Sugary cassava (*Manihot esculenta* Crantz): preliminary morphological characterization and agronomic evaluation[1].

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Depiction of cassava from Obelisk Tello representing food brought to humanity by the God Cayman of the Water.
Peruvian Chavin Culture in the Amazon.

ABSTRACT

In addition to the farina and table type of cassava, a new kind of cassava (sugary cassava) was, recently, identified and isolated under cultivation in Amazon. Biochemical and molecular characterization of this sugary storage root phenotype indicates unusual storage root traits, including high free sugar content (mainly glucose) and distinct starch molecule structure in comparison to the conventional cassava cultivated for farina and table harvesting propose (Carvalho et al. 2004). The sugary cassava type was unknown for the scientific community; there is no morphological and agronomic information about it. In complementation to our biochemical and molecular characterization research applied to the sugary cassava, here we present our preliminary morphological characterization and agronomic evaluation for our GENEBANK collection of this type of cassava grown in Amazon region. Sixteen sugary clones were grown in field plots at EMBRAPA-Amazonia Oriental in the Amazon for field evaluation in comparison with farina and table type of cassava. Morphological characterization showed the usual diversity in leaf, petiole, stem, and storage root as in the other types of cassava. No particular morphological characteristic could be used to distinguish sugary cassava from farina or table type of cassava, except the size, weight and density in water of the fresh storage root. Agronomic evaluation indicated a production of storage root fresh weight per plant varying from 2 to 10kg with 10-month growth, and dry weight of 9 to 22%, while the table and farina cassava produced 2-4kgFWt/plant and 30 to 40% dry weight. A new natural glucose syrup product has been developed with yield of about 9 and 7% fresh weight base

INTRODUCTION

A distinct type of cassava (*Manihot esculenta* Crantz) storage root with high water content has been known and used since pre-Columbian times by Brazilian Aborigines in the Amazon, under the name of Manipueira (Travaço, 1596; Lisboa, 1631; da Cunha, 1978). This type of cassava plant was named Mandiocaba by the early researchers in the Amazon and its cultivation was abandoned because of its low dry matter content, extremely low starch (2%) and high water content (de Albuquerque, 1969) in relation to cultivars used to produce farina (cassava flour) fresh consumption (table cassava). However, single accessions are still alive and are maintained in germplasm collections organized in Belém (EMBRAPA Amazonia Oriental) and Cruz das Almas (EMBRAPA Cassava and Fruit Crops) as reported in the germplasm catalogue (Fukuda *et al.,* 1996; de Albuquerque, 1969). In spite of this lengthy association with man, no specific biochemical characterization of this type of cassava has been made for centuries. Recently, L.J.C.B. Carvalho and his group (Carvalho *et al.,* 2000) announced several visits to the proposed center of origin and domestication of cassava in Brazil (Allem, 1994; Olsen and Schaal, 1999) in the search for additional diversity on this trait. They have reported the organization of a GENEBANK with a large number of rare clones, with a storage root showing novel features previously unknown to conventional cassava cultivars, including high free sugar content (Carvalho *et al*., 2000). The sugars and starch diversity of these clones are subjected to intense research in the Laboratory of Biochemistry and Biophysics of EMBRAPA-Genetic Resources and Biotechnology, focusing on understanding of the molecular genetics of the sucrose-starch biosynthetic pathway of this type of cassava clone (see Carvalho et al. 2004). To exploit this new trait diversity of cassava for direct human utilization and cassava breeding program, there is a need for characterization of theses clones. Due to the novelty of this type of cassava, there is no characterization or evaluation study on this kind of plant.

In this document we report a preliminary characterization and evaluation of a set of the sugary cassava, aiming to produce natural glucose syrup directly from the fresh storage root squash.

MATERIALS AND METHODS

Plant material: A set of sixteen clone of sugary cassava, one representative of farina and table cassava type were planted in the field facility of EMBRAPA Amazonia Oriental in Belem (PA) using conventional technical recommendation for commercial cassava. Plots of 5m long with three rows of plants spaced by 1m and 0.8m between plants were harvest 10 month after planting.

Morphological characterization: Standard morphological cassava descriptors, conventionally applied to germplasm collection of cassava (Fukuda *et al.,* 1996), were applied with some adaptation for the sugary cassava. Observations were triplicate within a period of 10-month growing season. Overall aspects of the plant, leaf, flower and storage root were also recorded by photography.

Agronomic evaluation: Ten month after planting (MAF) all the plants in the experimental plots were harvested for agronomic characteristics according the conventional procedure used for commercial cassava. Storage roots were evaluated for root number and quality, root length, root diameter, root fresh weight. Dry weight and water content were evaluated by freeze dry a sample of storage root.

Storage root processing and syrup extraction and yield: Sixty kilos of fresh storage root were processed in the Agroindustry Laboratory of EMBRAPA Amazonia Oriental. Three batches of storage root were processed separately. Storage root were harvest, washed and the peel removed before grained in an industrial mill. The whole mass was filtrated by centrifugation to remove solid tissue debris. The filtrate with brix superior to 9% was further concentrated to a brix of 60% for yield evaluation.

RESULTS AND DISCUSSIONS

Morphological characterization: Table 1 shows the morphological characterization of sugary cassava for its leaf, flower, stem and storage root. There is no particular characteristic that could distinguish sugary cassava plant from the farina and table type. Exceptions are the observations that the size and density of the storage root in water are not the same as the other type of cassava. Figure 1 display several aspects of the above ground plant part, its cultivation in Amazon as well as storage root. It is observed that the storage root of sugary cassava is usually large than the other type of cassava and it floats in water due to its low density caused by the low starch content (Figure 1 - Panel A). The root tissue observed in Figure 1 Panel B shows bigger parenchyma cells due to turgidity caused by the accumulation of sugar and the high osmolarity of these cells. The presence of starch in the storage root of the sugary cassava varies according to the region of the root, as revealed by the iodone test in the field. The presence of glucose is readily observed when tested with glucose strip test.

Agronomic evaluation: Table 2 shows several agronomic parameters evaluated. Sugary cassava showed higher yield capacity of storage root than traditional cassava. The yield of fresh weight storage root varied from 2 to 9kg/plant, while the other types of cassava the yield of storage root varies from 2 to 3.4kg/plant. Storage root of sugary has very low dry matter content and showed a very high percentage of rod storage in comparison to the other types of cassava. It is also observed the presence of rod process in later harvesting of the storage root as well as a quickly dark strip formation in the external vessels of the central cylinder after harvest (Figure 1, Panel C). Due to the sweet taste, the storage root has high preference by ants in its natural habitat (Figure 1, Panel C). Other characteristics are similar to the commercial cassava. The total water content of storage root of sugary cassava was also estimated by freeze dry a sample a set of clones. Percentage value of water content varies from 83 to 93% in the sugary cassava (Figure 2). Starch granule also presented diversity when stained with iodine and biochemical characterization (Carvalho et al. 2004) showing the presence of *waxy* cassava.

Glucose syrup yield: I*n order to add new value of utilization for cassava a process for extract and concentrate natural glucose from fresh storage root of sugary cassava was developed. Figure 3 shows the yield of 5 to 8% of fresh weight in a industrial pilot process. It is observed that glucose syrup with brix of 40% is obtained from fresh storage root of sugary cassava. Similar product is also obtained by acid hydrolysis of starch from corn and cassava. This new product has great advantage over the commercial product because it is natural and is not derived from any kind of hydrolysis of starch.*

Table 1 - Morphological characterization of sugary cassava.

Clone identification	Type of cassava	Leaves			Flowering		Stem		Storage Root						
		Petiole color	Terminal branch color	Apical leaf color	Flowering	Fruit set	External color	Cortex color	Epidermal color	Peduncle	Pellicle removal facility	Peel removal facility	External color	Phelogen color	Central cylinder color
Sementinha	Farina	Red	Green	Green	Present	Present	Pale brown	Pale green	Pale brown	Absent	Ease	Ease	nd	Yellow	Yellow
Abacate	Table	Green	Green	Green	Absent	Absent	Green	Cream	Pale brown	Absent	Ease	Ease	Pale brown	Cream	White
Cas.36.09	Sugary	Green	Green	Pale green	Present	Present	Pale brown	Dark green	Pale brown	Present	Ease	Ease	Pale brown	White	White
Cas.36.10	Sugary	Red	Purple/green	Purple/green	Present	Present	Pale brown	Dark green	Pale brown	Absent	Ease	Difficult	nd	Yellow	Cream
Cas.36.11	Sugary	Red	Purple/green	Purple/green	Present	nd	Golden	Dark green	Pale brown	Absent	Ease	Ease	Pale brown	Yellow	Yellow
Cas.36.12	Sugary	Red	Purple	Purple/green	nd	nd	Pale brown	Dark green	Pale brown	Absent	Ease	Difficult	Dark brown	nd	Cream
Cas.36.13	Sugary	Red	Purple/green	Purple	nd	nd	Dark brown	Pale green	Pale brown	Absent	Ease	Difficult	nd	Yellow	Cream
Cas.36.14	Sugary	Red	Purple/green	Purple	Absent	Absent	Dark brown	Pale green	Pale brown	nd	Ease	Difficult	Dark brown	Yellow	nd
Cas.36.15	Sugary	Red	Purple/green	Purple	nd	nd	Pale brown	Pale green	Pale brown	nd	Ease	Ease	Pale brown	Yellow	Cream
Cas.36.16	Sugary	Purple	Purple/green	Purple	Present	Present	Pale brown	Pale green	Pale brown	nd	nd	nd	nd	nd	nd
Cas.36.17	Sugary	Red	Purple/green	Purple/green	Present	Present	Dark brown	Pale green	Pale brown	nd	Ease	Difficult	Pale brown	Yellow	Cream
Cas 36.18	Sugary	nd	nd	nd	nd	nd	Silver	Pale green	Pale brown	Absent	Difficult	Ease	Dark brown	Yellow	Cream
Cas 36.19	Sugary	Purple	Purple/green	Purple/green	Present	Present	Orange	Pale green	Pale brown	Absent	Ease	Ease	Pale brown	Yellow	Cream
Cas 36.20	Sugary	Red	Purple/green	Purple	Absent	Absent	Dark brown	Pale green	Pale brown	Absent	Ease	Difficult	Pale brown	Yellow	Cream
Cas 36.21	Sugary	Red	Purple/green	Purple	Present	Present	Dark brown	Pale green	Pale brown	Absent	nd	nd	Pale brown	nd	nd
Cas 36.22	Sugary	Purple	Green	Pale green	nd	nd	Orange	Pale green	Pale brown	Absent	Ease	Ease	Pale brown		White

Table 2 - Agronomic evaluation of sugary cassava.

Clone identification	Type of cassava	Number of storage root per plant	Rod storage root (%)	High quality storage root (%)	Mean storage root length (cm)	Storage root diameter (cm)	Storage root fresh weight (kg/plant)	Dry matter (%)
Sementinha	Farina	11.0	12.5	87.5	34.7	5.2	3.4	42.86
Abacate	Table	6.0	0.0	100.00	30.0	7.0	2.0	34.71
Cas.36.09	Sugary	4.8	0.0	100.0	29.9	7.9	5.6	30.89
Cas.36.10	Sugary	3.0	33.3	66.7	24.0	12.5	3.8	8.60
Cas.36.11	Sugary	8.2	9.8	90.2	26.0	6.6	3.2	29.12
Cas.36.12	Sugary	5.8	41.4	58.6	21.4	7.9	3.3	6.97
Cas.36.13	Sugary	5.8	31.0	69.0	22.8	8.9	4.2	7.87
Cas.36.14	Sugary	8.2	34.1	65.9	31.5	9.6	8.2	7.91
Cas.36.15	Sugary	7.8	71.8	28.2	22.0	11.4	1.7	8.54
Cas.36.16	Sugary	11.4	19.3	80.7	29.6	9.2	7.4	6.31
Cas.36.17	Sugary	11.8	11.9	88.1	30.3	8.7	8.8	8.49
Cas 36.18	Sugary	16.4	1.2	98.8	27.1	6.9	8.6	7.53
Cas 36.19	Sugary	8.0	40.0	60.0	28.5	9.6	9.0	7.04
Cas 36.20	Sugary	6.7	4.5	95.5	26.6	6.0	4.5	25.86
Cas 36.21	Sugary	4.8	29.2	70.8	19.4	8.5	3.0	8.47
Cas 36.22	Sugary	5.0	62.5	37.5	26.2	4.6	7.1	16.70

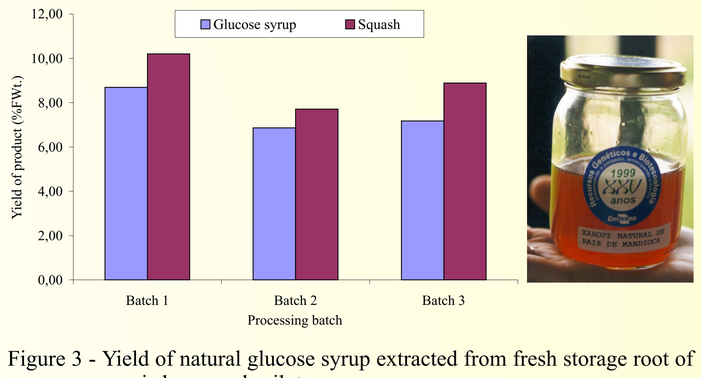

Figure 3 - Yield of natural glucose syrup extracted from fresh storage root of sugary cassava in large-scale pilot process.

CONCLUDING REMARKS

The results presented here, together with our biochemical and molecular biology studies, open up a new avenue of research in cassava in the field of starch and sugar production. Major important issues in the sugary cassava that are under intense research in our laboratory are:

1) High yield plant with early harvest (<10 month after planting).
2) Production of natural glucose syrup yielding about 5 to 8% of the fresh storage root, without the need of starch hydrolyzes.
3) Presence of *waxy* starches a low level.
4) The performance of sugary cassava in other regions of Brazil and other regions of the world.
5) Further research is also needed to use this clone in breeding program.

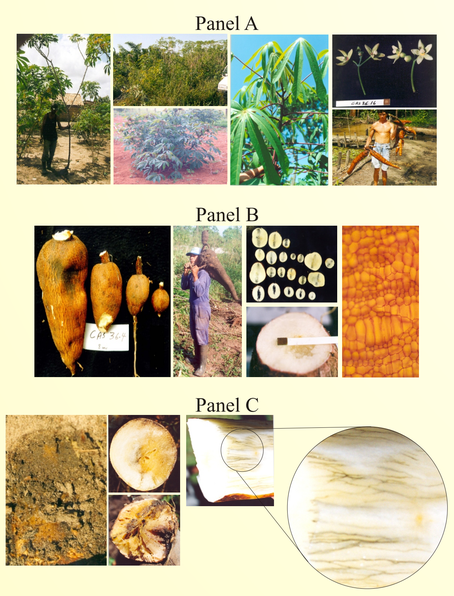

Figure 1 - Morphological characterization of sugary cassava type. **Panel A** Overall aspects of a sugary cassava plant and its cultivation in the Amazon. **Panel B** Some aspects of the storage root of the sugary cassava. **Panel C** Plague and deterioration observed in the storage root.

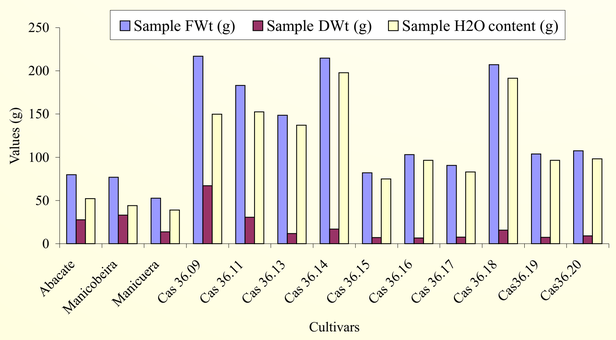

Figure 2 - Dry matter and water content in sugary cassava storage root.Total water content (mg) was estimated in a sample of sugary storage root by freeze-drying.

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