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CRUZ DAS ALMAS - BAHIA

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FOREWORD

The National Research Center for Cassava and Fruit Crops (CNPMF) presents a paper on harvesting and post harvest phases of cassava in Brasil, as a case study.

Cassava has been considered by the Brazilian Alcohol National Program (PROALCOOL) as one of the raw material for alcohol production. However, the successful utilization of cassava in this program will depend largely on the developing of improved technology for harvesting and also post harvest practices for storage and processing of roots.

This discussion is considered of greatest importance today since we are urged to develop efficient alternative energy sources.

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HARVEST AND POST-HARVEST OF CASSAVA (*Manihot esculenta* CRANTZ) IN BRASIL: A CASE STUDY

Jorge Luiz Loyola Dantas[1]
Mário Augusto Pinto da Cunha[2]

Introduction

The cassava, originary from Brasil, received little attention from agricultural research institutions in the past. Its wide adaptation to the most diverse edaphic and climatic conditions as well as the traditional knowledge about this crop accumulated through many years of cultivation as subsistence crop did not motivate researchers to improve some of the primitive cultural practices utilized by the low-income farmer.

A small number of cassava studies were carried out in a few states up to 1969. From that time up to 1975, a huge local research program was undertaken by the staff of the Escola de Agronomia da Universidade Federal da Bahia, which set the foundations for the actual Cassava National Research Program coordinated by the CNPMF. This research

[1] CNPMF Cassava Program Staff
[2] Head of the CNPMF/EMBRAPA

center has its headquarters in Cruz das Almas, State of Bahia.

Brasil produces around 26 million tons of cassava roots in 2.3 million hectares. So it has a low yield as a consequence of the factors listed below:

1) there is not a real stable price stimulus to the farmer as well as it lacks guarantees of production absorption;

2) there is not seed stem prices selection in relation to age, health, diameter and length;

3) plantations in marginal areas and inadequate planting times;

4) poor soil preparation and cultural practices;

5) liming and soil fertilization are minimum;

6) poor insect and disease control.

This paper reviews the actual harvest and post-harvest conditions in Brasil, research advances and focuses on what must be done to achieve a maximum efficiency on those crop phases.

Cassava Harvesting

Harvesting is the most laborious and expensive operation of cassava production. Soil type, moisture, root depth, branching and weed incidence are factors that can facilitate or difficult the operation.

Growth period

The time between planting and harvesting in a cycle of cassava production is variable. Cultivars are classified in early (cycle of 10 to 12 months), medium (cycle of 14 to 16 months) and late (cycle from 18 to 20 months). It is noticeable, nonetheless, that the duration of the growth period is shorter in the amazonian basin where cassava is harvested with 6 months and where fresh roots with mild HCN content ("aipins") have best quality between 8 and 10 months after planting.

Indexes for productivity evaluation

It has been observed that, for the same verieties, there is a positive correlation between root production and plant height, diameter of the stems, branching height of the main stem and intensity of leaf color. The harvest index is a way to measure the yield potential of a cultivar, when associated to other agronomic characteristics. The formula to calculate harvest index is given bellow:

$$HI = \frac{\text{Root yield weight}}{\text{Root yield weight + above ground weight}} \times 100$$

Planting systems

Furrow planting, as in industrial plantations, requires placing the seed piece in a horizontal position, at 10 cm depth. Vertical planting or at certain angle to the surface of the soil may difficult harvesting because these systems favor deeper penetration of the roots into the ground.

For mechanical harvesting, the most suitable planting systems is that on ridges or beds, although they have to be built with hand tools since no mechanical planters for this system have been developed.

Preliminary results from an experiment on "Planting systems and harvesting methods", which is in progress at the CNPMF, indicate the advantage of planting in beds (Table 1).

Table 1 - Planting system effects on harvesting efficiency

Harvesting method	Furrow Planting		Ridge Planting	
	Yield* t/ha	Loss % to manual	Yield* t/ha	Loss % to manual
Manual	17.50	-	18.32	-
Tractor with lister plow	12.45	29	17.95	2
Tractor with moldboard plow	11.88	32	15.44	16
Tractor with lifter SANS	11.94	32	15,87	14

* Low yields attributed to early harvesting.

Harvesting time

Some of the previous considerations gave some indications of the best time for cassava harvesting. Beside those, there are some economical factors such as market, prices and hand labour availability.

Actually, harvesting time is defined by taken into consideration the time course of nutrient uptake, growth curves, water potentials, starch, fiber and other root and above ground components of the cassava plant, aiming the best economical utilization.

The best time for harvesting is that in which plant are in a rest period, it is to say, when due to weather conditions, low temperatures and almost no rainfall, the plants loose their leaves after reaching maximum yield and starch reserves.

Very seldom, cassava is harvested before the eighth month of the growth cycle except for the very early varieties, under special growing conditions. In the Northeast harvest takes place usually after the 12^{th} month of growth where the farmers harvest small areas weekly between 12 and 18 months after planting to make cassava flour which is marketed accordingly to their financial needs.

In the south of Brasil, cassava is harvested only from the 17th month, since the period beetween two rainy seasons is very dry and more or less cold.

Meanwhile, in large plantations with industrial purpose, where harvest must not be restricted to narrow periods of the year, the limits can be expanded by planting early, medium and late varieties. In this way harvesting can be accomodated throughout the year. In this system some areas must be dedicated to the production of planting material.

Starch percentage in the roots and yield are reduced if harvest is anticipated. Normally, as long as the plants maintain their foliage they will be syntethizing reserve carbohydrates for their roots and consequently early harvesting stops this process (Table 2).

Harvesting methods

In most cases harvesting in done by hand labour. This is favored by traditionally planting in small scale. Consequently, harvesting becomes the most important component of production costs. In the State of Bahia, about 11% of the total production cost are related to harvesting while in the State of Espirito Santo harvesting costs rise to 22%, average of three production systems.

Table 2 - Effect of plant age and harvesting time on starch content of cassava roots[1]

Age (months)	Fresh weight (kg/ha)	Starch (%)	Starch (kg/ha)	Year (months)
8	16,950	30.51	5,171	June
9	19,240	33.56	6,456	July
10	19,800	32.98	6,200	August
11	17,350	30.50	5,291	September*
12	17,050	28.78	4,906	October*
13	16,074	30.27	5,138	November*
14	19,266	30.55	5,885	December
17	28,850	31.52	9,039	March**
19	28,650	34.05	9,755	May **
20	31,700	34.25	10,857	June **
21	36,750	34.41	12,645	July **
22	34,400	34.78	11,964	August**
23	34,550	32.98	11,394	September*
24	34,250	28.88	9,891	October

[1] Mendes, 1940, In: Conceição, A.J. A mandioca. 1979

(*; **): Starch fluctuation due to harvesting time.

Manual harvesting

In light textured soil, cassava is harvested by grabbing the plants from the base of the stem and pulling the roots out of the ground, shaking off the excess of soil that comes on them. However, in heavy textured soils a hoe or pick is used to remove some soil from around the plant before pulling it. The roots that remain in the soil must be recovered with hoes. Once out of the ground the roots are cut off from the stem, piled in several points across the field called "bandeiras" where shuttle vehicles are loaded. These "bandeiras" are normally located at approximately twenty meters from each other in order to facilitate loading. The roots may be afterwards placed in plastic boxes or loaded by hand or carts to be carried to the main transportation system.

The efficiency of manual harvesting is variable depending on several factors. A man may harvest from 800 to a 1000 kg/day, when the conditions are favorable. There are indications, however, that under unfavorable conditions such as excess of weeds or poor stand the efficiency could be as low as 500 kg/day.

Machanical harvesting

It is mainly used in sandy soils. In this case it becomes necessary to cut the stems at approximately 30 cm above the ground either manually or with a weed mower.Then, several instruments may be used to dig out the roots such us moldboard, disc and lister plows.

A plow drawn by animal or motor traction is also utilized to dig the roots. These plows must have big wings and penetrate the soil at least 20 cm. All other operations are done manually.

In Brasil as well as in other countries, new harvesters are being developed and some are already being tested on the farm. The cassava harvesters developed are those of the Ceará Máquinas Agrícolas (CEMAG, Fortaleza), Instituto Agrônomico de Campinas (IAC, São Paulo), Instituto Nacional de Tecnologia (INT, Rio de Janeiro), José J. Sans S/A Indústria e Comércio (São Paulo), Centro Internacional de Agricultura Tropical (CIAT, Colombia), International Institute of Tropical Agriculture (IITA, Nigéria) and a project of the "Sociéte DELFOSSE" (Machinisme Agricole Tropical). Also in the region of Araras (São Paulo) are found harvesters of one and two bodies, of simple construction and with ample regulation of the angle of incidence to the soil.

Meanwhile, the only harvesting machine in the market was developed by "Richter Engineering Ltd.", from Austrália, which is sold in two versions, one fitted to a Massey Ferguson tractor 165 and the other auto-motor with a performance of 2.4 ha/day.

Transportation

It is important that between harvesting and processing do not elapse more than 24 hours, otherwise the process of deterioration will be initiated. The roots are carried in sacks, trucks or cars pulled by tractors. During transportation most care must be given to avoid wounding that would facilitate penetration of pathogens. A medium size truck would transport between 4000 and 6000 kilograms of fresh roots and a pick-up truck will carry between 1000 and 1200 kilograms.

Post-harvest Aspects of Cassava Production

The search for new alternatives for cassava utilization is viewed with great enthusiasm and expectation since beside the aim for lowering production costs and reducing environmental polution resulting from the agro-industry that utilizes this crop as raw material, it could bring sizeable benefits to mankind.

Studies are being developed with the objective of improving cassava for human and aminal nutrition since the growing need for staple foods with high nutritive value in order to attend population growth. The possibility of protein production by the action of microorganism on processing residues is being explored.

More research is needed in order to develop tecniques to avoid post-harvest deterioration of the roots.

Cassava for industrial purpose gives important products and by-products for human, animal and industrial utilization. According to the volume, objective and local of the operation, cassava processing factories are classified as:

a. Small rural factories (simple processing): rasps, ground rasps, starch, flour, fermented flour, animal feed from foliage and root mixtures.

b. Small, medium and large urban factories (relatively simple transformations): rasp, flour, bakery flour (integral), starch, tapioc, sagu, beiju, pre-cooked flour, pre-gelatinized starch, white dextrine, cream dextrine, liquid dextrine (glue), dextrose, pure glucose, raw glucose, ground leaves without petioles, tiquira (alcoholic beverage), animal feed.

c. Chemical industry (products obtained by fermentation and enzymatic processing): acetone, amylic alcohol, butylic alcohol, ethylic alcohol, methylic alcohol, propylic alcohol, glycerine, glycerol, butylenic glycerol, ethylenic glycerol, methylic glycerol, propylenic glycerol, sorbitol. Subproducts: specific yeasts and proteinaceous feeds or "Xilempes".

d. Others: diverse organic acids; hydrolized and frac tionated products made of glycose, esterified products such as mineral and organic esters, aldehydes; alcoche mistry; synthetic rubber and other products.

The instalation of large destilleries for alcohol pro duction will result in large volumes of effluents with high polluting effects. An alternative for utilization of this waste is the production of biogas, obtained by anaerobic fermentation. The residues obtained in the di gestors could be then utilized as fertilizers.

Storage for planting material

The implantation of a good crop needs of high quality planting material. The difference between planting and harvesting dates creates the need for storage of planting material in order to maintain high germination rates.

Cassava is a plant that propagates vegetatively having a low multiplication rate relative to other starch pro duzing crops (Table 3).

Storage place

The place for storage of stems must be protected from direct solar radiation and excess of moisture and should be located near to the planting area. Mechanical injury to the buds and epidermis should be avoided, since wounds are entry points for pathogens.

Table 3 - Seed multiplication factor to 4 starch producing crops in commercial stands[1]

Crop	Days to Harvest	Harvesting per year	Multiplication factor
Rice	120	2	6400
Corn	120	2	90000
Potato	150	2	100
Cassava	300	1	30

[1] TORO,J.C. Métodos de propagação rápida de yuca. In: Curso especial de aperfeiçoamento para pesquisadores de mandioca. CIAT, Cali, 1975. cap.74. 8f.

Storage systems

The stems may be stored under a tree or a roaf placing them in a vertical or horizontal position in areas where frost does not occur (Table 4).

Table 4 - Effect of stem conservation system upon bud germination[1]

Conservation system	Bud germination after planting
Vertical position*	70
Horizontal position*	50
Planted after harvesting	100

* In relation to the soil surface.

[1] La'ras Experimental Station. Lavras, Minas Gerais.

Vertical position

The stems of the same size are leaned on the trunk of trees or wooden frames protected from direct sunlight. Once piled, the stems must be taken to maintain the cover of straw very dry otherwise fungi will develop inside the pile. Another way of storing in vertical position is done by earthing the end of the stems approximately 10 cm bellow the surface. The ground must remain moist. The stems will root and sprout indicating good storage conditions in spite of damage to some buds.

Horizontal position

The stems are piled horizontally on the ground. In this position more buds will sprout relative to the vertical position and consequently more buds are lost.

Some farmers use to store their stems in this position without cutting of the "cepa" (mother seed piece). Since that part is rich in water and since dehydration comes about with higher intensity from the cut ends to the center, the stems with "cepa" remain viable for longer time.

In those regions subjected to frost, the stems must be stored in tunnels similar to clamp storages (Fig. 1 and 2) or in beds (Fig. 3) to avoid freezing or damage to the buds.

A good practice that may be followed to avoid the difficulties of storaging, such as additional expenses , loss of planting material, dehydration, etc., is to have a seed production area within the farm (Table 4).

Storage period

Storage period depends on stem maturity and diameter. As it is not uniform, some problems due to pathogens and insects can arise. Losses due to dehydration, diseases and pests are correlated to previous selection os stems.

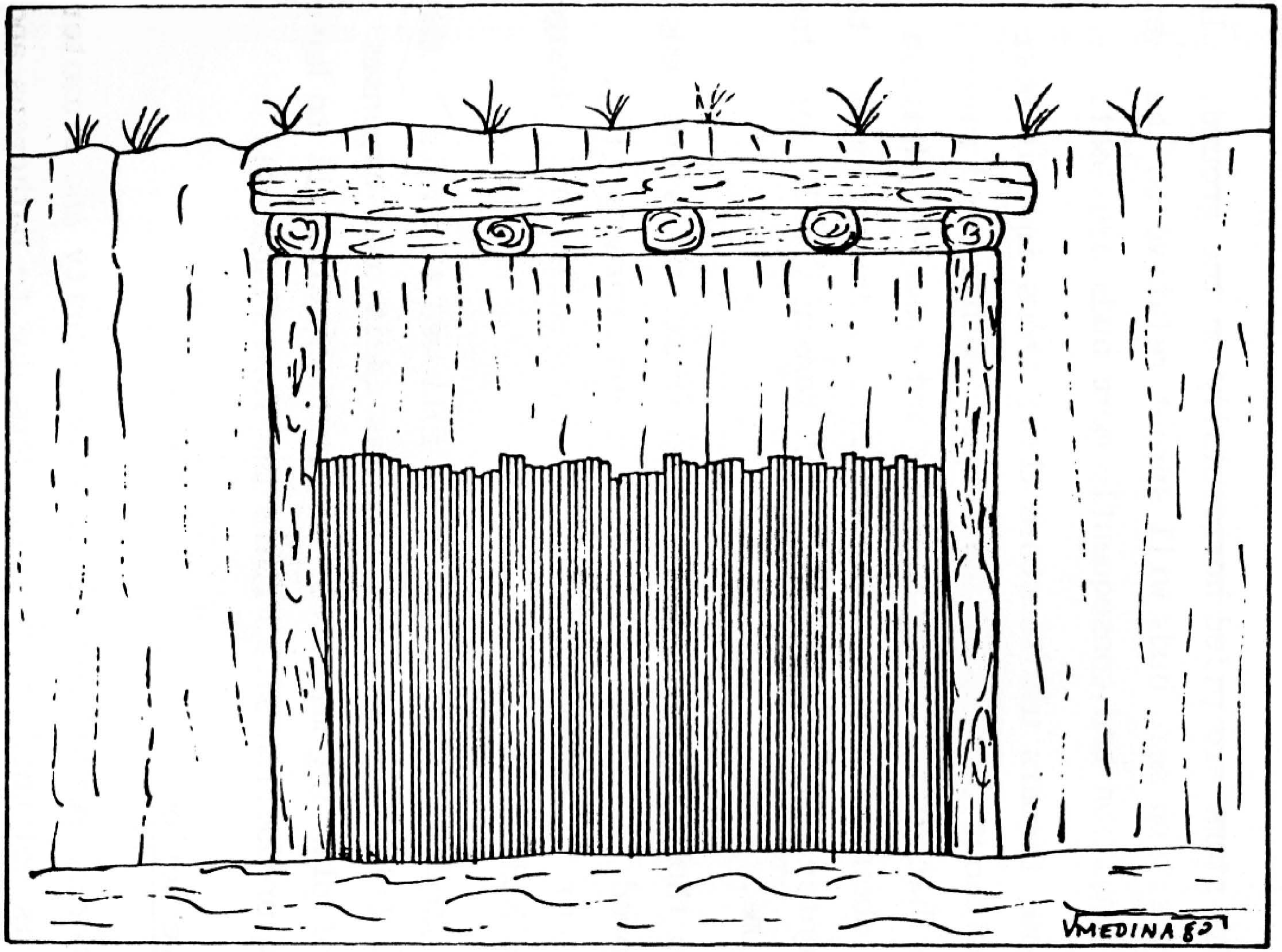

FIG. 1 - Cassava stem cuttings conservation in tunnels in areas subjected to frost damage.

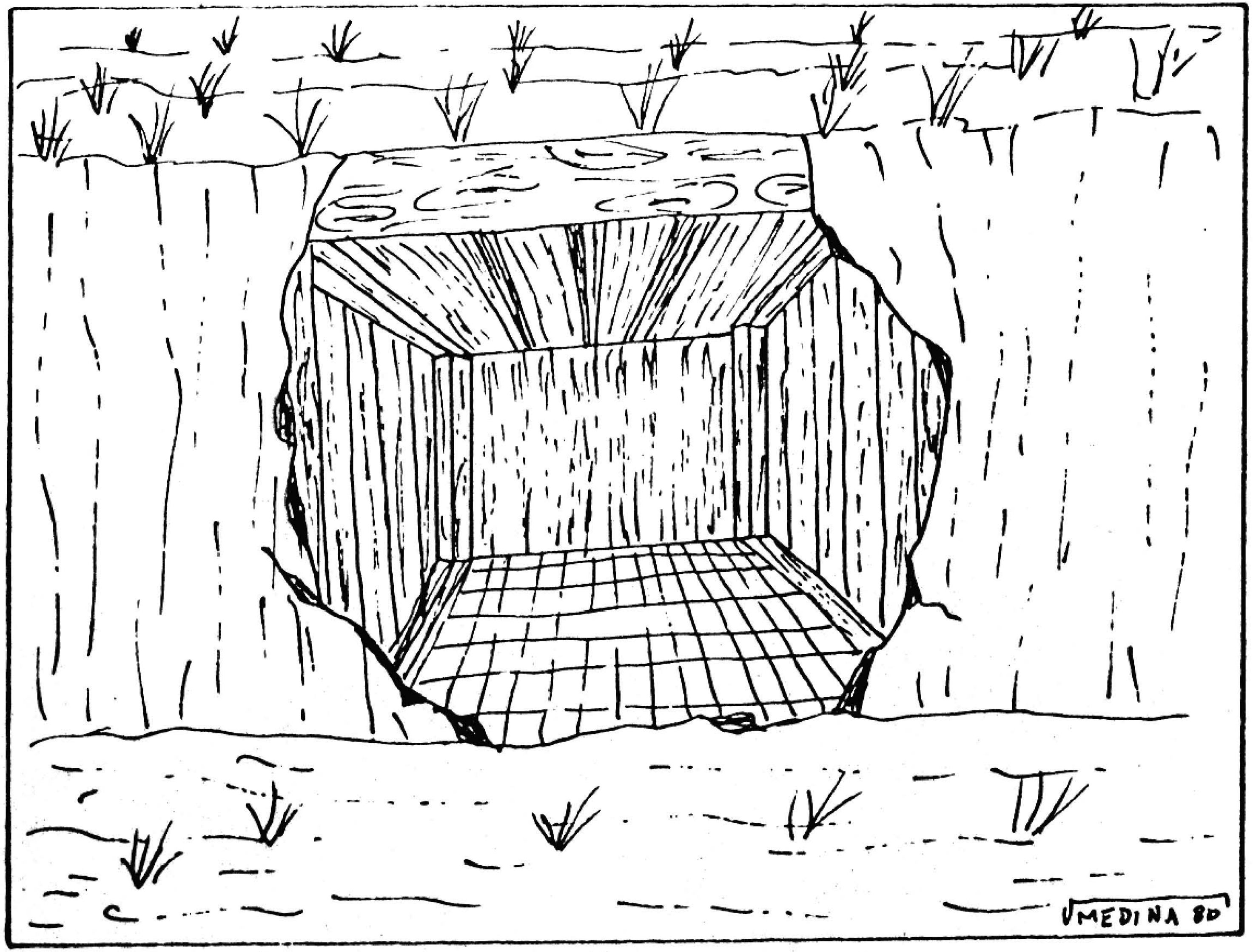

FIG. 2 - Cassava stem cuttings conservation in tunnels in areas subjected to frost damage.

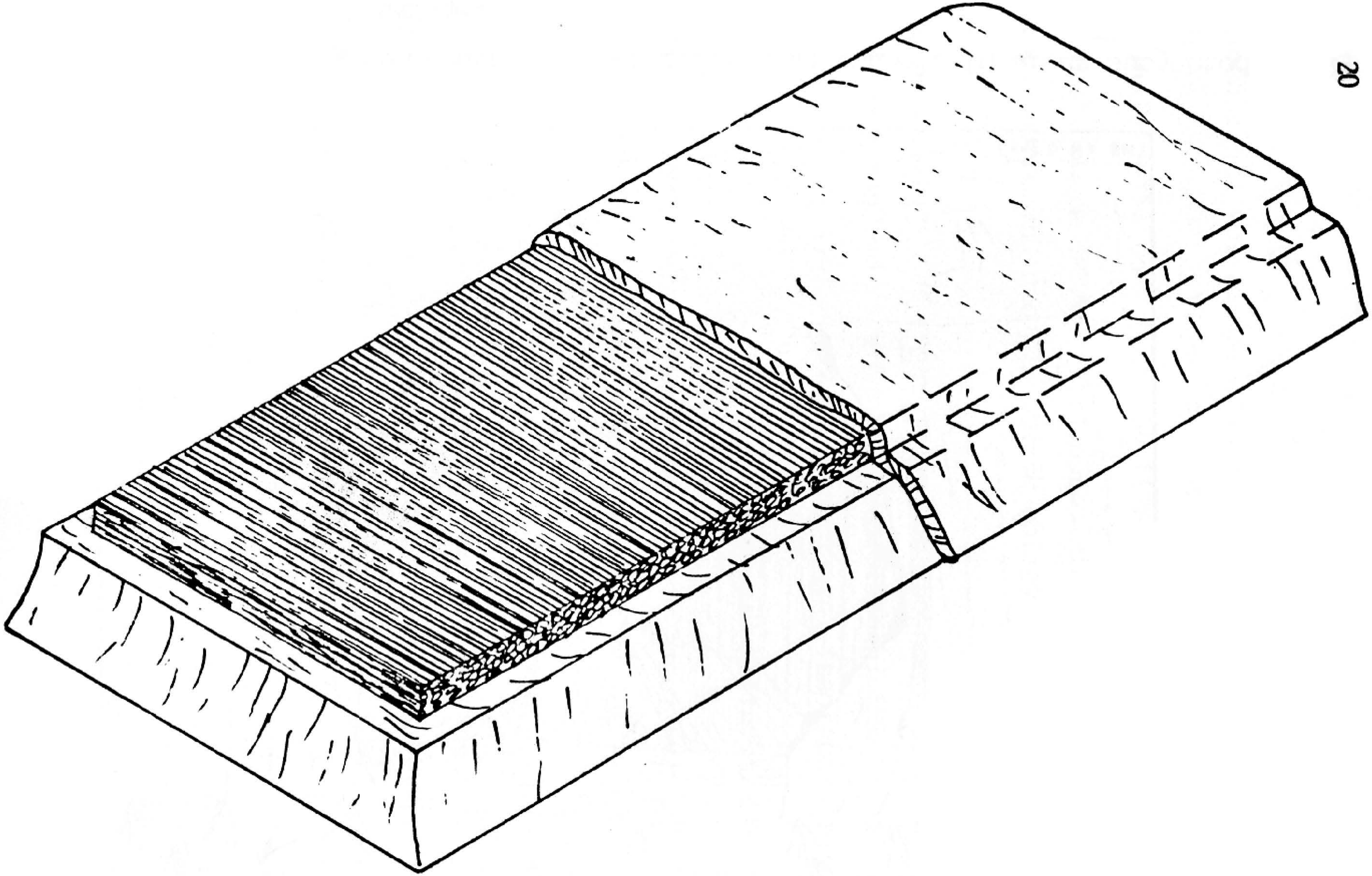

FIG. 3 - Cassava stem cuttings conservation in bed in areas subjected to frost damage.

For the Cerrado region, where humidity is low the conservation period varies from 30 to 90 days and the longer the storage time the greater will be the losses after planting.

Results from trials conducted at CNPMF showed that up to 4 months of conservation period did not influence cassava yield,

It is recommended, during storage, the application of fungicides and insecticides, in order to protect the stems againt occasional insect and pathogen attack.

Root conservation "in natura"

Cassava roots present low conservation capacity after harvesting. The deterioration process is influenced by climatic conditions, mechanical damage during harvesting and varietal differences.

The immersion of damage roots in paraffin for 5 min showed good control during 23 days[1]. In that trial, 8 cultivars were treated with benzoic and lactic acids, at 1 and 5% a.i., which did not show the same effect (Table 5).

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[1]Nobre, A. Anais do V$^{\underline{a}}$ Reunião da Comissão Nacional de Mandioca. Sete Lagoas, MG, 1971. p. 43-46.

Table 5 - Effect of paraffin treatment on cassava root conservation in a period of 23 days (field and laboratory)

Varieties	5 days	11 days	17 days	23 days
Grande Preta	+ +	+ +	+ +	+ +
Uvar	+ +	+ +	+ +	+ +
Veada Branca	+ +	+ +	+ +	+ +
Branca de Santa Catarina	+ +	+ +	+ +	+ +
Saracura	+ +	+ +	+ +	+
Rosa	+ +	+ +	+ +	+
Brava de Pádua	+ +	+ +	+ +	+ +
Aipim Baiano	+ +	+ +	+ +	+ +
Testemunha	- -	- -	- -	- -

+ + = latex exudation, clean pulp, no discoloration;
+ = latex exudation with light darkening around the treated area;
- = discoloration of the pulp;
- - = rotten.

Experiments carried out at CNPMF indicated that the resistance to deterioration is genetically controlled[2]. Eighty-

[1]FUKUDA, W.M.G.; MENDES, R.A. & SILVA, S.P. Relatório Técnico Anual. CNPMF/EMBRAPA, Cruz das Almas, BA, 1978.

six cultivars were tested and acoording to the observations at 3, 7 and 11 days after harvesting, seven of them showed deterioration resistance during 11 days under field conditions, while 44 did not present any deterioration symptoms during the same period, under shade conditions. This fact indicates a promounced influence of environment on the process (Table 6).

Table 6 - Resistance to post-harvest root deterioration in 86 cassava carieties shaded under field conditions. CNPMF, 1978

Days to harvest	Conservation condition	Reistance degree*		
		R	MR	S
		---number of varieties---		
03	field	43	21	22
	shade	79	6	1
07	field	17	35	34
	shade	66	17	3
11	field	7	18	61
	shade	44	29	13

* R = Resistant; MR= Medium resistant; S= Susceptible

Root conservation as rasp

This is the most convenient process, since it keeps all the root starch. Jointly with the conversion of rasps in pellets it is one of the products for cassava export. The classical process of root conservation is by dehydra tion. Roots are washed, peeled and sun dried on a cement or brick yard.

The humidity content of roots is around 60 to 70% and in order to storage them it is necessary to reduce the humidity content to about 13%. Cultivars whose roots have lower humidity percentage will present higher dried matter yield.

As the conversion of cassava in rasps induces irre versible changes in the product, its rehydration will not recover integrally the same characteristics of the fresh product.

From the rasps one can produce flour, fine powder, alcohol, tapioc, etc., which are used in human and animal nutrition.

In relation to rasps preparation in the farm, several trials were carried out, testing drying on cement yard and compacted ground. While the first method presented good results, because of increased heat absorption, making the drying process easier and faster, the latter was not considered viable due to soil wetting, which difficults drying.

The cement yards should have a light slope with lateral ditches to facilitate water drainage.

Regarding to storage, some experiences have been done in Brasil and for the Northeastern Region plastic (polie-thylene and polypropylene) bags proved well. On the other side, cotton bags, whice were used in Ceará State, caused some storage problems. In the South and Central Regions other trials were run with heap (granary) storage, giving satisfactory preliminary results.

Cassava flourhouses

Cassava is used in several ways in human and animal nutrition and in the production of many by-products. This fact is very important to the cassava grower, since his product can be sold fresh ("in natura") or converted to flour. This assures to the grower 80% of his family income and thus his economic support.

The transformation of the raw material in flour, ta-pioca cake and tapioca is difficult and it requires an empirical but diversified knowledge. The process has evol-ved in all different regions of the world, including Bra-sil, and this is one of the main regional factors, being its usage peculiar for each region.

In the cassava flourhouses the work is done systema-tically, since the machines, men and equipments are schema-tically distributed making good use of space and manual work, which is almost family labor. They are in general rustic buildings enclosing a clay or metalkim (oven), constructed in the most protected part of the house, a wood or metal screw press and a motor, which can be manual or moved by gasoline, oil or electricity. In those houses, located near to the grower house , the cassava is converted into flour, starch, tapioca,etc.

In the later five years it has been noticed a great interest in the construction of flourhouses, mainly due to the modern equipments found in the market. This caused an increase in the prices of land renting and also of flour . The number of flourhouses increased 50% in the later five years, against 35 and 15% in the later 5-10 and 10-20 years, respectively.

The cassava processing line can be described as follows:

1st step: harvesting - Carried out all year round , it is intensified in winter; it is done by hand with the help of common tools;

2nd- step: peeling - 100% manual, carried out during afternoon or at night. People stay in cyrcle around the cassava pile. One of them holds the root and peels one half of it, longitudinally; then, other person, with the clean hands, holds the peeled side and peels the other half;

3rd step: grinding - It requires three persons to carry it over, being generally initiated in the morning ;

two persons move the motor wheel, while the other rasp the cassava root. With modern motors, the work is done by one person, who presses the root against a rasp cylinder moving in high rotation;

4 th step: squeezing (pressing) - A nylon cloth or coconut leaf is put in the bottom of the press and the wet mass placed on it; then the press lid is put in place and the press operated many times, until the mass becomes completely dried. Generally, the last pressed mass stays in the screw press overnight, depending on the quality of flour to be prepared.

In order to make good use of the cassava residue, a clay recipient is put under the screw press, to collect the by-product. After decantation this material is put to dry under direct sun where starch is obtained or it is mixed with the mass and salt, to produce tapioca or tapioca cake, after toasting.

From the residue, 80% is drained to a hole in the ground, where it is kept with other vegetal residues during 12 months, being then used as organic fertilizer in the cassava plantings.

5th step: toasting-Generaly, after the 3rd day of work, toasting is initiated. It takes one hour to toast 40 liters (2 quarters) of fluor, depending on the mass quality, on the fuel used and on the operator's skill.

6th step: screening (bolting) - Three types of screen are used, each one corresponding to the quality of the product to be prepared. The final product is then put en bags, which vary in size (50 or 60 kg). The storage is done in protected (covered) places, until comercialization that occurs weekly, in local and open fairs.

Some adaptations have taken place in the flourhouses resulting in alterations in the social and economic aspects of its production, but the flour ir still the basic food of low income people.

Conclusions

The energetic crisis that effects all the world imposed a new order in relation to cassava research and farmer production. Brasil's government has created the Alcohol National Program that will require a constant supply of raw material for alcohol production.

As a consequence, harvest and post-harvest phases of cassava crop must be improved in order gain in yield and avoid losses that actually make unfeasible the cassava utilization in the alcohol industry.

It is suggested a new attention to harvester designs and testing. Also, the plant architecture mus be studied if plants adapted to mechanical harvesting have to be developed.

Post-harvest phases need many improvements to lessen the risks that follow conservation and transformation of cassava products. The land value and the big areas required for planting will no more permit to conserve roots in the field. The fuel high cost is another item to play a strong force in the transportation that, at the present moment, must be easily done to avoid root deterioration. Besides that, cassava roots have 60-70% of water in their composition and this must be of concern in the transportation.

The cassava germplasm bank has to be evaluated for resistance to root deterioration. Studies on sun light and wind drying of roots have to be stimulated.

There must be a joint effort of agronomy and technology research centers for a real solution to the problems that affect harvest and post-harvest of cassava crop.

The National Research Center for Cassava and Fruit Crops, that belongs to the Brazilian Agricultural Research Corporation, is coordinating the Cassava National Research Program. Cassava mechanization and alternative uses have been estabilished as priorities within this program and the research centers and experimental stations are playing a role in the search for solutions to harvest and post-harvest problems.

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