint was used for additional protection and to enhance the machine's aesthetic appeal.

2.5.8 Assembly Method

The assembly of the machine components was done using bolts and nuts, facilitating easy disassembly for maintenance. This method is widely used in engineering projects, such as:

- Plant installations
- Electrical setups
- Civil construction work

In this project, bolts and nuts were used to:

- Attach the drum to the frame.
- Secure the petrol-powered engine to the trolley, ensuring stability during operation.

2.6 Equipment and Machining Processes Used in the Construction

2.6.1 Drilling Machine

- **Type:** Hand or pillar drilling machine.
- **Usage:** Drilling stationary work piece held in a vice.

2.6.2 Milling Machine

- **Usage:** Cutting keyways on the grater shaft for precise fitting.

2.6.3 Lathe

- **Functions:** Boring, turning, and facing tasks requiring high precision.

2.6.4 Hand Processing Plant/Cutting Disc Machine

- **Disc Sizes:** Available in 9mm, 7mm, and 4mm diameters.
- **Usage:** Cutting and processing materials to required specifications.

2.6.5 Arc Welding Machine

- **Function:** Used with electrodes and tongs for joining metals.
- **Processes:**
    - **Tacking:** Temporary, easy-to-break joins for alignment.
    - **Stitching:** Firm joins for thin metals.
    - **Running:** Strong, permanent joins for thick metal plates.
- **Equipment:** Mild steel electrode (12-gauge, 2.5mm diameter) and welding glasses for safety.

2.6.6 Bending Machine

- **Usage:** Bending sheet metal up to 5mm thickness to desired angles.
- **Example:** Bending 3mm grater sheets to a 130° angle.

2.6.7 Table Shear

- **Function:** Cutting sheets under 3mm to 4mm thick with straight edges.

2.6.8 Pedestal Processing Plant Machine

- **Usage:** Sharpening tools and drill bits for precision work.

2.7 Principle of Operation

The mini pap processing machine operates on the principle of attrition:

- **Power Transmission:** A petrol engine supplies power, which is transmitted to the grinding discs via a V-belt.
- **Grinding Discs:** The discs have slightly rough surfaces facing each other and are mounted on a shaft with bearings. The relative motion between the discs grinds the grains into a fine paste.
- **Assembly and Maintenance:** Components are designed for easy disassembly, making maintenance straightforward and ensuring reliable, long-term operation.

3. Results and discussion

The Table 1 presents the time taken for the different grains to be grated by the machine

S/N	Grains and Quantity	Time Taken

1	Maize (1.2kg)	13mins
2	Guinea Corn (1.2kg)	8mins
3	Millet (1.5kg)	10mins

The mini pap processing machine was tested with three different grains commonly used for pap production: maize, guinea corn, and millet. The tests focused on evaluating the machine's grating efficiency and the overall quality of the processed product. The performance of the machine was assessed based on the time taken to achieve a smooth consistency for each grain and the effectiveness of the sieving process in removing unwanted particles.

3.1 Grating Efficiency and Time Analysis

The performance of the machine was first evaluated by grating 1.2 kg of maize. It took 13 minutes to reduce the maize into a smooth paste. Maize, being a harder and denser grain, posed more resistance during the grating process, resulting in a longer processing time. This outcome indicates that while the machine is capable of handling tougher grains, it requires more time and effort to process them compared to softer grains. The extended grating time for maize also reflects the inherent challenges associated with processing harder grains, which is critical for ensuring the final product's quality in terms of texture and consistency.

In contrast, guinea corn, which was also tested in a quantity of 1.2 kg, took significantly less time to grate, requiring only 8 minutes. The reduced time can be attributed to the softer texture and smaller grain size of guinea corn, which allows for quicker and more efficient processing. The shorter grating time demonstrates the machine's high efficiency in handling grains that are less dense and more malleable. This efficiency is crucial for small-scale producers who need to process grains quickly without compromising the quality of the output.When testing with 1.5 kg of millet, the machine grated the grains in 10 minutes, despite the larger quantity. Millet's small grain size and relatively soft texture contributed to this efficiency, enabling the machine to process a larger volume in a relatively short period. The ability to handle a greater quantity of grain without a substantial increase in processing time indicates that the machine is suitable for handling various volumes efficiently, which is beneficial for small-scale production where both time and resource optimization are critical.

3.2 Quality of the Grated Product and Sieving Process

After grating, the paste from each grain type was subjected to sieving to ensure the removal of grain shafts and other unwanted particles. The sieving process was effective across all grain types, yielding a smooth and fine paste that is ideal for pap production. The successful removal of unwanted particles through sieving confirms the machine's ability to produce a high-quality product that meets the necessary standards for pap preparation.Multiple passes through the machine were employed to achieve the desired paste consistency for each grain type. This iterative approach ensured that the paste was adequately refined and free from any residual coarse particles, which is crucial for producing a smooth and consistent pap. The ability to process the grains multiple times without significant deterioration in performance highlights the machine's robustness and reliability.

The results from the tests indicate that the mini pap processing machine is highly effective in grating various grains used in pap production. The machine demonstrates excellent performance across different grain types, showcasing its versatility and efficiency. The findings suggest that the machine is well-suited for small-scale and household use, providing an efficient solution for producing high-quality pap with minimal effort and time.The ability of the machine to handle different grains effectively and produce a smooth, fine paste through efficient sieving highlights its potential impact on improving pap production processes. By reducing processing time and labour requirements, the machine can enhance productivity and ensure consistent product quality, making it an invaluable tool for small-scale pap producers and households seeking to streamline their production processes.

4. Conclusion

The study presents a mini pap processing machine designed for small-scale producers, showcasing its efficiency across various grains like maize, guinea corn, and millet. It processes 1.2 kg of maize in 13 mins, 1.2 kg of guinea corn in 8 mins, and 1.5 kg of millet in 10 mins, highlighting its versatility and effectiveness. Material selection, including food-grade stainless steel and mild steel, ensures durability and affordability, while modular design aids in easy maintenance. The machine's adaptability to different grain types addresses the needs of small-scale producers, enhancing productivity and quality. Emphasis on locally sourced materials and simple manufacturing processes reduces costs and facilitates maintenance. Future improvements could focus on optimizing the grinding mechanism and integrating advanced features like automated feeding systems. Overall, the machine represents a significant advancement in small-scale pap production, aligning with the needs of local communities and contributing to food security and economic development.

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