Harvesting and Processing

PROCEEDINGS OF A WORKSHOP HELD AT
CIAT, CALI, COLOMBIA
20-21 APRIL 1978

EDITORS: EDWARD J. WEBER
JAMES H. COCK
AMY CHOUINARD
The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences; and communications. IDRC is financed solely by the Government of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

© 1978 International Development Research Centre
Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa

Weber, E. J.
Cock, J. H.
Chouinard, A.
IDRC
Centro Internacional de Agricultura Tropical (CIAT)


UDC: 633.68

Microfiche edition available
Cassava Harvesting and Processing

Proceedings of a workshop held at CIAT, Cali, Colombia, 24–28 April 1978

Editors: Edward J. Weber,1 James H. Cock,2 and Amy Chouinard3

Cosponsored by the
International Development Research Centre
and the
Centro Internacional de Agricultura Tropical, CIAT

1Senior Program Officer, Agriculture, Food and Nutrition Sciences Division, Latin American Regional Office, International Development Research Centre, Bogota, Colombia.
2Leader, cassava program, CIAT, Cali, Colombia.
3Editor, Communications Division, International Development Research Centre, Ottawa, Canada.
Contents

Foreword  Edward J. Weber and James H. Cock  ...................... 3–5
Participants ................................................................. 6
Cassava Processing in Southeast Asia  Robert H. Booth and
Douglas W. Wholey ....................................................... 7–11
Cassava Processing for Animal Feed  Rupert Best ...................... 12–20
Cassava Chipping and Drying in Thailand  N.C. Thanh and
B.N. Lohani ................................................................. 21–25
Small-Scale Production of Sweet and Sour Starch in Colombia  Teresa
Salazar de Buckle, Luis Eduardo Zapata M., Olga
Sofia Cardenas, and Elizabeth Cabra ................................ 26–32
Large-Scale Cassava Starch Extraction Processes  Bengt Dahlberg .... 33–36
Cassava Flours and Starches: Some Considerations
Friedrich Meuser ......................................................... 37–40
Alcohol Production from Cassava  Tobias J.B. de Menezes .......... 41–45
Prospects of Cassava Fuel Alcohol in Brazil  Wilson N. Milfont Jr ... 46–48
Use of Fresh Cassava Products in Bread Making  Joan Crabtree,
E.C. Kramer, and Jane Baldry ........................................ 49–51
Harvesting: A Field Demonstration and Evaluation of Two Machines
David C. Kemp ......................................................... 53–57
Follow-up Evaluation of Two Harvesting Machines
Dietrich Leihner ......................................................... 58–59
Agronomic Implications of Mechanical Harvesting  James H. Cock,
Abelardo Castro M., and Julio Cesar Toro ......................... 60–65
Economic Implications of New Techniques in Cassava Harvesting
and Processing  Truman P. Phillips ................................. 66–74
Discussion Summary .................................................. 75–78
References ............................................................ 79–83
Alcohol Production from Cassava

Tobias J.B. de Menezes
Instituto de Tecnologia de Alimentos, Sao Paulo, Brazil

Abstract. Alcohol production from cassava is a means for countries like Brazil to cope with their energy demands. The basic technology in the process, which involves washing and peeling, milling, cooking, saccharification, fermentation, and distillation, has been defined but could be improved by the introduction of measures that optimize the energy output and minimize energy inputs. Some of the possibilities include introducing continuous hydrolysis of starch, controlling wastes, and commercially using the by-products.

Brazil consumes 700 000 barrels of oil daily, of which 80% comes from external sources. In 1972, the price of oil was U.S. $1.88/barrel, but by 1976 the price had increased to U.S. $13.00, increasing Brazil's expenditures to $3 billion and forcing the government to reevaluate its energy sources. A program was launched to intensify the search for renewable sources of fuel as a substitute for the nonrenewable fossil sources. Because of the large agricultural areas in the country, one suitable source of fuel appeared to be high-carbohydrate content crops, such as sugarcane, cassava, babacu-palm, sugar sorghum, and the sweet potato, which can be used to produce ethyl alcohol (Table 1).

Thus, the government elaborated the Brazilian Alcohol Production Plan, proposing to mix ethyl alcohol with gasoline in a ratio of 1:4 by 1980, and in a ratio of 4:1 by 1990. To attain this objective, cultivation of the raw materials will have to be increased meteorically. The area of sugarcane cultivation will have to be expanded sixfold, and cassava plantations increased eightfold. In other words, these two crops will account for half of the whole area cultivated at present in Brazil.

The plan is ambitious, and it promises a number of spinoffs for the economy, including development of the agroindustrial complex of the country.

The production of alcohol from cassava is not new in Brazil. It was undertaken from 1932 to 1945, when energy sources were very limited because of the war. During that period, 60 million litres of ethanol were produced annually for gasoline blending, this being more than that produced for beverages. Three cassava alcohol distilleries were opened, and several more were installed but never opened. By 1935, one of the plants located in the town of Divinopolis in the state of Minas Gerais was producing about 800 000 litres annually (Gravata 1943).

After the war, when the supply of gasoline was reinstated, the idea of using alcohol as motor fuel was abandoned, and the cassava alcohol plants were closed down. The lack of interest is difficult to explain because ethanol derived from cassava is of a high quality, similar to cereal alcohol, and could have found several applications other than for fuel. Possibly it was due to the fast expansion of the sugar plantations and the resulting surplus of molasses, which was sufficient to produce the required amount of alcohol. In addition, this expansion coincided with the technological development in Brazil of the distillation and rectification processes that improved the quality of the ethanol obtained from molasses.

With the reemergence of the energy crisis, the production of ethanol for motor fuel has received new impetus, and cassava is again being considered as an important carbohydrate source. Cassava is one of the most efficient photosynthesizing plants known; it has a high carbohydrate content, with roots containing 20–45% of starch and 5.0% reducing sugars. On a dry-matter basis, the starch content reaches 90%. At present, this plant, which shows good resistance to disease and plagues and tolerance to adverse soil and climatic conditions, emerges as an excellent source of carbohydrates for the production of alcohol for gasoline blending or as a raw material for the petrochemical, pharmaceutical, beverage, and perfume industries. It is generally agreed that
Industrial yield corresponding to 80% of the theoretical yield.

The production of alcohol from cassava is practical in places where the soil is not suitable for sugarcane. In some ways, sugarcane has obvious advantages over cassava. Its juice is directly fermentable, and the bagasse — the by-product of juice extraction — can be used as fuel for steam generation. There are, however, a number of advantages also in the utilization of cassava roots. For example, it would encourage research into agricultural methods and the manufacture of the amylolytic enzymes utilized in the saccharification of starch. Also, if the technology for the fermentation of alcohol from starchy materials, which is already very advanced, were combined with technology for continuous hydrolysis of starch to make the process continuous and automatic, the increased yield per unit time in smaller and more compact installations would make cassava competitive with sugarcane.

Generally, the manufacturing process for cassava alcohol is similar to that for cereal grain alcohol (Teixeira 1964, 1966), differing only in the steps relating to the raw-material preparation (Fig. 1).

### Washing, Peeling, and Grating

The roots are weighed and then simultaneously washed and peeled in a washer-peeler to remove the impurities that might interfere with heat penetration during cooking. At one time, whole roots were commonly used, but this practice resulted in a longer cooking time and less efficient process. Moreover, bigger cookers were required for the same amount of raw material.

The roots are then passed to a special grater, of the type used in the manufacture of starch or cassava flour. The purpose of grating is to increase the surface area of the raw material and thus to shorten the cooking, hydrolysis, and fermentation times.

If cassava chips are used instead of roots, washing and peeling can be bypassed, and the chips sent immediately to be dry ground in a hammer mill, similar to that used in corn milling (Teixeira 1966).

### Cooking and Saccharification

The ground pulp is cooked to release the starch grains that are bound to the lignocellulosic compounds of the roots. During cooking, the starch grains absorb water, swell up, and break, forming a gel. Then, a portion of α-amylase is added, and the cassava slurry liquefies. In an intermittent cooker, the process takes about 30–60 minutes, whereas in continuous, horizontal cookers with agitation of the slurry and direct steam

---

**Table 1. Alcohol yield of the main carbohydrate sources in Brazil.**

<table>
<thead>
<tr>
<th>Sources</th>
<th>Present production levels</th>
<th>Crop productivity (t/ha/year)</th>
<th>Alcohol yield*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>95</td>
<td>45</td>
<td>67</td>
</tr>
<tr>
<td>Cassava</td>
<td>26</td>
<td>12</td>
<td>180</td>
</tr>
<tr>
<td>Sugar sorghum²</td>
<td>—</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Babacu-palm</td>
<td>30–210</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>2</td>
<td>15</td>
<td>125</td>
</tr>
</tbody>
</table>

*Industrial yield corresponding to 80% of the theoretical yield.

²Average production during 4 years.

³Alcohol produced from the stalks from a single annual crop.
injection, the time is much shorter, netting economies in energy and space and inactivating fewer enzymes.

The cassava starch — a polysaccharide — must be broken down into fermentable sugars before being utilized by the alcoholic yeast. The process is called saccharification. The use of an efficient and low-cost saccharifying agent is of paramount importance in the production of alcohol from starchy materials. Saccharification can be carried out by two processes. The first, the hydrolysis process, employs hydrochloric or sulfuric acid. It is not currently recommended because it yields low quantities of alcohol due to the partial degradation of sugar by the acid. In addition, the continued use of acid causes equipment corrosion and increases the risks of accident.

The second process, the biological process, uses amylolytic enzymes that can be obtained from several sources. In the Western countries, barley malt is traditionally used, whereas in the East, moulds that grow on rice or wheat bran are commonly used.

In recent years, modified versions of the biological process have been developed. In France, the amyllo process using rhizopus was initiated, and in the United States the mould bran process (Banzon et al. 1949) was introduced. Also in the U.S., the submerged fermentation process (Underkofler et al. 1946; Le Mense et al. 1947) was devised and was successfully used by Teixeira et al. (1950) in the saccharification of cassava mash for alcohol production. All these processes resulted in yields equivalent to those obtained with malt and higher than those obtained with acid. In Brazil, the malt enzyme of plant origin is not widely available and its import price is high; thus, emphasis has been placed on the use of prefabricated microbial enzymes. They have definite advantages over the submerged cultivation and mould bran processes because they do not require additional installations in the distilleries or specialized labour for their production.

The breakdown of gelatinized starch occurs via the hydrolysis of the α-1,4 links that join the glucose molecules into long chains, and also via the hydrolysis of the α-1,6 links that form the branch points of the amylopectin component of starch. Malt contains three important enzymes for starch breakdown: α-amylase, β-amylase, and α-glucosidase (also called maltase). Alpha-amylase splits the α-1,4 bonds randomly within the molecules, forming dextrins, which are small chains of glucose. This makes the gelatinized starch slurry less viscous and produces more chain ends for the action of the saccharifying enzyme. Beta-amylase also breaks the α-1,4 links of dextrin and starch but only from the nonreducing ends of the molecules, resulting in maltose formation. Neither of the enzymes attacks the α-1,6 linkages, their combined action converting only 85% of the starch into reducing sugar (Aschengreen 1969). The α-glucosidase splits the α-1,6 linkages of the maltose and dextrins, thus completing the hydrolysis of starch into fermentable sugar.

Two microbial enzymes — the heat-stable bacterial α-amylase and the fungal amylo-glucosidase — can be used together to produce the same result. The former is the liquefying agent and the latter is the saccharifying agent. Bacterial α-amylase works in the same way as malt α-amylase, although it shows some different properties, having lower stability at low pH and more stability at higher temperatures. Amylo-glucosidase breaks down the α-1,4 and α-1,6 links of starch and dextrin molecules to release glucose.

In the distilleries, malt saccharification is carried out in the saccharifier, which is a tank with heating, cooling, and agitating devices. The enzyme is added to the mash at the optimum temperature for enzyme activity and is then pumped to the fermenting vats. The system using prefabricated enzymes is similar, but the two enzyme preparations are added at quantities, pH, temperature, etc. specified by the manufacturer. The saccharification is completed in the vats simultaneously with fermentation.

**Fermentation**

The first step in fermentation is the preparation of the starter, during which the alcoholic yeast multiplies until a quantity sufficient to initiate fermentation in the vats is obtained. Using a test tube culture of the yeast, the multiplication is carried out in flasks containing sterilized medium and is continued until the desired cell population has been produced and transferred to fresh growth medium — an amount equal to 5–10% of the must in the vats.

Before the must is inoculated, nutrients, mainly nitrogen and phosphorus, are added. The pH should be 4–5.0.

The alcoholic fermentation is an exothermic process, and thus cooling devices must be used to keep the temperature around 30 °C, the optimum temperature for the yeast activity. The fermentation takes 36–48 hours. However, using a heavy inoculum and adding micronutrients to the must, (Nagodawithana 1974) reduces the time considerably.
Fermentation can be continuous or batch. In the continuous system, the must is added continuously, and the wine is collected at the same rate of flow. The wine is pumped to the distillation columns and should be carefully handled to avoid contamination and to prevent yeast mutation. In Brazil, batch fermentation is used with some variations that render it semicontinuous, allowing for the reutilization of the inoculum and recovery of the yeast (Lima 1977).

At the end of the fermentation process, the wine passes through a screen to remove the sands and is then centrifuged to recover a fraction of the yeast, part of which can be used as food or animal feed and part of which can be reintroduced into the vats to reinitiate fermentation.

The wine contains 7–11% ethanol by volume, which can be separated from the hydroalcoholic solution by boiling. The ethanol evaporates before water and can be captured in a rectifying column at 50% by volume; in a second column it can be concentrated to 97.2%.

Ethanol that is being produced for gasoline blending must be concentrated to 99.9%. Sometimes a dehydration compound, such as sodium acetate or calcium oxide, is added to the ethanol to dry up the rest of the water. At other times, a substance that promotes the separation of the ethanol from the water may be used or a liquid having a high water absorption capacity, such as glycerin, glycols, or potassium carbonate solution in glycerol, may be added.

By-products

Stillage is a spent wash resulting from the distillation of wine and is obtained in the proportion of 12 parts for each part of alcohol. It is a highly polluting waste, which, when not properly controlled, causes serious environmental problems. There are not yet any satisfactory means for treating it because most methods result in costs that are not totally compensated. Dehydration of the waste, which contains about 6.0% total solids, does not appear to be economically viable at present. However, stillage can be fed directly to cattle or poultry, a common practice in the cassava distilleries in the past.

The cassava stillage can also be used as a fertilizer, although the quantities and procedure for adding it to the soil have not yet been worked out. Experience in using sugarcane stillage (30–40 t/ha) may be applicable.

There are other possibilities for by-product uses that need investigation before the production of motor fuel alcohol increases phenomenally. Among these is the use of stillage as a substrate to grow fungus that reduces its polluting strength and at the same time produces protein for animal feed. Another is the potential for stillage in the manufacture of several fermentation products, such as enzymes, vitamins, and antibiotics. The second-grade alcohol and fusel oil (50 and 6 litres per 1000 litres of anhydrous alcohol, respectively) could be used commercially.

Also, several industrial applications exist for the CO₂ produced during fermentation (Lima 1977). At wine screening, another by-product is fibre residues amounting to 1.0% of the raw material; they could be retained for use in animal feed.

The importance of using by-products is underlined by figures from the Curvelo Alcohol Distillery, in the State of Minas Gerais. In the course of 320 operating days, an estimated 5000 t of animal feed, 115 000 litres of fusel oil, 960 000 litres of second-grade alcohol, 10 000 t of CO₂, and 2.4 billion litres of stillage are expected to be produced (Lima 1977).
At present, sugarcane and cassava are the main raw materials proposed for the manufacture of motor fuel alcohol; however, the feasibility of using the latter is highly dependent on the optimization of the liquefaction and saccharification steps, which require an extra input of energy. It is estimated that in the batch process for cassava alcohol production, 1.8 kg steam per kg of cassava is required, corresponding to 0.7 kg of wood fuel. However, in the continuous process, with an efficient heat recovery system, the energy consumption can be considerably reduced. Thus, a distillery with a daily capacity of 150 000 litres would consume approximately 200 m³ of wood per day or 40 tons of fuel oil/day. Although wood is a renewable energy source, its use results in forest devastation with the associated problems, and thus the cassava stems should not be overlooked as a fuel source. They could supply 70% of the fuel required for the distillery operation.

**Costs**

The cost of cassava alcohol has not yet been precisely determined due to the wide and frequent fluctuations of the price of the raw material. However, in a study undertaken at the Instituto de Tecnologia de Alimentos, it was shown that in a pilot distillery with a daily capacity of 1000 litres, the price of 1 litre of alcohol was Cr. $3.10 in November 1975, based on a yield of 180 litres per ton of cassava. The raw material was 29% of the cost (Cr. $180.00/t). Extrapolating the results to a distillery with a daily capacity of 100 000 litres the cost of the alcohol is reduced to Cr. $2.45/litre, not including the gains possible from the commercialization of the by-products. In future, the exact costs will be available from the new Petrobras distillery at Curvelo.

Petrobras is installing a cassava alcohol distillery with a daily production of 60 000 litres in the State of Minas Gerais. It is expected that the results achieved will eventually confirm the feasibility of this enterprise, thus providing confidence in the utilization of cassava as a raw material. The distillery will serve as an experimental plant to test improvements in technology. Similar plants are proposed throughout Brazil; five have been approved and two are under consideration by the Brazilian National Alcohol Committee (Table 2).

### Table 2. Program for the production of alcohol from cassava.

<table>
<thead>
<tr>
<th>Firm</th>
<th>Location</th>
<th>Daily ('000)</th>
<th>Annually (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Approved projects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petrobras</td>
<td>Curvelo (MG)</td>
<td>60</td>
<td>18</td>
</tr>
<tr>
<td>Colonizadora SINOP</td>
<td>SINOP (MT)</td>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td>Cia de Distritos Industrials de S. Catarina (CODISC)</td>
<td>Litoral Sul (SC)</td>
<td>120</td>
<td>36</td>
</tr>
<tr>
<td>Construtora Ocidental</td>
<td>Luzitania (GO)</td>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td>Quimica Industrial Paulista</td>
<td>Sobral (CE)</td>
<td>180</td>
<td>54</td>
</tr>
<tr>
<td>Alcool Maniva</td>
<td>Sapé (PE)</td>
<td>120</td>
<td>36</td>
</tr>
<tr>
<td><strong>Projects under consideration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elizeu Batista S.A. (CELIBA)</td>
<td>Calcavel (CE)</td>
<td>60</td>
<td>18</td>
</tr>
<tr>
<td>Agrobras S/A</td>
<td>Ureuci (PI)</td>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>990</td>
<td>297</td>
</tr>
</tbody>
</table>

Source: I.A.A., Secretary for the National Commission on Alcohol, 6 June 1977, proposals for the installation of alcohol distilleries already accepted for the National Alcohol Program (Lima 1977).