CHAPTER 21

Natural Cassava Drying Systems

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Cassava is a major tropical crop. It has high potential for the development of agroindustries such as the manufacture of balanced rations for animals. However, if cassava starch is to replace cereal grains in such industries, the crop's starchy roots must first be dried.

Cassava can be dried either naturally or artificially. Methods differ not only in the technology used but also in their costs. Natural drying takes advantage of solar and wind energy, which restricts drying times to the year's dry seasons. In contrast, artificial drying demands a different type of energy such as fossil fuels (oil, coal, or gas) or agricultural residues (sugarcane bagasse or rice husks). It does not depend on climatic conditions.

Despite being restricted to dry times of the year, sun and wind drying is usually economic and very useful in sites where other energy sources are limited or costly. Natural cassava drying is simple and easy for farmers to carry out.

Farmers may organize themselves into associations and cooperatives for the integrated exploitation of the cassava crop (i.e., production, processing, and marketing), thus creating an alternative to the instability of the fresh-cassava market. Such organization also presents the possibility of marketing a higher production (Best and Gómez 1983).

Producing Dried Cassava Chips

Dried cassava chips are produced as follows: cassava roots are harvested, weighed, and chipped. The chips are then dried, packed, and stored. Optional operations may include washing the roots before chipping, or milling the already dried chips, depending on market requirements (Figure 21-1).

Harvest

Cassava is harvested manually and is transported in several vehicles to the drying plant, either packed or in bulk (Figure 21-2). As soon as possible, the roots are subjected to quality control. At harvest, stem fragments are removed, stones and accompanying lumps of earth are discarded, and those roots that look infested are separated.

Cassava roots that have low dry matter (DM)[4] content negatively affect the efficiency and profitability of the process. They are therefore considered as being of lesser quality. Dry matter content depends not only on the variety planted and on edaphoclimatic conditions, but also on the age and plant health of the crop at harvest.

Once harvested, the roots should be taken quickly to the plant so that they are immediately processed. Roots that are processed later than 48 hours after harvest will deteriorate rapidly and their drying results in a poor quality product.

Weighing the fresh roots

In the drying plant, cassava roots are weighed on a platform scale that can carry several sacks at once, thus facilitating the operation (Figure 21-3).

Weighing the roots before drying and the chips afterwards permits the determination of "yield", both for

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4. For an explanation of this and other abbreviations and acronyms, see *Appendix 1: Acronyms, abbreviations, and Technical Terminology*, this volume.

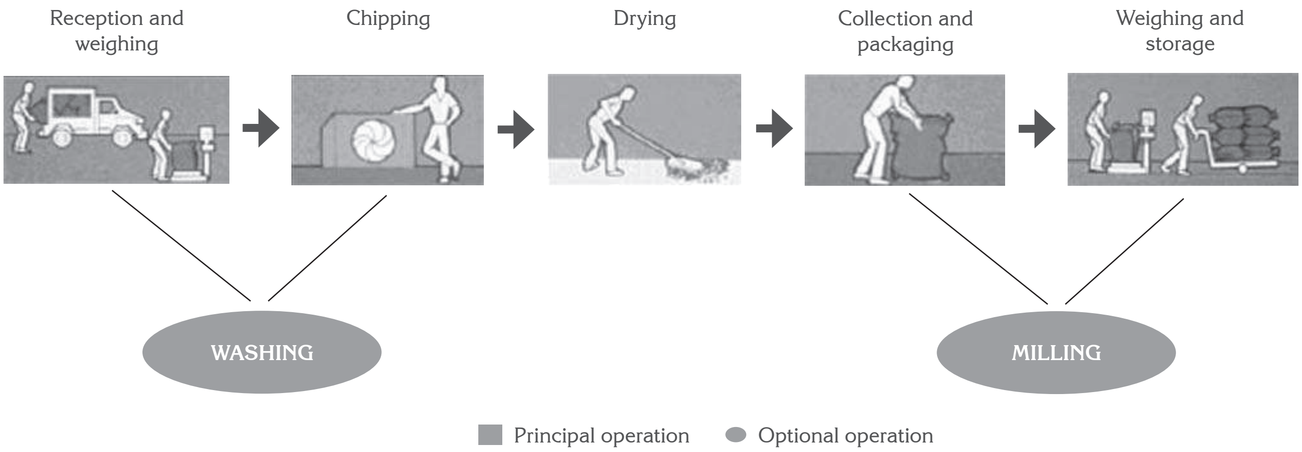


Figure 21-1. Obtaining dried chips from cassava roots, using natural processing.

Figure 21-2. Manual harvesting of cassava roots and their transport to the drying plant.

the cassava varieties used and the process itself. Cassava varieties differ in their yields of dried chips. Hence, identifying the region's best yielding varieties becomes highly important. Furthermore, a given variety may present a certain yield in one drying process and another in a different process. To control such differences, the variety must be evaluated and weighed according to the evaluation of different lots of roots.

Washing

If soil is left adhering to fresh roots, the dried product may have high ash content, especially of silica, which will reduce its quality.

Soil adheres to roots when they are harvested during a rainy season or from heavy soil. Hence, the

Figure 21-3. Weighing sacks of cassava roots.

roots must be washed in either small troughs or washing machines, as shown in Figure 21-4. These machines consist of a rotary drum that shakes the roots while washing them with a pressurized water jet applied inside or outside the drum. In a natural drying plant, cassava roots almost never need washing because drying occurs at the same time as harvesting, that is, in summer. The roots therefore arrive from the field with little soil adhering.

Cassava roots destined for animal feed do not need to have the inner or outer root peel removed.

Chipping

To dry roots more quickly, as large a root surface area as possible should be exposed to the air. This is

(A) **(B)**

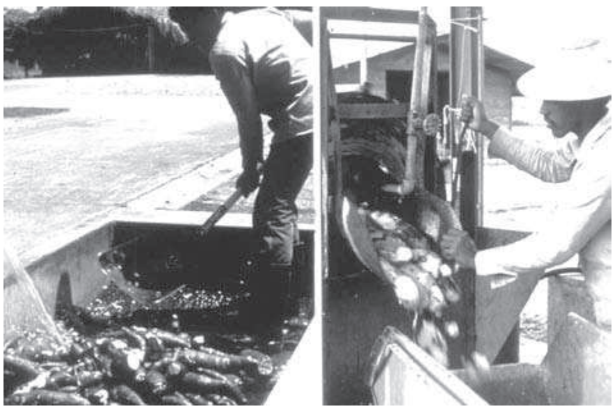


Figure 21-4. Washing cassava roots in troughs **(A)** or with a machine that features a rotary cylindrical drum **(B)**.

Figure 21-5. Cassava chipping machine in operation, using a "Thailand" type disk.

achieved by cutting them into small and uniform pieces, that is, into chips, a task that can be carried out with a chipping machine (Figure 21-5).

Drying

The drying of cassava chips involves eliminating most of the moisture they contain when they are fresh. The resulting dried product can be stored over long periods, without deterioration. The most common methods of drying chips can be classified according to level of technology and cost:

- Continuous drying in rotary dryers or conveyor belt
- Drying by batches in dryers with static layers and using forced hot air
- Natural drying, using solar and wind energy, on concrete floors or on inclined trays

Selection of method depends largely on the amount of cassava roots to be dried, availability of capital, labor costs, and availability of relatively inexpensive energy sources. In this chapter, natural drying is described.

Natural drying takes advantage of solar energy and of the action of air currents to evaporate moisture from cassava chips. Two technologies are available: drying on concrete floors (or in Spanish called *patios*) and drying on inclined trays.

Technology 1:
Drying Cassava Chips on Concrete Floors

With this technology, cassava chips are spread out on concrete floors so that they are exposed to the direct action of both solar radiation and the latent heat of surrounding air currents. This stage includes two basic operations: spreading the chips in the drying area and turning them over frequently until they are completely dry.

Spreading the chips

A wheelbarrow is used to deposit freshly cut chips into small heaps that are then raked out uniformly over the drying floor's surface (Figure 21-6).

Each square meter of floor should carry 8 to 12 kg of fresh chips, a load that should dry within 2 days under normal climatic conditions. A larger amount of chips per square meter will delay drying, thus reducing the drying plant's efficiency and degrading the chips' final quality. A smaller quantity, however, will not take advantage of the plant's productive capacity.

Turning the chips

All the chips must be consistently dried so that the end product is of good quality. To achieve uniform drying, the chips should be turned over every 2 hours (i.e., 6 to 8 times a day), especially during the initial hours of drying, when most of the moisture is lost.

At night, the chips may remain spread out on the concrete floor, unless rain is likely. In this case, the chips should be stacked at the highest level of the concrete floor and protected by a plastic or canvas cover. The next morning, they are spread out again. Turning over, done with a wooden rake, should continue until the chips are dried. The rake's tines form furrows that expose moist areas of floor to direct solar radiation (Figure 21.7).

Figure 21-6. Wooden rakes are used to spread cassava chips over the concrete floor.

Collecting and packing

When the chips' moisture content is 10% to 12%, they are collected and packed. In drying plants, this level of moisture is determined by feel. If the chips are sufficiently dry, they break easily when squeezed between fingers. They can also be used as writing chalk.

Collecting chips requires two types of shovels: one wide and wooden, and used to pile up the dried chips (Figure 21-8); the other is short and metal, and used to

Figure 21-7. Cassava chips are turned over every 2 hours, using wooden rakes. The rakes may be constructed at the plant itself, especially for this task.

Figure 21-8. Dried cassava chips are collected by piling them up in the concrete floor, using a wooden shovel.

pack the heaps into bags or sacks of either polypropylene or fique (also called *cabuya*; from the plant *Furcraea andina* Trel.). For this task, two people are usually needed: one to keep the sack's mouth open as the other shovels in the dried chips. A metal funnel can also be used, with its stem emptying into an open sack suspended from a framework (Figure 21-9). A fique sack can carry 40 to 50 kg, but if the dried chips are tamped down as the sack is filled, the weight can be higher (Figure 21-10).

Milling

Transporting cassava chips to distant places is costly because of their low weight per unit of volume. Hence, chips are sometimes milled to obtain flour, which is then packed in bags of either polypropylene, paper, or cloth. Milling is carried out with a hammer mill, to which cloth filters are adapted to capture the fine powder that results from the operation (Figure 21-11).

Figure 21-9. A metal funnel facilitates packing the dried cassava chips.

Figure 21-10. Tamping down dried chips in sacks. Sacks weighing over 50 kg can then be obtained.

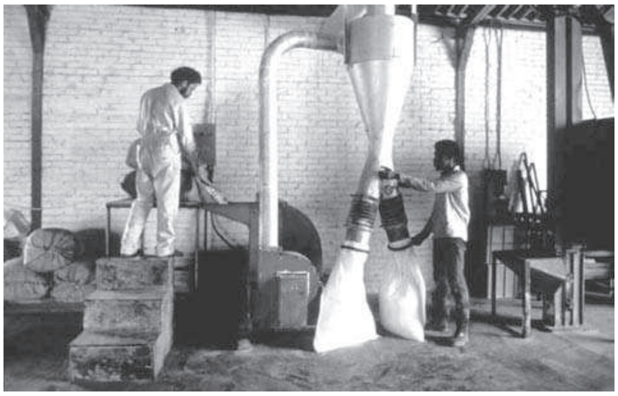


Figure 21-11. Milling dried cassava chips.

However, cassava is usually marketed as chips because quality control of flour in consumer companies or concentrate-feed factories is not easy.

Storage

The drying plant should have a storeroom where the dried chips are kept until shipped to purchasing companies. The sacks should be stacked on wooden platforms or pallets (Figure 21-12).

If storage conditions are adequately controlled, the dried chips (i.e., with 10% to 12% moisture content) can be stored for as long as 6 to 12 months without their quality deteriorating. Optimal conditions are achieved if the storeroom is kept very clean and if aeration mechanisms are installed that adequately move moisture between storeroom and exterior.

If storeroom humidity is too high, the dried chips absorb the moisture, which, together with high starch content, stimulates the growth of fungi on the chips. These produce toxins that ultimately prevent the chips' use as animal feed.

Figure 21-12. In the storeroom, sacks of dried cassava chips should be stacked on pallets or wooden platforms.

Stored dried chips can also be attacked by insect pests. At least 38 species of insects, mostly of the order Coleoptera, have been identified, although the important ones are those that can reproduce in the chips. Studies conducted at CIAT indicate that *Araecerus fasciculatus* and *Sitophilus oryzae* can cause major losses of dried chips (Figure 21-13).

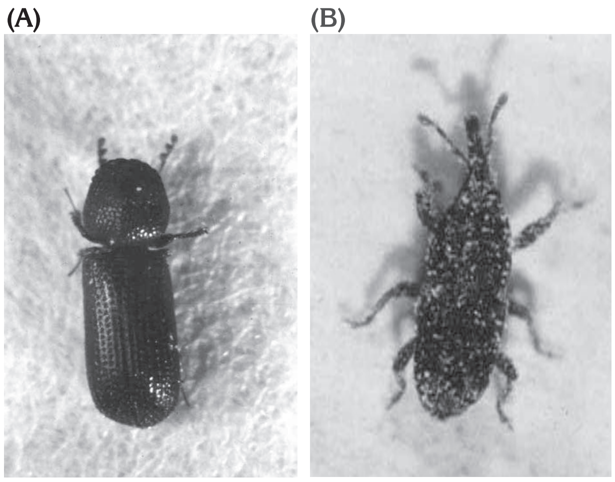


Figure 21-13. The weevils *Araecerus* sp. **(A)** and *Sitophilus oryzae* **(B)** can cause major losses to stores of dried cassava chips.

Figure 21-14 illustrates the moisture loss curve at different stages of the drying procedure for cassava chips, from harvest to storage, and indicates the normal duration of each stage.

Quality standards for dried cassava chips

Dried chips are used mainly to totally or partially substitute cereal grain in the formulation of balanced feeds for animals. Their quality should therefore be adjusted to the standards required by the companies processing this product (Table 21-1). In addition to

Table 21-1. Basic standards for quality as required by companies using dried cassava.

Component or aspect	Standard
Moisture content (%)	12.0
Crude fiber, maximum (%)	5.0
Ash, maximum (%)	3.5
Fungi and yeasts, maximum count (cfu/g)	100,000
Aflatoxins and ochratoxins	Absent
Total cyanide (ppm)	100
Coliforms, total (cfu/g)	600
Presentation	Chips

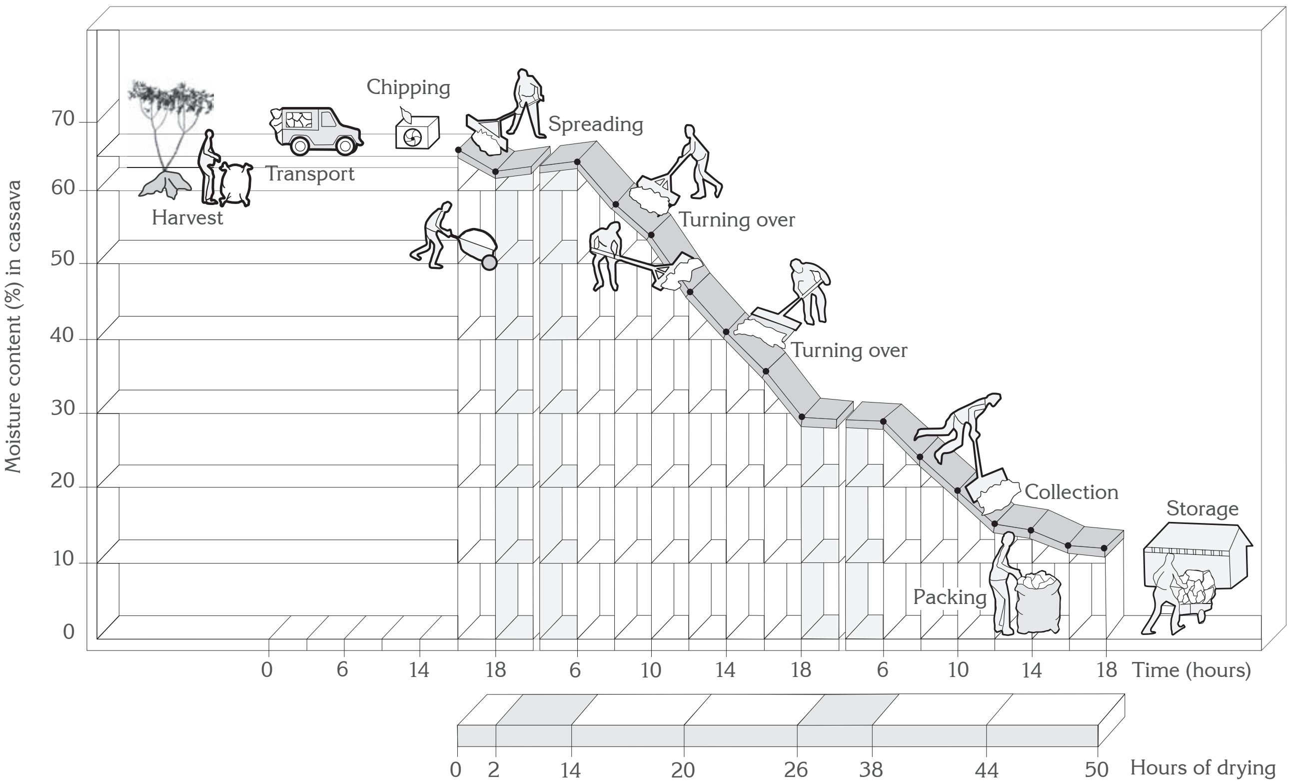


Figure 21-14. Moisture loss curve at different stages of drying cassava chips, assuming normal conditions. The duration of each stage and of the entire process is also indicated.

these standards, the product should comply with the following requisites: it should be fresh, have no fermenting odor, and present no signs of insect attack or contamination.

Infrastructure of a cassava drying plant

Before installing a cassava drying plant, its location should be carefully chosen with respect to its distance from sites supplying the raw material and access to good roads. Also desirable are nearby sources of water and electric power. The minimum infrastructure of a drying plant consists of a drying concrete floor, an area for chipping, and a storeroom.

Drying concrete floor. Cassava chips are exposed to solar radiation on a surface designed to resist exposure to the sun, that is, it will not crack. It must also be smooth to permit easy sliding of the rakes and shovels used to spread, turn over, and collect cassava chips. The drying area should not be surrounded by trees, buildings, or other similar obstacles that may reduce natural ventilation or shade the area. Furthermore, the natural slope of the land should be taken into account so that the concrete floor has a slope that allows rainwater to drain.

The construction of a drying floor is specific to each region, making it highly advisable that farmers participate in its construction, as it will be built under their organization. Hiring an expert mason should always be recommended so that he leads the works. Construction is as follows:

- The first step is *to choose the area* that the patio will occupy. Plant cover is removed, the land leveled, and the exposed surface compacted. Good compaction guarantees the work's quality. During compaction, the center of the concrete floor should remain at a higher level than the sides. Such "crowning" will facilitate rapid drainage of rainwater.

- The *floor's foundations* are then made at the perimeter of the concrete floor. The foundations should be 20 to 30 cm wide and 30 to 40 cm deep, and built with either poured or block concrete. The floor itself is also made of either poured or block concrete. If only people are passing through its area, then the floor may be 10 cm thick, but if heavy motor vehicles are expected to circulate on the floor, then it should be 15 to 20 cm thick and reinforced with iron.

  The concrete should be a mixture of cement, clean sand, gravel that is free of earth and lumps, and water. The proportions for mixing depend on the soil's characteristics. In general, clayey soils require a mixture of cement, sand, gravel at 1:2:3, and sandy soils at 1:3:4. However, the correct proportions of these components depend on the mason's or builder's experience. Table 21-2 indicates the quantities of the elements needed to prepare one cubic meter of concrete according to the specified mixture.

- The third step is *to pour the concrete* onto the area prepared for the floor. The area of construction should be divided into slabs of 2 × 2 m, leaving narrow separations in between, into which "expansion joints" are placed. These are simply wooden strips that are removed at the end of the work (Figure 21-15A). To reduce the risk of the floor cracking, pieces of iron rod should be placed between slabs, so that they serve as joining elements when the slabs meld (Figure 21-15B).

- The fourth step, once the floor is cast, is *to finish and correct* it, including fixing any remaining cracks. The wooden strips serving as expansion joints are then removed and the separations between slabs filled with either a mortar made of cement and sand or with tar. Figure 21-16 shows the final appearance of a drying area.

The division of the drying area into 2 × 2 m slabs has the advantage of helping workers distribute adequate amounts of cassava chips per unit of area.

Table 21-2. The quantities of cement, sand, gravel, and water needed to prepare 1 cubic meter of concrete, according to the proportions required.

Proportions	Component			
	Cement (kg)[a]	Sand (m^3)	Gravel (m^3)	Water (L)
1:2:2	420	0.670	0.670	192
1:2:3	350	0.555	0.835	158
1:2:4	300	0.475	0.950	135
1:3:3	300	0.715	0.715	135
1:3:4	260	0.625	0.835	124
1:3:5	230	0.555	0.920	101
1:3:6	210	0.500	1.000	94

a. One cubic meter of cement is sufficient for 12.5 m^2 of flooring, 8 cm thick.

(A)

(B)

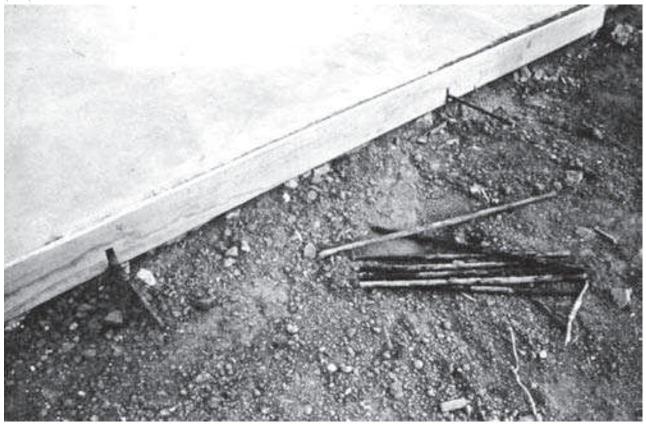


Figure 21-15. Expansion joints are placed between concrete slabs **(A)**, together with iron rods **(B)**.

Figure 21-16. Final appearance of a drying concrete floor for cassava chips.

Applying the recommended load of fresh chips at 12.5 kg/m^2 of floor, a slab of 4 m^2 (2 × 2 m) should receive 50 kg. This quantity is about the same as a wheelbarrow load. Simply put, a barrow load per slab is the optimal load for the drying area.

Chipping area. The area where the chipping machine is installed should be sufficient to allow workers to move easily and also leave room for the raw material to be chipped. A chipping area of 16 m^2 (i.e., 4 × 4 m) is adequate for plants that have 500 to 1000 m^2 of drying floor.

This area should also have roofing to shade the workers and prevent the chipping machine from deteriorating through the action of sun and rain. In addition, next to this area, roofing should be built to cover the reception site for the roots, protecting them from sun and rain, and preventing their quality from deteriorating. This additional roofing can be constructed with typical materials of the region (Figure 21-17).

Figure 21-17. View of the roofing complex used to cover the cassava chipping machine and to protect the fresh cassava roots received for processing.

The chipping area should be close to where roots are received to prevent unnecessary movement within the plant. The slope of the floor in this area should be away from the drying area so that washing water from the chipping machine and rainwater do not drain over the chips being dried (Figure 21-18).

The chipping area will be subject to vibrations and its floor must therefore support a higher weight per unit area than that of the drying area. Its floor should therefore be resistant, having foundations that are of poured or block concrete. The foundations should be 40 cm deep and 40 cm wide, and the floor 15 cm thick, being composed of a mixture at 1:3:5 (Figure 21-19). A wooden framework supports this area's roofing, which may consist of zinc sheets, asbestos-cement tiles, or typical materials of the region (e.g., palm leaves).

Storeroom. The storeroom guards the dried cassava chips, tools, and equipment used for drying. The storeroom's size depends on the drying plant's capacity, periodicity of shipping the product, and future expansions of drying capacity.

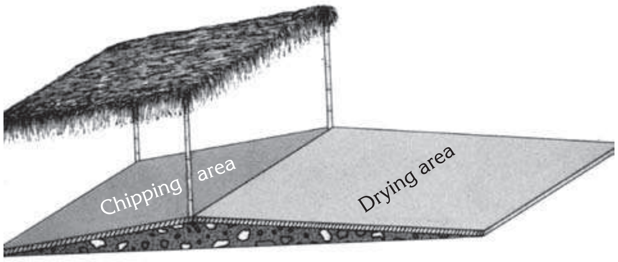


Figure 21-18. The floor of the cassava chipping area must slope away from the drying area for the chips.

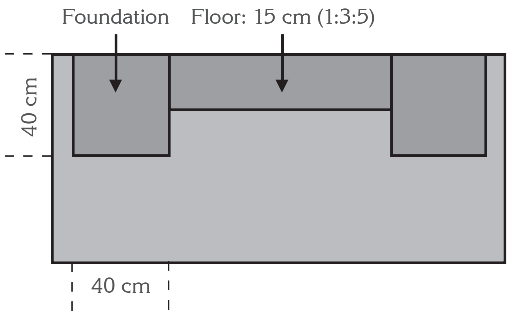


Figure 21-19. The cassava chipping area should have a resistant floor.

About 350 kg of dried chips can be stored in 1 m^3 of storeroom. One that is 140 m^3 (10 × 4 × 3.5 m) can store about 30 t of dried chips, which is the production of a 1000-m^2 drying concrete floor over 18 days. If the dried product is shipped from the plant every 2 weeks, the storeroom will not have problems of congestion or aeration. A 1-m space should be left between the top of the stored stack of dried chips and the storeroom's ceiling.

The storeroom's foundations should be 30 to 50 cm deep and 40 cm thick. If the walls are very long, columns should be constructed in the wall every 3 or 4 m and the foundation under each column should be 60 to 70 cm (Figure 21-20).

The storeroom's basic structure consists of the following elements:

- Lower tie beams placed immediately above the foundations, and perfectly joined to give the walls solid support.
- Columns.
- Walls made of brick or concrete blocks.
- Upper tie beams to bind the columns and support the roofing (Figure 21-21).

Figure 21-20. Laying down a foundation to support the external walls of a storeroom.

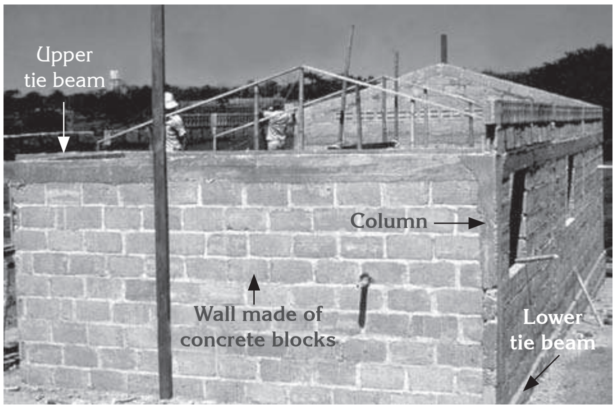


Figure 21-21. Elements of a storeroom's basic structure.

The storeroom should have mechanisms that control aeration or change of air. The opening of all doors for a short time is also useful. Concrete fretwork placed along the upper lengths of the walls (Figure 21-22) forms a good system for ventilating the storeroom, particularly when insecticide applications

Figure 21-22. Wall with concrete fretwork running along its upper length.

are carried out. However, such fretwork is not suitable for long-term storage.

The roofing consists of a framework of wooden beams that support asbestos-cement tiles, zinc sheets, or typical materials of the region. It should be gabled, with adequate slopes.

Before constructing the storeroom floor, a cement base must be set to serve as an initial floor to prevent moisture from creeping up to the surface of the real floor. On this base, the final floor, consisting of a reinforced but thin slab of concrete, is placed. It must be as smooth as possible. The bags of dried cassava chips must not be allowed to have direct contact with the floor. Hence, wooden platforms or pallets that rise 10 to 15 cm high from the floor should be installed and the sacks of dried chips stacked on these.

The storeroom's external structures should include a pathway around it and good drainage that will prevent rainwater from accumulating and forming muddy areas.

Equipment for a drying plant

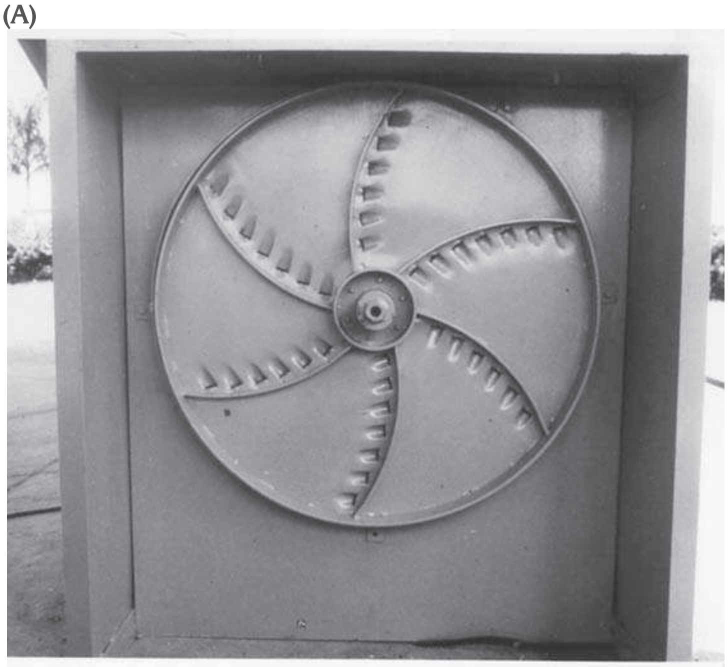
The minimum equipment for a drying plant consists of the following: platform scale, chipping machine, tools for drying and collecting chips (wheelbarrow, wooden rakes, and shovels), sacks, and a plastic or canvas cover to protect the concrete floor when necessary.

Platform scale. The platform scale should be able to weigh several sacks at once. A 500-kg capacity is acceptable for natural drying plants.

Chipping machine. Commonly used models are known as "Thailand" (Figure 21-23A) or "Colombia" (Figure 21-23B) types. The "Thailand" machine basically consists of a metal structure and cutting disk. The structure supports the pulleys, linchpin for the disk, and feed hopper. The motor's support is also coupled to the machine's main structure, as in the "Colombia 1" type (Herrera et al. 1983), (Figure 21-23B).

The machine may be powered by either an electric or internal combustion (gasoline or diesel) motor. The gasoline motor should have between 8 and 10 hp (Figure 21-24), whereas an electric motor may have 5 hp. This motor is the most important component of the plant's equipment because any deficiency in its operation alters the normal drying process. The workers must therefore be adequately trained to run it and give it rigorous maintenance.

(A)



(B)

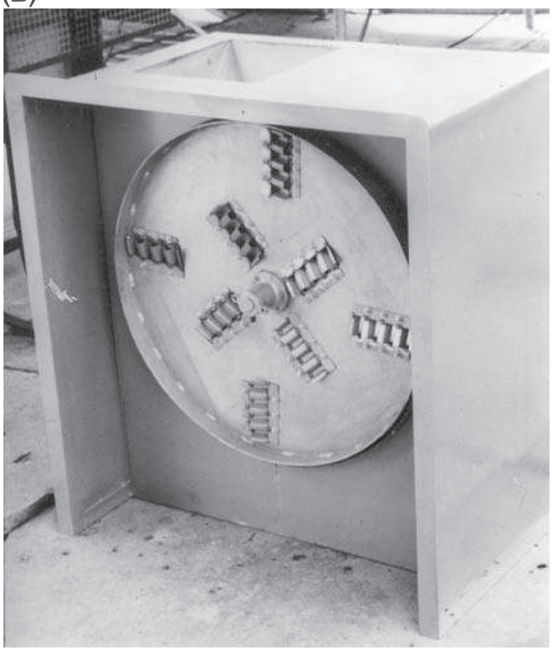


Figure 21-23. Cassava chipping machines, type "Thailand" **(A)** and type "Colombia" **(B)**.

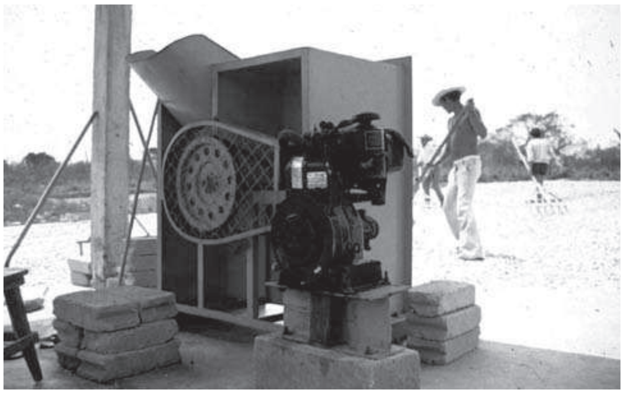


Figure 21-24. An 8-to-10-hp internal combustion motor (gasoline) is needed to operate a cassava chipping machine.

Implements for drying and collecting. The following tools are needed:

- An ordinary *wheelbarrow* with a 50-kg capacity. It is used to distribute cassava chips into heaps on the drying concrete floor at a barrow load per area of 2 × 2 m.

- Several *wooden rakes* to spread and turn over cassava chips. Their form and dimensions are indicated in Figure 21-25A.

- Two types of *shovels* to manage the dried chips. One type is wooden, with the blade being wide, flat, rectangular, and finishing on a fine edge to help pile up the chips (Figure 21-25B). The other type of shovel is the usual metal one. These are used to pick up and pack the chips.

- A sufficient number of *sacks* for both purchasing fresh cassava roots, and for storing and marketing dried chips. The best sacks are those of fique or jute, which have a larger capacity and can be used several times over. Polypropylene sacks have a smaller capacity and last for less time but are less expensive.

- A *plastic cover* to protect cassava chips in the drying concrete floor from unforeseen rains. During winter, the plastic helps dry the chips, albeit on a small scale. For a plant with 500 m^2 of concrete floor, a 250-m^2 plastic cover is sufficient.

Conditions for establishing the natural drying plant

A drying plant will be successful if its management of the production, processing, and marketing of dried chips is well planned and coordinated. Having real data on each stage is therefore indispensable when analyzing the economic feasibility of setting up a plant. The following aspects should be considered:

- Production of fresh cassava roots in the plant's area of influence
- Plant size and capacity for processing dried chips
- The correct administration and operation of the plant
- The financing required
- Marketing the dried cassava chips

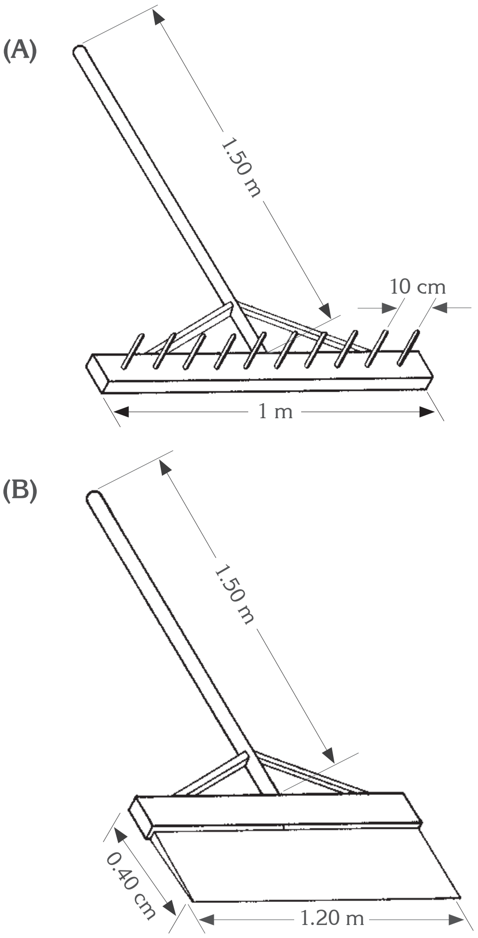


Figure 21-25. Tools for cassava chip drying: **(A)** wooden rake to spread and turn over chips; and **(B)** wooden shovel for piling up dried chips.

Cassava production in the plant's area of influence. The timely production of fresh cassava roots—the drying plants' raw material—is a significant factor to consider before installing such a plant.

Roots are usually available for processing only when the fresh-cassava market has surpluses, as this market is, in many places, the principal and almost exclusive channel for marketing cassava. Hence, the offer of raw material for dried chips becomes discontinuous and seasonal. To ensure a continuous and sufficient offer, the cassava crop's productivity must increase considerably. Production costs would therefore be reduced, making root prices more competitive and the cassava-drying agribusiness more profitable.

The organization of farmers in the region into cooperatives or associations that produce and process cassava roots, and receive technical assistance and credit from official entities, is an initiative that would ensure availability of roots for the drying plant. Hence, these groups must incorporate farmers able to obtain good cassava production. Otherwise, the plant would depend on the offer of raw material from farmers outside its area, thus making it dependent and vulnerable as a company. Hence, the socioeconomic profile of a cassava drying plant's potential owners is, perhaps, the most important factor in its establishment and size.

In the Colombian North Coast, cassava-drying companies are constituted by farmers with little capacity to produce cassava. They therefore have difficulties in achieving an acceptable level of profitability. Thus, when a cooperative or association is organized to operate a drying plant, it must establish a suitable procedure for selecting its members to ensure supplies of the raw material needed for the plant's efficient operation.

Plant size and capacity.

Plant size. Feasibility studies and experiences so far obtained indicate that the minimum area for the profitable drying of cassava chips is 500 m^2. To date, plants of 1000 to 2000 m^2 of drying floor have functioned with good results. A new plant should therefore begin with 500 m^2 to expand later when the farmers have completely mastered the drying technique (Ospina and Best, 1984).

To discover the size of the future plant, the area's cassava production must be calculated and the socioeconomic profile of the plant's potential owners described. This information should indicate the probability of obtaining enough raw material and of maintaining the company stable.

The quantity of chips that a plant can dry depends on three factors: the duration of summer, the load of chips that can be dried per square meter, and the drying area's capacity.

Duration of the dry season. Natural drying is based on the use of solar energy. Hence, the summer months of the region where the plant will be established must be known. In the Colombian North Coast, for example, the main dry months are December to March and part of April. A second semester of dry climate is July to September. In total, the region has about 20 weeks during which drying can take place.

Load of fresh chips per square meter. The optimal load of chips (kg) for drying per square meter of floor for 2 days is then determined. Two days is used for calculation because the most efficient advantage is taken of the plant in this time, with three batches of chips being dried per week. In the Colombian North Coast, the optimal chip load is 12.5 kg/m^2. On days of little solar radiation, during climatic transitions, smaller loads are used.

Determining a plant's capacity. A plant's capacity for processing is calculated by using the previous three parameters: plant size, duration of summer, and fresh chip load (Table 21-3).

Amount of fresh chips that can be dried per year. The annual capacity for drying per square meter of concrete floor would be:

$$12 \text{ kg/m}^2 \text{ per batch} \times 3 \text{ batches/week} \times 20 \text{ weeks/year} = 720 \text{ kg/m}^2 \text{ per year}$$

Hence, on a 500-m^2 floor, 360,000 kg, that is, 360 t, of fresh chips could be dried per year.

Determining the conversion factor (c.f.). The amount of dried chips that can be obtained from a given batch of fresh cassava roots may be discovered by first determining a conversion factor for the cassava variety that was harvested. To calculate it, the cassava's moisture content should be determined, both at the beginning and end of the drying process.

Table 21-3. Value of parameters determining a plant's capacity for processing dried cassava chips in the Colombian North Coast, 2000.

Parameter	Unit
Duration of the dry season	20 weeks
Load of fresh cassava chips	12 kg/m^2
Drying time per batch	2 days
Batches per week	3
Drying area	500 m^2

The c.f. is a parameter that relates directly with the dry matter (DM) content in the cassava being processed. When roots have been attacked by disease or a pest (e.g., cassava hornworm), DM content at harvest may be very low and thus the c.f. would be very high. Climatic conditions (e.g., rain during harvest) may also affect a variety's DM content and therefore its c.f.

Another factor that affects the c.f. is the farmers' management of the drying technology. For example, if they dry the chips too much (i.e., to less than 12%), the c.f. is high.

The c.f. can be calculated, using, for example, 1000 kg of chips from recently harvested fresh cassava roots that had a moisture content of 65%, and were dried on a concrete floor until the final moisture content was 12%. If a sample of 398 kg of chips is then taken, the c.f. would therefore be:

$$\text{c.f.} = 1000/398 = 2.5$$

Note that the DM should be constant. The 1000 kg of roots, which had 65% moisture content, had 650 kg of water and 350 kg of DM. On drying, most of the water was eliminated from the chips, but the DM was conserved. Accordingly, the 398 kg of dried chips at the end of the process should contain 350 kg of DM. The remaining 48 kg would represent the 12% of final moisture content in the chips.

Calculating dried chip production. The c.f. can be used to calculate the quantity of dried chips that the plant can produce per year. If we assume that the 360 t of fresh chips (FC) that a plant of 500 m^2 processes in 1 year will yield 144 t of dried chips (DC), then the c.f. is 2.5:1 (FC to DC), that is:

$$\frac{360 \text{ t FC}}{144 \text{ t DC}} = 2.5 \text{ FC to } 1 \text{ DC}$$

The c.f. of 2.5 can then be used to calculate the likely production of dried chips from different fresh-chip loads of the same variety processed at the same plant.

Table 21-4 shows the quantities of dried chips that are obtained from processing fresh cassava roots according to drying area and period of drying.

Administration and operational organization. A natural cassava drying plant functions correctly if the plant's group of farmer-owners is well organized. The plant should therefore have a manager or administrator, a treasurer, and a production head.

Table 21-4. Quantities of dried cassava chips obtained by plants with different-sized drying areas and summers of different duration.

Drying area (m^2)	Dry climate (weeks/year)	Annual capacity for processing[a]		Required production (ha/year)[b]
		Fresh roots (t)	Dried chips (t)	
500	12	216	87	27
	16	288	115	36
	20	360	144	45
1000	12	432	174	54
	16	576	230	72
	20	720	288	90
2000	12	864	348	108
	16	1152	460	144
	20	1440	576	180

a. Using a conversion factor of 2.5:1, where 2.5 t of fresh cassava roots is processed into 1 t of dried cassava chips.
b. Calculated area, assuming that the cassava variety yields 8 t/ha of fresh cassava roots.

- The *manager* or *administrator* is responsible for the company's general functioning. He or she coordinates all the plant's activities and technical assistance services, and is also the company's legal representative. The manager must therefore be a dynamic person who is respected by the other member farmers.

- The *head of production* is responsible for organizing working groups (groups of members or of contracted personnel) to guarantee timely supplies of raw material. He or she must also verify results of quality control of the end product.

- The *treasurer* is in charge of making payments and collecting debts. Together with the manager, the treasurer is responsible for establishing an accounting system that allows members to know the outcomes of management.

Although these three positions (manager, production head, and treasurer) imply an administrative cost for the drying plant, they help guarantee its good operation.

Natural cassava drying plants also require a certain amount of labor. Each company organizes its work force according to its conditions. Sometimes, members or their families work at the plant but, usually, the plant becomes a source of employment for its rural hinterland, especially if employment opportunities are limited.

Table 21-5 lists the types of labor needed for the different operations of a drying plant. Note that the 48 working-hours and maximum of six workers required to process 6 t of fresh cassava roots represent one working day (8 working-hours) for each ton processed.

Financing. To construct and initiate a drying plant, investments must be made in three well-defined areas:

Table 21-5. Labor needed to chip and dry one batch of 6 t of fresh cassava roots.

Tasks	Workers (no.)	Hours (no.)	Working hours (total)
Weigh and chip the roots	4	3	12
Spread out the cassava chips	3	3	9
Turn over and mix the cassava chips	3	3	9
Collect, pack, and store the chips	6	3	18
Total			**48**

plant construction, capital for the plant's operation, and production of raw material.

- Plant construction. The construction costs of a drying plant are specific to each region or country, and depend on the availability and price of materials. The values listed in Table 21-6 indicate that a 500-m^2 plant in the Colombian North Coast needs an initial investment of about US$15,680, according to the National Federation of Cassava Producers, Processors, and Traders (FEDEYUCA 2001, pers. comm.).

- Plant operation. The plant needs a working capital to pay labor, acquire raw material and sacks, and pay freight and administrative costs. The working capital must be available when the plant begins processing. Table 21-7 separates the categories comprising the working capital underlying a plant's operation over 30 days (FEDEYUCA 2002, pers. comm.).

- Production of raw material. In most cases, no credit lines exist to finance cassava crops, but

Table 21-6. The investment needed to make a 500 m^2 concrete floor for a natural cassava drying plant, Colombian North Coast, 2001.

Work, tool, or element	Quantity	Unit value (US$/m^2)	Total for item (US$)[a]	Total for category (US$)
Installations				**11,500**
Concrete floor (m^2)	500	15	7500	
Storeroom (m^2)	40	70	2800	
Wire mesh (rolls, 1 m wide)	100	2	200	
Roofing for chipping machine (m^2)	25	40	1000	
Equipment				**2,000**
Chipping machine	1	900	900	
5-hp electric motors	2	350	700	
500-kg capacity platform scale	1	400	400	
Tools				**380**
Wheelbarrows	4	30	120	
Metal shovels	6	10	60	
Wooden rakes	10	10	100	
Wooden collectors	10	10	100	
Others				**375**
Polypropylene sacks	300	0.25	75	
Plastic cover (10 × 50 m, caliber 6)	1	300	300	
Subtotal				**14,255**
Unforeseen contingencies (10%)				**1,425**
Working capital[b]				**3,940**
Total investment (US$)				**19,620**

a. Exchange rate, January 2001: US$1 = Col$2200.
b. Table 21-7 presents the distribution of the working capital by category.

Table 21-7. Working capital used for 30 operational days of a drying plant with a 500m^2 concrete floor having a load of 12 kg/m^2 and 12 batches, Colombian North Coast, 2001.

Category or input	Quantity	Unit value (Col$)	Rubric value (Col$)
Fresh cassava roots (t)	72	80,000	5,760,000
Working days (units)	80	15,000	1,200,000
Sacks (units)	700	500	350,000
Freight (t, dried chips)	30	45,000	1,350,000
Total (Col$)			**8,660,000**
Total (US$)[a]			**3,940**

a. Exchange rate, January 2001: US$1 = Col$2200.

acquiring one is a must. Credit should be timely, sufficient, and preferably of an association type, as this will enable all company members to produce cassava and thus guarantee adequate supplies of raw material.

Farmers may go to state entities or cooperatives when searching for financing. To construct the plant, long-term credit lines with promotional interests should be preferred, as the plant's initial period of operation (1 to 2 years) is critical as farmers adapt to the new agroindustrial alternative. Furthermore, farmers need to enjoy lasting institutional support that will guarantee adequate training in the technical and accounting aspects of the company's effective operation.

Marketing dried cassava chips. The principal market of dried chips comprises processing industries for concentrate feeds, especially for poultry and pigs. However, most cassava-producing countries of Latin America import grains to manufacture this feed instead of using dried cassava chips to substitute imported grains. The factor that most influences substitution is the price of dried chips, compared with that of grains such as maize and sorghum. At the time of writing the price of dried chips is 70% or 80% of the grain price.

The price of dried cassava chips depends on processing costs and, mainly, on the cost of raw material (Table 21-8). The next major cost is that of labor (including administration), which represents almost 10% of total costs.

Consequently, all possible effort must be dedicated to increasing the crop's productivity, for example, planting high-yielding varieties and developing best agronomic practices that reduce the costs of root production. If the costs stay down sufficiently, then dried cassava chips can be marketed to give an adequate profit margin (Table 21-9).

Table 21-8. Structure of production costs per ton of dried cassava chips for a cassava drying plant with a 500m^2 drying concrete floor.

Costs (concept or category)	Value (Col$)
Fixed costs	**27,500**
Administration[a]	12,500
Depreciation[b]	15,000
Variable costs	**240,500**
Raw material[c]	200,000
Labor[d]	37,500
Expenses[e]	3,000
Marketing expenditures	**53,000**
Packaging[f]	8,000
Freightg	45,000
Total production cost per ton of dried cassava chips[h]	**321,000**

a. Salaries of the Administrator: Col$450,000 per month, 4 months period (Col$1,800,000). The total production of dry cassava chips during the period is 144 MT.
b. Based on investment costs of US$19,620 and 20 years depreciation period.
c. 2.5 t of fresh cassava roots at Col$80,000/t.
d. 2,5 man/days per MT dry cassava chips (1 man/day= Col$15,000
e. Sacks in fique, cloth, etc.
f. 20 clean fique sacks, each with a 50-kg capacity.
g. Transport from the drying plant to the buyer (concentrate-feed plant), maximum of 150 km.
h. Exchange rate, January 2001: US$1 = Col$2200.

Table 21-9. Calculation of net income per ton of dried cassava chips produced in the previous example.

Concept	Value (Col$)
Costs	
Cassava processing	76,000
Freight[a]	45,000
Raw material (fresh cassava roots)	200,000
Total	**321,000**
Sale price[b]	**335,250**
Net earnings	**14,250**

a. Transport from Sincelejo to Medellín.
b. Product sold in Medellín.

Technology 2:
Drying Cassava Chips on Inclined Trays

Trays

This drying method takes maximum advantage of the drying capacity of wind as it circulates through cassava chips placed on trays. The trays have a wooden framework, and a base of plastic mesh that holds the chips during drying.

Materials. The plastic mesh is strengthened by adding chicken wire netting with 1-inch-diameter holes (Figure 21-26A). The dimensions shown in the figure enable the tray to be handled by two workers. Although the tray's size may vary with the cassava material available in the region, the mesh is standard at 35 perforations per square centimeter, as anything with larger apertures would result in increased losses. With the use of a suitable mesh, losses are less than 3% of dried chips.

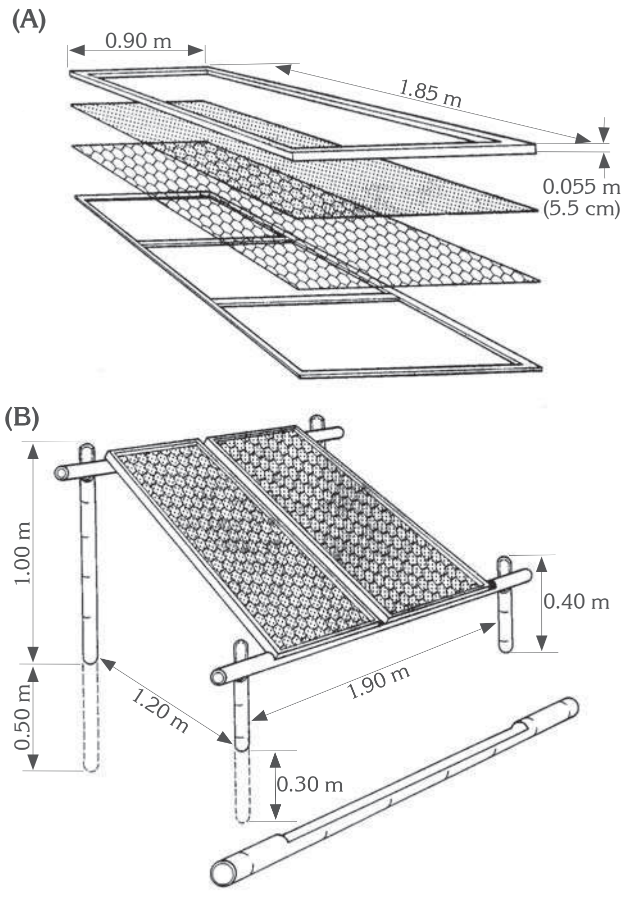


Figure 21-26. **(A)** Dimensions of a tray. **(B)** Placement of tray on supports made from bamboo or building (giant) bamboo. (Adapted from Best 1979.)

Fresh cassava chips are spread over the trays, which are then placed on beams of bamboo or building (giant) bamboo supported by two rows of posts, with the front row being shorter than the back row. The trays thus remain on a slope of 20° to 25° that takes maximum advantage of the direction and strength of the wind (Figure 21-26B).

Management. Once fresh chips are obtained, the trays are filled in at the same site where chipping took place (Figure 21-27) before being taken to the supports.

Another option is to first place the empty trays on the supports (Figure 21-28) and then fill them with

Figure 21-27. A worker fills the trays with fresh cassava chips as a chipping machine operates behind him.

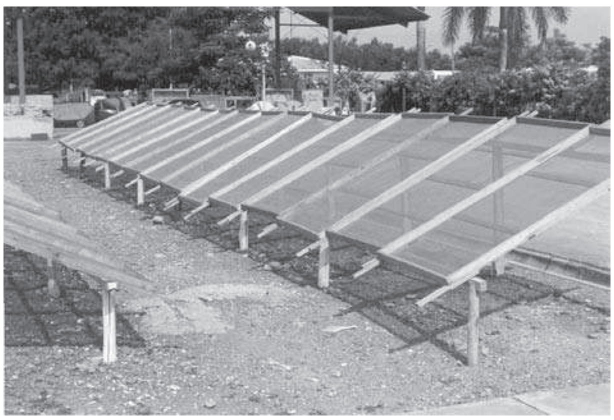


Figure 21-28. Empty trays are placed on their supports.

fresh chips brought by wheelbarrow. The agreed-upon quantity of chips is then placed on each tray and spread over the tray's surface (Figure 21-29).

The weight of cassava chips does not have to be exactly the same for each tray. An average weight is achieved by first measuring a suitable quantity per tray into a container and then spreading the chips over the tray. When shovels are used to directly load the trays (Figure 21-27), the amount of cassava can vary. If trays have different dimensions, the chip load for each is obtained by multiplying the tray's area by the appropriate figure in column 3 of Table 21-10 (tray load in kg/m^2).

The trays can be left on the supports overnight to take advantage of the wind's action. If rain is predicted, the trays should be stacked horizontally (i.e., one above the other) under roofing or outside and protected with a canvas or plastic cover until the next day. The lowest tray of the stack should be sitting on two posts of bamboo (or building bamboo), thus keeping all trays off the ground. The next morning, the trays should be moved back to their supports. Once the chips have attained the appropriate moisture content, they should be collected and packed.

Figure 21-29. Fresh cassava chips are spread over trays already in position.

Table 21-10. Relationship between cassava chip load on inclined trays (L/T) and wind speed.

Wind conditions	Speed (m/s)	L/T (kg/m^2)
Calm, smooth breeze	<1	10
Constant breeze	1–2	10–13
Constant wind	>2	13–16

SOURCE: Best (1979).

The quantity of chips placed on the trays depends largely on wind speed (Table 21-10). The higher the wind speed, the greater will be the quantity of cassava chips that can be dried without needing to turn them over. However, if the load is more than 16 kg/m^2, the chips will need to be turned over.

As illustrated in Figure 21-30, drying in trays is faster than drying on floors for a given load of chips. One reason for this difference is that chips in the trays continue losing moisture during the night, because air circulation does not stop. In contrast, when drying is carried out on concrete floors, chips lose only a small quantity of moisture during the night, as wind speed at floor level is low.

Drying time

Initial stage. Initially, fresh chips lose moisture rapidly and air circulation (wind) is more important than air temperature and humidity. If wind speed is sufficient, this stage can be completed even if the sky is cloudy. Furthermore, drying can be carried out at night. As a result, in dry times, the chips may lose a considerable amount of moisture if left on the trays and their supports during the night. To best take advantage of this period, cassava may be chipped in the afternoon hours. Table 21-11 illustrates the effect of the principal factors of drying time, especially wind speed.

In contrast, fresh chips left spread on concrete floors during the night lose only a small part of their moisture, for the reasons mentioned above: low wind speed at ground level and infrequent turning over.

Final stage. In the final drying stage, when moisture content is about 30%, moisture loss is very slow (Figure 21-31) and the high temperatures at mid-day are needed to complete the process. During this stage, air humidity should be less than 65% so that the chips' final moisture content is suitable for storage. Sometimes, particularly in the rainy season, relative humidity is high; drying should continue until the climate improves.

Several trials were conducted in different sites in Colombia to determine drying times under different climatic conditions (Table 21-12). The following conclusions summarize the work:

- Drying almost always takes more than 10 hours (1 day), but less than 20 hours (2 days). Only under exceptional environmental

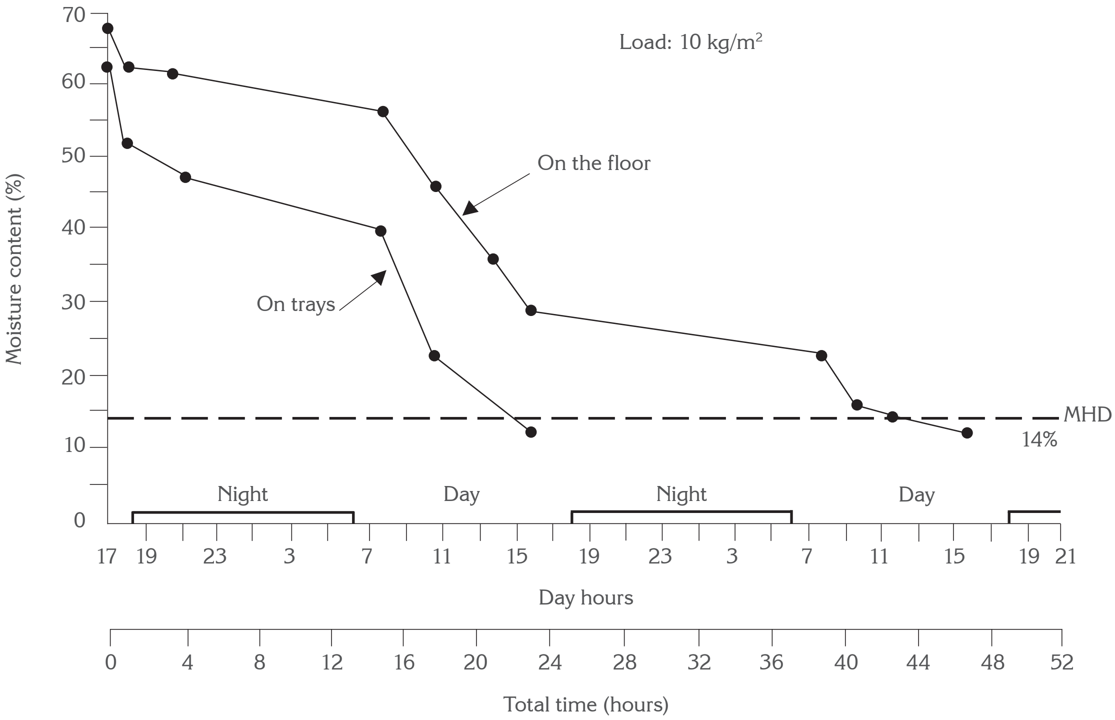


Figure 21-30. Comparison of two drying curves for cassava chips. One curve is for concrete floors and the other is for sloping trays (see text). MHD = maximum level of humidity accepted during drying.

Table 21-11. Drying time for fresh cassava chips cut at different hours of the day.

Site	Average climatic conditions throughout trial					Hours needed to dry to 14% moisture content on:				
	Altitude (m above sea level)	Temp. (°C)	r.h. (%)	Wind (m/s)	Solar radiation ($cal/cm^2.s$)	Floor ($5 kg/m^2$) at 8:00[a]	Inclined trays (load of $10 kg/m^2$) at:			
							8:00[a]	11:00[a]	14:00[a]	17:00[a]
Sevilla	1250	25	73	1.14	0.74	9	14	10	9	11
Espinal	430	29	60	0.66	0.66	11	13	10	9	6
Palmira	1000	26	68	1.26	0.61	14	12	9	6	8
Caicedonia	1100	26	69	0.90	0.72	14	14	12	11	15 (16%)[b]
El Darién	1450	23	72	1.73	0.70	13	13	12	12	11 (15%)[b]

a. Time at which trial began.
b. Percentages indicate moisture content at that hour.
SOURCE: Best (1979).

conditions will cassava chips dry in less than 1 day. In places where wind speed and solar radiation are low, drying may take as long as 3 days.

- About the same number of hours per square meter is needed for drying, but the weight of chips in trays is almost double that of those on the concrete floor.

- In very moist areas, rapid drying requires a high wind speed (e.g., at Sevilla, Espinal, and El Darién).

Chip size

Chip size influences drying time: the finer a chip is, the shorter the time to release the moisture in its tissues. Table 21-13 shows the range of chip dimensions used

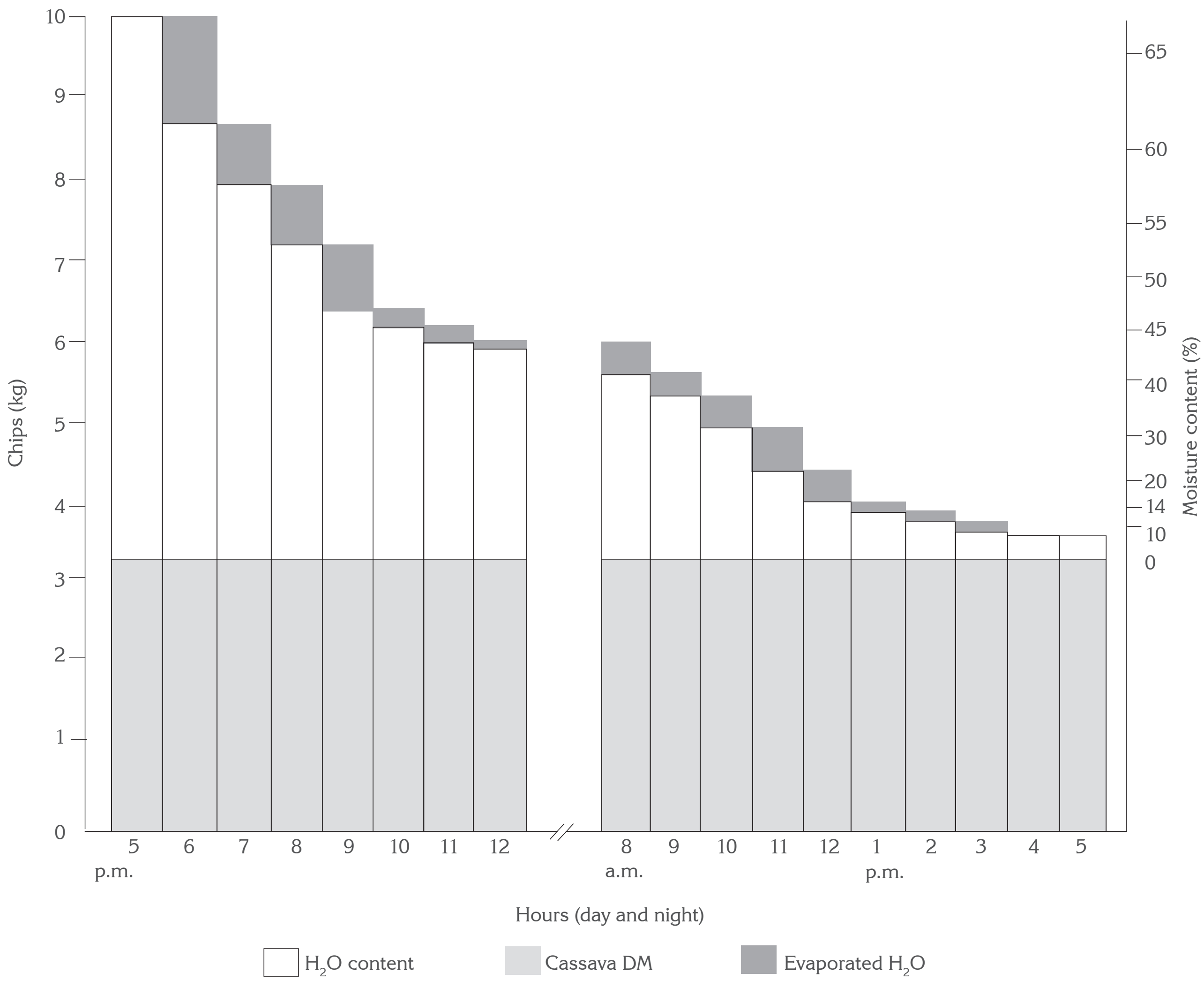


Figure 21-31. Typical drying curve for cassava chips on trays. Note the moisture loss in relation to the hour of the day, starting at 5:00 p.m. and recording during the night (from Best 1979). DM: dry matter.

Table 21-12. Time needed[a] between 8:00 and 18:00 hours to dry fresh cassava chips to 14% moisture content in five different sites.

Site		Climatic conditions of site				Time (hours) on:	
	Altitude (m above sea level)	Temp. (°C)	r.h. (%)	Wind (m/s)	Solar radiation (cal/cm^2.s)	Trays (10 kg/m^2)[b]	Floor (5 kg/m^2)[b]
Sevilla	1250	22	78	1.0	0.71	13	13
Espinal	430	30	64	0.9	0.65	12	10
Palmira	1000	26	66	1.2	0.61	13	15
Caicedonia	1100	26	67	0.8	0.58	19	17
El Darién	1450	24	70	1.9	0.73	12	11

a. Values averaged over three trials.
b. The value in parentheses is the cassava chip load.
SOURCE: Best (1979).

by different chipping machines currently used to process fresh roots. Table 21-14 lists the characteristics of the overall material promade up of typical chips. As can be observed, no machine produced more than 46% of typical chips. Reasons include imperfect adjustment of disks with the front, variation in speed of feed, and diversity of fresh-root size (Castillo and Hernández, 1985).

Net drying times

Figures 21-32 and 21-33 show the net drying times for three types of chips in the concrete-floor systems (10, 12, and 14 kg/m^2) and inclined trays (10, 12, 14, 16, 18, and 20 kg/m^2). Drying was carried out between 8:00 and 18:00 hours every day. The net time does not include the 14 hours of night. Average environmental conditions at CIAT, the site of the trials, were as follows:

- Environmental temperature: 23.5 °C
- Relative humidity: 75%
- Solar radiation: 0.73 cal/cm^2 per min
- Wind speed: 1.12 m/s
- Rainfall: 80 mm/month

For a given load, the difference between the two systems is noticeable. On concrete floors, the chips practically did not differ in drying time. "Malaysia" chips tended to perform better only for loads of 10 and 12 kg/m^2. For drying on inclined trays, no differences were found between the finer "Malaysia" chips and the rectangular "Brazil" or "Colombia" chips. Net drying times for the rougher "Thailand" chips were quicker by 2 or 3 hours than for the other chips. Figures 21-34

Table 21-13. Range of typical sizes (in mm) expected for fresh cassava chips.

Type of chipping machine	Length	Width	Thickness
"Thailand"	60–80	25–30	4–7
"Brazil"	50–70	10	4–6
"Malaysia"	50–80	4–6	4–6

Table 21-14. Percentages of different types of fresh chips produced according to type of chipping machine.

Type of chipping machine	Traditionally cut chips	Thinly cut chips	Finely cut chips
"Thailand"	42	34	24
"Brazil"	46	35	19
"Malaysia"	35	29	36

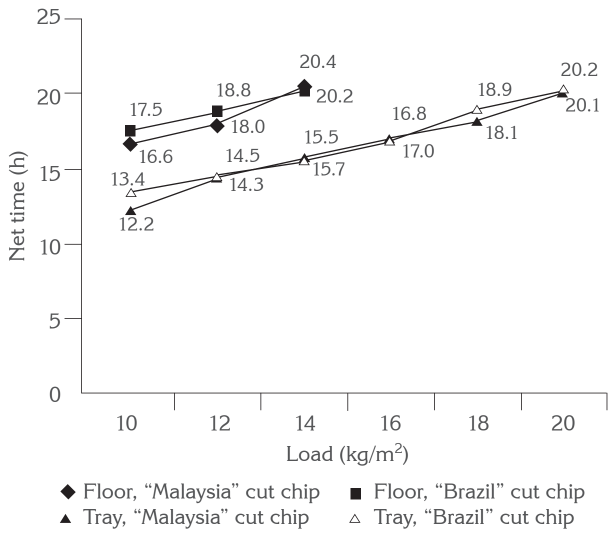


Figure 21-32. Net times for drying "Brazil" and "Malaysia" cut cassava chips, and dried on concrete floors or inclined trays.

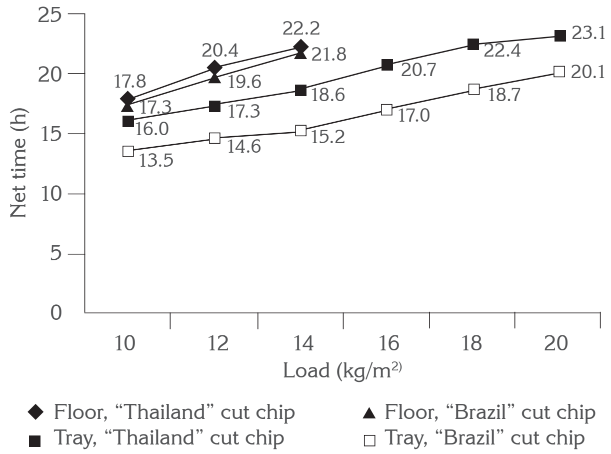


Figure 21-33. Net times of drying "Thailand" and "Brazil" cut cassava chips, and dried on concrete floors or inclined trays.

and 21-35 show the results in terms of dried chips per day and per each square meter of drying surface. This parameter permitted the selection of the best load for a specific site or region.

Costs

Drying on inclined trays is a good alternative for drying fresh chips in places where constructing concrete floors is not possible because of inclined land or insufficient resources. Table 21-15 compares costs of materials for constructing a concrete floor versus trays.

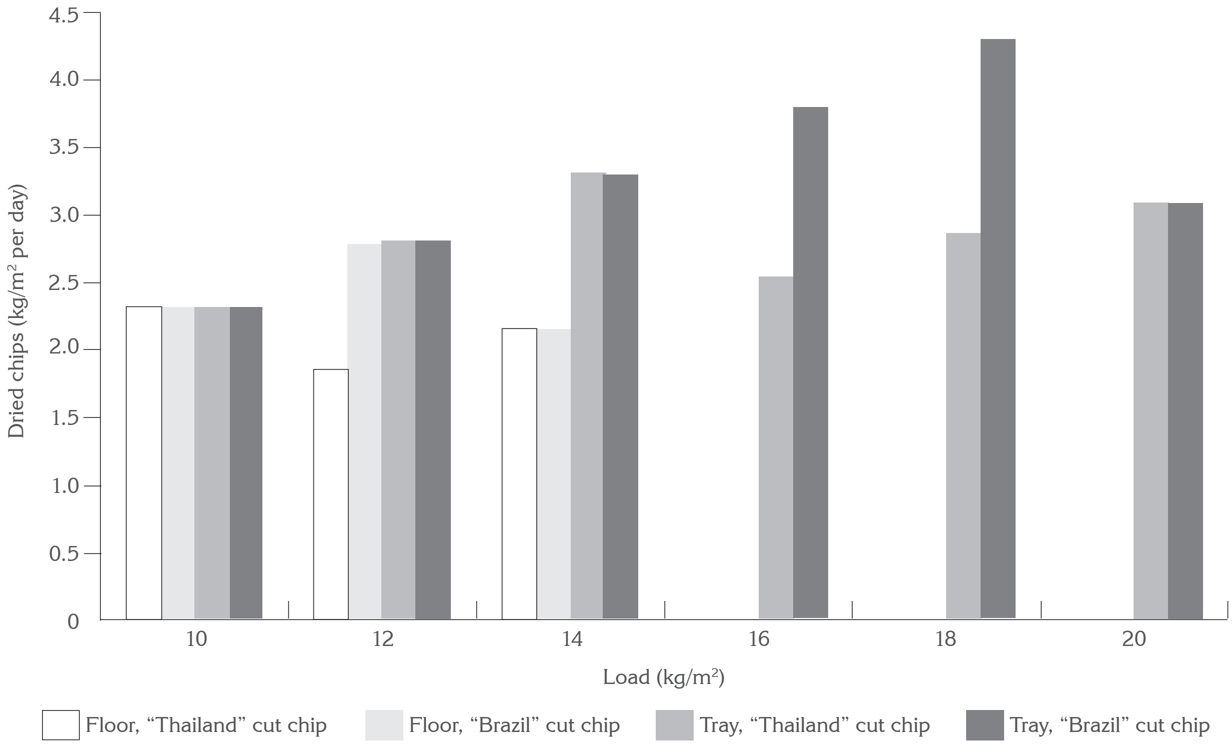


Figure 21-34. Production of "Thailand" and "Brazil" cut cassava chips, dried on concrete floors or inclined trays.

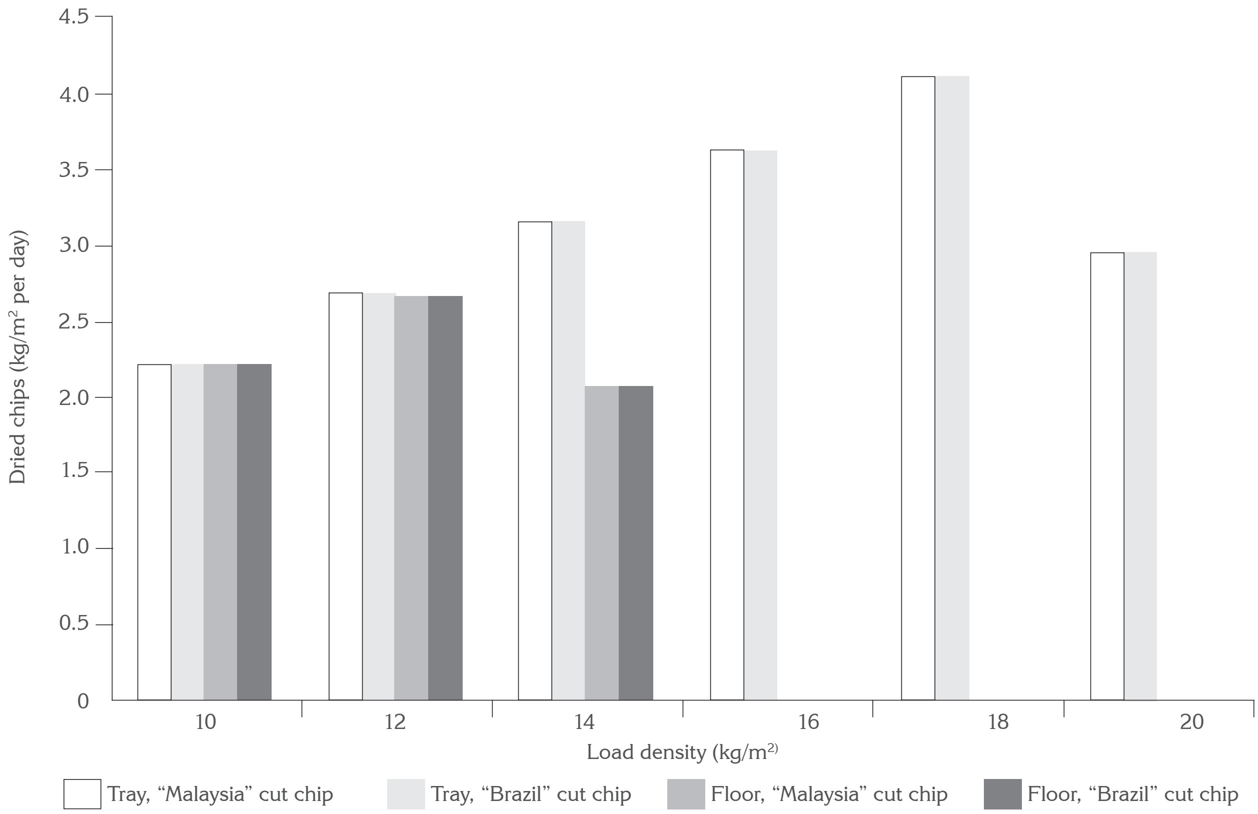


Figure 21-35. Production of "Brazil" and "Malaysia" cut cassava chips, dried on concrete floors or inclined trays.

Table 21-15. Comparison of costs of materials needed for 100 m^2 of drying surface, whether as a concrete floor or as trays, March 2001

Material (unit)	Unit cost (Col$)	Units needed	Total cost (Col$)
Concrete floor			
Cement (50-kg sacks)	13,000	40	520,000
Sand (m^3)	15,000	5	75,000
Gravel (m^3)	30,000	10	300,000
Tar (kg)	4,000	20	80,000
Wooden planks (2.8 × 0.24 × 0.025 m)	8,000	30	240,000
Subtotal			**1,215,000**
Unforeseen contingencies (10%)			130,000
Labor (60%)			805,000
Total			**2,150,000**
Cost per square meter of surface	21,500		
Inclined trays			
Wood (2.8 × 0.24 × 0.025 m)	8,000	42	336,000
Chicken wire netting (roll of 1.2 × 36 m)	39,500	3.2	126,400
Plastic mesh (roll of 0.9 × 30 m)	150,000	3.8	570,000
Nails (kg)	1,500	10	15,000
Frames (3 m × 2 cm × 2 cm)	3,000	100	300,000
Subtotal			**1,347,400**
Unforeseen contingencies (10%)			134,740
Labor (60%)			890,000
Total			**2,372,140**
Cost per square meter of surface	23,700		

SOURCE: Best (1979).

Infrastructure. The cost per square meter of drying surface is larger for trays than for concrete floors. However, if the larger carrying rate of the tray system is taken into account, savings in the total investment would be evident. The trays' maintenance costs and their duration depend on the care with which they are handled. The concrete floor, in contrast, needs little maintenance and is long lasting.

Inclined trays notably simplify the management of cassava chips, as the chips do not need turning over. Moreover, the labor needed for the entire process with trays is about 25% less than that required for a concrete floor (Table 21-16). Table 21-17 presents the flow of activities for three workers who dry 3 t of cassava on 190 m^2 of inclined trays (load = 16 kg/m^2). Total working hours spent was 19.5. If 2.5 is taken as the conversion factor, the working hours needed for producing 1 t of dried cassava would be 16.2 (about 2 working days).

Investment. Table 21-18 details the investments needed to install a plant with 300 m^2 of inclined trays and a capacity to dry 5 t of fresh cassava every 2 days.

Table 21-16. Comparison of the labor needed to chip one ton of cassava roots and dry on either concrete floors or inclined trays.

Activity	Working hours	
	Floor	Trays
Weigh and wash roots	3	3
Chip roots	2	2
Subtotal	**5**	**5**
Spread the chips	2	2
Turn the chips over (4 × a day)	1.5	
Collect and cover chips at night	1	1
Spread out again in the morning	1.5	1
Turn the chips over (4 × a day)	1.5	
Collect and pack chips	2	2
Subtotal	**9.5**	**6**
Total labor	**14.5**	**1**

SOURCE: Best (1979).

This is equivalent to a plant with a 500-m^2 concrete floor. Table 21-19 records the processing costs of a drying plant in the Colombian North Coast. Data were provided by FEDEYUCA in August 2000. The costs

Table 21-17. Timetable of activities to dry 3 t of fresh cassavaa on inclined trays.

Activity	Workers (no.) in hour of the day:													
	6	7	8	9	10	11	12	13	14	15	16	17	18	19
First day														
Weigh and chip roots		2												
Spread out chips			1											
Collect and cover													2	
Second day														
Uncover trays		2												
Collect												3		
Store													3	

a. Drying area = 190 m2; total working hours: 19.5; working hours per ton of cassava: 16.2; conversion factor: 2.5.

Table 21-18. Investment needed for a natural drying plant with a tray area of 300 m^2 and a capacity to dry 5 t of fresh cassava chips every 2 days, February 2001.

Concept	Unit value (US$)[a]	Total value (US$)[a]	Rubric totals (US$)[a]
Installations			**6,280**
Trays (300 m^2)	12/m^2	3,600	
Storeroom (40 m^2)	46.80/m^2	1,872	
Wire mesh (100 m)	1.00/m^2	100	
Roofing for the chipping machine (25 m^2)	28.30/m^2	708	
Equipment			**1,700**
Chipping machine, type "Colombia"	700.00	700	
2 electric motors (5 hp)	300.00	600	
500-kg capacity platform scale	400.00	400	
Tools			**180**
4 wheelbarrows	30.00	120	
6 metal shovels	10.00	60	
Others			**60**
300 sacks	0.20	60	
Subtotal			**8,220**
Unforeseen contingencies (10%)			822
Working capital (30 days)[b]		4,000	4,000
Total			**13,042**

a. Exchange rate, March 2001: US$1 = Col$2300.
b. Calculation table:

Working capital (Col$) needed to operate the plant normally for 30 days	
Fresh cassava roots = 72 t × Col$75,000 per ton	5,400,000
Working days = 80 × Col$12,000 each	960,000
Sacks = 600 × Col$300 each	180,000
Dried cassava chips = 30 t × Col$45,000 (freight per ton)	1,350,000
Total working capital (Col$)	**7,890,000**

Table 21-19. Cost structure of a cassava drying plant with 300 m^2 of inclined trays, Colombian North Coast, August 2000.

Concept or cost	Value (Col$)	Value (%)
Fixed costs		
Administration	3,000	
Depreciation		
Financial costs		
Maintenance	4,500	
Subtotal	**7,500**	**3.5**
Variable costs		
Raw material[a]	187,500	
Labor[b]	24,000	
Expenses	3,000	
Unforeseen contingencies		
Subtotal	**214,500**	**78.0**
Marketing expenses		
Packaging	7,000	
Commission		
Freight[c]	45,000	
Subtotal	**52,000**	**18.5**
Total costs + expenses	**274,500**	**100.0**

a. From 2.5 t of fresh cassava roots, 1 t of dried cassava is obtained.
b. Two working days to produce 1 t of dried cassava.
c. Freight from Sincelejo to Medellín.

include freight from Sincelejo to Medellín. For a typical North Coast plant, processing costs is more than Col$40,000 per ton of dried chips and the profit obtained is about Col$25,000 (Table 21-20).

Table 21-20. Costs of processing 1 t of dried cassava chips and perceived profit[a], Colombian North Coast.

Category	Col$[b]
Raw material	187,500
Processing	42,000
Freight	45,000
Total production costs	274,500
Sale price[c]	300,000
Net earnings	25,500

a. As perceived by the Cooperativa CooproAlgarrobos, Chinú, Department of Córdoba, Colombia, August 2000.
b. Note that the cost data offered by this table must be updated when considering a specific project.
c. At the concentrate-feed plant.

Appendix:

Determining Dry Matter Content of Fresh Roots, using the Specific Gravity Method

Julio César Toro[5] and Alonso Cañas[6]

Dry matter (DM) and starch contents, expressed as percentages in cassava roots, are often called quality factors. They vary greatly among different cassava varieties. These factors are closely related to the soil's potassium content, crop's age, and the climate (mainly rainfall and soil moisture). They also depend heavily on the absence or severity of attacks from defoliating pests (e.g., thrips and hornworm) and other defoliating agents such as hail (Celis and Cadavid 1978, pers. comm.).

To calculate the DM yield of roots at harvest from fresh root yield, the following methods are used:

- Conventional *laboratory* techniques that require much work and time.
- A *hydrometer* similar to that used for potato tubers. Apparently, it can be adapted to cassava roots (G Gómez 1977, pers. comm.).
- *Specific gravity* method for roots, which has been applied ever since the relationship between that parameter and DM and starch contents in roots was verified.

Determining specific gravity (SG) is simple, useful, and within the reach of farmers on their farms or of companies processing cassava flour or starch.

Elements for determining specific gravity

The method requires the following elements:

- A beam balance that can weigh gram by gram to 3 kg, and has divisions in decigrams.
- A container that can carry sufficient water to submerge the sample.
- A metal mesh basket, with a square base, and able to carry 3 kg of cassava roots.
- Several bags, either plastic or paper, that can carry 3 kg of cassava.
- Plastic or nylon string or cord, 2 m long.
- An S-shaped hook.
- A plank, 25 × 60 cm, which is large enough to act as a small table for carrying the balance. The plank has a central perforation (Ø at 5 cm) just underneath the balance's weighing plate.
- A four-legged framework for the plank. The framework may be 50 cm wide and 73 cm long.
- A pencil or a permanent ink marker.
- A machete or wooden spatula.

Conducting the specific gravity method

Taking samples. Samples of recently harvested roots should be collected, taking 3 or 4 samples per variety or plot and ensuring they are representative, that is, that they include large and small roots, both thick and thin. Each sample should weigh more than 3 kg. The roots are cleaned with the blunt edge of a machete or wooden spatula and the rootlets and peduncles cut off. They are then packed into previously marked bags and taken to the site where measurements will be made. This site should not be exposed to air currents, as these affect readings from the balance.

Fresh root weight in air (FRWA). Each bagged sample is weighed individually. All samples should have similar FRWA in that the weight is not less than 3.0 kg (Figure 21A-1A). The relative uniformity of the weight helps correct possible erroneous readings, in that if a large difference is seen, then the sample can be re-weighed to immediately verify its weight. If sample weights do not vary, such repetition becomes unnecessary. Once the FRWA is obtained, the sample is re-packed into its bag. The roots in each sample do not have to be entire.

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Fresh root weight in water (FRWW). The metal mesh basket, tied to a nylon cord, is introduced into a container full of water in such a way that it remains balanced. The other end of the cord is tied to the S hook, which, in its turn, is hung by its upper curl from the lower extremity of the balance's linchpin, which passes downwards through the perforation in the plank (Figure 21A-1B). The basket should remain totally submerged. Neither the basket nor the cord should touch or even brush against any object.

Once assembled, the balance is calibrated to zero to eliminate the weight of the elements described above, and the sample of roots is then placed into the basket (Figure 21A-1C). Figure 21A-1D gives an overall view of the equipment as it weighs the sample in water. The FRWW is noted beside the respective FRWA. Once the weights of all the samples are obtained, the SG is calculated for each case, using the following formula:

$$SG_C = \frac{FRWA}{FRWA - FRWW} \qquad (1)$$

The result should have four decimal figures. Table 21A-1 was developed by Wania G. Fukuda (cited in Toro and Cañas 1983) to obtain percentages of DM from cassava roots as derived from specific gravity ("density", in the table). The original table was later expanded with new entries and densities ranging from 1.0200 to 1.1900. The following regression equation led to Table 21A-1.

$$DM\ (\%) = 158.26\ (SG) - 142.05 \qquad (2)$$

These tables are applied to cassava varieties harvested 10 to 12 months after planting, under normal cassava production conditions in Colombia (CIAT 1978).

Table 21A-1 was used to prepare another, even shorter, table (Table 21A2) for finding only the most usual DM values (%) for roots (i.e., between 20% and 46%), knowing the corresponding FRWW. This is expressed in grams and takes only one decimal figure. The FRWA of 3.0 kg is taken because the table can then be summarized, and a correct reading of the FRWW is more likely. Cours (1951) verified that a variation of 16.7 g in the FRWW can indeed alter the DM content value by 1%.

Determining DM content (%) in cassava roots through the SG method is an easily adoptable practice that can be very useful for identifying those cassava varieties that have higher DM content.

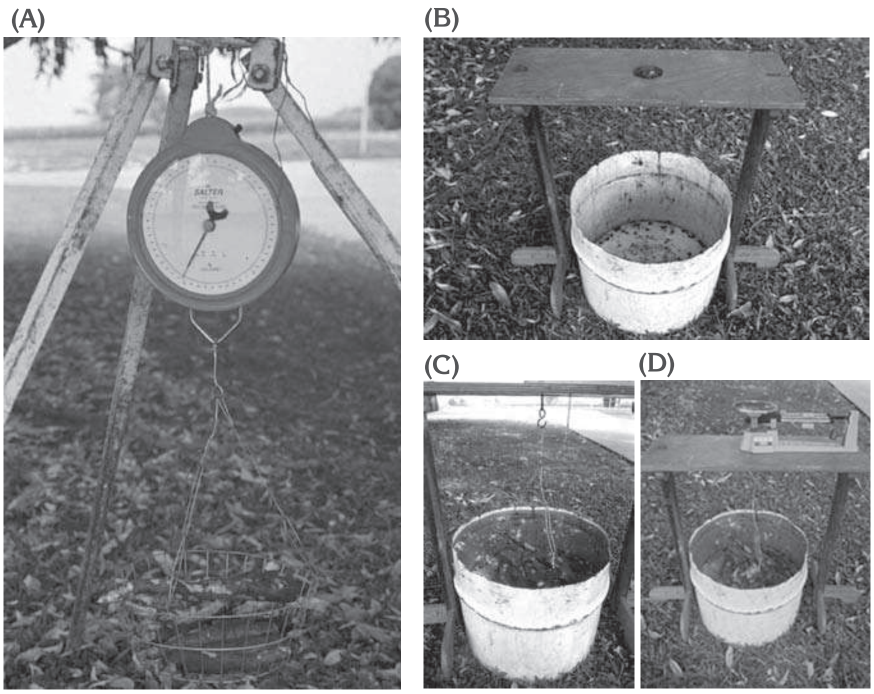

Figure 21A-1. Measuring the values for "weight in air" (FRWA) and "weight in water" (FRWW) of cassava roots. From these data, the specific gravity is calculated and, from a table, the percentage of dry matter in the sample roots is obtained. **(A)** Balance for weighing in air. **(B)** Plank with perforation, its supporting framework, and the water container. **(C)** Balance, cord, S-shaped hook, and metal basket containing cassava roots. **(D)** Overall view of the equipment used for measuring "weight in water".

Table 21A-1. Determining dry matter (DM) content in cassava roots, using the specific gravity (or density) method.

Density (SG)	DM (%)	Density (SG)	DM (%)	Density (SG)	DM (%)
1.0200	19.53	30	23.12	65	26.79
05	19.61	35	23.20	70	26.87
10	19.69	40	23.28	75	26.95
15	19.76	45	23.36	80	27.03
20	19.84	50	23.43	85	27.10
25	19.92	55	23.51	90	27.18
30	20.00	60	23.59	95	27.26
35	20.08	65	23.67	1.0700	27.34
40	20.15	70	23.75	05	27.42
45	20.23	75	23.82	10	27.50
50	20.31	80	23.90	15	27.57
1.0255	20.39	85	23.98	20	27.65
60	20.47	90	24.06	25	27.73
65	20.54	95	24.14	30	27.81
70	20.62	1.0500	24.22	35	27.89
75	20.70	05	24.29	40	27.96
80	20.78	10	24.37	45	28.04
85	20.86	15	24.45	50	28.12
90	20.93	20	24.53	55	28.20
95	21.01	25	24.61	60	28.28
1.0300	21.09	30	24.68	65	28.35
05	21.17	35	24.76	70	28.43
1.0310	21.25	40	24.84	75	28.51
15	21.33	45	24.92	80	28.59
20	21.40	50	25.00	85	28.67
25	21.48	55	25.07	90	28.74
30	21.56	60	25.15	95	28.82
35	21.64	65	25.23	1.0800	28.90
40	21.72	70	25.31	05	28.98
45	21.79	75	25.39	10	29.06
50	21.87	80	25.46	15	29.14
55	21.95	85	25.54	1.0820	29.22
60	22.03	90	25.62	25	29.30
1.0365	22.11	1.0595	25.70	30	29.37
70	22.18	1.0600	25.78	35	29.45
75	22.26	05	25.86	40	29.53
80	22.34	10	25.93	45	29.61
85	22.42	15	26.01	50	29.69
90	22.50	20	26.09	55	29.77
95	22.57	25	26.17	60	29.84
1.0400	22.65	30	26.25	65	29.92
05	22.73	35	26.32	70	30.00
10	22.81	40	26.40	75	30.08
15	22.89	45	26.48	80	30.16
20	22.97	50	26.56	85	30.23
25	23.04	55	26.64	90	30.31
		60	26.71	95	30.39

(Continued)

Table 21A-1. (Continued.)

Density (SG)	DM (%)	Density (SG)	DM (%)	Density (SG)	DM (%)
1.0900	30.47	35	34.14	70	37.80
05	30.55	40	34.22	75	37.88
10	30.62	45	34.29	80	37.96
15	30.70	50	34.37	85	38.04
20	30.78	55	34.45	90	38.12
25	30.86	60	34.53	95	38.19
30	30.94	65	34.61	1.1400	38.27
35	31.01	70	34.69	05	38.35
40	31.09	75	34.76	10	38.43
45	31.17	80	34.84	15	38.51
50	31.25	85	34.92	20	38.59
55	31.33	90	35.00	25	38.66
60	31.41	95	35.08	30	38.74
65	31.48	1.1200	35.15	35	38.82
70	31.56	05	35.23	40	38.90
75	31.64	10	35.31	45	38.98
80	31.72	15	35.39	50	39.05
85	31.80	20	35.46	55	39.13
90	31.87	25	35.54	60	39.21
95	31.95	30	35.62	65	39.29
1.1000	32.03	35	35.70	70	39.37
05	32.11	40	35.77	75	39.44
10	32.19	45	33.85	80	39.52
15	32.26	50	35.93	85	39.60
20	32.34	55	36.01	90	39.68
25	32.42	60	36.09	95	39.76
30	32.50	65	36.16	1.1500	39.84
35	32.58	70	36.24	05	39.91
40	32.65	75	36.32	1.1510	39.99
45	32.73	1.1280	36.40	15	40.07
1.1050	32.81	85	36.48	20	40.15
55	32.89	90	36.55	25	40.23
60	32.97	95	36.63	30	40.30
65	33.05	1.1300	36.71	35	40.38
70	33.12	05	36.79	40	40.46
75	33.20	10	36.87	45	40.54
80	33.28	15	36.95	50	40.62
85	33.36	20	37.02	55	40.69
90	33.44	25	37.10	60	40.77
95	33.51	30	37.18	65	40.85
1.1100	33.59	35	37.26	70	40.93
05	33.67	40	37.34	75	41.01
10	33.75	45	37.41	80	41.08
15	33.83	50	37.49	85	41.16
20	33.90	55	37.57	90	41.24
25	33.98	60	37.65	95	41.32
30	34.06	65	37.73		

(Continued)

Table 21A-1. (Continued.)

Density (SG)	DM (%)	Density (SG)	DM (%)	Density (SG)	DM (%)
1.1600	41.40	10	43.12	15	44.76
05	41.48	15	43.19	20	44.83
10	41.55	20	43.27	25	44.91
15	41.63	25	43.35	30	44.99
20	41.71	30	43.43	35	45.07
25	41.79	35	43.51	40	45.15
30	41.87	1.1740	43.59	45	45.22
35	41.94	45	43.66	1.1850	45.30
40	42.02	50	43.74	55	45.38
45	42.10	55	43.82	60	45.46
50	42.18	60	43.90	65	45.54
55	42.26	65	43.98	70	45.61
60	42.33	70	44.06	75	45.69
65	42.41	75	44.13	80	45.77
70	42.49	80	44.21	85	45.85
75	42.57	85	44.29	90	45.93
80	42.65	90	44.37	95	46.00
85	42.72	1.1795	44.45	1.1900	46.08
90	42.80	1.1800	44.52		
95	42.88	05	44.60		
1.1700	42.96	10	44.68		
05	43.04				

SOURCE: CIAT (1978).

Table 21A-2. Calculation of dry matter (DM) content in cassava roots, using the value "fresh root weight in water" (FRWW)[a].

FRWW	DM (%)	FRWW	DM (%)
58.8	20	296.0	34
77.4	21	311.8	35
95.8	22	327.4	36
112.6	23	342.8	37
130.6	24	359.0	38
148.3	25	371.9	39
165.8	26	386.7	40
183.1	27	401.5	41
198.9	28	416.0	42
215.8	29	430.4	43
232.5	30	443.5	44
248.9	31	457.6	45
265.2	32	471.5	46
280.1	33		

a. Assuming that the "weight in air" (FRWA) of each sample is equal to 3000 g. The specific gravity method is applied indirectly.

SOURCE: CIAT (1979).

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To save space, the acronym "CIAT" is used instead of "Centro Internacional de Agricultura Tropical".

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