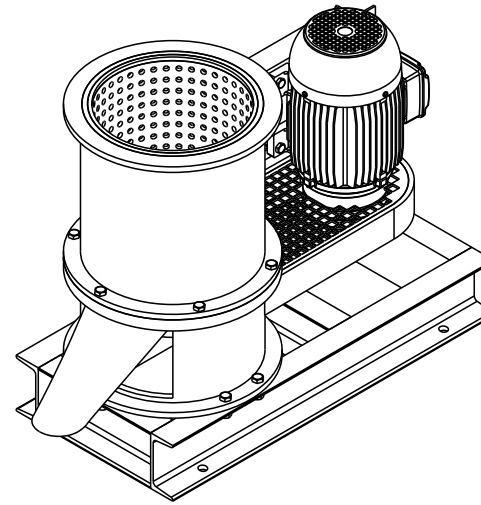
CAVA2
CASSAVA: ADDING VALUE FOR AFRICA PHASE II

How to evaluate the performance of

CASSAVA PEELING MACHINES

Aditya Parmar & Marcelo Precoppe



Booklet 1

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Preface

This booklet is the first of a 6-part series of booklets on performance evaluation of cassava processing equipment. These technical booklets are developed keeping in mind their target audience of local equipment manufacturers in developing countries, particularly Sub-Sharan Africa. The purpose is to determine the various performance parameters with simplistic techniques requiring no sophisticated instruments.

The online version of these booklets is available at: www.cassavatech.com.

At cassavatech.com we help cassava processors to learn how to choose suitable equipment and what performance parameters to ask for. These booklets series are a complement to that information provided, where equipment manufacturer can demonstrate to their potential customers the performance of the machine regarding the listed performance parameters.

A list of all the booklets in this series is provided below.

Booklet Number	Name
1	**How to evaluate the performance of CASSAVA PEELING MACHINES**
2	How to evaluate the performance of CASSAVA GRATERS
3	How to evaluate the performance of CASSAVA PRESSES
4	How to evaluate the performance of CASSAVA PNEUMATIC DRYERS
5	How to evaluate the performance of CYCLONES
6	How to evaluate the performance of HAMMERMILLS

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CAVA II

Cassava: Adding Value for Africa (CAVA II) is a project led by the Federal University of Agriculture Abeokuta, Nigeria, working closely with the Natural Resources Institute. CAVA II aims to improve the livelihoods of smallholder farmers and processors in Nigeria, Ghana, Tanzania, Uganda, and Malawi.

CAVA II works across the value-added cassava chain, it interacts directly with farmers to improve the profitability of cassava sales, both through increasing overall market demand and through boosting farmer yields.

Authors

Dr Aditya Parmar is a Crop Postharvest Scientist at the Natural Resources Institute, University of Greenwich, UK. He obtained his PhD at University of Kassel, Germany. His research interest lies in techniques to assess, monitor, and reduce food losses and wastes along the value chains.

Dr Marcelo Precoppe is a Crop Postharvest Technologist at the Natural Resources Institute, University of Greenwich, UK. He obtained his PhD at University of Hohenheim, Germany. His research interest lies in using Participatory Approach coupled with Engineering Design Process to develop technologies suitable to village-based small-sized enterprises.

How to evaluate the performance of CASSAVA PEELING MACHINES

Aditya Parmar & Marcelo Precoppe

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2021

Peeling in the food industry

Peeling is one of the most important unit operations in food industry which involves the removal of the outer layer of food material. The most commonly used peeling methods, used in the food industry, are mechanical, chemical, or thermal.

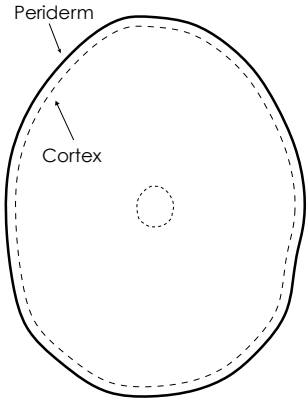
Mechanical peeling is the most popular peeling method, due to the simplicity of the operation and low cost. A mechanical peeler may either be composed of rotating knives or abrasive drums. The operation can be continuous or batch. For the product with irregular shapes such as root crops (potatoes, sweet potato, cassava) additional manual hand-peeling may be required. The processes where two methods of peeling are combined to improve peeling performance are known as two-stage peeling, which involves, for example, the first stage of abrasive peeling, and then the hand-peeling with a knife.

In a **chemical peeling**, the food passes through a hot bath of a chemical solution to remove the skin. In most cases, the chemical solution is alkaline, however, sometimes enzymes and acids are also used. Chemical peeling has an advantage that it is suitable for the products with irregular shape and size, and it is very effective in removing the whole peel. However, establishing and maintaining a chemical peeling plant operation is expensive and requires careful control over temperature, exposure time and concentrations of the hazardous chemicals. Moreover, a significant amount of water is required to wash off the peel and residue of the chemical used in the peeling process. Chemical peeling methods are becoming less common due to their environmental and safety hazard.

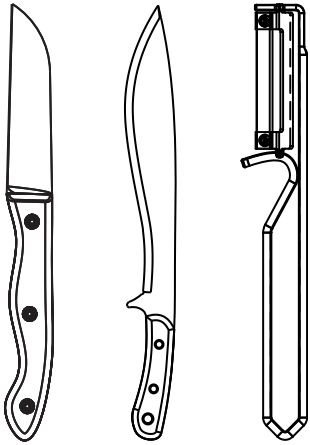
Thermal peeling is perhaps the most advanced and product-specific method. The most common thermal peeling method is high-pressure steam peeling. Thermal peeling methods are known for their high effectiveness regarding minimal peel retention and material losses, in addition to lower water consumption. Other thermal peeling methods which are common in the food industry are flash steam peeling, and flame peeling.

Cassava peeling

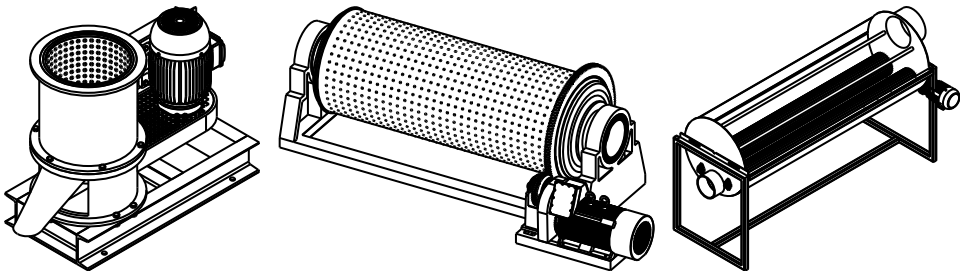
Peeling is the very first step in cassava processing. Cassava peel is composed of two layers, an outer corky layer called periderm and the cortex. The periderm resembles a thin brown bark of a tree. The cortex is a white layer of thick peel. For all cassava products other than starch, both layers need to be removed. The peel represents about 20% of the root weight, but this value varies according to the variety and agronomical practices.



Peeling cassava roots **manually** with a kitchen knife or a peeling knife is the most common method used when both layers of the cassava peel need to be removed. One of the best hand peeling technique is cutting the cassava root longitudinally only up to the depth of the cortex using a knife and peeling off the whole cortex and cork layer from one end to another. Specific peeling knives for cassava can improve the peeling operation, increasing productivity, reducing root losses, and alleviating work drudgery.



Most of the currently available **mechanical peelers** for cassava are based on a rotating abrasive surface. Their popularity lies in the simplicity of the fabrication, operation, and maintenance. Based on the geometry and orientation of the abrasive drum these peelers can be further divided into two categories namely, **mounted vertical** and **horizontal drum** type.



Other mechanical peelers are based on a rotating knife where blades rotate against the roots. This kind of peeler is used less frequently because of its higher maintenance cost, as the knives need to be replaced frequently.

Performance assessment

A cassava peeler should completely remove the peel without removing the useful part of the root. Performance of cassava peelers, in general, are poor. The main reason is the various crevices and depressions on the surface of the cassava, plus the variable root's shape, size, weight, and texture. One way to improve the mechanical peeling operation is to sort the roots according to size. Cassava peeling machines are evaluated based on their **peel retention**, **root losses**, **throughput**, **energy consumption** and **water consumption.**

Peel retention

Peel retention is the percentage weight of the peel remains attached to the roots after the peeling process. When roots are under-peeled, the remaining parts of the peel on the root reduces the quality of the final processed products by changing its composition, colour, texture, and toxicity levels. To measure **peel retention**, it is necessary to have:

- Cassava roots
- Knife
- Weighing scale

The **cassava** roots should be freshly harvested and have no part of the stalk or stem attached to them. They should not be broken or cut and should have the whole of its peel attached. The **knife** should be sharp, made of stainless-steel and suitable for cassava peeling.

Step 1. Select 50 kg of roots (use the weighing scale).

Step 2. Run the peeler.

Step 3. In a batch process, stop the machine after recommended residence time and observe visually if the roots are properly peeled. For a continuous process, stop the machine when all the roots have gone through and have been ejected from the equipment.

Step 4. With the knife, carefully remove any peel that remains attached to the roots, collecting the material.

Step 5. Measure the weight of the material that has been manually removed.

Step 6. Divide the weight of the manually removed material by 50 (the initial weight of the roots measure on Step 1). This is **peel retention**.

Root losses

Root losses are the percentage weight of the cassava root removed during the peeling process. When roots are over-peeled the useful part of the cassava is wasted. To measure **root losses,** it is necessary to have:

- Cassava roots
- Knife
- Weighing scale

Step 1. Select 50 kg of roots (use the weighing scale).

Step 2. Carefully hand peel these 50 kg and make sure only the peel is removed without losing any root material.

Step 3. After peeling, measure the weight of the peeled roots and note down the value. This is the **weight of the hand-peeled roots**.

Step 4. Select another 50 kg of roots.

Step 5. Run the peeler.

Step 6. In a batch process, stop the machine after the recommended residence time and observe visually if the roots are properly peeled. For a continuous process, stop the machine when all the roots have gone through and have been ejected from the equipment.

Step 7. Measure the weight of the peeled roots and note down the value. This is the **weight of the machine-peeled roots**.

Step 8. Now subtract the **weight of the hand-peeled roots** (Step 3) from the **weight of the machine-peeled roots** (Step 7).

Step 9. Divide the value obtained (in kg) on Step 8 by 50 (the initial weight in kg of the roots measure on Step 1). This is the **percentage root losses**.

Throughput

Throughput of the peeling machine is the mass of roots that can be peeled in a certain amount of time and it is expressed in kilograms per hour (kg/h). The throughput of a peeling machine depends on the time taken to peel a certain quantity of roots. Therefore, it depends on the **resident time**, the amount of time the roots reside in the peeling machine before being satisfactorily peeled. Throughput is obtained by dividing the total weight of the cassava loaded into the peeling machine by the time required to be peeled. To measure **throughput**, it is necessary to have:

- Cassava roots
- Weighing scale
- Stopwatch or a regular watch

Step 1. Select 100 kg of roots (use the weighing scale).

Step 2. Load the roots into the peeler and start the stopwatch simultaneously with the peeling machine.

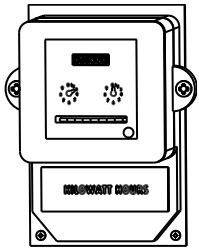
Step 3. In a batch process, stop the machine and the stopwatch after the recommended resident time and observe visually if the roots are properly peeled. For a continuous process, record the time until all the roots have gone through and have been ejected from the machine.

Step 4. Now divide the weight of the cassava roots (Step 1) by the recorded time (in hours). This is **throughput**.

Specific energy consumption

The energy consumption of a cassava peeler is assessed by its **specific energy consumption**. That is the number of electric units or amount of fuel (petrol or diesel) consumed to peel 1 kg of cassava. For machines running on an electric motor the amount of energy used is measured in kilowatt-hours (kWh) and therefore specific energy consumption is expressed as kilowatt-hour per kilogram of cassava roots (kWh/kg). For machines running on internal combustion engines, it can be expressed as litres of fuel per kilogram of cassava roots (L/kg). To measure **specific energy consumption of a peeling machine running on electric motor**, it is necessary to have:

- Cassava roots
- Weighing scale
- Electricity meter



The **electricity meter** (also called kilowatt-hour meter or energy meter) is a device that measures the amount of electric energy consumed.

Step 1. Select enough roots to run the peeling machine for at least 1 hour. Measure its weight using the scale.

Step 2. Switch-off all electric appliances and keep them off until the end of the measurements.

Step 3. Note down the **initial reading** in kWh from the electricity meter.

Step 4. Run the peeler.

Step 5. In a batch process, stop the machine after recommended resident time and observe visually if the roots are properly peeled. For a continuous process, stop the machine when all the roots have gone through and have been ejected from the equipment.

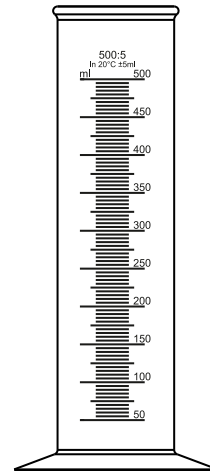
Step 6. Note down the **final reading** from the electricity meter.

Step 7. Subtract from the final electricity reading the initial reading (Step 3). This is the amount of **electric energy consumed**.

Step 8. Divide the electric energy consumed by the amount of root measured in Step 1. This is the **specific energy consumption**.

To measure **specific energy consumption of a peeling machine running on internal combustion engine**, it is necessary to have:

- Cassava roots
- Weighing scale
- Graduated cylinder



A **graduated cylinder**, also known as measuring cylinder, is a piece of equipment used to measure the volume of liquids.

Step 1. Select enough roots to run the peeling machine for at least 1 hour. Measure its weight using the scale.

Step 2. Fill the fuel tank of the peeling machine to the maximum level.

Step 3. Run the peeler.

Step 4. In a batch process, stop the machine after the recommended resident time and observe visually if the roots are properly peeled. For a continuous process, stop the machine when all the roots have gone through and have been ejected from the equipment.

Step 5. Using the graduated cylinder, measure the amount of fuel needed to bring the level in the tank back to its maximum. This is the **amount of fuel consumed**.

Step 6. Divided the amount of fuel consumed by the amount of root measured in Step 1. This is the **specific energy consumption.**

Specific energy cost

To compare the specific energy consumption of a peeling machine running on an electric motor with the specific energy consumption of a peeling machine running on an internal combustion engine it is necessary to convert it to **specific energy cost.** To calculate this simply multiply the specific energy consumption by the cost of electricity or fuel. For example, if the specific energy consumption is 0.02 kWh/kg and the price of 1 kWh is $0.50, the specific energy cost will be: 0.02 kWh/kg × 0.50 $/kWh = 0.01 $/kg.

Specific water consumption

Water consumption is assessed by determining the equipment's specific water consumption, that is, the amount of water needed to peel one kilogram of roots. It is expressed in litres of water per kilogram of roots (L/kg) or in kilograms of water per kilograms of roots ($kg_{water}/kg_{cassava}$). To measure **specific water consumption**, it is necessary to have:

- Cassava roots
- Weighing scale

Step 1. Select enough roots to run the peeling machine for at least 20 minutes. Measure its weight using the scale.

Step 2. Place a watertight container, to collect the wastewater (peel-water slurry) coming out of the peeling machine.

Step 3. Run the peeler.

Step 4. In a batch process, stop the machine after the recommended resident time and observe visually if the roots are properly peeled. For a continuous process, stop the machine when all the roots have gone through and have been ejected from the equipment.

Step 5. Using the weighing scale, measure the weight of the roots after peeling.

Step 6. Using the weighing scale, measure the **weight of the wastewater**.

Step 7. Subtract the weight of unpeeled cassava (Step 1) from the weight of the peeled cassava (Step 5). This is the **weight of the peel**.

Step 8. Subtract the **weight of the peel** from the weight of the wastewater (Step 6). This is the **weight of the water consumed.**

Step 9. Divide the **weight of the water consumed** by the weight of the unpeeled roots (Step 1). This is the **specific water consumption**.

Worked examples

Peel retention

To measure the peel retention of a peeler, **50 kg** of cassava was inserted in the machine. After all the roots were peeled, any peel that remained attached to the roots were carefully removed with a knife. The total weight of the peels removed with the knife was **3 kg**. What is the peel retention of this equipment?

$$\text{Peel retention} = \frac{\text{Weight of the peel that remained attached to the roots}}{\text{Weight of the cassava roots before peeling}}$$

$$\text{Peel retention} = \frac{3\ \text{kg}}{50\ \text{kg}} = 0.06 = 6\%$$

*Peel retention of this equipment is **6%**.*

Root losses

To measure the root losses of a peeler, **50 kg** of cassava was carefully hand peeled, without losing any root material. After peeling, the weight of the peeled root was **40 kg**. Then, another **50 kg** of cassava was inserted into the peeling machine. After machine peeling, the weight of the peeled root was **30 kg**. What are the root losses generated by this equipment?

$$\text{Root losses} = \frac{\text{Weight of the hand peeled roots - Weight of the machine peeled roots}}{\text{Weight of the cassava roots before peeling}}$$

$$\text{Root losses} = \frac{40\ \text{kg} - 30\ \text{kg}}{50\ \text{kg}} = \frac{10\ \text{kg}}{50\ \text{kg}} = 0.20 = 20\%$$

*Root losses are **20%**.*

Throughput

What is the throughput of a peeling machine able to peel **100 kg** of cassava roots in **30 minutes?**

$$\text{Throughput} = \frac{\text{Weight of the roots loaded to the peeler}}{\text{Time needed to peel it}}$$

$$\text{Throughput} = \frac{100\ \text{kg}}{30\ \text{min}} = \frac{100\ \text{kg}}{0.5\ \text{hour}} = 200\ \text{kg/hour}$$

*The throughput of the equipment is **200 kg/hour**.*

Specific energy consumption

To determine the specific energy consumption of a peeling machine running on electric motor, **100 kg** of cassava roots were separated. All electric appliances and equipment were switched-off and a reading of **12349.0 kWh** was made from the energy meter. All other electric equipment remained switched-off. The peeling machine was switched-on, and the 100 kg of cassava was peeled. A new reading of **12351.5 kWh** was made from the energy meter. What is the specific energy consumption of this peeling machine?

$$\text{Specific energy consumption} = \frac{\text{Final electricity reading - Initial electricity reading}}{\text{Weight of the cassava roots before peeling}}$$

$$\text{Specific energy consumption} = \frac{12351.5\ \text{kWh} - 12349.0\ \text{kWh}}{100\ \text{kg}} = \frac{2.5\ \text{kWh}}{100\ \text{kg}} = 0.025\ \text{kWh/kg}$$

*Specific energy consumption of this peeling machine is **0.025 kWh/kg**.*

To determine the specific energy consumption of a peeling machine running on internal combustion engine, **100 kg** of cassava roots were separated, and the fuel tank of the equipment was filled to its maximum level. The peeling machine was switched-on, and the 100 kg of cassava was peeled. To bring the fuel tank back to its maximum level **5 litres** of diesel was needed. What is the specific energy consumption of this peeling machine?

$$\text{Specific energy consumption} = \frac{\text{Fuel consumed}}{\text{Weight of the cassava roots before peeling}}$$

$$\text{Specific energy consumption} = \frac{5\ \text{litres}}{100\ \text{kg}} = 0.05\ \text{L/kg}$$

*Specific energy consumption of this peeling machine is **0.05 L/kg**.*

Specific energy cost

Calculate the specific energy cost of a peeling machine running on electric motor that has a specific energy consumption of **0.025 kWh/kg**. Also, calculate the specific energy cost of a peeling machine running on internal combustion engine with specific energy consumption of **0.05 L/kg**. Consider the cost of electricity **$0.50 per kWh** and the cost of fuel is **$2.00 per litre**.

$$\text{Specific energy cost} = \text{Specific energy consumption} \times \text{Fuel cost}$$

$$\text{Specific energy cost} = \frac{0.025\ \text{kWh}}{1\ \text{kg}} \times \frac{\$0.50}{1\ \text{kWh}} = 0.0125\ \$/\text{kg}$$

$$\text{Specific energy cost} = \frac{0.05\ \text{L}}{1\ \text{kg}} \times \frac{\$2.00}{1\ \text{L}} = 0.10\ \$/\text{kg}$$

*The specific energy cost of the machine running on electric motor is **0.0125 $/kg** and the specific energy cost of the machine running on internal combustion engine is **0.10 $/kg**.*

Specific water consumption

To measure the specific water consumption of a peeler, **50 kg** of cassava was separated and inserted into the machine. The equipment run until all the roots were peeled. After peeling, the weight of the peeled root was **40 kg**, and the weight of the wastewater was 30 kg. What is the specific water consumption of this equipment?

$$\text{Weight of the peel} = \text{Weight of the roots before peeling} - \text{Weight after peeling}$$

$$\text{Weight of the peel} = 50\ \text{kg} - 40\ \text{kg} = 10\text{kg}$$

$$\text{Specific water consumption} = \frac{\text{Weight of the wastewater} - \text{Weight of the peel}}{\text{Weight of the cassava roots before peeling}}$$

$$\text{Specific water consumption} = \frac{30\ \text{kg} - 10\ \text{kg}}{50\ \text{kg}} = \frac{20\ \text{kg}}{50\ \text{kg}} = 0.4\ \text{kg}_{\text{water}}/\text{kg}_{\text{cassava}} \approx 0.4\ \text{L/kg}$$

*The specific water consumption of the equipment is **0.4 L/kg**.*

This booklet is the first of a 6-part series of booklets on performance evaluation of cassava processing equipment. Aim is to empower equipment manufacturers on evaluating cassava peeling machine, this booklet describes important performance indices for mechanical cassava peelers along with a step-by-step guide to calculating them.

Contact

Federal University of Agriculture
Abeokuta, P.M.B. 2240, Nigeria
+234 805 5249 564
cava2@funaab.edu.ng
cava2.org

Natural Resources Institute, University of Greenwich
Chatham Maritime, Kent, ME4 4TB, United Kingdom
+44 (0)1634 88 0088
nri-info@greenwich.ac.uk
www.nri.org