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Evaluation of cassava starch as raw material according to the characteristics of the granules

Avaliação do amido de mandioca como matéria prima de acordo com as características dos grânulos

Evaluación del almidón de yuca como materia prima según las características de los gránulos

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Abstract

In this study, the physicochemical characteristics of starch extracted from ten different cultivars of cassava roots, from different soils, were investigated. There are significant ($p<0.05$) variations in the proportion of starch damaged during extraction, even in samples of the same cultivar. Amylose content differs among cultivars and even within the same cultivar harvested in different soils (varying from 20.00 to 24.07%). According to the type of soil the starch samples showed distinct values for the crystallinity index. This indicates the need for the physicochemical characterization of starch samples to be carried out even when they originate from the same cultivar. The results obtained can be used as support tools for improvement of cassava genetics, optimizing the process of selection and maintenance of a genetic bank. The results, coupled with chemometric analyses (PCAs and *clusters*), allowed to distinguish cultivars according to their physicochemical and functional peculiarities, suggesting their potential to be used by industries and as food.

Keywords: Cassava; Cultivar; Granule; Starch.

Resumo

Neste estudo, foram avaliadas as características físico-químicas de amidos extraídos de dez diferentes cultivares de mandioca, cultivadas em diferentes tipos de solos. Há significativas variações nas proporções de amido danificado durante a extração, mesmo em amostras da mesma cultivar. O teor de amilose difere entre cultivares e mesmo dentro das mesmas colhidas em diferentes solos (variando de 20,00 a 24,07 %). De acordo com o tipo de solo, os amidos apresentaram distintos valores para o índice de cristalinidade. Este resultado indica a necessidade de caracterização de amidos, mesmo quando têm origem em uma mesma cultivar. Os resultados obtidos podem ser usados como ferramenta suporte para melhoramento da mandioca, otimizando o processo de seleção e manutenção de um banco genético. A análise quimiométrica (PCAs e agrupamentos), permite distinguir cultivares de acordo com as suas características físico-químicas e peculiaridades funcionais, sugerindo seus distintos usos.

Palavras-chave: Mandioca; Cultivar; Grânulo; Amido.

Resumen

En este estudio, se evaluaron las características fisicoquímicas de almidones extraídos de diez cultivares diferentes de yuca, cultivados en diferentes tipos de suelo. Existen variaciones significativas en las proporciones de almidón dañado durante la extracción, incluso en muestras del mismo cultivar. El contenido de amilosa difiere entre cultivares e incluso dentro de las mismas cosechas en diferentes suelos (que van del 20,00 al 24,07%). Según el tipo de suelo, los almidones presentaron diferentes valores para el índice de cristalinidad. Este resultado indica la necesidad de caracterizar los almidones, incluso cuando proceden del mismo cultivar. Los resultados obtenidos se pueden utilizar como una herramienta de apoyo para mejorar la yuca, optimizando el proceso de selección y mantenimiento de un banco genético. El análisis quimiométrico (PCAs y racimos), permite distinguir cultivares de acuerdo a sus características físico-químicas y peculiaridades funcionales, sugiriendo sus diferentes usos.

Palabras clave: Yuca; Cultivar; Gránulo; Almidón.

1. Introduction

Cassava root is a raw material originating from the Brazilian Amazon rainforest and is a major source of starch in tropical countries. One of the main advantages of cassava as a raw material for starch production is that pure granules can be easily obtained (Marcon *et al.*, 2009), which is not what commonly happens with most starch sources.

There is a growing interest in the use of cassava starch to replace synthetic polymers (Qin *et al.*, 2019, as coating material constitution (Benevides et al., 2020), and others important applications. However, the decision on the use of natural raw materials must consider the influences of the environment and other factors on the chemical characteristics that may interfere in the industrial processes where these raw materials are used.

Structurally, starch is a homo-polysaccharide composed of chains of amylose and amylopectin. Amylose consists of glucose units connected by α-glycosidic linkages (1, 4), yielding a straight chain that may have small branches (Liu, 2005). Because amylopectin consists of glucose units linked at α (1, 4) and branching points of α (1, 6), it forms a branched structure (Whistler & Paschal, 1965).

To increase the use of starch as a raw material, it is necessary to know its functional properties and behavior. This knowledge can be acquired through elucidation of the granular structure and its physicochemical relationship (Sabaté-Rolland *et al.*, 2012). Even when they originate from the same source, starch granules can show important differences which affect the determination of its numerous applications (Chatakanonda *et al*., 2003; Marcon *et al*., 2009). The characterization data is provided for the use of starches from different plant sources in several different areas of application, from their use as food (Blagbrough *et al*., 2010) to the use of their polymers for the production of biodegradable films (Versino & García, 2014).

In this study, principal component analysis (PCA) and clusters were used aiming to build descriptive models to aid in the interpretation of the results of the chemical and structural properties of the starch granules, and to allow their association with the different growing regions and functional properties investigated.

2. Methodology

Ten different cassava cultivars were supplied by the EPAGRI (Agency for Agricultural Research and Rural Extension in Santa Catarina State). The harvesting of each of the ten cultivars was performed in triplicate in different locations, from cassava plants belonging to a single growing cycle (Table 1).

The samples of starch were extracted from each cultivar of cassava, from different types of soil, according the proceeding of Maieves *et al*. (2011), were the samples were peeled manually, cut into cubes (approximately 2x2x2 cm each) and triturated in water (1:4 w/v), with an industrial blender (MetVisa, LQL 10). The resulting mass was filtered through cheesecloth. The fibrous pulp retained in the filter was returned to the cheesecloth so that new extractions were performed until the filtrate became totally transparent.

The “starch milk” (water and starch) was left to stand until the starch granules completely sedimented. Then, it was re-suspended until the supernatant became transparent. The sedimented matter was dehydrated at 45°C in a forced air oven (Fabbe), ground in a Mellita coffee mill to 100 mesh, packaged in polyethylene bags as the primary packaging and then kept in a hard plastic box as the secondary packaging until the analysis was carried out.

The analysis of lipids (AOAC 920.85) was performed according to the methodology of the Association of Official Analytical Chemists (AOAC, 2005). The proportion of starch damaged during the extraction process was determined through the Megazyme kit – Assay Procedure K-SDAM 02 (*Megazyme International Ireland Limited*, Wicklow, Ireland) (Megazyme, 2008). The content of amylose in the cassava starch granules was determined according to the procedure described by Williams *et al*. (1970). The amylose and amylopectin samples used to construct the standard curve were obtained from cassava starch, extracted according to the method proposed by McCready and Hassid (1943).

The X-ray diffraction was performed through the powder method, using a Philips X´Pert diffractometer under the following conditions: Cu Kα1 radiation, with λ 1.54056 Å. Scanning at 2θ was performed at 0.05 degree intervals every second. The relative crystalline index (CI) was quantitatively determined as proposed by Hayakawa *et al*. (1997).

The size and shape of the granules of the starch samples were compared by scanning electron microscopy (SEM). Samples (pool of three batches) were attached with double-sided tape, onto an aluminum support with a gold layer of 350 Å of thickness in a vacuum device (Polaron E5000). The size of the granules was measured using the Measure IT software.

The enzymatic susceptibility was determined by adapting the Sandstedt and Mattern (1960) procedure. The profile of enzymatic susceptibility was traced from the plot of the percentage of maltose produced over time for the different starches investigated in the present work. The swelling power and the solubility index were determined following the procedure suggested by Leach *et al*. (1959), at 50, 60, 70, 80 and 90 °C.

All the analysis was carried out in triplicate. A one-way analysis of variance at the α = 0.05 significance level was performed. Significance of differences between means was estimated applying the Tukey test. Statistical calculations were performed using the Statistica 7.0 software (StatSoft, USA). Analysis of Pearson correlation between variables was carried out and the data were also subjected to multivariate statistical analysis, using the methods of principal components (PCA) and of clusters by implementing the required *script* using the R language (v.2.15.2).

Table 1 - Names of the ten cassava root cultivars investigated, their places of origin and types of soil.

Cultivars	**Type of soil***	**Places of origin****
STS 2/03-10 (white root)	Neossolo Quartzarênico	Jaguaruna
SCS 252 - Jaguaruna	Neossolo Quartzarênico	Jaguaruna
Mandim Branca	Neossolo Quartzarênico	Jaguaruna
STS 1302/96-3 - Vermelhinha	Neossolo Quartzarênico Argissolo	Jaguaruna Morro da Fumaça
SCS 253 - Sangão	Neossolo Quartzarênico Argissolo	Jaguaruna Morro da Fumaça
STS 1311/96-1	Neossolo Quartzarênico	Jaguaruna
STS 1302/96-4	Neossolo Quartzarênico	Jaguaruna
Preta	Argissolo	Sangão
STS 1309/96-7	Neossolo Quartzarênico	Jaguaruna
STS 2/03-7	Neossolo Quartzênico	Jaguaruna

*Types of soil classified according to the SiBCS - Brazilian Soil Classification System (EMBRAPA, 1999). **Towns in Santa Catarina State, Brazil.
Source: Authors.

3. Results and Discussion

The starch granules may have different sizes, shapes and structural characteristics which can result in different responses to shear or crushing during the extraction process. There were significant ($p<0.05$) differences in terms of starch damage, even in samples from the same plant source (Table 2). STS 1302/96-3 – Vermelhinha grown in Argissolo (0.82%), showed an increased fragility and smaller size of the granule and Mandim Branca grown in Neossolo Quartzarênico (0.14%), showed a lower fragility to breakage during the milling processes. It is expected that the cultivar which displayed the highest degree of starch damage would be different from the others in terms of its starch characteristics, such as increased enzyme susceptibility and greater swelling power at low temperatures (Karkalas *et al*., 1992).

In spite of lipids being present in lower concentrations, they can affect functional properties of starch. Present mainly in cereal starches, lipids affect gelation and modify the rheological behavior of pastes (Radhika *et al*., 2008) and also inhibit the crystallization, thereby reducing retrogradation (Wang & White, 1994). The concentration of lipids in the starches studied was somewhat homogeneous, around 0.11% (Table 2). Comparing with the results for cassava starch obtained by Mali *et al*. (2006) of 0.28%, the lipid values in this study can be considered low. They were below those referred by Hu *et al*. (2018) considering that cereal starches can presents around 1% of lipids. Most of these lipids are present in the granules as inclusion complexes with amylose because un-complexed lipids are removed in the starch extraction process (Wang & White 1994) and thereby affect the rheological properties.

The results of this study (Table 2) confirm the fact that there are different percentages of amylose in cultivars of the same plant, and that cultivar STS 1309/96-7 showed a higher amount of amylose (24.07%) compared to the others, whose values were mostly around 20%. In studies on cassava starch carried out by other authors, the values obtained for amylose varied from 17.17 to 31 % (Sabaté-Rolland *et al*., 2012).

Table 2 - Amylose content, crystallinity index, damaged starch and lipids (DBW) in starch extracted from different cassava cultivars.

Cultivar	**(1)Damaged starch**	**(1)Lipids**	**(1)Amylose**	**Crystallinity Index**
		(%)		
STS 2/03-10	$0.54^{g} \pm 0.01$	$0.056^{a} \pm 0.003$	$20.55^{a,b} \pm 0.48$	$44.30^{a,b} \pm 0.39$
SCS 252 – Jaguaruna	$0.61^{g,h} \pm 0.02$	$0.118^{a,b,c} \pm 0.011$	$21.15^{a,b} \pm 0.97$	$34.74^{c,d} \pm 0.34$
Mandim Branca*	$0.32^{d,e} \pm 0.02$	$0.199^{b,c} \pm 0.082$	$19.51^{a} \pm 0.27$	$46.73^{b} \pm 2.08$
Mandim Branca**	$0.14^{a} \pm 0.02$	$0.217^{c} \pm 0.039$	$21.52^{a,b} \pm 0.26$	$40.57^{a,b,c} \pm 1.89$
STS 1302/96-3 – Vermelhinha*	$0.82^{j} \pm 0.0$	$0.193^{b,c} \pm 0.073$	$20.91^{a,b} \pm 0.47$	$39.61^{a,b,c} \pm 4.10$
STS 1302/96-3 – Vermelhinha**	$0.23^{b,c} \pm 0.005$	$0.098^{a,b} \pm 0.003$	$19.69^{a,b} \pm 0.47$	$40.94^{a,b,c} \pm 1.66$
SCS 253 – Sangão*	$0.62^{h,i} \pm 0.03$	$0.176^{b,c} \pm 0.077$	$20.88^{a,b} \pm 0.83$	$31.76^{d} \pm 1.59$
SCS 253 – Sangão**	$0.33^{d,e} \pm 0.02$	$0.106^{a,b,c} \pm 0.025$	$21.86^{a,b,c} \pm 0.18$	$34.63^{c,d} \pm 0.43$
STS 1311/96-1	$0.32^{d,e} \pm 0.03$	$0.110^{a,b,c} \pm 0.003$	$21.96^{b,c} \pm 1.42$	$42.90^{a,b} \pm 0.48$
STS 1302/96-4	$0.26^{c,d} \pm 0.03$	$0.111^{a,b,c} \pm 0.009$	$20.13^{a,b} \pm 0.68$	$43.21^{a,b} \pm 0.04$
Preta	$0.69^{i} \pm 0.03$	$0.109^{a,b,c} \pm 0.006$	$21.31^{a,b} \pm 0.78$	$41.13^{a,b,c} \pm 0.17$
STS 1309/96-7	$0.38^{e,f} \pm 0.04$	$0.111^{a,b,c} \pm 0.009$	$24.07^{c} \pm 1.61$	$40.16^{a,b,c} \pm 1.74$
STS 2/03-7	$0.38^{e,f} \pm 0.03$	$0.115^{a,b,c} \pm 0.007$	$21.50^{a,b} \pm 0.19$	$40.71^{a,b,c} \pm 1.73$

(1) Data were reported as means ± Standard Deviation (n = 3). Values in the same column with different superscript letters are significantly different ($P < 0.05$), according to the Tukey test. *Sample of cassava root cultivated in Argissolo. **Sample of cassava root cultivated in Neossolo Quartzarênico; DBW: dry basis weight.
Source: Authors.

The amylose and amylopectin proportions in the granules can also result in differences in the starch crystallinity. According to Cheethan and Tao (1998), the index of relative crystallinity of native starch samples ranges from 15 to 45%, depending on the plant species, and various methods are used for the evaluation including acid hydrolysis, X-ray diffraction and ^{13}C -NMR. In this study different crystallinity index was obtained according to the type of soil (Table 2), the results obtained in Neossolo Quartzarênico showed no major differences, and Mandim Branca showed the greatest difference between the values obtained for the two soil types. Thus, the soil type does not appear to affect the crystallinity index of the starch.

The values obtained in the present study ranged from 31.76 to 46.73%, with no significant ($p>0.05$) differences between the highest and lowest starch crystallinity index values. However, cultivars SCS 252 – Jaguaruna and SCS 253 – Sangão (grown in Argissolo) showed values close to that of 31.0% reported by Srichuwong *et al.* (2005).

The crystalline starch region is formed by the side chains of amylopectin, while the amorphous region is composed of amylose and branched amylopectin. Thus, the crystallinity of the starch is mainly related to the double helices formed by the branching of amylopectin (Hoover, 2001). This is in agreement with the results obtained for the Mandim Branca cultivar (grown in Argissolo), which has the lowest percentage of amylose and consequently the highest relative crystallinity. However, cultivar STS 1309/96-7, which showed the highest amylose content, did not show the lowest crystallinity index. Therefore, other factors, such as the molecular structure of amylose and amylopectin, may affect the crystallinity index of starch granules.

All samples of cassava starch were extracted at a same procedure, but some of they presented fragile granule, which can be related with the same response on industrial extraction. Since the damaged starch granules are more susceptible to the action of enzymes (Karkalas *et al*., 1992), susceptibility to α-amylase was observed only in starches from cultivars that had the highest degree of damaged starch.

The results have a high degree of homogeneity, and for all of the cultivars the starches showed low enzymatic susceptibility, except for the starch from the cultivar STS 1302/96-3 – Vermelhinha grown in Argissolo, which was more susceptible to enzymatic attack. Therefore, this cultivar could be used for the production of alcohol since it is more susceptible to enzyme action than other cultivars. Because of its higher hydrolysis rate, this starch could also be used to produce modified starches, such as fat replacement products.

The hydrolysis rate for the starch of cultivar STS 1302/96-4 was high during the first 48 hours, followed by a decrease throughout a period of up to 72 hours. The higher hydrolysis rate in the first hours of incubation may be due to a rapid initial action of the enzyme α-amylase in the amorphous areas of granules, and thus producing maltose. This result can also be explained by the lower percentage of damaged starch observed for this cultivar in relation to others that were subjected to hydrolysis.

The microscopic analysis revealed a high degree of homogeneity in the shape of the cassava starch granules, which were rounded, oval, cupuliform, mitriform, biconcave convex, and of varying sizes. The size and shape of the starch granules are important factors for determining their potential applications. For example, small granules (2.0 μm) can be used as fat substitutes since the size of the droplets are similar to those of lipids, even though the grain size desirable for this purpose is obtained only with modification (Alcázar-Alay & Meireles, 2015).

The distribution was normal with a predominance of granules with diameters between 9.11 and 17.86 μm (cultivar STS 1311/96-1) and with smaller diameters between 5.54 to 14.24 μm (cultivar STS 1302/96-4). This verifies the fact that besides the size and shape of the granules varying according to the botanical source, small variations may occur between cultivars or cultivars of the same plant species.

Ladeira *et al*. (2013) reported average diameters of 20 μm. Those values are according than those found in this present study. STS 2/3-10, SCS 252 Jaguaruna, STS 1302/96-3 (Vermelhinha) and STS 2/03-7 cassava roots, produces larger starch granules and have higher enzymatic susceptibility.

The amylose and the lipid content have a significant effect on granule swelling capacity when heated in excess water (Morrison *et al.*, 1986). Starch with high amylose content does not swell as much as those with a lesser content; this is because the amylopectin fraction is responsible for the swelling and amylose acts as a diluent factor This statement is in agreement with the results obtained in this present study (Table 3), suggesting that the higher amylose content of the starch noted for cultivar STS 1309/96-7 limited swelling of the granules at almost all the temperatures, and thus influencing on the swelling power. The same analogy would not serve as an explanation for the low swelling power of cultivar Mandim Branca, from Argissolo, since it showed a low amylose content.

Perhaps the amount of lipid present in this cultivar in relation to the others is directly interfering in the swelling power through steric hindrance. Upon analyzing the same cultivar, Mandin Branca, grown in two different types of soil, the cultivar from Argissolo showed a lower amount of amylose and a higher swelling power in relation to the cultivar grown in Neossolo Quartzarênico.

Despite the starch sample from cultivar STS 1302/96-3 – Vermelhinha from soil Quartzarênico having a lower percentage of amylose in comparison with the sample from

Argissolo, its swelling power was only higher at temperatures above 60 °C. This fact is explained by the increased strength of hydrogen bonds, which keeps the structural arrangement. The cultivar STS 1302/96-3–Vermelhinha from Quartzarênico soil changed only after the gelatinization temperature was above 60 °C.

Since the starch sample from cultivar STS 1302/96-3 – Vermelhinha grown in Argissolo has the highest intrinsic viscosity (3.52 $mL.g^{-1}$) among the cultivars studied (non published data), a higher swelling power was also expected; however, this fact was only observed at 50 °C. This may have occurred because this cultivar has the second highest lipid content, which may be added to the starch granule through inclusion complex. Moreover, a higher swelling power at the rest of the temperatures analyzed was expected. Another explanation could be the fact that this cultivar has the highest proportion of damaged starch and premature swelling at lower temperatures since the broken regions facilitate penetration of water.

Even though the starch sample for cultivar Preta showed a high swelling power at temperatures from 60 to 80 °C, this was not observed for its solubilization index, although it does not contain a lower amount of amylose in relation to the other cultivars. Perhaps, this fact can be explained by much of the amylose in this cultivar being very heavily involved with the crystalline arrangement of amylopectin (Whistler & Paschal, 1965).

It is possible to note that solubility increases with the increase in temperature and becomes more accentuated after 60 ° C. This is so because starch gelatinization begins from this temperature on. During gelatinization, the crystalline structure of starch is broken due to the relaxation of hydrogen bonds and water molecules interact with the hydroxyl groups of amylose and amylopectin, thereby causing a swelling of the starch granules and in partial solubilization (Hoover, 2001).

The construction of the descriptive model based on the calculation of the principal components allowed to detect patterns of similarity and some inferences on the chemical behavior and structural properties of the starch granules studied. Based on the nearby location of the cultivars in the eigenvectors of the PCA, it is possible to discriminate the cultivars according to their characteristics and, from that, infer what specific industrial and/or food applications are more suitable for these starches.

In the principal component analysis applied to the data of the chemical and structural properties of the starch granules analyzed, the first three components showed 27.19, 24.48 and 18.08% of variation, respectively, expressing 69.75% of the total variance (Figure 1). The swelling power and solubility index variables are positively correlated in PC1+, while the enzymatic susceptibility and damaged starch represent the most significant variables in PC1-. The second component is mainly correlated to the size of granules in PC2+ and to the crystallinity index in PC2-. The variables with the largest expressed factorial contributions in the third component were the lipid content in PC3+ and the amylose concentration in PC3-.

Cultivars SCS252 Jaguaruna and STS1302 96-3 grown in argissolo are located in PC1-/PC2 +, close to the eigenvectors corresponding to enzymatic susceptibility and damaged starch, precisely because they have higher values for these variables. These starches could be used to produce modified starches, such as fat replacement products, since they have a higher hydrolysis rate. The damaged starch and susceptibility to enzymatic activity variables showed a positive correlation (Pearson correlation, r = 0.504) for these samples.

Amylose and swelling power showed a negative correlation (r = -0.339) and they are configured in the PCA in opposite quadrants because the amide fraction responsible for granule swelling is amylopectin. Solubility and swelling power showed a positive correlation (r = 0.472).

Cultivars STS 1309-96-7 and STS 203-10 are located in PC1 and PC2 - together with the eigenvector related to amylose, these cultivars have the highest amylose content and therefore showed limited swelling power. These starches with high amylose contents could be used for preparation of foods that need to be crisp and resilient, such as chips.

Table 3 - Solubilization index and swelling power of cassava starches at several temperatures.

Solubilization index					
Cultivar	**Temperature (°C)**				
	50	**60**	**70**	**80**	**90**
STS 2/03-10 (raiz branca)	0.52	3.10	11.65	17.89	24.67
SCS 252 – Jaguaruna	0.14	2.73	10.98	18.37	28.34
Mandim Branca *	0.28	3.06	6.84	18.51	29.16
Mandim Branca **	0.15	1.92	15.84	20.60	28.87
STS 1302/96-3 – Vermelhinha *	0.29	2.95	10.38	16.61	28.67
STS 1302/96-3 – Vermelhinha **	0.21	5.50	12.85	15.61	30.32
SCS 253 – Sangão *	0.60	2.61	10.28	15.72	29.30
SCS 253 – Sangão **	0.65	2.56	12.87	14.72	30.37

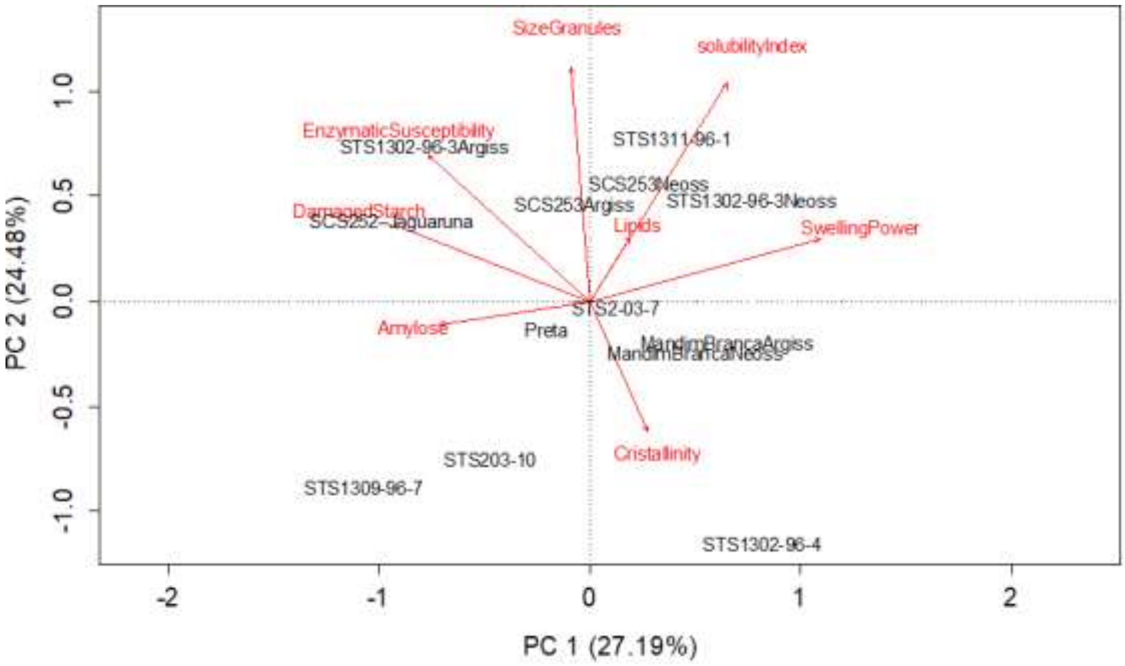
STS 1311/96-1	0.66	2.07	10.59	13.71	30.73
STS 1302/96-4	0.43	2.47	9.54	15.93	25.60
Preta	0.73	3.31	11.19	20.05	26.33
STS 1309/96-7	0.35	1.36	8.55	18.72	21.81
STS 2/03-7	0.49	1.89	10.98	21.54	31.13
Swelling power					
STS 2/03-10 (raiz branca)	2.74	9.12	21.74	28.77	37.89
SCS 252 – Jaguaruna	2.20	8.42	21.22	28.97	34.37
Mandim Branca *	2.06	8.09	20.85	30.99	40.31
Mandim Branca **	1.95	6.49	18.04	28.39	40.03
STS 1302/96-3 – Vermelhinha *	3.15	10.29	19.64	25.61	38.02
STS 1302/96-3 – Vermelhinha **	2.20	9.85	20.53	28.79	42.76
SCS 253 – Sangão *	2.36	10.59	19.77	28.51	38.96
SCS 253 – Sangão **	2.26	10.10	22.87	27.61	42.41
STS 1311/96-1	2.23	8.94	23.01	30.79	42.38
STS 1302/96-4	2.29	10.91	22.35	32.41	41.06
Preta	2.84	12.88	22.92	35.32	41.09
STS 1309/96-7	2.01	5.29	16.15	28.06	35.93
STS 2/03-7	2.16	8.05	20.83	30.01	38.95

*Sample of cassava root cultivated in Argissolo. **Sample of cassava root cultivated in Neossolo Quartzarênico.
Source: Authors.

These starches also showed improved properties in film-forming and lower digestibility than those with higher levels of amylopectin and thus they promote a slower emptying of the intestinal tract. Moreover, they are pointed out for showing a lower glycemic response and could therefore be suitable for diets with a low glycemic index.

Samples of the cultivar Mandim Branca grown in Neossolo Quartzarênico and Argissolo are grouped and located close to the eigenvector referred to the crystallinity index, corroborating the information that the type of soil does not affect the crystallinity of these starch granules. A certain degree of crystallinity is desirable when used in the pharmaceutical industry to maintain the specificity of drug release and other functional properties.

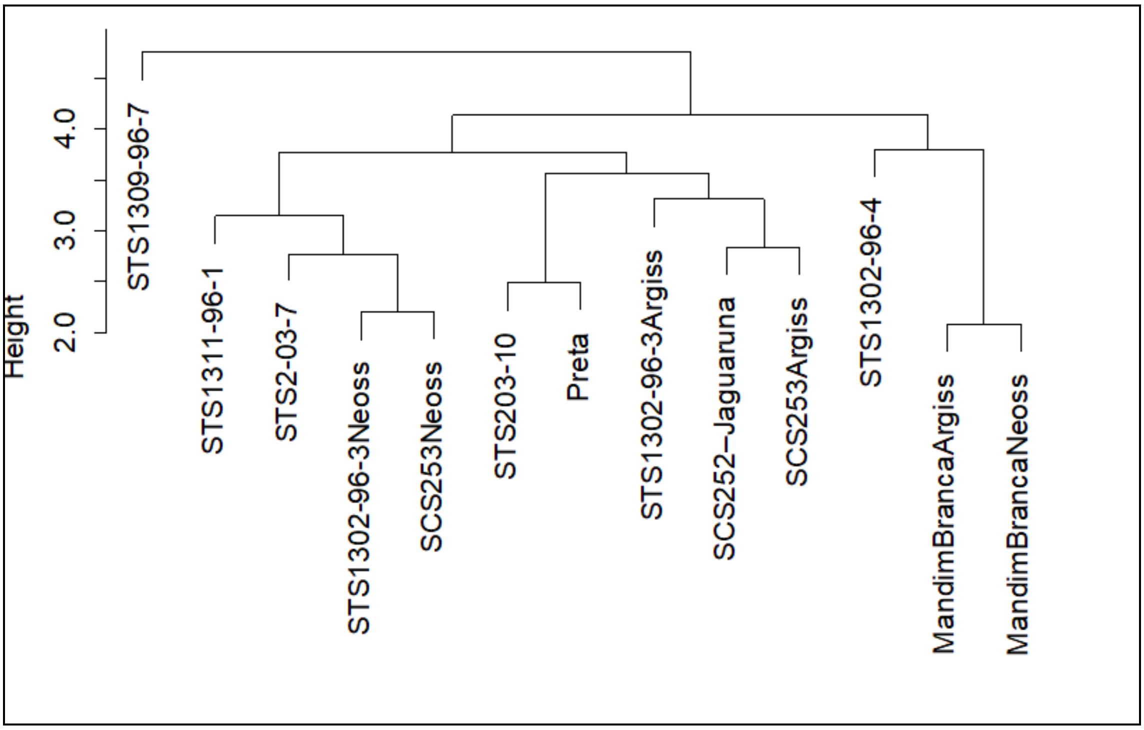
Figure 1 - Principal components analysis (PCAs) scores scatter plot of chemical and structural properties of the starch granules.



Source: Authors.

The principal components analysis allowed for the acceptable separation among the starches of the cassava cultivars evaluated. The similarities were defined based on the distance (Euclidean distance) between two samples using arithmetic average (UPGMA). The cultivars with greater similarity in their chemical and structural properties of the starch granules are represented by cluster hierarchical analysis in Figure 2. The cophenetic correlation (similarity between genotypes members of the same cluster) was 79.45%.

Figure 2 - Similarity of starches of different cassava cultivars in respect to their chemical and structural properties. Hierarchical cluster dendrogram analysis UPGMA method with 79.45% of cophenetic correlation.



Source: Authors.

It is assumed, therefore, that the concomitant use of the technologies employed in this work is of great interest to investigate the structural characteristics of the starch granules originating from *M. esculenta*.

4. Conclusions and Suggestions

The results obtained can be used as support tools for improvement of cassava genetics, optimizing the process of selection and maintenance of a genetic bank. Additionally, these results emphasize the importance of the maintenance of this cultivar on farms run by small farming families in southern Brazil, as well as in germplasm banks, in order to preserve them because they represent an important source of plant genetic resources with promising nutritional and industrial features.

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