Ciência Rural, Santa Maria, v.46, n.9, p.1514-1520, set, 2016 http://dx.doi.org/10.1590/0103-8478cr20150905
ISSN 1678-4596 CROP PROTECTION

Physico-chemical characterization of banana varieties resistant to black leaf streak disease for industrial purposes

Caracterização físico-química de variedades de banana resistentes à sigatoka negra para fins industriais

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ABSTRACT

Cultivated bananas have very low genetic diversity making them vulnerable to diseases such as black-Sigatoka leaf spot. However, the decision to adopt a new banana variety needs to be based on a robust evaluation of agronomical and physical-chemical characteristics. Here, we characterize new banana varieties resistant to black-Sigatoka leaf spot and compare them to the most widely used traditional variety (Grand Naine). Each variety was evaluated for a range of physic-chemical attributes associated with industrial processing and flavor: pH, TTA, TSS/TTA, total sugars, reducing sugars and non-reducing sugars, humidity, total solids and yield. The Thap Maeo variety had the highest potential as a substitute for the Grand Naine variety, having higher levels of total soluble solids, reducing sugars, total sugars and humidity. The Caipira and FHIA 2 varieties also performed well in comparison with the Grand Naine variety. Cluster analysis indicated that the Grand Naine variety was closely associated with varieties from the Gross Michel subgroup (Bucaneiro, Ambrosia and Calipso) and the Caipira variety, all of which come from the same AAA genomic group. It was concluded that several of the new resistant varieties could potentially substitute the traditional variety in areas affected by black-Sigatoka leaf spot disease.

Key words: ***Musa*** *spp., postharvest, raw material, aptitude, multivariate analysis.*

RESUMO

A cultura da banana tem baixa diversidade genética, tornando a espécie susceptível a doenças dizimadoras como a Sigatoka negra. No entanto, a adoção de novas variedades necessita de avaliações agronômicas e físico-químicas. Neste estudo, as variedades de banana, resistentes à Sigatoka negra, foram caracterizadas e comparadas com a variedade tradicional (Grand Naine). Cada variedade foi avaliada considerando-se critérios relevantes para a agroindústria, como pH, sólidos solúveis totais, acidez total titulável, relação SST/ATT, açúcares totais, açúcares redutores e não redutores, umidade, sólidos totais e rendimento no processamento. A variedade Thap Maeo apresentou-se como a variedade mais potencial para substituição da Gran Naine na indústria, com altos teores de sólidos solúveis totais, açúcares redutores, açúcares totais e umidade. As variedades Caipira e FHIA 2 também podem substituir a Grand Naine. Na análise de agrupamentos, verificou-se que a variedade Grand Naine esteve muito próxima das variedades do subgrupo Gros Michel (Bucaneiro, Ambroisa e Calipso) e também da variedade Caipira, apresentando no seu genoma o grupo AAA. Conclui-se que há opções de variedades resistentes para substituição da variedade tradicional, nas regiões afetadas pela Sigatoka-negra.

Palavras-chave: ***Musa*** *spp., pós-colheita, matéria-prima, aptidão, análise multivariada.*

INTRODUCTION

Banana production is very widely distributed throughout tropical zones of the world and it is, in general, constant and mostly non-seasonal (ROBINSON & SAÚCO, 2010). The evolution of most banana cultivars occurred in the Asian continent from the ***Musa acuminata*** species (A genome) or by inter-specific crosses with ***M. balbisiana*** (B genome). This generated different combinations of the A and B

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Received 06.22.15 Approved 03.28.16 Returned by the author 05.14.16
CR-2015-0905.R2

genomes, and resulted in diploid, triploid or tetraploid genotypes (DUFOUR et al., 2009), with 22, 33, or 44 chromosomes, respectively (SIMMONDS & SHEPHERD, 1995; AURORE et al., 2009).

Low genetic variability of cultivated bananas significantly increases their susceptibility to diseases such as black leaf streak disease (BLSD), caused by ***Mycospharella fijiensis*** Morelet and considered to be the most severe disease of cultivated bananas (CHURCHILL, 2011). Given the high susceptibility of cultivated bananas to pathogens, the development of resistant varieties is a vital tool for effective crop management (CORDEIRO et al., 2005). The worldwide cultivation of bananas is largely based on banana clone from the Cavendish subgroup, the Grand Naine (JANICK, 1998) variety that is extremely prone to black leaf streak disease. Moreover, black leaf streak disease in the production field can affect the metabolic processes of fruit ripening (SARAIVA et al., 2013).

The development of new banana varieties that are resistant to this disease is a major focus of the agro-businesses across the world (FERRIS et al., 2009). Some researchers have studied the differences among the varieties of banana destined for regional and local markets but not for the industry (LUCAS et al., 2012; BUGAUD et al., 2014). The majority of processed banana products are for desserts like candies, mariola and other sweets (FERRAZ et al., 2002; ALMEIDA & GODOY, 2004).

The objective of the present study was to evaluate the physico-chemical characterization of resistant banana varieties, comparing their attributes to the traditionally used Grand Naine variety for industrial purpose.

MATERIALS AND METHODS

The characteristics of resistant banana varieties and the traditionally used Grand Naine are described in table 1. All bananas were grown at the Banana Germplasm Bank at Embrapa's Cassava and Fruits in Cruz das Almas, Bahia, Brazil. Some of these varieties were recommended by Embrapa (JESUS et al., 2013).

Five replicates of each variety were used for the analysis, with each replicate originating from a single plant. Bunches were picked, with the fingers at stage 2 of maturation (green coloration) (MENDOZA & AGUILERA, 2004, VON

Table 1 - Genomic and physical characteristics of banana varieties.

Varieties	Genome	Subgroup	Genealogy	Characteristics
Grand Naine	AAA	Cavendish	Cultivar 'Cavendish'	Known as water bananas susceptible to both Sigatokas. Selected by producers, being the most cultivated variety.
Caipira	AAA	Ibota	Cultivar ('Western Africa')	Small and sweet fruits little known in the market, resistant to yellow and black Sigatoka and ***Fusarium***. Selected by producers and recommended by Embrapa.
FHIA 02[1]	AAAB	Prata	Prata Anã hybrid (FHIA)	Fruits similar to those of Prata Anã, susceptible to ***Fusarium***, moderately resistant to yellow and black-Sigatoka. Hybrid created by FHIA.
Thap Maeo	AAB	Mysore	Cultivar of the 'Mysore' type (Thailand)	Very productive, small fruits similar to the silk type banana but with different flavor, resistant to both yellow and black Sigatoka and ***Fusarium***. Selected by producers and recommended by Embrapa.
FHIA 18[2]	AAAB	Prata	Prata Anã hybrid (FHIA)	Prata type fruits which drop easily, resistant to Black Sigatoka, moderately resistant to yellow Sigatoka and susceptible to ***Fusarium***. Hybrid created by FHIA and recommended by Embrapa.
Bucaneiro	AAA	Gross Michel	High Gate hybrid (Jamaica)	Fruits similar to Gross Michel, not tested in the market, resistant to black-Sigatoka and ***Fusarium***. Hybrids from Jamaica and introduced in Brazil.
Ambrosia	AAA	Gross Michel		
Calipso	AAA	Gross Michel		

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SOURCE: SILVA, Santos-Serejo and Cordeiro (2004); SILVA et al. (2001).

LOESECKE, 2008). Bunches were pulverized with 2 cloroetilphosphonic-acid (500ppm) and stored in cold chambers at (15°C, 90% RH) until the analysis. Physico-chemical evaluation was carried out at stage 6 level of maturation (all yellow). Samples were prepared with ten banana fingers (each were replicated).

The pH was evaluated by a direct reading using a pHmeter method 017/IV (INSTITUTE ADOLFO LUTZ, 2005). Total soluble solid levels (TSS) were carried out by direct readings using refractometer method 932.12 (AOAC, 2000). Total Titrable Acidity (TTA) were obtained by titration, method 942.15 (AOAC, 2000). Sugar/acidity was determined by using the TSS/TTA ratio. Total solids and humidity data were obtained utilizing an incubator and were dried at 70°C, method 920.151 (AOAC, 2000). Reducing sugar and total sugar levels were determined by spectophotometry using the DNS (3.5 –Dinitrate – Salicilic), reagent with a reading at 540 nm (MILLER, 1959). For total sugars, hydrolysis was carried out. Non-reducing sugars were obtained by calculating the difference between total sugars and reducing sugars multiplied by a 0.95 conversion factor (conversion for sucrose). Mass yield evaluation was obtained by gravimetry (weight of peeled banana/weight of banana with peel x 100).

The experiment used a complete random block design. Analysis of variance was carried out and averages of the treatment were grouped by the Duncan test at 5% probability. Multivariate cluster analyses techniques were also carried out. Statistical analyses were performed with Statistic and Gene Computer Software for Genetics and Statistics.

RESULTS AND DISCUSSION

Physico-chemical profiles of the varieties

Banana varieties varied considerably in their physico-chemical characteristics (summarized in Table 2 and Table 3). Caipira variety gave the highest pH among the varieties in this study although it did not differ significantly from the Grand Naine and Ambrosia varieties. Critical pH value for food processing is above 4,6 due to ***Clostridium botulinum*** growth. JESUS et al. (2004) reported higher pH values for the Caipira variety (4.68) when it was compared to the Thap Maeo and FHIA 18 varieties, with pH 4.37 and 4.60 respectively. SOUZA et al. (2013) and BEZERRA & DIAS (2009), observed no significant variance of pH, when evaluating varieties FHIA 18, Thap Maeo and Caipira.The FHIA 02 and Thap Maeo varieties had the lowest pH values. GIBERT et al. (2009) reported similar values of pH for Cavendish groups.

The FHIA 02 variety had the highest TTA values followed by the Thap Maeo variety, SOUZA et al. (2013). This fact was also confirmed by JESUS et al. (2004), which noted high levels of ATT for variety Thap Maeo (0.53). BEZERRA & DIAS (2009) also reported high levels in TTA for the variety Thap Maeo. The less acid varieties were the Caipira and Grand Naine, both containing 0.34g malic acid $100g^{-1}$. JESUS et al. (2004) also observed smaller TTA values in the Caipira range (0.25). Using less acid bananas, acidification is necessary to create products such as sauces, candy, fruit pulp and fruit syrup (DE MARTIN et al., 1985).

Table 2 - Physico-chemical characteristics of different banana varieties.

Variety	pH	TTA % malic acid	TSS ºBrix	TSS/TTA	Mass yield %
Bucaneiro	4.97 b	0.42 cd	19.25 cd	46.21 bc	71.13 bc
Calipso	4.94 b	0.42 cd	18.52 d	45.39 bc	66.37 ab
Thap Maeo	4.72 c	0.58 ab	22.13 a	38.31 bc	72.58 a
Caipira	5.27 a	0.34 d	21.50 ab	65.05 a	71.90 a
FHIA 18	4.69 c	0.50 bc	19.75 cd	39.15 bc	62.98 b
Ambrosia	5.10 ab	0.42 cd	20.53 bc	52.63 ab	62.19 b
FHIA 02	4.59 c	0.64 a	21.31 ab	33.00 c	61.99 b
Grand Naine	5.14 ab	0.34 d	21.53 ab	63.10 a	65.89 b
Mean	4.92	0.45	20.56	47.85	66.88
CV(%)	3.26	18.68	4.81	20.11	7.81

Averages followed by the same letter belong to the same group (Duncan test at 5% probability).

Table 3 - Physico-chemical characteristics of different banana varieties.

Variety	Total Sugars % glucose	Reducing Sugars % glucose	Non-reducing Sugars % sucrose	Humidity %	Total Solids %
Bucaneiro	15.23 cd	17.41 c	2.94 bc	78.81 abc	21.19 de
Calipso	15.61 bcd	17.74 c	2.91 bc	79.37 a	20.62 e
Thap Maeo	19.77 a	20.64 ab	1.86 c	75.34 e	24.65 ab
Caipira	11.18 e	17.83 c	7.20 a	76.00 de	23.99 ab
FHIA 18	17.00 abc	18.33 c	2.18 c	78.32 abc	21.67 cde
Ambrosia	14.26 cde	18.63 bc	5.08 ab	77.29 bcd	22.70 bcd
FHIA 02	18.88 ab	20.89 a	2.95 bc	76.58 cde	23.41 abc
Grand Naine	12.61 de	18.70 bc	6.72 a	76.91 cde	23.08 abc
Mean	15.56	18.77	3.98	77.32	22.66
CV (%)	16.37	8.27	62.00	1.70	5.80

Averages followed by the same letter belong to the same group (Duncan test at 5% probability).

Thap Maeo had the highest TSS level, although this did not statistically differ from the Grand Naine, FHIA 02 and Caipira varieties. The Calipso variety showed the lowest TSS value, not differing from the Bucaneiro and FHIA 18 varieties. Similar results were observed by BEZERRA & DAYS (2009), where the varieties Thap Maeo and FHIA 18 had the lowest rates of SST (respectively, 78.95 and 77.48). For agro-businesses, high levels of TSS are desirable because less fruit is needed for the product concentration (NASCIMENTO et al., 2003). Some varieties of banana can present higher concentration of TSS like Robusta variety (KUDACHIKAR et al., 2011). The TTA/TSS index provides information on fruit flavor. Caipira variety gave the highest value (not differing from the Grand Naine variety or the Ambrosia variety). The lowest TTA/TSS relation was reported in the FHIA 02, Thap Maeo and FHIA18 varieties.

Fruit mass yield is related to the mass of the edible part of the banana and is of paramount economic importance in the industry since it is directly related to profitability. The varieties were characterized by only small variations in fruit mass yield, the highest values provided by Thap Maeo, FHIA 18 and Bucaneiro varieties. The FHIA 02 had the lowest yield with 66%.

Thap Maeo, FHIA 02 and FHIA 18 varieties had the highest total sugar levels (Table 3). JESUS et al. (2004). High levels of total sugars (AT) were also observed in the variety Thap Maeo (23.9%). Most of the evaluated genotypes had total sugar values between 17.41 and 18.70g glucose $100g^{-1}$. In contrast, there was a variation in the composition of reducing sugars.

The FHIA 2 variety had the highest reducing sugar levels although it did not differ statistically from the Thap Maeo. The lowest values were observed in the Bucaneiro and Calipso varieties. Presence of these sugars is a great importance to banana cultivators, since they are involved in reactions of non-enzymatic darkening during processing (OETTERER et al., 2006). The Caipira variety showed the highest non-reducing sugar content (not differing statistically from the Ambrosia variety). The lowest non-reducing sugar values were observed in the Thap Maeo and FHIA 18 varieties.

Calipso, Bucaneiro and FHIA 18 had the highest humidity level. Similar results were observed for BEZERRA & DIAS (2009), which identified differences between varieties FHIA 18 (75.91%), Caipira (75.30%) and Thap Maeo (74.01%). The lowest humidity levels were observed in the Thap Maeo and the Caipira. Results reported by JESUS et al. (2004) showed that Thap Maeo moisture was 72.9%. Lower humidity is an advantage for the industry since all banana derived products involve the loss of water during processing (SOLÉ, 2005). Total solids were inversely proportional to the quantity of water in the raw materials analyzed. Thus, the highest values were observed in the varieties with the lowest humidity.

Comparison of resistant varieties with the traditional variety

Resistant banana varieties with the greatest potential for substituting for the Grand Naine variety should be those characterized by

highest levels of total tritable acidity, total soluble solids, reducing sugars, total sugars, highest mass yield and lowest humidity levels. The most competitive variety was Thap Maeo, which performed well in six criteria: total soluble solids (3%), total tritable acidity (68%), reducing sugars (57%), total sugars (10%), mass yield (10%) and humidity (reduction of 2%). Caipira variety also had good substitution potential, possessing four desirable characteristics compared to the Grand Naine variety: total soluble solids (3%), total sugars (6%), mass yield (12%) and humidity (reduction of 2%). The FHIA 02 variety also competes with the Grand Naine variety for four characteristics: total tritable acidity (87%), reducing sugars (50%), total sugars (12%) and humidity (reduction of 0.4%).

Less competitive varieties included the Bucaneiro with three superior characteristics: total tritable acidity (24%), reducing sugars (21%) and mass yield (8%). Likewise, the Calipso variety had a very similar profile to the Bucaneiro: total tritable acidity (23%), reducing sugars (24%) and mass yield (1%). FHIA 18 and Ambrosia had a similar profile when compared to the Grand Naine. They were more competitive than the traditional variety for total tritable acidity, with increments of 46% (FHIA 18) and 23% (Ambrosia). The levels of reducing sugars were 35% higher than the sugars of the Grand Naine for the FHIA 18 and 13% for the Ambrosia.

Cluster analysis

Two clusters with some degree of similarity were distinguished by the cluster analysis (Figure 1). Cluster 1 is formed by the Bucaneiro, Calipso, Ambrosia, Grand Naine and Caipira varieties. These genotypes contain the A genome, despite the fact that the Grand Naine and Caipira are triploids and the other three tetraploids. The observed association between the Bucaneiro and Calipso varieties and their proximity to the Ambrosia variety is a result of the three being complete siblings, Gros Michel hybrids and progenies of the same parental genotypes. Cluster 2 contains the FHIA 18, FHIA 2 and Thap Maeo varieties, which all contain the B genome. The varieties closest to the Grand Naine were the Ambrosia and the Bucaneiro and the most distant variety was the Thap Maeo (verified by Mahalanobis distance D^2).

CONCLUSION

In conclusion, the Thap Maeo variety possesses the greatest number of advantages for processing in comparison to the traditional variety (Grand Naine), followed by the Caipira and FHIA 02 varieties. These varieties have great potential to substitute for the Grand Naine variety in areas that suffer from black leaf streak disease. Future research needs to assess the potential for large-scale production of these varieties and evaluate the economic feasibility of replacement.

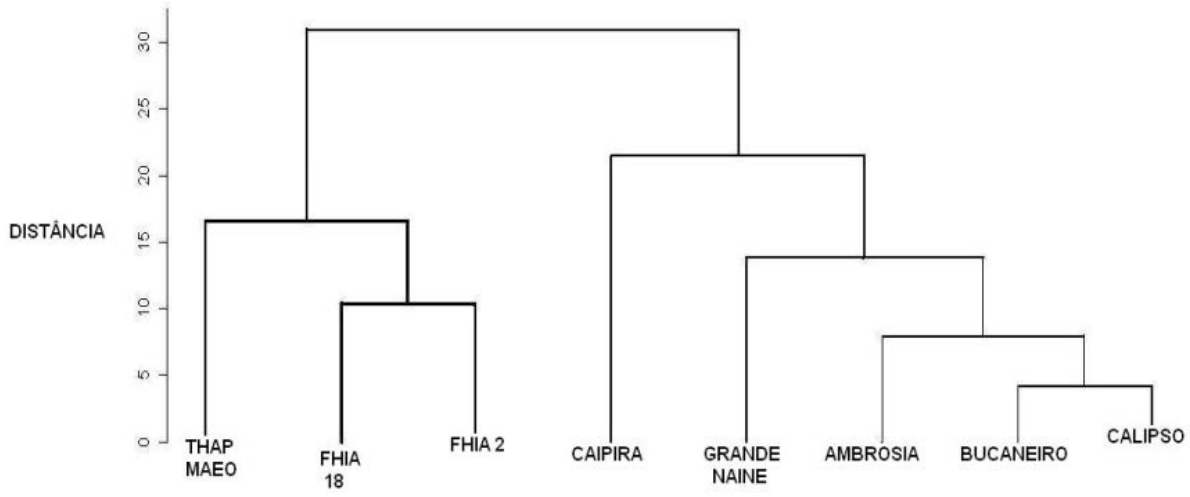

Figure 1 - Cluster analysis of different banana varieties.

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