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Genetic divergence of cassava genotypes from Petrolina

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ABSTRACT. This study aimed to evaluate cassava genotypes to identify the ones with the best nutritional values for ruminant diets. Nine genotypes were used: Amansa Burro (BGM 549), Aramaris (BGM 116), Brasília, Cambadinha (BRS Guaíra), Curvelinha, Engana Ladrão (BGM 1269), Trouxinha (BGM 1468), BRS Gema de Ovo, and BRS Dourada. A completely randomized block experimental design with nine treatments (genotypes) and three blocks (replicates) were employed. The roots were analyzed for dry matter production (DMP) in tonnes per hectare, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), starch, and *in vitro* dry matter digestibility (IVDMD). The multivariate analysis was carried out using Ward's hierarchical agglomerative clustering based on Mahalanobis distance. The groups formed were evaluated by Scott-Knott test. The group formed by genotype Engana Ladrão was chosen as the best one for having the highest DMP t ha^{-1} and IVDMD values and the lowest NDF and ADF contents.

Keywords: genetic dissimilarity; *Manihot esculenta*; Ward's method.

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Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most widely grown plants worldwide and its starch-rich roots have been the energetic base of over 700 million low-income people in several countries (Marcon, Avancini, & Amante, 2007).

Cassava is grown in all Brazilian states, but is particularly important in the Northeast region because it grows in poor soils, is resistant to drought, and is able to survive among weeds and pests. For that reason, the crop is present in the entire semi-arid portion of the Northeast region, where most crops cannot achieve high productivity (Cavalcanti & Araújo, 2000).

Nonetheless, the use of cassava roots *in natura* is partially limited by hydrogen cyanide contents, thus they are most often used in ruminant feed in grated form, which is a simple way of preserving cassava based on grinding sun-dried fresh roots that eliminates hydrogen cyanide due to its volatile character (Cavalcanti & Araújo, 2000).

Knowing the chemical and energy composition of foods determines both their value and nutritional shortcomings. The nutritional characteristics of each food must be known so that they can be properly employed. Grated cassava has 87.67% dry matter, 2.47% crude protein, 68.85% starch, 11.75% neutral detergent fiber (NDF), and 4.27% acid detergent fiber (ADF) (Rostagno et al., 2005).

Genetic divergence studies are essential to understand the genetic variability of populations and facilitate monitoring germoplasm banks (Cruz, Ferreira, & Pessoni, 2011). According to Bertini, Teófilo, and Dias (2009), genetic divergence has been studied aiming to select matrices for hybrids or from crossbreeding divergent genotypes to form new populations. Therefore, these studies produce important information for preservation and use of varieties (Toquica, Rodríguez, Martínez, Cristina Duque, and Tohme, 2003).

According to Cruz, Regazzi, and Carneiro (2012), according to some similarity or dissimilarity criterion, clustering analysis aims to divide an original group of observations into several groups.

Based on genetic similarity according to the Jaccard index, Oliveira, Baliza, Souza, Carvalho, and Assis (2012) investigated ten cassava clones obtained by polycrossing to detect the molecular similarity with table and industrial cultivars established on the market through microsatellite markers, which were effective to identify new cassava clones appropriate for *in natura* consumption but not industrial use.

The present study aims to assess the genotypes with the best nutritional value.

Material and methods

Nine cassava genotypes recommended for cultivation in the semi-arid region of the Northeast region of Brazil were evaluated (Table 1).

Table 1. Main characteristics and use of the studied cassava genotypes.

Genotypes	Characteristic Main	Use
Amansa Burro	Adapted to the semiarid; leaf retention in the dry season.	industrialist
Aramaris	Resistance to root rot.	industrialist
Brasília	Adapted to the semi-arid altitude; high content of starch and thin film.	industrialist
BRS Guaíra	Adapted to the semi-arid altitude; high content of starch and thin film.	industrialist
Curvelinha	Resistance to bursting; late harvest.	industrialist
Engana Ladrão	Adapted to the semiarid; leaf retention in the dry season.	industrialist
Trouxinha	Adapted to the semiarid; leaf retention in the dry season.	industrialist
BRS Gema de Ovo	Precocious; rich in pro-vitamin A (4mg g^{-1} beta-carotene).	Table
BRS Dourada	Precocious; rich in pro-vitamin A (4 mg g^{-1} beta-carotene).	Table

Source: Araujo and Almeida (2013).

A completely randomized block experimental design with nine treatments (genotypes) and three blocks (replicates) was employed. The cassava was planted on May 4th, 2006 at Embrapa Semi-Arid in the city of Petrolina, Pernambuco State, Brazil, latitude 09°23'34"S, longitude 40°30'28"W, altitude 376 m, mean annual rainfall of 400 mm, and semi-arid tropical climate type BshW in the Köppen classification with a short wet season in the summer and mean minimum temperature of 20°C. The roots were harvested on October 26th, 2007 and mean root production, in t DM ha^{-1}, was assessed.

No liming or fertilization was applied in the experiment since the goal was to simulate the production conditions employed in the region, where most producers do not use these practices. The meteorological data over the experimental period (Table 2 and 3) were obtained from the agrometeorological station of Bebedouro (Petrolina, Pernambuco State, Brazil 09°09'S 40°22'W).

The root samples for laboratory analyses were pre-dried in a forced air oven at 55°C and then ground with a 1 mm sieve. The resulting material was stored in airtight plastic containers.

The analyses determined values of pre-dried matter, dry matter (DM) at 105°C, crude protein (CP) according to the Lee (1995), and NDF and ADF according to Van Soest, Robertson, and Lewis (1991). Starch was determined using the amyloglucosidase α-$amylase^{-1}$ method (McCleary, Gibson, & Mugford, 1997). *In vitro* dry matter digestibility (IVDMD) was assessed according to the technique recommended by Tilley and Terry (1963), which was modified for use in the artificial rumen fermenter DAISYII (ANKOM®) according to Holden (1999).

Table 2. Meteorological data for the period under study (part 1).

Month/year	Precipitation (mm)	Average global solar radiation (ly day^{-1})	Average heat stroke (hours)	Average temperature (°C)
may/06	3,5	269,4	5,4	24,1
jun/06	7,6	238,5	3,4	22,5
jul/06	7,2	268,6	5,6	22,4
aug/06	0,2	351,1	8,1	23,7
sep/06	8	413	8,7	25,9
oct/06	2,9	402,3	7,9	27,8
nov/06	74,9	474,8	8	27
dec/06	14,2	477,9	7,9	28,2
jan/07	35,6	482,9	8,1	28,4
feb/07	145,9	403	5,2	25,8
mar/07	4	404,3	7	26,6
apr/07	12,2	415,2	7,2	26,9
may/07	9,2	339,5	5,7	26
jun/07	0,5	369,2	6,1	24,8
jul/07	9,2	395,1	6,3	24,1
aug/07	1,6	436,9	6,7	24,4
sep/07	1,6	478,1	7,7	25,8
oct/07	0	525,6	7,6	27,4
Average	18,79	396,97	6,81	25,66
Sum	338,3	7145,4	122,6	461,8

Table 3. Meteorological data for the period under study (part 2).

Month/year	Minimum temperature (°C)	Maximum temperature (°C)	ur (%)	Average evaporation (mm)
may/06	x	30,9	74	5
jun/06	x	29,1	76	4,8
jul/06	x	29,7	69	6,3
aug/06	x	31,5	60	9
sep/06	x	33,3	56	9,1
oct/06	22,3	34,4	56	8,8
nov/06	21,8	33,5	70	8,1
dec/06	22,8	35,2	56	9,3
jan/07	23,1	35,4	55	9,1
feb/07	22,2	31,2	76	5,7
mar/07	21,6	32,4	73	7,3
apr/07	21,6	33,8	60	7,2
may/07	21,3	32,1	63	6,9
jun/07	19,4	31,1	61	7,2
jul/07	19,1	30,6	63	7,1
aug/07	18,5	31,3	55	8,2
sep/07	19,8	32,5	51	10
oct/07	21,3	34,2	49	11
Average	21,14	32,34	62,39	7,78
Sum	274,8	582,2	1123	140,1

Prior to the multivariate analysis, the variables (t DM roots ha^{-1}, CP, NDF, ADF, IVDMD, and starch) were submitted to Lilliefors (1967) and Bartlett (1937) tests to verify normality and homoscedasticity, respectively.

The multivariate analyses were performed using the software R, in which Ward and Joe (1963) method was applied based on Mahalanobis distance and Rand (1971) index to determine the number of groups.

The averages of the variables of the clusters formed were compared by Scott and Knott (1974) test at 5% probability of type-I error.

Results and discussion

Figure 1 shows the results obtained with the hierarchical clustering analysis performed by Ward and Joe (1963) method based on Mahalanobis distance and using the Rand (1971) index to determine the number of clusters. Six clusters were formed. The first was made up by genotype Gema de Ovo; the second, by genotype Dourado; the third, by genotype Engana Ladrão; the fourth, by genotypes Guaíra and Trouxinha; the fifth, by genotype Amansa Burro; and the sixth, by genotypes Brasília, Aramaris, and Curvelinha.

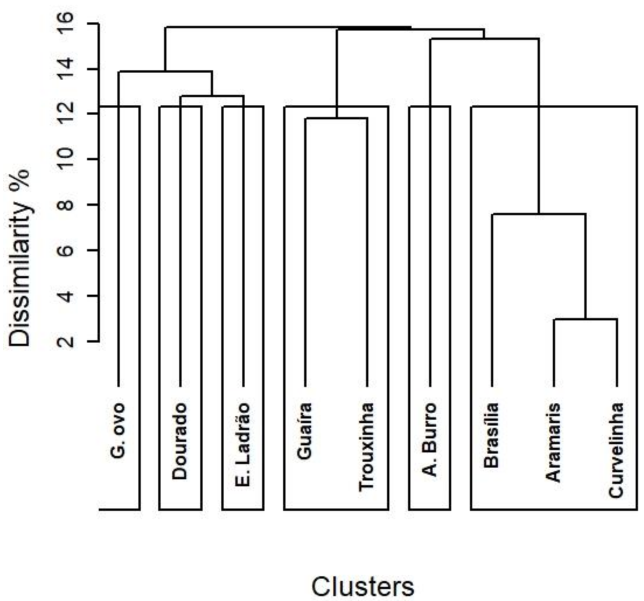

Figure 1. Dendogram of genetic dissimilarity of cassava genotypes.

Mahalanobis distance ranged from 3.37 to 19.63 (Table 4), which indicates the greatest similarity between Engana Ladrão and Trouxinha and the greatest difference between Guaíra and Dourado.

Table 4. Mahalanobis distance matrix of the original data for the 9 genotypes of Embrapa Semiarid, Petrolina, Pernambuco State.

Genotypes	Aramaris	Brasília	Guaíra	Curvelinha	Dourado	E.L.*	Gema	Trouxinha	A.B.*
Aramaris	0.00								
Brasília	10.42	0.00							
Guaíra	11.89	4.02	0.00						
Curvelinha	5.66	6.52	7.22	0.00					
Dourado	8.46	18.62	19.63	13.17	0.00				
Engana L.	9.28	7.83	7.01	4.64	15.24	0.00			
Gema	3.97	8.01	10.08	5.77	11.49	8.93	0.00		
Trouxinha	8.61	6.38	4.99	3.68	15.54	3.37	8.18	0.00	
Amansa B.	8.14	7.08	9.33	7.10	16.03	10.76	6.40	9.19	0.00

*E:L: Engana Ladrão; A.B.: Amansa Burro.

Table 5 shows the mean values of t DM roots ha^{-1}, contents of CP, NDF, ADF, and starch, and IVDMD of the clusters formed.

Cluster III had the highest ($p < 0.05$) t DM roots ha^{-1} values, while cluster IV was intermediate and clusters I, II, V, and VI had the lowest production. The results of this experiment show the production potential of genotype Engana Ladrão in the semi-arid region of the Brazilian Northeast, where Silva et al. (2009) had previously assessed the productivity of cassava in the state of Piauí and found the highest yields for genotypes Engana Ladrão and Do Céu.

CP content was similar ($p > 0.05$) among all genotypes. The values found in the present study match those observed in nutritional charts of swine and poultry (Rostagno et al. 2005) and bovine feed (Valadares Filho, 2006), which show cassava roots have low CP contents (between 2.2 and 3.4%). According to Van Soest (1994), animal diet must contain at least 7% CP to prevent alterations in ruminal fermentation and reduction of DM intake. Therefore, using cassava roots entails adjusting the protein concentration, which will depend on the other components of the diet and the requirements of the animals.

Clusters 1 and II had the highest ($p < 0.05$) NDF content, while clusters V and VI had intermediate values and clusters III and IV had the lowest contents. Clusters I and V had the highest ($p < 0.05$) ADF content, while cluster I had intermediate values and clusters III, IV, and VI had the lowest contents. According to Buitrago (1990), cassava skin represents between 15 and 20% of the total root weight and holds most of its fiber. It is likely that the genotypes with the highest fiber content are those with the highest proportion of skin in the root.

Clusters IV and V had the highest ($p < 0.05$) starch content, while clusters I, III, and VI had intermediate values and cluster II had the lowest contents. Genotype Amansa Burro (cluster V) had been reported in the literature as having high starch content (Borges, Fukuda, & Rossetti, 2002).

Table 5. Root production in tons of dry matter per hectare (PMS), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), starch and in vitro dry matter digestibility (IVDMD) of the groups formed.

Items	Clusters						*CV%
	I	II	III	IV	V	VI	
Genotypes	Gema de Ovo	Dourado	Engana Ladrão	Guaíra e Trouxinha	Amansa Burro	Brasília, Aramaris e Curvelinha	
Variables	Cluster average						
PMS t ha^{-1}	2,0 C	2,4 C	7,5 A	4,2 B	1,8 C	3,2 C	33,77
PB %	4,7	4,9	4,6	4,7	2,2	2,94	29,97
FDN %	17,3 A	17,2 A	11,4 C	10,5 C	14,9 B	14,1 B	13,63
FDA %	6,8 B	7,7 A	5,8 C	4,7 C	7,9 A	6,0 C	11,57
Amido %	85,0 B	73,5 C	85,9 B	89,1 A	88,8 A	86,1 B	4,05
DIVMS %	90,6 C	90,1 C	94,1 A	93,2 A	86,9 D	91,6 B	1,31

Averages followed by distinct letters on the line represent difference by the Scott and Knott (1974) test ($p < 0,05$). *Coefficient of variation (CV).

Clusters III and IV had the highest ($p < 0.05$) IVDMD values, followed by cluster VI, clusters I and II, and cluster V. The results obtained are in accordance with Alves de Brito, Rodella, and Deschamps (2003), who reported the increase in cell-wall components reduces its degradability by ruminants, which is confirmed by the correlation between IVDMD and NDF and ADF, i.e., an increase in fiber content leads to a reduction in IVDMD. However, starch content did not impact IVDMD (Table 6).

Table 6. Correlation between in vitro dry matter digestibility (IVDMD) with starch, neutral detergent fiber (NDF) and acid detergent fiber (FDA).

Variable	STARCH	FDN	FDA
DIVMS	Ns	-0.55**	-0.77**

Ns = Not significant; **(p < 0,01).

Conclusion

Genotype Engana Ladrão stands out nutritionally among the genotypes assessed for having the highest DMP t ha^{-1}, lowest content of NDF and ADF, and highest IVDMD.

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