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Design and Development of a Mini Electrically Powered Taro Grating Machine for Rural Food Processing in PNG

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Abstract

Food security is becoming a big problem in Papua New Guinea and other places, especially as the population grows and the weather changes. Taro is one of the main root crops in PNG and is an important food for many people. It is not only a basic food but is also becoming more valuable in markets because many people want to buy it, both fresh and processed. But like other root crops, taro goes bad quickly and starts to rot a few days after it is harvested. Because of this, it is hard for Local farmers to sell fresh taro far away or keep it for a long time. One way to preserve taro and reduce waste is by grating it into pulp and using it to prepare various food products or drying it for storage. In this study, a multi-purpose electrically powered taro grating machine was designed, built, and tested. The machine uses grater blades set at two different tooth angles of 25˚ and 30˚ to improve grating performance as well as its quality. Test results showed that the blade with a 30˚ angle produced better grating efficiency because it offered more grip on the taro and reduced the amount of un-grated material. This machine provides a faster, safer, and more hygienic method for grating taro, and can help small-scale farmers reduce waste, add value to their crop, and increase income.

Keywords
Design Optimisation, Natural frequency, Machine performances, Factor of Safety.

1. Introduction
According to Bourke et al., in Papua New Guinea (PNG), especially in the highlands and lowlands, farming is not just about growing food-it is a way of life. Most families rely on subsistence gardening to feed their households. The common crops grown and eaten every day include sweet potato (locally called *kaukau*), cassava, taro, banana, and sago. These starchy foods form the main part of the daily diet in almost every home in PNG and are mostly eaten boiled, roasted, or prepared into traditional dishes. Traditionally, people prepare these foods by peeling and chopping them. This simple method has been used for generations. However, to make food preparation more interesting and to introduce variety in texture and taste, people started using the grating method. Grating means rubbing the food against a rough surface to cut it into fine pieces. This process helps in making new kinds of dishes using the same crop.

Figure 1. Traditional Taro Grating Tool used in PNG.

Figure 1 shows a simple hand-held grater used in Papua New Guinea for taro preparation. Made from scrap metal with punched holes, it requires manual scraping - a slow, tiring process that wastes some taro and risks metal bits in food. This highlights why better grating tools are needed.

The traditional taro grater used in PNG is simple and handmade. It consists of two main parts: a wooden frame and a grating sheet. The grating surface is made by hammering nails through an aluminum sheet to create sharp, jagged points. These act like teeth that shred the food when it is rubbed across the surface. The aluminum sheet is tightly fixed to the wooden frame with screws to keep it stable. This tool is operated manually and requires the user to push the taro back and forth over the surface.

Due to these problems, there is a growing need for better tools to process taro and other root crops, especially in rural areas. Like cassava in other countries, taro in PNG has the potential to contribute not just to household food security, but also to income generation. However, post-harvest deterioration becomes a major problem. Taro begins to spoil within just a few days due to its high-water content—just like cassava, which deteriorates after 2–3 days of harvesting. This leads to waste and economic loss unless the crop is processed quickly.

To address these issues, a new electrically powered taro grating machine was designed and built as part of this study. The goal was to make grating easier, faster, safer, and more hygienic by using food-safe materials that do not rust or react with food, as stated in.

2. Literature Review

Cassava and taro are staple foods in many parts of Papua New Guinea. These root crops are a major part of the local diet and play an important role in food security. In many rural areas, people still use traditional tools like knives and hand graters to process cassava and taro. These manual methods are slow, require a lot of effort, and lead to low productivity. Because of this, researchers have started designing machines to help grate or grind these crops more efficiently.

This literature review compares key studies on cassava grinding machines and explores how these machines can also be used for taro, another important root crop in tropical regions. The review focuses on five main areas:

- **Efficiency** – how well and quickly the machines work
- **Power Sources** – what kind of energy the machines use
- **Sustainability** – how the machines impact the environment
- **Safety** – how safe the machines are for the users
- **Cultural Adaptation** – how suitable the machines are for rural communities and local practices

Two main machines are discussed in this review. According to Bello et al. (2020), their machine is designed to work both manually and with electricity. This dual-function cassava grater helps users continue processing even during power blackouts. The machine uses a rotating drum to grind cassava into pulp, and the pulp flows out through chute outlets that can be operated by hand.

On the other hand, Tambari et al. (2014) designed a pedal-powered cassava grinding machine aimed at helping rural farmers who don't have access to fuel-powered engines. This machine works by using human energy, where the user pedals to rotate the grinding shaft through a chain and belt system. This makes it affordable and useful for people in low-income or off-grid areas.

The aim of this review is to analyze these two machines and identify their strengths and weaknesses, especially in terms of their possible use for taro grinding. It also highlights areas where more research is needed to improve machine designs for better performance, safety, sustainability, and cultural fit.

2.1 Efficiency of Cassava and Taro Grinding Machines

The main priority in designing root crop grating machines is achieving maximum efficiency. The electrical operation of cassava processing achieved 82.7% efficiency while manual operations reached 79.5% according to Bello et al. (2020). Around 0.42 of mechanical advantage and 58.59 kg/hour in output capacity were reported by Tambari et al. (2014) for their pedal-powered cassava machine.

3. Design Methodology

How this machine was built and analyzed (Figure 2)

- SolidWorks performs modelling and providing data (running all sorts of simulations)
- Microsoft excel serves as the main tank for data
- MATLAB is used as the main unit for performing computation

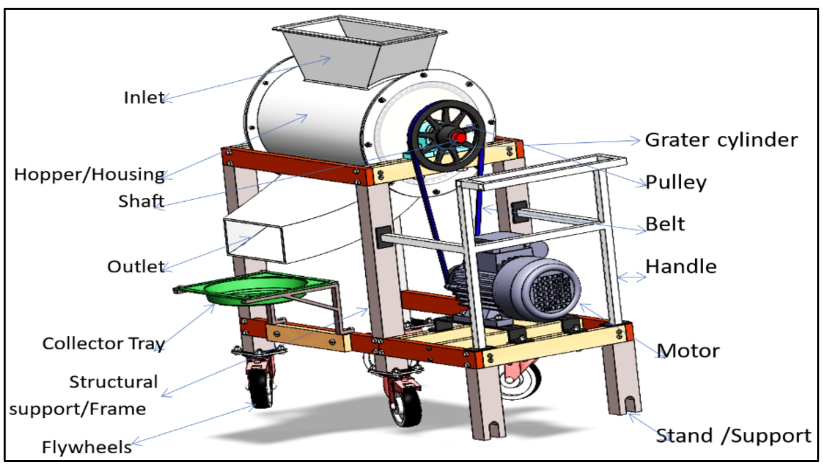

Figure 2. Isometric view of a Mini Taro Grater Machine Designed.

3.1 Simulation and Optimization

Main types of simulations that SolidWorks performs are from Cad knowledge.(2020, April 10) Static Structural, Frequency (Hawk Ridge Systems. (2014, July 25), Buckling (GoEngineer. (2019, January 4)) and Fatigue (Hawk Ridge Systems (2014, September 2), including environmental impacts- Sustainability analysis (TriMech Tech Tips Channel. (2015,Marcg).

Excel stored the simulation data for each part in SolidWorks in different single Sheet- Only one file
MATLAB runs the optimisation and other computation that are data driven- every data is pre-processed after importing out from excel. MATLAB fundamental programming (MathWorks Documentations, MATLAB. (2025). Mathworks.com) are scripts (Scripts - MATLAB & Simulink. (2021). Mathworks.com), functions (Functions - MATLAB & Simulink. (2025). Mathworks.com) and classes (Classes - MATLAB & Simulink. (2025). Mathworks.com).

4. Results and discussions

Results that will be discussed comes from design optimization and other design considerations such as, monitoring the vibrations of the structures, environmental impact of the machines during the development process, safety and Costs.

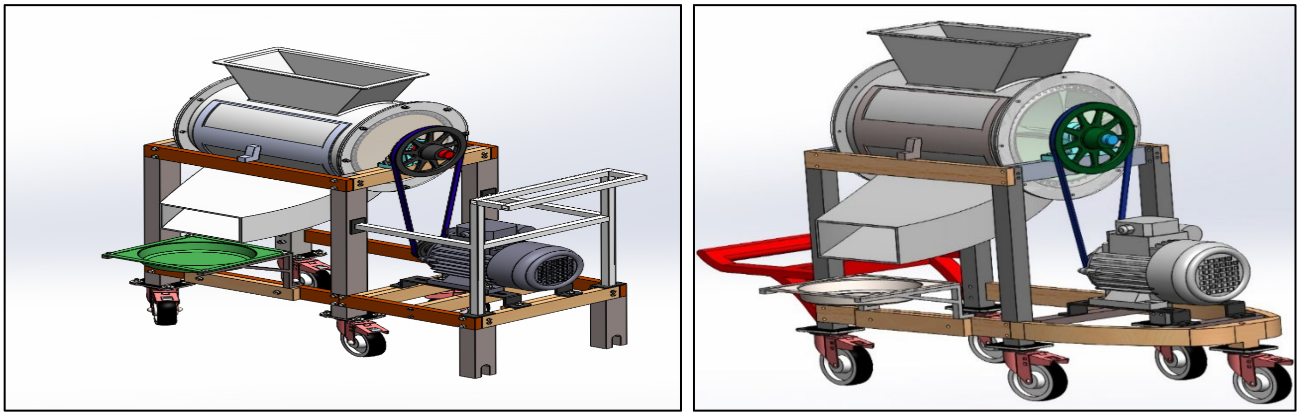

Figure 3. The effect of design optimization. Left hand side shows the initial assembly and the right-hand side shows the optimized version of initial model.

The modified assembly comes from factors like (Figure 3), minimizing weight while having the best stiffness, functionality and performance. Reducing cost and minimizing weights and optimized factor of safety are the 3 main objective of the optimization of this design.

As can be seen clearly from Figure 4- Figure 5, some components dimensions and overall shape has changed, material changed, while some components with minimum mass at initial assembly were maximized in modified assembly- due to some design consideration.

4.1 Structural Analysis-Post Optimization

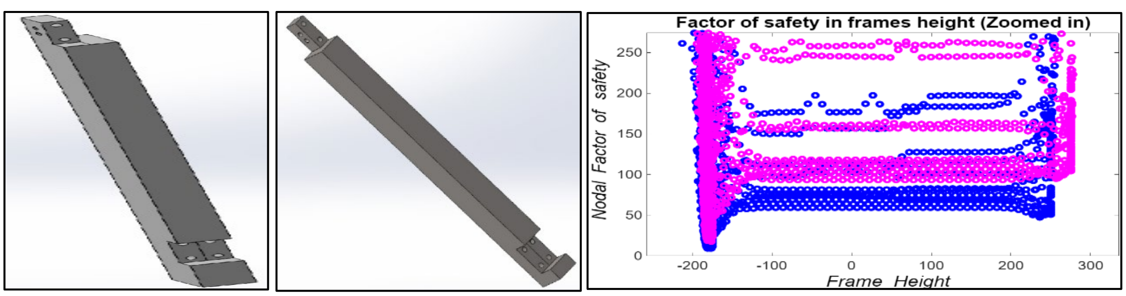

Figure 4. The supporting frames of the machine. Left, the initial structure, middle is the frame after performing two static and a design study. On the right is where, factor of safety of each version were compared.

4.1.1 Beams Optimization

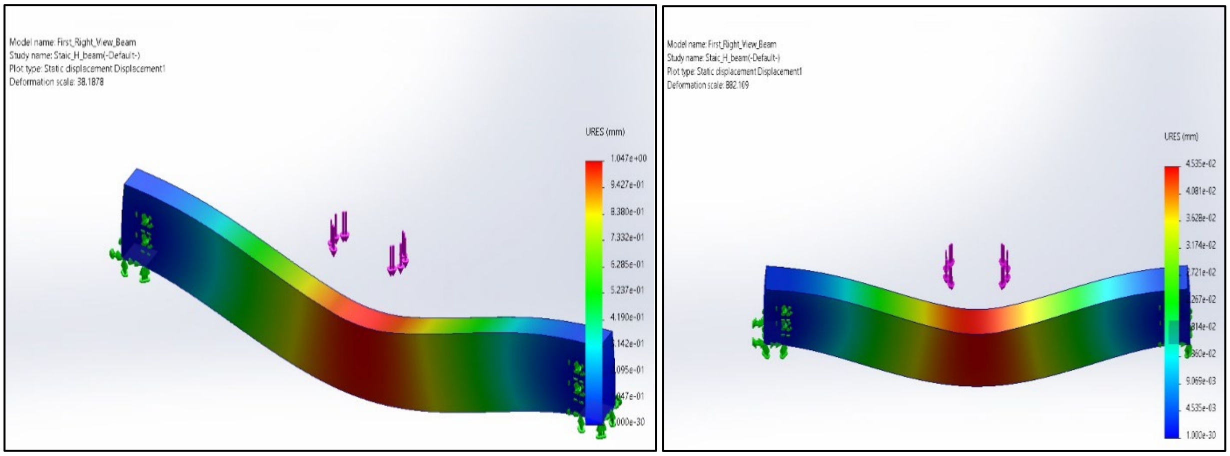

Figure 5. Shows how wood beams were changed to aluminum alloy due to deformations.

4.2 Vibration Analysis

Analysis that determines the natural frequencies of the assembly's frame. After identified (one or more), the overall assembly frequency must be shifted away from these modes.

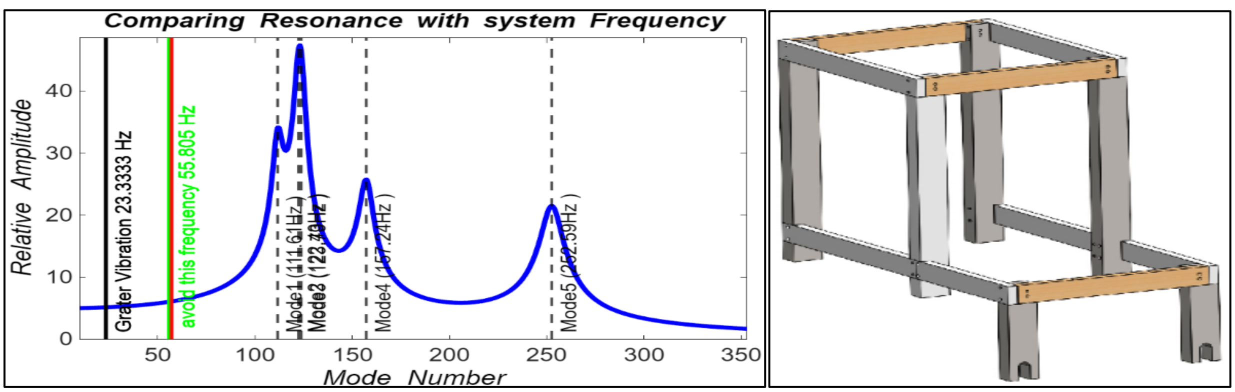

Figure 6. The frequency modes of our assembly's frame.

This Figure 6, we need to avoid theses five modes, i.e.; the frequencies of our system need to be shifted away from these modes. If our structure vibration matches one of these modes, then there will be a catastrophic failure in our machines. From this plot, the border coloured red and green represents the safe and danger region in which our system frequency must and must not cross this boundary. Simulations and data are taken from SolidWorks. As can be seen the vibration/frequency of our system (design) is labelled in heavy black line (Grater frequency). From the data from modes data gives us the frequency, period and mode number of this frames.

What might happen if the frequency of our system matches one of this five modes.
This frame will start vibrating which can cause loosening of bolts and nuts, crack propagation along the frames, and can leads to total failure of our design. Therefore, even though, there is a small force acted upon our design and the frequency matches any of these five modes, then there is a possibility that our system will fail.

4.3 Environmental Impact (Sustainability) Analysis

Every part was analyzed and the material assigned to each part were changed if that part has higher carbon footprint, higher energy consumption, air pollution and water pollution. We used Australia as the manufacturer of this part and the result about the environmental impact. The result shown at the right-hand side of Figure 6 and Figure 7 demonstrates that, we need to consider changing the material applied to this housing, because carbon emission during the process of making this part to finished product is nine percent higher than the previous ones.

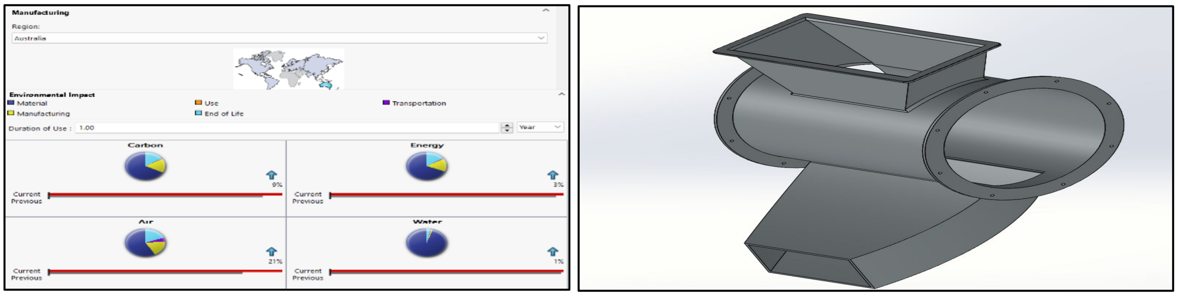

Figure 7. The environmental impact of feeder Housing, analyzed in SolidWork.

4.4 Cost Analysis

Total Cost is around 2,350 - 3,300 PGK

The total estimated cost of making the taro grater machine is between PGK 2,350 and PGK 3,300 (Table 1). This amount includes all the main parts such as the hopper, grater cylinder, shaft, bearings, frame, belt and pulley system, and an electric motor. Among all these, the electric motor is the costliest, which is expected because it powers the entire machine.

Other important costs include the steel frame, which gives strength to the machine, and the grater drum, which is the part that does the actual grating. Small items like bolts, nuts, washers, and materials for welding and painting are also included to make sure the machine is fully built and ready to use.

Table 1. The estimated cost of our whole machine

No.	Component	Description / Notes	Estimated Cost (PGK)
1.	Hopper	Sheet metal, funnel-shaped, welded	100 - 150
2.	Belt Design	Belt + 2 pulleys (one on motor, one on shaft)	120 - 180
3.	Motor Design	1.5–2 HP Electric Motor (single phase)	900 - 1,200
4.	Shaft Design	Mild steel shaft (machined ends)	100 - 200
5.	Ball Bearings	2 standard sealed bearings (e.g., 6204)	60 - 100
6.	Grater Cylinder	Stainless steel or mild steel with perforated grating teeth	200 - 300
7.	Unloading Tray	Sheet metal, guiding structure with tray	60 - 100
8.	Bolts, Nuts & Washers	Full fastener kit (M8, M10, etc.)	50 - 80
9.	Frame	Square tubes, mild steel (cutting + welding + wheels)	250 - 350
10.	Welding Type	Arc welding (MMAW); cost includes rods and labor	150 - 200
11.	Painting and Color	Primer + top coat spray/brush painting	100 - 150

The estimate also includes a small extra amount for miscellaneous items like screws and rubber pads that might be needed during assembly. Prices may vary depending on whether new or recycled materials are used, and where the parts are bought from.

In general, the machine is affordable and well-suited for village use, small businesses, or family farms, helping to save time and reduce manual labour when grating taro in and around PNG.

Overall cost for modified assembly can fall to around 70 percent of the initial assembly cost.

Note: According to Solid Solutions. (2016, May 18). *SOLIDWORKS Assembly Costing,* Cost of this machine can be computed in SolidWorks-cost analyser.

4.5 Proposed Future Work

This machine can be improved if the wheel mechanism is fully analyzed, in other words, it functionality can be improved if we can analyze and understand the dynamics of its wheels. Additionally, a control system of the motor can be integrated within the machine- can be created with MATLAB if specialized hardware is available.

5. Conclusion

This project was about designing and building a small taro cratering machine. In many parts of Papua New Guinea, people eat taro every day. After taro is peeled, it still needs to be cleaned to remove small Fibers and rough skin. Normally, this is done by hand, which takes a lot of time and effort, and can cause injuries. Our machine helps make this final cleaning step faster, easier, and safer. The first design focused on building a strong frame. After testing, we found some weak points and improved them in the second version. The second version has better support and a stronger structure. It is more stable and works better when used for longer times.

The machine uses a motor to spin a drum that cleans the taro. We worked to choose the right motor speed and power so that it cleans well without damaging the taro. We also plan to add a speed control so people can adjust it based on how soft or hard the taro is. We added safety features like a cover to protect users from moving parts and rubber feet to stop the machine from sliding. All the parts that touch the taro are made from safe materials and can be cleaned easily. This makes the machine safe and clean to use.

The machine is made for families, small farmers, and local groups. It can clean many taro roots at once, saving time and energy. This means people can spend less time cratering taro and avoid getting hurt. The taro also comes out cleaner and more even. Although we are still doing some final tests, we are happy with what we have built. The second version of the machine shows big improvements. The next step is to test it with real taro and get feedback from users so we can make it even better. In the end, we achieved our main goal: to design a taro cratering machine that is simple, safe, and helpful for the community. It is easy to use, uses local materials, and solves a real problem. We hope this machine will help many people and inspire others to keep improving it in the future.

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