Harvesting and Processing

PROCEEDINGS OF A WORKSHOP HELD AT
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21-22 APRIL 1978

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Cassava Harvesting and Processing

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Cassava Chipping and Drying in Thailand

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Abstract. Experiments were carried out comparing cassava drying techniques and testing the effects on drying of different chip forms and sizes. Cassava chips of various shapes and sizes (circles, rectangles, cubes, strips, and slices) produced by Thai and Malaysian cutters were investigated, and solar drying methods using plain cement floors, blacktopped floors, and shelf driers, as well as artificial drying, were compared. It was observed that both blacktopped floors and perforated shelf driers were faster means of drying than regular cement floors and that drying time was influenced by the shapes and sizes of chips. The data were statistically analyzed and regression equations were developed, providing significant and useful information in the chipping and drying studies of cassava.

Cassava, Manihot esculenta Crantz, also called tapioca or manioc, is a starch-producing tropical root crop. It ranks seventh among staple foods in the world and is ubiquitous to Africa and Asia. As a crop, cassava's popularity with farmers is due to several attributes: it is easy to plant, requires little attention, withstands drought and short periods of flood, grows in relatively poor soils, and yields well compared to many other crops. The yield varies from region to region and strain to strain with 2–3 kg of root per plant being common. Improved strains that yield more than 10 kg of root per plant are now available. The optimum yield can be achieved by having 3000–10 000 plants/ha.

Cassava as Food and Feed

Cassava is used as a staple food by about 200 million people in the tropics, and large amounts are exported to temperate countries. The United States and the European Economic Community (EEC) are the main importers of cassava products, with the USA being the largest single market for cassava starch and importing most of it from Thailand. Demand for cassava chips and pellets has increased in recent years in the EEC because of higher grain costs. Cassava is used as a substitute for barley, maize, etc. in livestock feed, mainly for dairy cattle, beef cattle, goats, pigs, and chickens. At present, cassava seldom constitutes more than 10% of compound feeds, but occasionally up to 40% is used.

In the future, cassava has great potential as livestock feed, especially with the rising prices of animal products and quality meat. Future demand will depend on consumption of livestock products, changing composition of reared livestock, changing dependency on compound feed, and increasing livestock numbers. All indications are that demand for cassava for inclusion in animal feed in the EEC will increase in Belgium, Italy, and Germany more rapidly than in France and the Netherlands. The United Kingdom and Denmark are also potential buyers of cassava feedstuff. Compound feed demand is closely related to livestock product demand and can be estimated from it. The United Kingdom and Denmark, as members of the EEC and as practitioners of a common agricultural policy (CAP), are experiencing pressures to increase livestock production due to increased livestock prices. Therefore, the compound feed market is expanding substantially; however, the share that cassava products will command has not yet been determined.

The prospects for the utilization of cassava products indicate that the animal feed sector is one of the most promising not only in developed countries but also in certain developing countries where people can afford intensively produced meat. Taiwan's imports of feed grains have
increased from 94 000 t in 1964 to more than 1 million t in 1971. In addition, Japanese buyers, who have previously relied on imported maize for feed, now seem to be active in the cassava market. This suggests new opportunities for export in a number of tropical countries.

Cassava Chipping and Drying in Thailand

The total world market comprises both domestic consumption and international trade. In Thailand, where production of cassava has increased sharply since 1956, the crop occupies about 2% of the country's planted area and is almost entirely for export.

The production of cassava chips in Thailand is a relatively simple procedure consisting of chipping the roots and then spreading them on large concrete surfaces in the open air. Sun drying usually requires 2–3 days with periodic turning of the chips (until the moisture content reaches 13–15%). Currently, however, drying periods are very short, and the moisture content is rarely reduced below 19%. Sand and waste products, such as cassava fibres, are often added to the chips to minimize the drying time and make the process economically viable. The high moisture content means that the cassava is a favourable medium for the growth of bacteria and mould. It appears, therefore, that there is a need for cost-effective methods for reducing drying time and ensuring acceptable levels of moisture content.

Sun drying of cassava chips on plain cement floors is the most common practice. Discounting weather conditions, the chips' shape and thickness mainly determine drying time, but the colour of the cement also has some influence. For instance, black surfaces absorb more heat energy and reach higher temperatures than do plain surfaces, thus reducing drying time.

Drying Methods: a Study

In our study, various shapes and sizes of cassava roots were cut manually and dried on different drying media (Table 1) in an attempt to measure their effects on drying times. Chips mechanically cut using Thai and Malaysian machines were also tested. The Thai cutter was designed to produce irregular, large chips with a capacity of about 9–14 t/hour with 6–8 hp engines. The Malaysian cutter, type Jenis-B, designed by the National Institute for Scientific and Industrial Research (NISIR) consists of two blades producing cassava slices (0.2–0.3 cm thick) at one side and strips approximately 8 × 0.65 × 0.65 cm on the other side. With a total capacity of about 3.8 t/hour of chips, it uses a 2 hp engine and has two advantages over the Thai machine: the chips are uniform, and the pulp can be collected separately from the bulk mass of the chips.

The manually and mechanically cut chips were sun dried on 2 m × 2 m natural cement and black concrete floors and on trays. The chips on the floors were turned periodically until the moisture content reached 13–15%. Turning the chips increases air circulation and aids heat transfer by convection, thus speeding drying. In tray drying, turning is not required if the trays are porous (chicken wire, netting, etc.).

A three-tier tray drier was designed and studied as an alternative to concrete floor drying. It consisted of four trays that could be adjusted to any of three positions, one horizontal and two tilted at an angle of 20° to the horizontal, either up or down (Fig. 1).

The trays on one side were made of bamboo lattice work, the upper one having 2-cm² holes and the lower one 1.3-cm² holes. On the other side, chicken wire was used, and the upper tray had 2-cm² holes and the lower one 0.6-cm² holes. The lowest level tray was made of plywood and had 1.3 cm clearance from the ground. Trays were designed in such a way that the dried product on the upper levels would fall onto the lower level trays, when unhooked, for subsequent collection.

Sun drying is at times unreliable, because it depends on solar radiation. Artificial drying, on the other hand, maintains a consistent environment and may be considered as an alternative. In the present study, artificial drying was carried out on a thermostatically controlled electric hot plate.

During drying tests, the moisture content of the chips was determined at regular intervals of 1 or 2 hours. Thermometers were provided to record ambient and contact surface temperatures.

Results and Discussion

The study was carried out during the hot season (between March and July 1975) when the air temperature varied between 28 and 35 °C. After 24 hours of solar radiation on the cement floor, the chips contained 15–17% moisture, but the slices (0.1–0.2 cm) contained 14% in 12 hours. An increase in moisture was noted between 2000 and 0800 hours due to the absorption of condensation caused by cooling of the night air. During daylight, the difference between the floor temperature and that of the ambient air was about 6–7 °C.
On the black concrete surface, the chips and strips contained 14% moisture after 9 hours of drying. The cubes (1 cm³) also approached 14%. No improvement or deterioration occurred between 1800 and 0800 hours; however, a slight decrease in moisture was noted on the 2nd day of drying.

The chips drying on the trays were better looking and more uniformly dried than those drying on concrete floors. The moisture content measured in the slices and strips after 14 hours was 14% or less. A hot plate maintained at 70 °C reduced moisture content to 14% within 4–5 hours for all the chip sizes.

### Cost Considerations

Although artificial drying is more reliable than sun drying, it requires higher initial investment and may not be feasible for many cassava processors. Concrete drying and tray drying, on the other hand, may mean only limited increases in expenditures — for example, the concrete slabs used by starch manufacturers in Chonburi Province, Thailand, could be used at times for chip drying. In addition, the operating costs for concrete and trays are quite low and, for the latter, may be offset by the land that is freed for other purposes.

---

**Table 1. Shapes and sizes of cassava chips.**

<table>
<thead>
<tr>
<th>Shape</th>
<th>Diam (D)</th>
<th>Length (L)</th>
<th>Width (W)</th>
<th>Thickness (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CR₁</td>
<td>4.5</td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>CR₂</td>
<td>4.5</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Rectangle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT₁</td>
<td>8</td>
<td>2.5</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>RT₂</td>
<td>8</td>
<td>5</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>RT₃</td>
<td>8</td>
<td>2.5</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>RT₄</td>
<td>8</td>
<td>5</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Cube</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CU₁</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>CU₂</td>
<td>2</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Strip, ST</td>
<td></td>
<td>6</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Slice, SL</td>
<td></td>
<td></td>
<td></td>
<td>0.1–0.2</td>
</tr>
</tbody>
</table>

---

*Fig. 1. A trial load on a shelf-tray drier, a), a cross-section, b).*
Chip Form and Size

A second investigation was carried out during the rainy season, September–October 1975, this time focusing on sun drying chips in slices and strips produced using a knife, an ice-shaver, and a Malaysian cutter. The residual-moisture content versus time-of-drying was recorded. Temperatures varied between 28 and 31 °C.

Manually cut strips and slices dried very rapidly on the black concrete floor, and the acceptable level of moisture content (12–14%) was achieved in about 10–12 hours. The thin chips also reached 14% moisture content within 12–14 hours on a conventional drying floor. The same remarks apply to the drying performance of strips and slices produced commercially using a Malaysian cutting machine, although the chips were larger than those that were manually cut. A 13% moisture content was attained in strips after 14, 13, and 12 hours when dried on a simple concrete floor, the shelf drier, and a black-painted floor, respectively. During the 1st day of drying, the moisture content in strips was reduced to 30, 26, and 20% respectively. During the night, the moisture content increased by about 2% in most cases and the acceptable level of moisture content (14%) was reached on the 2nd day between 0800 and 1200. Slices required a longer drying time than strips, as previously observed, but the difference was not substantial. The same level of moisture content (13%) in slices was attained after 16, 15, and 13 hours on a plain cement floor, the shelf drier, and a blacktopped floor, respectively.

Statistical Analysis

The general trend of the data showed that a polynomial of the form $y = a - b_1X - b_2X^2 - \ldots - b_nX^n$ could predict the behaviour. Computer programs were thus developed to fit a polynomial equation of any order and at the same time to plot the original and the estimated data from the model. The computer program was run in IBM 370/145. The regression coefficients were tested for their significance at 95% by making analysis of variance and then performing the F-test.

Floor temperature ($T_f$) was highly correlated to the ambient temperature ($T_a$). A second degree polynomial represented the relationship between ambient and floor temperatures for all the drying techniques except for shelf drier (middle shelf) for which a third-order polynomial was found representative. The relations proved to be:

**Cement Floor**

$$T_a = 11.71 + 0.632 T_f - 0.00256 T_f^2$$

**Blacktopped Cement Floor**

$$T_a = 19.15 + 0.289 T_f + 0.0007 T_f^2$$

**Shelf Drier**

Upper Shelf (chicken wire)

$$T_a = -38.9 + 3.56 T_f - 0.042 T_f^2$$

Middle Shelf (bamboo-net)

$$T_a = -393.95 + 34.85 T_f - 0.946 T_f^2 + 0.0085 T_f^3$$

Lower Floor (wooden)

$$T_a = -26.57 + 2.83 T_f - 0.0325 T_f^3$$

It may be observed from Fig. 2 that the floor temperatures of cement floor, blacktopped floor, and shelf driers (upper shelf) are respectively 33.5, 35, and 30.2 °C when the ambient temperature is 30 °C. The middle and lower shelf of the shelf drier at the same ambient temperature only reached temperatures of 29.5 and 30.4 °C, respectively, even though the shelf drier outperformed the unpainted concrete floor. The superiority of the shelf drier is due to the circulation of the ambient air through layers of the chips. Other results from the equations support the experimental findings.

The length of time needed to dry the chips is quite important for producers and may be calculated by using regression equations. The equations for the chips of various shapes and sizes and for different drying techniques have been developed and may be obtained by writing to the authors.

Conclusions

Some conclusions can be drawn from the study:

- Chip drying time can be shortened to a large extent using a blacktopped drying floor or a perforated shelf drier; however, the shelf drier may not be feasible for large-scale use. At present, it appears that the black-floor drying technique is the most promising.

- Drying duration is greatly influenced by the shapes and sizes of cassava chips. It has been demonstrated that slices and chips produced by a Malaysian cutting machine are excellent in terms of drying efficiency.

- This cassava study, which was conducted during the two major seasons of the year, did not indicate any noticeable difference in drying efficiency between the rainy and hot seasons in Thailand. Heat transfer by convection in the rainy season seemed to compensate for heat transfer by conduction in the hot season.

- The efficiency of conventional floor drying could be improved by chopping the cassava into thin strips or slices.

- Regression equations that were developed from the study show a significant relationship
between ambient and floor temperatures for different types of drying media. Also polynomial regression models for cassava drying can be used to relate moisture content with hours of drying.

Note: Not all the experimental points are plotted for Figs. (a) and (b).

Legend:
- Experimental Data
- Fitted Regression Line

Fig. 2. Ambient versus floor temperatures for cement floor, blacktopped cement, and shelf drier.

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