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ORIGINAL ARTICLE

Chemical characterization of roots of bitter cassava sampled in Pará state, Brazil

Caracterização química de raízes de mandioca-brava coletadas no estado do Pará

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ABSTRACT: Cassava (*Manihot esculenta* Crantz) is a plant from the Brazilian Amazonia which presents wide genetic variability. Since it is one of the most consumed foods in the world, efforts to generate more nutritive cultivars are necessary. The objective of the present study was to characterize twenty genotypes of cassava from an Active Germplasm Bank (AGB) in Pará state, Brazil, according to physicochemical characteristics of the root: moisture, ashes, total soluble solids, total titratable acidity, pH, total carotenoids, free and total cyanide, total protein, glucose, fructose, sucrose and starch. The values of moisture, ashes and soluble solids ranged from 60.53 to 71.96%, 1.22 to 1.80%, and 2.33 to 3.78%, respectively. Total titratable acidity ranged from 1.83 to 3.35% and pH from 5.68 to 6.50. The concentration of total carotenoids ranged from 2.34 to 9.76 μg g^{-1}, and total and free cyanide from 177.98 to 691.71 mg kg^{-1} and 20.29 to 135.19 mg kg^{-1}, respectively. The protein concentration varied between 0.18 and 0.73%, which was considered low. The sugar figures ranged from 0.17 to 0.53%; 0.03 to 0.39%, and 0.14 to 0.40% for glucose, fructose and sucrose, respectively, and starch ranged from 18.65 to 36.01%. These results indicate a high phenotypic variation for chemical traits in samples of bitter cassava collected in Pará state, as well as potential for gains in genetic breeding.

RESUMO: *A mandioca (Manihot esculenta Crantz) é uma planta de origem na Amazônia brasileira que apresenta ampla variabilidade genética. Por ser um dos alimentos mais consumidos do mundo, esforços para geração de cultivares mais nutritivas são necessários. O objetivo foi caracterizar 20 genótipos de mandioca mantidos em um Banco Ativo de Germoplasma (BAG), localizado no Brasil, estado do Pará, quanto às características físico-químicas das raízes: umidade, cinzas, sólidos solúveis totais, acidez titulável total, pH, carotenoides totais, cianeto total e livre, proteína bruta, glicose, frutose, sacarose e amido. Os valores de umidade, cinzas e sólidos solúveis totais variaram de 60,53 a 71,96%; 1,22 a 1,80% e 2,33 a 3,78% respectivamente. A acidez titulável total variou de 1,83 a 3,35%, e o pH entre 5,68 e 6,50. A concentração de carotenoides totais variou de 2,34 a 9,76 μg g^{-1}, e cianeto total e livre variaram de 177,98 a 691,71 mg kg^{-1} e 20,29 a 135,19 mg kg^{-1} respectivamente. A concentração de proteína variou de 0,18 a 0,73%, sendo considerados baixos. Os valores de açúcares variaram entre 0,17 e 0,53%; 0,03 e 0,39%, e 0,14 e 0,40% para glicose, frutose e sacarose respectivamente, e o amido variou de 18,65 a 36,01%. Isso indicou alta variação fenotípica para caracteres químicos nas amostras de mandiocas-bravas coletadas no estado do Pará e potencial para ganhos no melhoramento genético.*

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1 Introduction

Cassava (*Manihot esculenta* Crantz) is considered one of the main sources of calories in the tropics, where its roots are transformed in several products. It has been long stated that, in developing countries, nutrient-rich genotypes would be a great plus as they could contribute to fill the nutrition needs of populations who lack access to a wide diversity of foodstuff (Nestel et al., 2006).

According to cyanogenic glicosides concentration in the roots, cassava is classified in bitter or sweet cassava. Sweet cassava has HCN concentrations below 100 mg HCN kg^{-1} and bitter cassava show concentration above 100 mg kg^{-1} HCN (McKey et al., 2010).

Results of physic-chemical characterization of cassava germplasm were previously obtained and a significant difference among the chemical composition of different genotypes has been verified (Chávez et al., 2005; Padonou et al., 2005; Charoenkul et al., 2011; Silva et al., 2014; Sánchez et al., 2014).

There are evidences that cassava domestication has occurred in the southwestern border of Amazonia, which now corresponds Rondônia and Mato Grosso States in Brazil (Léotard et al., 2009). Possibly, the genetic variability of cassava in nearby regions, such Pará State, is high and it deserves to be evaluated. Thus, the hypothesis of this work was that there is variation for physicochemical characters in the roots of cassava sampled Pará State. To test this, the objective was to characterize 20 genotypes of bitter cassava sampled in Pará as to the chemical characters moisture, ashes, total soluble solids, total titrateable acidity, pH, total carotenoids, free and total cyanide, crude protein, glucose, fructose, sucrose and starch from the fresh roots.

2 Materials and Methods

Twenty genotypes of bitter cassava (Table 1) from an Active Germplasm Bank (AGB) established at Pará State were used in this study. The essay was performed in the Municipality of Tracuateua, State of Pará (00°46'18"S and 47°10'35"W) in 2009/2010, in a randomized block design with three repetitions. Plots were made up of five lines of five plants, and roots were harvested from nine plants located within the central lines.

The soil of Tracuateua is classified as typic hapludox, according to USDA soil taxonomy. The climatic conditions of this region are of the Awi type, according to Koppen's classification, and are divided into two seasons: a rainy one, from December to May, and a less rainy one, from June to November. Its average rain precipitation is of 2,500 mm per year; average temperature of 27.7 °C, and average air humidity of 84%.

The trial planting was done on a 1.0 m × 1.0 m spacing, with tillage and plowing for soil preparation and only one fertilizer application performed with nitrogen, phosphorous and potassium, using 10 - 28 - 20 formula 35 days after the planting of the stakes, where 40 g of fertilizer were used per planting spot. No irrigation was performed.

The harvesting was carried out one year later. The roots were washed with water, packed in plastic bags and stored in a cold chamber at a temperature kept between -18 a -10 °C for conservation until the time all of the lab analyses were to be performed.

The following chemical features of the roots were assessed: total cyanide, free cyanide, total carotenoids, moisture, ashes, pH, total titrateable acidity, total soluble solids, glucose, fructose, sucrose, starch, and crude protein.

The analysis of moisture, ashes, pH, total titrateable acidity and soluble solids were performed according to total titrateable

Table 1. Identification of twenty genotypes of cassava sampled in Pará State, Brazil in the years of 2008/2009/2010 and that belong to a germplasm bank.
Tabela 1. Identificação de vinte genótipos de mandioca coletados no Estado do Pará em 2008/2009/2010 e que pertencem ao banco de germoplasma.

Genotypes	State	Municipality	Year of sample
Genotype one	PA	Terra Alta	2008
Genotype two	PA	Bragança	2009
Genotype three	PA	Terra Alta	2009
Genotype four	PA	Tracuateua	2009
Genotype five	PA	Terra Alta	2009
Genotype six	PA	Terra Alta	2009
Genotype seven	PA	Terra Alta	2009
Genotype eight	PA	Terra Alta	2009
Genotype nine	PA	Tracuateua	2009
Genotype ten	PA	Bragança	2009
Genotype eleven	PA	Bragança	2009
Genotype twelve	PA	Igarapé Açu	2009
Genotype thirteen	PA	Igarapé Açu	2009
Genotype fourteen	PA	Terra Alta	2009
Genotype fifteen	PA	Bragança	2009
Genotype sixteen	PA	Terra Alta	2008
Genotype seventeen	PA	Igarapé Açu	2010
Genotype eighteen	PA	Terra Alta	2009
Genotype nineteen	PA	Igarapé Açu	2009
Genotype twenty	PA	Igarapé Açu	2009

acidity to AOAC (1997). Crude protein concentration was established by means of the micro-Kjeldahl technique, in accordance with the AOAC (1980) method.

Determination of cyanogenic compounds (free and total cyanide) was obtained in accordance with, which consists of extracting such compounds with farther reaction with chloramine T and isonicotinate 1.3-dimethyl barbiturate and spectrophotometric determination at 605 nm (Essers et al., 1993).

The analysis of total carotenoids was performed in accordance with the methodology described by Rodriguez-Amaya (2001) and reading on spectrophotometer on wave length of 450 nm.

Determination of glucose, fructose, and sucrose was performed in accordance with the methodology described by Stitt et al. (1989). Starch was also determined on the basis of enzymes, pursuant to Trethewey et al. (1998). Reading for determination of absorbency and quantification of starch and of glucose, fructose and sucrose sugar was done on spectrophotometer fit for Elisa plates on wave length of 340 nm.

Variance analysis (ANOVA) and media comparison test were performed taking into account the drawing in randomized blocks with three repetitions. Each repetition was made up by three replicates, with the average being established as from such replicates.

3 Results and Discussion

Based on the variance analysis, it was verified that the F test ($p < 0.05$) was significant for the majority of the characters assessed. The starch character was the only one not showing variation amongst the genotypes. The coefficient of variation fluctuated from 1.80% for pH to 33.24% for fructose (Tables 2 to 4).

Moisture values ranged from 60.53% in Genotype twenty to 71.96% in Genotype three (Table 2). The results were similar to those found by Padonou et al. (2005), who have described a variation of 80.9 to 60.3% of moisture in roots of fresh and peeled cassava. Moisture is an important parameter to determine food properties (Barbosa-Cánovas et al., 2007), since roots with high water content come to a physiological and microbiological deterioration process quickly after being harvested (Padmaja et al., 1982).

Table 2. Analysis of moisture, ashes, total soluble solids, total titatreable acidity and pH on humid basis of roots of 20 genotypes of bitter cassava that belong to the germplasm bank in the Pará State, Brazil.

Tabela 2. Análise de umidade, cinzas, sólidos solúveis totais, acidez titulável total e pH em base úmida de raiz para 20 genótipos de mandioca brava que pertencem ao banco de germoplasma no Estado do Pará, Brasil.

Genotypes	Moisture (%)	Ashes (%)	Total Solluble Solids (%)	Total Titatreable Acidity (%)	pH
Genotype one	ab 68.1 ± 1.7	abc 1.7 ± 0.1	ab 3.5 ± 0.4	bc 2.9 ± 0.1	bcd 6.11 ± 0.1
Genotype two	ab 67.6 ± 4.1	abcd 1.5 ± 0.1	ab 3.0 ± 0.4	efg 2.4 ± 0.1	cdef 6.02 ± 0.1
Genotype three	a 72.0 ± 3.8	ab 1.8 ± 0.1	ab 2.8 ± 0.4	ef 2.4 ± 0.0	abc 6.19 ± 0.1
Genotype four	ab 65.5 ± 1.0	abcd 1.5 ± 0.1	ab 3.0 ± 0.2	efgh 2.3 ± 0.1	abc 6.35 ± 0.1
Genotype five	ab 69.2 ± 3.7	abcd 1.4 ± 0.2	ab 2.6 ± 0.3	efgh 2.3 ± 0.0	f 5.68 ± 0.1
Genotype six	ab 66.9 ± 4.7	abc 1.7 ± 0.2	ab 2.9 ± 0.2	efgh 2.3 ± 0.1	bcde 6.06 ± 0.1
Genotype seven	ab 64.4 ± 2.8	abcd 1.6 ± 0.0	ab 3.0 ± 0.3	cd 2.7 ± 0.1	abc 6.31 ± 0.1
Genotype eight	ab 69.7 ± 0.9	d 1.2 ± 0.1	ab 3.0 ± 0.5	cd 2.7 ± 0.1	abc 6.21 ± 0.2
Genotype nine	ab 62.5 ± 3.5	abcd 1.6 ± 0.3	ab 3.4 ± 0.4	gh 2.1 ± 0.1	abc 6.24 ± 0.0
Genotype ten	ab 68.3 ± 1.3	a 1.8 ± 0.1	ab 3.2 ± 0.3	b 3.1 ± 0.2	abc 6.34 ± 0.0
Genotype eleven	ab 68.6 ± 6.0	abc 1.7 ± 0.0	ab 3.3 ± 0.5	a 3.4 ± 0.1	abc 6.18 ± 0.1
Genotype twelve	ab 65.6 ± 1.2	abcd 1.5 ± 0.2	b 2.3 ± 0.4	gh 2.1 ± 0.1	def 5.79 ± 0.3
Genotype thirteen	ab 65.0 ± 5.9	bcd 1.4 ± 0.0	ab 3.1 ± 0.3	efgh 2.4 ± 0.1	acb 6.24 ± 0.1
Genotype fourteen	ab 62.00 ± 0.7	abc 1.6 ± 0.1	ab 3.0 ± 0.2	h 2.1 ± 0.0	ab 6.38 ± 0.1
Genotype fifteen	ab 63.2 ± 1.9	bcd 1.4 ± 0.0	ab 3.0 ± 0.4	ef 2.4 ± 0.1	ab 6.38 ± 0.0
Genotype sixteen	ab 70.9 ± 7.4	abcd 1.4 ± 0.1	ab 3.0 ± 0.6	i 1.8 ± 0.0	abc 6.24 ± 0.1
Genotype seventeen	ab 66.4 ± 4.36	abcd 1.5 ± 0.1	a 3.8 ± 0.4	efgh 2.3 ± 0.1	abc 6.34 ± 0.1
Genotype eighteen	ab 64.2 ± 2.6	abcd 1.5 ± 0.2	ab 2.9 ± 0.3	de 2.5 ± 0.0	ef 5.73 ± 0.1
Genotype nineteen	ab 64.5 ± 3.4	cd 1.4 ± 0.0	ab 2.7 ± 0.1	efgh 2.3 ± 0.1	abc 6.24 ± 0.1
Genotype twenty	b 60.5 ± 1.8	abc 1.7 ± 0.1	ab 3.1 ± 0.6	fgh 2.2 ± 0.0	a 6.50 ± 0.1
*CV (%)	5.4	8.1	14.3	3.3	1.8

Averages followed by the same letters in the column do not differ significantly between them (Tukey test at 5% significance). Cells with average and standard deviation. *CV (%) coefficient of variation.

Contents of ashes varied from 1.22 (Genotype eight) to 1.80% (Genotype ten) (Table 2), which is close to or higher than the maximum of 1.5% required by applicable legislation. Charoenkul et al. (2011) had quantified contents of ashes on cassava meal that varied from 1.50 to 2.34%, similar to what was found in this study. Values of ashes higher than 1.5% can be an indicator of significant levels of minerals and they must be evaluated in a further analysis.

Total soluble solids, total titrateable acidity and pH values ranged from 2.33 to 3.78%, 1.83 to 3.35% and 5.68 to 6.50, respectively (Table 2).

The highest concentration of total carotenoids found among the genotypes was 9.76 μg g^{-1} of fresh pulp on Genotype one. Genotype eleven showed the lowest concentration among the measured genotypes, with an average of 2.34 μg g^{-1} (Table 3). The levels of total carotenoids of the eleven genotypes evaluated (Table 3) were similar to the values obtained by Ortiz et al. (2011) in 35 genotypes of cassava and by Chávez et al. (2005), who evaluated 1789 genotypes of cassava hybrids from the germplam bank of the International Tropical Agriculture Centre (CIAT) located in Colombia, and verified that total carotenoid concentrations varied from 1.02 to 10.40 μg g^{-1} of fresh cassava. It shows that in the Pará State there are genotypes with considerable levels of carotenoids contents.

In countries where cassava is the basic staple for their population diet, the use of genotypes of yellow pulp containing even moderate concentrations of total carotenoids, such as 3.6 to 6.4 μg g^{-1}, as found in various genotypes assessed here, can help to mitigate vitamin A deficiency (Vilama et al., 2009). To this end, cassava needs to be consumed cooked, since if submitted to lengthier processes there would be a great loss of carotenoids.

Samples evaluated showed high cyanide contents and are not recommended for direct consumption. Cyanide is highly toxic for the cells, since it generates an extremely stable complex with transition metals that are essential for proteins function (Ubalua, 2010). However, they represent potential breeders for crosses with low cyanide content genotypes to provide genotypes with higher concentration of total carotenoids, since crossings between bitter and sweet cassavas can generate genotypes with low HCN contents (Valle et al., 2004).

Table 3. Concentration of total carotenoids, cyanogenic compounds and crude protein present in fresh pulp of bitter cassava roots from a germplasm bank in the Pará State, Brazil.

Tabela 3. Concentração de carotenóides totais, compostos cianogênicos e proteína bruta presente na polpa fresca de raízes de mandioca brava pertencentes ao banco de germoplasma no Estado do Pará, Brasil.

Genotypes	Total Carotenoids (μg g^{-1})	Total Cyanide (mg kg^{-1})	Free Cyanide mg kg^{-1})	Crude Protein (%)
Genotype one	a 9.6 ± 1.5	ef 320.9 ± 4.7	cdef 56.4 ± 4.1	a 0.7 ± 0.0
Genotype two	b 7.2 ± 1.3	a 691.7 ± 50.2	fghi 41.1 ± 6.3	c 0.5 ± 0.0
Genotype three	b 7.1 ± 0.5	e 346.5 ± 22.0	hij 35.3 ± 5.4	b 0.6 ± 0.0
Genotype four	c 5.0 ± 0.2	ghij 217.3 ± 22.7	ghij 35.9 ± 6.5	c 0.5 ± 0.0
Genotype five	cd 4.7 ± 0.9	bc 565.7 ± 12.3	defghi 48.0 ± 6.2	c 0.5 ± 0.0
Genotype six	cde 4.3 ± 0.5	ij 194.5 ± 2.3	ij 30.1 ± 2.7	e 0.4 ± 0.0
Genotype seven	de 2.9 ± 0.4	ab 603.4 ± 76.8	cd 65.9 ± 11.8	g 0.2 ± 0.0
Genotype eight	de 2.7 ± 0.2	cd 484.2 ± 56.5	a 135.2 ± 0.7	e 0.4 ± 0.0
Genotype nine	e 2.6 ± 0.3	efgh 291.4 ± 8.6	c 73.4 ± 10.5	f 0.3 ± 0.0
Genotype ten	e 2.5 ± 0.2	d 443.4 ± 17.5	defg 54.4 ± 1.0	e 0.4 ± 0.0
Genotype eleven	e 2.3 ± 0.5	fghij 246.9 ± 9.1	cde 63.5 ± 3.7	c 0.5 ± 0.0
Genotype twelve	**n.d.	d 461.8 ± 25.7	defgh 51.3 ± 1.2	f 0.3 ± 0.0
Genotype thirteen	n.d.	efg 307.8 ± 19.5	j 20.3 ± 2.2	e 0.4 ± 0.0
Genotype fourteen	n.d.	efgh 292.4 ± 13.9	b 106.8 ± 6.5	c 0.5 ± 0.0
Genotype fifteen	n.d.	efghi 283.6 ± 28.9	cdef 59.2 ± 1.8	b 0.6 ± 0.0
Genotype sixteen	n.d.	efghi 269.3 ± 14.1	ghij 35.9 ± 5.7	c 0.5 ± 0.0
Genotype seventeen	n.d.	fghij 248.0 ± 18.5	b 95.0 ± 5.7	f 0.3 ± 0.0
Genotype eighteen	n.d.	ghij 224.7 ± 22.4	cdef 55.0 ± 11.6	b 0.6 ± 0.0
Genotype nineteen	n.d.	hij 205.5 ± 26.2	hij 34.2 ± 1.6	d 0.4 ± 0.0
Genotype twenty	n.d.	j 178.0 ± 9.9	efghi 47.1 ± 2.9	b 0.6 ± 0.0
*CV (%)	14.8	8.5	11.5	2.6

Averages followed by the same letters in the column do not differ significantly between them (Tukey Test at 5% significance). Cells with average and standard deviation. *CV (%) coefficient of variation. **n.d.: not determined for total carotenoids characteristic.

All genotypes have shown contents of total cyanide above 100 mg kg^{-1} of fresh pulp and are considered toxic, and they are deemed to belong in the group of bitter cassava. Total cyanide content variation went from 177.98 in Genotype twenty to 691.71 mg kg^{-1} in Genotype two. Free cyanide content had variation ranging from 20.29 to 135.19 mg kg^{-1} of fresh pulp on Genotypes thirteen and eight, respectively (Table 3).

For cassava breeders in the North region, yellow-rooted cassava is used for flour production, since there is a preference for this type of flour. Also, yellow roots are used for the production of *tucupi*, the fermented juice of cassava, which is usually yellow colored. Thus, these genotypes may be tested for recommendation regarding production of cassava meal or *tucupi* and production of starch. Values are among the range obtained by Sánchez et al. (2009), who detected a variation of 14 to 3274 mg HCN kg^{-1}, with 327 mg HCN kg^{-1} on average.

The concentration of raw protein varied from 0.18 on Genotype seven to 0.73% on Genotype one (Table 3). Ceballos et al. (2006) have described a range of 0.95 to 6.42% of protein, which means that the materials assessed cannot be considered a good source of proteins. Although the low level of proteins may have a very undesirable effect onto the subsistence of people, the low content of proteins in cassava roots makes it a source of energy with low allergenic potential (Ceballos et al., 2006), specially as a meal for children.

Glucose contents varied from 0.17 in Genotypes seven and nine to 0.53% in Genotype four; fructose contents varied from 0.03 on Genotype fifteen to 0.39% on Genotype five; and sucrose contents varied from 0.14 on Genotype fifteen to 0.40% on Genotype seventeen (Table 4). Thus, the sugar with higher concentration was glucose, followed by sucrose and fructose.

The starch content varied from 18.65 to 36.01% on Genotypes nine and four, respectively, with average of 26.31%. Genotypes two, four, seven, thirteen, seventeen and nineteen showed starch contents higher than 30% (Table 4). It is well known the great variation of this component among genotypes of cassava (Sánchez et al., 2009). Starch content is one of the principal parameters for cassava genetic breeding (Ceballos et al., 2012). But, it is a component that is very influenced by environmental conditions and physiological states of the plant (Benesi et al., 2008). Perhaps the higher variation

Table 4. Determination of glucose, fructose, sucrose and starch concentrations in cassava fresh root from the germplasm bank Pará State, Brazil.
Tabela 4. Determinação de concentrações de glucose, fructose, sacarose e amido em raízes frescas de mandioca de banco de germoplasma no Estado do Pará, Brasil.

Genotypes	Glucose (%)	Fructose (%)	Sucrose (%)	Starch (%)
Genotype one	efg 0.18 ± 0.00	de 0.17 ± 0.04	abcde 0.30 ± 0.03	a 20.19 ± 3.10
Genotype two	cdefg 0.24 ± 0.01	de 0.16 ± 0.07	abcdef 0.29 ± 0.02	a 30.1 ± 1.31
Genotype three	bcdefg 0.28 ± 0.00	bcde 0.20 ± 0.02	abcdefg 0.28 ± 0.03	a 26.24 ± 3.07
Genotype four	a 0.53 ± 0.04	cde 0.19 ± 0.04	abcd 0.35 ± 0.10	a 36.01 ± 5.20
Genotype five	ab 0.44 ± 0.01	a 0.39 ± 0.09	abc 0.38 ± 0.01	a 27.24 ± 2.78
Genotype six	g 0.15 ± 0.01	de 0.09 ± 0.01	efg 0.20 ± 0.03	a 26.73 ± 8.47
Genotype seven	fg 0.17 ± 0.01	de 0.07 ± 0.00	abcd 0.35 ± 0.01	a 33.99 ± 2.45
Genotype eight	bcdefg 0.28 ± 0.01	abc 0.36 ± 0.10	abcde 0.32 ± 0.05	a 20.02 ± 12.41
Genotype nine	fg 0.17 ± 0.02	abcd 0.23 ± 0.01	abcde 0.31 ± 0.02	a 18.65 ± 7.60
Genotype ten	cdefg 0.25 ± 0.03	de 0.12 ± 0.01	bcdefg 0.24 ± 0.02	a 29.21 ± 4.11
Genotype eleven	efg 0.18 ± 0.01	de 0.11 ± 0.01	ab 0.38 ± 0.02	a 22.33 ± 3.74
Genotype twelve	abcd 0.37 ± 0.08	de 0.13 ± 0.07	abcdef 0.28 ± 0.08	a 23.80 ± 8.95
Genotype thirteen	bcdefg 0.30 ± 0.06	de 0.10 ± 0.02	cdefg 0.24 ± 0.10	a 31.98 ± 1.60
Genotype fourteen	abcdef 0.35 ± 0.06	de 0.08 ± 0.00	defg 0.23 ± 0.02	a 26.84 ± 5.04
Genotype fifteen	defg 0.19 ± 0.05	e 0.03 ± 0.01	g 0.14 ± 0.04	a 19.04 ± 2.39
Genotype sixteen	cdef 0.23 ± 0.02	ab 0.38 ± 0.02	abcde 0.31 ± 0.04	a 19.22 ± 6.07
Genotype seventeen	ab 0.46 ± 0.14	abcd 0.24 ± 0.16	a 0.40 ± 0.05	a 30.02 ± 2.45
Genotype eighteen	abcde 0.36 ± 0.11	de 0.14 ± 0.08	abcdefg 0.27 ± 0.04	a 26.80 ± 1.63
Genotype nineteen	abc 0.41 ± 0.12	de 0.18 ± 0.09	bcdefg 0.24 ± 0.03	a 32.89 ± 3.60
Genotype twenty	cdefg 0.22 ± 0.04	de 0.07 ± 0.01	fg 0.15 ± 0.04	a 24.9 ± 10.78
Overall average	0.29	0.17	0.28	26.31
*CV (%)	20.75	33.24	16.18	21.80

Averages followed by the same letters in the column do not differ significantly between them (Tukey test at 5% significance). Cells with average and standard deviation. *CV (%) coefficient of variation.

measured by coefficient of variation may have influenced the analysis and no variation was detected among genotypes.

Starch and sugar are important for the production of cassava meal and *tucupi* (fermented cassava juice), since as they are submitted to fermentation processes, these substances may impact the final quality of the product, given that during the fermenting process a decrease on starch and sugar contents and an increase on total acidity take place, and that has hampered the fitting of cassava meal to the parameters demanded by current Brazilian legislation. The variability of chemical characters in cassava genotypes may result in the lack of standardization of its marketed byproducts on the North region of Brazil, such as tucupi and cassava meal, which calls for standardization and further studies have to focus on providing a better quality product for the end consumer.

Thus, the results indicate that there is considerable chemical characters of cassava root to explore in genetic breeding programs for Pará State. They also emphasize the importance of maintaining these genetic resources in germplasm banks, since this variation can be explored in the form of controlled crosses by other genetic breeding programs.

4 Conclusions

There is significant phenotypic variation for chemical characters of root of bitter cassavas sampled in Pará State and conserved in a germplasm bank of the State. The germplasm bank conserves genotypes with considerable contents of carotenoids and starch, and they are potential genitors for genetic breeding programs. Other characters such as moisture, ashes and pH indicated that these genotypes are suitable to generate food products and need to be studied concerning agronomical characters. Proteins and sugars contents are low in the genotypes evaluated, as expected for cassava.

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