Original article

Comparison of characteristics of bananas (*Musa* sp.) from the somaclone CIEN BTA-03 and its parental clone Williams

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Comparison of characteristics of bananas (*Musa* sp.) from the somaclone CIEN BTA-03 and its parental clone Williams.

Abstract — Introduction. Banana plants (*Musa* sp.) face problems caused by diseases such as Yellow Sigatoka (*Mycosphaerella musicola*), which is responsible for significant economic losses. Through micropropagation techniques, a somaclone variety called CIEN BTA-03 resistant to this disease was obtained. The purpose of this study was to compare fruits of somaclone CIEN BTA-03 and its parental clone Williams. **Materials and methods**. Fruits from both clones were studied, determining shape, weight, dimensions, proportions, pulp viscosity and consistency, total solids, soluble solids, pH, titratable acidity, sugars, ash, total phenolic content and crude fiber, and analyzing their color, odor and taste. **Results and discussion**. Clones differed in shape, weight and [pulp/peel] ratio. Pulps also differed in viscosity, pH, and soluble solids, sugars and phenolic compound contents. Differences between the two clones favored clone CIEN BTA-03, since it was better ranked for the color, odor and taste characteristics. **Conclusion**. Despite being resistant to Yellow Sigatoka, somaclone CIEN BTA-03 shows better sensory characteristics than its parental clone Williams.

Venezuela / *Musa* / *Mycosphaerella musicola* / variety trials / agronomic characters / chemical composition / organoleptic properties

Comparaison des caractéristiques du somaclone de bananier CIEN BTA-03 (*Musa* sp.) et de son clone parental, Williams.

Résumé — Introduction. La culture du bananier (*Musa* sp.) doit faire face à divers problèmes dont certaines maladies comme la Sigatoka jaune (*Mycosphaerella musicola*). Cette maladie entraîne des pertes économiques considérables. À l'aide de techniques de micropropagation, une variété de bananier somaclonale a été obtenue. Cette variété nommée CIEN BTA-03 est résistante à la Sigatoka jaune. Notre étude a cherché à comparer les fruits du somaclone CIEN BTA-03 et de son clone parental Williams. **Matériel et méthodes**. Les fruits des deux clones ont été caractérisés selon leur morphologie et composition, dont leurs forme, poids, dimensions, proportions, viscosité de la pulpe et consistance, contenu en solides totaux, solides solubles et sucres, pH, acidité totale, cendres, composition phénolique totale et en fibre brute, ainsi que selon les caractéristiques organoleptiques telles que la couleur, l'odeur et le goût. **Résultats et discussion**. Les clones étudiés ont présenté des différences de forme, poids, ainsi que de rapport [pulpe/peau]. D'autre part, les pulpes se sont différenciées par leur viscosité, pH, solides solubles, contenu de sucres et composition phénolique totale. Les différences trouvées entre les deux clones étudiés nous permettent d'établir que le clone CIEN BTA-03 possède des caractéristiques favorables de couleur, odeur et goût. **Conclusion**. Outre le fait d'être résistant à la Sigatoka jaune, le somaclone CIEN BTA-03 a de meilleures caractéristiques sensorielles que son parent Williams.

Venezuela / *Musa* / *Mycosphaerella musicola* / essai de variété / caractère agronomique / composition chimique / propriété organoleptique

1. Introduction

Banana (*Musa* sp.) is a very important fruit worldwide. Only citrus fruit surpasses its global production, which was close to 70 Mt in 2002; this represents a 16.37% increase in a 5-year period. [1].

Asia is the main banana-growing continent in the world (50.56%), followed by South America (25.35%), Africa (10.46%) and Central America (9.02%). India is the main banana-producing country (23.02%), which is followed by Ecuador (10.88%) and Brazil (9.16%) [1].

Banana is a major dietary source of vitamin and potassium for people living in production areas. Likewise, it is an employment and currency source because of its high commercialization level. Only 23% of the global banana production were exported in 1999 (with an estimated value of $4,727,042,000). However, many countries such as Ecuador, Costa Rica, Guatemala, Honduras, and Panama, among others, export a large part of their production [1].

One of the biggest problems facing banana cultivation is the presence of pathogens, which reduce the harvest yield. Banana plants are mainly affected by Black Sigatoka (*Mycosphaerella fijiensis*), Panama disease (*Fusarium oxysporum*) and Yellow Sigatoka (*Mycosphaerella musicola*). That last fungus produces leaf spots, which reduce the photosynthetic area, affecting bunch growth. Yellow Sigatoka causes significant economic losses, since fruits show low-quality features due to premature ripening, and small size, low weight and angular shape of the fruit [2, 3]. Likewise, the banana pulp gets a slightly pink color, acid taste and higher tannin content [4, 5].

Since Yellow Sigatoka affects a high percentage of banana plantations throughout Latin America, remarkable efforts have been made to control this devastating disease [2, 6, 7]. In this regard, international institutions have designed strategies to control plagues and diseases by developing banana and plantain varieties resistant to the disease [8, 9], controlling its high incidence through structural characteristics that act as physical barriers [3, 10] or biochemical mechanisms activated after the pathogen has penetrated [5, 11–14].

Developing resistance to diseases through genetic enhancement has been tried for several vegetable species. Regarding the *Musa* gender, applying this strategy is particularly difficult because fruit varieties with commercial value are parthenocarpic [15]. Therefore, non-conventional methods such as micropropagation have been used. This method makes it possible to produce materials with genetic differences, known as somaclonal variations. Somatic mutations of banana have produced materials with considerable agronomic value. Many of them are commercially exported worldwide [9, 16, 17].

A somaclonal variant resistant to Yellow Sigatoka, called CIEN BTA-03, was obtained from studies with Musaceae and micropropagation techniques [8] by inducing adventitious buds of the triploid Williams (Cavendish subgroup), which is susceptible to the disease. Additionally to its resistance to Yellow Sigatoka, that somaclonal variant has distinguishing characteristics, such as leaves 1.4 times thicker than those of the Williams clone, fewer stomas per area in both the upper and lower epidermis [3, 10] and higher phenolic compound content [14]. Moreover, cytogenetic analysis evidenced that both CIEN BTA-03 and the clone Williams have mosaic chromosomic structures: 65% of the cells of the variant have more than 33 chromosomes and 35% of them have less than 33 chromosomes, while 22% of Williams' have more than 33 chromosomes and 78% less than 33 chromosomes [13]. The results of molecular analysis using polymorphic DNA markers randomly amplified and group analysis (cluster) show that the somaclonal variant CIEN BTA-03 (AAAA) is not closely related to the Cavendish subgroup, where the parent cultivar Williams (AAA) is grouped [12, 13]. More recently, the genetic relationship between the clone Williams and CIEN BTA-03 was analyzed using microsatellite markers; the study concluded that there is a big genetic relationship between the tetraploid somaclone and its parental triploid clone Williams, although the somaclone CIEN BTA-03 does not cluster in the Cavendish subgroup [18]. On the other hand, it is worth mentioning that the somaclone CIEN BTA-03 shows good agronomic characteristics since it produces 34.53 kg bunches with a productivity index of 0.28 kg per day [14].

Differences found so far between CIEN BTA-03 and the clone Williams determined the need to assess other characteristics of these clones to make a more complete analysis.

The purpose of this study is to characterize the fruits of both clones in terms of physical, chemical and sensory aspects, to test quality parameters, and to identify similarities or differences between the studied clones.

2. Materials and methods

2.1. Materials

The fruits studied were cultivated at the *Estación Experimental de Samán Mocho* of the Agronomy Faculty of the Central University of Venezuela, located in Carabobo State, Venezuela. Three bunches of each clone were used. Ninety fruits were randomly chosen from different locations in the bunch. Except for the weight, dimension and proportion determinations, all analyses were done in triplicate.

All the physical analyses were carried out on fresh fruits on the same day. Once separated from the pulp, the skin was cut into small pieces and macerated for its analysis.

2.2. Methods

2.2.1. Physicochemical measurements

Intact fruits were subjected to weight, dimension (length and diameter) and skin/pulp proportion analyses. Consistency and viscosity were determined on macerated pulp using a Bostwick consistometer and a Brookfield viscosimeter (LTF, spinder No. 4 at 35 °C), respectively. The pH analysis was done with a Metrohm pH-meter, 620 [19]. The results of soluble solids were expressed as °Brix at 20 °C and determined with a Bausch & Lomb refractometer, 33.46.10 [20]. Likewise, total solids, titratable acidity up to pH 8.1, ash, reducing sugars, total sugars, crude fiber [19] and total phenolic content were accurately analyzed [21].

2.2.2. Sensory evaluations

Thirty non-trained panelists were asked to rate 1-cm-thick banana slices. A 6-point hedonic scale was used to rate color, odor and taste, where 6 means “like very much”, 4: “neutrality” and 1: “dislike very much”. Samples were codified with three randomly chosen digits and given to the panelists on trays, varying their position. Panelists were instructed to eat some crackers and drink some water before tasting each sample.

2.2.3. Statistical analysis

Variation analysis and Duncan’s multiple range test ($P = 0.05$) were used to compare the results obtained from the analysis of the different samples.

3. Results and discussion

3.1. Physical characteristics of fruits and pulp

Fruits from the Williams and CIEN BTA-03 clones showed different shapes. The fruit from the somaclone CIEN BTA-03 was less curved than the fruit from Williams (*figure 1*).

Figure 1.
Silhouettes of clones Williams and CIEN BTA-03 (*Musa* sp.).

Table I.
Morphological characteristics of fruits from clones Williams and CIEN BTA-03.

Clone	Weight (g)	Dimensions (cm)		[Weight/length] ratio	Proportions (%)		[Pulp/skin] ratio
		Length	Maximum diameter		Pulp	Skin	
Williams	160.37 ± 12.33[a]	15.88 ± 0.97[a]	13.23 ± 0.43[a]	10.10	72.62 ± 1.77[a]	27.38 ± 1.77[a]	2.80
CIEN BTA-03	153.49 ± 14.08[b]	16.66 ± 0.90[a]	12.52 ± 0.10[b]	9.21	69.19 ± 2.46[b]	30.81 ± 2.46[b]	2.25

Means within columns followed by the same letter are not significantly different according to Duncan's multiple range test (P = 0.05). Number of replicates for weight and dimensions is n = 90 and for proportions, n = 30.

Table II.
Physical parameters of the pulp of fruits from clones Williams and CIEN BTA-03.

Clone	Viscosity (cP)				Consistency (cm·30 s^{-1})
	6 rpm	12 rpm	30 rpm	60 rpm	
Williams	12330[a]	8085[a]	3934[a]	2667[a]	6.7[a]
CIEN BTA-03	5500[b]	3750[b]	2560[a]	1920[b]	6.9[a]

Means within columns followed by the same letter are not significantly different according to Duncan's multiple range test (P = 0.05). Number of replicates: n = 3.

Besides shape dissimilarities, fruits from both clones showed statistically significant differences regarding weight and maximum diameter. However, there were no length contrasts (*table I*).

The pulp proportion of clone Williams' fruit (*table I)* is slightly higher than that of the somaclone CIEN BTA-03.

Clone CIEN BTA-03 had lower pulp viscosity values than those of Williams (*table II*).

The pH value of the clone Williams' fruit was slightly lower than that of CIEN BTA-03's. However, there were no contrasts in titratable acidity contents, or in ash and crude fiber contents.

Significant differences were observed in phenolic compounds' values, with 0.93% for the somaclone CIEN BTA-03 and 1.52% for Williams.

In the sensory analysis, the clone CIEN BTA-03 was remarkably the best ranked for odor, taste and especially color.

The weight of the two clone's fruits is higher than that reported by other researchers for varieties such as Montel and Gran Enana [20, 22, 23]. However, the weight as well as the [weight/length] ratio reported for the fruits of both clones is similar to those reported for the Enana variety [23].

Both clones have almost the same skin proportion as bananas in general [15] (approximately 33%). The [pulp/skin] ratio of CIEN BTA-03 (2.26) is similar [24] to that of Pachabale (2.17) and Rajabale (2.19); nevertheless, that ratio is higher than the one reported for the Enana variety (1.3) [23], whose pulp content is 56.52% compared with the 69.19% found for the CIEN BTA-03 fruits.

Differences in viscosity values do not necessarily mean differences in the total solid contents of both clones. The total solid content of clone CIEN BTA-03 is similar to that reported [23] for Enana (23.95%).

Table III.
Chemical parameters of the fruit pulp from clones Williams and CIEN BTA-03.

Clone	Total solids (%)	Soluble solids (ºBrix)	PH	Titratable acidity[1] (%)	Total sugars (%)	Reducing sugars (%)	Ash (%)	Total phenolic compounds[2] (%)	Crude fiber (%)
Williams	24.72[a]	20.75[a]	4.90[a]	0.30[a]	16.54[a]	15.83[a]	0.93[a]	1.52[a]	0.49[a]
CIEN BTA-03	24.13[a]	22.50[b]	5.20[b]	0.30[a]	14.61[b]	13.85[b]	0.91[a]	0.93[b]	0.48[a]

[1] = as citric acid, [2] = as tannic acid.

Means within columns followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$). Number of replicates: $n = 3$.

3.2. Composition and sensory evaluation of the fruit pulp

The pulp of the fruits studied showed differences in their soluble solid contents, which is obviously related to differences in sugar contents (*table III*). The pulp of CIEN BTA-03 had the lowest reducing sugar content, but the highest total sugar content, which probably affects the taste of both pulps as observed in the sensory evaluation (*table IV*). The soluble solid value of the CIEN BTA-03 pulp is close to that of other banana varieties [23, 25–27].

The total sugars content (14.61%) of clone CIEN BTA-03 could be considered as relatively low, despite being much higher than contents reported for the Gran Enana variety [23], and the Spanish Enana and Latin-American Enana cultivars. This value is also close to that of the "Pineo Gigante" and "Pineo Martinico" varieties [26].

The pH values reported by different researchers fluctuate between 4.11 and 5.20 [20, 23, 25–28]. Therefore, the value for clone CIEN BTA-03 was found to be at the upper limit of this scale. Similarly, the titratable acidity content of the somaclone is similar to that of other bananas [20, 24–26].

Since phenolic compounds are associated with darkening, bitter taste and astringency in bananas, the difference in total phenolic content of the two clones could explain the good taste and low enzymatic darkening tendency of clone CIEN BTA-03. Therefore, this characteristic may be associated with the better evaluation of taste and color of CIEN BTA-03, compared with Williams (*table IV*).

Table IV.
Pulp sensory analysis of fruits from clones Williams and CIEN BTA-03. A 6-point hedonic scale was used to rate color, odor and taste with 6: like very much; 4: neutrality; 1: dislike very much.

Clone	Colour	Odor	Taste
Williams	3.93[a]	4.27[a]	4.13[a]
CIEN BTA-03	5.87[b]	5.93[b]	5.67[b]

Means within columns followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$). Number of replicates: $n = 30$.

It can be inferred that differences in reducing and total sugar contents could have affected the taste of both clones. Indeed, it has been reported that differences in fructose, glucose and saccharose contents affect the taste of the Montel variety [20].

The differences in pH, soluble solids, reducing sugars, total sugars and total phenolic compounds (*table III*) seem to be favorable to clone CIEN BTA-03.

Finally, clone CIEN BTA-03 was ranked higher than Williams for sensory fruit evaluation (*table IV*), indicating that the detected differences in the physicochemical characteristics have a favorable effect on consumer acceptation of the clone CIEN BTA-03.

4. Conclusions

The shape of fruits from somaclone CIEN BTA-03 was less curved than that of fruits from its parental somaclone. The weight and pulp proportion of CIEN BTA-03 were relatively low.

Besides differing in pH, the two clones differed in the soluble solid content, sugar content and total phenolic compounds, which seems to favor the somaclone CIEN BTA-03 because it was the best ranked in color, odor and taste.

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Comparación de las características del somaclón de banano CIEN BTA-03 (*Musa* sp.) y de su clon progenitor, Williams.

Resumen — **Introducción**. El cultivo del banano (*Musa* sp.) debe afrontar diversos problemas entre los que figuran enfermedades como la Sigatoka amarilla (*Mycosphaerella musicola*). Esta enfermedad provoca pérdidas económicas considerables. Mediante técnicas de micropropagación, se obtuvo una variedad de banano somaclonal. Dicha variedad, llamada CIEN BTA-03, es resistente a la Sigatoka amarilla. Nuestro estudio tenía como objetivo la caracterización de los frutos del somaclón CIEN BTA-03 y de su clon progenitor, Williams. **Material y métodos**. Los frutos de ambos clones se caracterizaron según su morfología y composición tomando en cuenta su forma, peso, dimensiones, proporciones, viscosidad de la pulpa y consistencia, contenido de sólidos totales, sólidos solubles y azúcares, pH, acidez total, cenizas, composición fenólica total y de fibra bruta, así como características organolépticas como el color, olor y sabor. **Resultados y discusión**. Los clones estudiados presentaron diferencias de forma, peso y en la relación [pulpa/piel]. Por otro lado, las pulpas se diferenciaron por su viscosidad, pH, sólidos solubles, contenido de azúcares y composición fenólica total. Las diferencias encontradas entre los dos clones estudiados permiten afirmar que el clon CIEN BTA-03 posee características favorables de color, olor y sabor. **Conclusión**. Además de su resistencia a la Sigatoka amarilla, el somaclón CIEN BTA-03 tiene mejores características sensoriales que su progenitor Williams.

Venezuela / *Musa* / *Mycosphaerella musicola* / ensayos de variedades / características agronómicas / composición quimica / propiedades organolépticas