Incidence of the harvesting age on the behavior of postharvest characteristics of Dominico Hartón Plantain (*Musa* AAB Simmonds)

Efecto de la edad de cosecha en las características poscosecha del plátano Dominico-Hartón (*Musa* AAB Simmonds)

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Abstract

In this study a physical, chemical and physiological characterization of Dominico Hartón plantain grown in the Belalcázar municipality (Department of Caldas, Colombia) during harvest and postharvest was carried out. The research was performed with fruits of 14, 16 and 18 weeks after flowering. Every two days until senescence changes in weight, firmness, parameters of color L*a*b*, pulp/peel ratio, maturity index, pH, humidity, starch, respiration rate and ethylene rate were measured. This study used a longitudinal repeated measures design, balanced, with a three-level factor. The factor evaluated was harvesting time and the response variables were the physicochemical parameters. The results showed variation in weight near to 7%, the tint color parameter was between -61.46 and 86.74, chroma between 26.31 and 37.11 and ΔE of 1.4603 to 8360, the pH ranged from 6.2 to 3.98, pulp/peel of 2.53 to 4.11, the relationship °Brix/acidity of 11.36 to 26.2, humidity content between 60.56% and 56%, starch between 51.7% and 67% DM, the CO_2 production rate between 3.4 and 8.9 g/kg.h, ethylene from 24 to 225 µL/kg.h. The maturation parameters showed climacteric behavior and total days to ripening were 9, 14 and 21 for the fruits of 18, 16 and 14 weeks from flowering.

Key words: Agronomic characteristics, Dominico Hartón, maturation, physicochemical characteristics, postharvest.

Resumen

En el departamento de Caldas, Colombia, se realizó la caracterización fisica, química y fisiológica durante las fases de cosecha y poscosecha del plátano Dominico Hartón (*Musa* AAB Simmonds) cultivado en el municipio de Belalcázar. La investigación se hizo con frutos de 14, 16 y 18 semanas después de la floración. Cada 2 días y hasta senescencia se evaluaron los cambios de peso, firmeza, parámetros de color L*a*b*, relación pulpa/cáscara, índice de madurez, pH, humedad, almidones, índice de respiración y tasa de etileno. En este trabajo se utilizó un diseño longitudinal de medidas repetidas, balanceado, con un factor en tres niveles. El factor evaluado fue el tiempo de cosecha y las variables de respuesta fueron los parámetros fisicoquímicos. Los resultados mostraron variación en peso cercanas a 7%, el parámetro de color tinte varió entre -61.46 y 86.74, el croma entre 26.31 y 37.11 y el ΔE entre 1.4603 y 8.360, el pH varió entre 6.2 y 3.98, una relación pulpa/cáscara entre 2.53 y 4.11, la relación °brix/ acidez entre 11.36 y

26.2, la humedad entre 60.56% y 56%, el almidón entre 51.7% y 67% de MS, la tasa de producción de CO_2 entre 3.4 y 8.9 g/kg por hora, el etileno entre 24 y 225 µlt/kg por hora. Los parámetros de maduración mostraron comportamiento climatérico y los días a maduración total fueron de 9, 14 y 21 para los frutos de 18, 16 y 14 semanas desde floración.

Palabras clave: Características agronómicas, características físico-químicas, Dominico Hartón, maduración, poscosecha.

Introduction

In the coffee growing region of Colombia plantain production is estimated to be 60% of the national yield of this product, being important the crop of Dominico Hartón (*Musa* AAB Simmonds). The main production centers are in the coffee area of the Andean zone, where 234,000 ha produce 67% of the national production. In the Department of Caldas, the cultivated area is estimated in 194,249 ha with a production of 679,655 t in 3101 productive units. At the national level, this crop generates around 300,000 direct employments fixed during the year, meaning that, approximately 60,000 families are dedicated to work in this crop all over the country, and Caldas participates with about 4.8% (DANE, 2012).

Plantain losses in the Andean region happen mainly during harvest and postharvest due to bad practices during cutting and storing in the farm, deficient transport to the distribution centers and lack of technology for postharvest management and conservation. In the town of Belalcázar (Caldas) losses can reach 10% of the production, equivalent to 6 t per week according to the data of the storing center in the town. These losses can be reduced if it is taken into account the morphology, physiology and effects of the physical, chemical and biological processes happening during postharvest phase and the shelf life of the fruit (Arrieta *et al.*, 2006; Barrera *et al.*, 2010). Plantain producers in Belalcázar harvest the fruit between the 14 and 18 week after flowering, they do not consider agroclimatic conditions, which cause harvest losses and rejection in the postharvest. Studies on postharvest behavior show that during the plantain ripening process several changes take place. Arcila (2002) found that ripening can be extended till 20 days, and Morrello and Kader (2012) consider that harvest is performed according to experience, filling or angle of the fruit. Arcila *et al.* (2002) determined that the chemical composition, ripening and postharvest behavior of plantain grown in Quindío, vary with the harvesting age. Physiological ripeness of this fruit has an strong influence on the physical quality, organoleptic characteristics and shelf life in storage (Reid, 2002). Harvesting age affects time till ripening and fruit senescence (Cayón *et al.*, 2000); Azcón-Bieto and Talón (2008) and Barrera and Cayón (2004) found that respiration rate depends also on the harvesting age and it is an indicator of the speed of product deterioration.

The objective of this research was to develop technical information about the suitable time for Dominico Hartón plantain harvesting in Belalcázar, Colombia, aiming to get higher yield, better quality and longer shelf life of the product.

Materials and methods

For this study samples of Dominico Hartón harvested in Belalcázar were used. This town is located at the southwestern of the department of Caldas (Colombia), with 1800 to 2300 mm annual rainfeed, temperatures between 18 and 24°C and sandy loam soils of average fertility. In the raining season samples (clusters) were identified, which were observed each two days for their physical and chemical properties starting on the 14, 16 and 18 weeks after flowering till over-ripening of the fruits according to their visual aspect. For sample collection, clusters were labelled with tapes on plants after the first appearance of the flower capsule. In total, there were selected nine clusters, three per each harvesting week.

From each cluster were taken the second and third hand and from each one of them were taken the three central fruits (fingers). Length was measured from the floral tip till the initial point of the pedicel in the crown; to determine the measurement point for central perimeter (*P*), weight and pulp/peel ratio the total weight (whole fruit) and separate parts (pulp and peel) were taken using an digital analytical balance Mettler Toledo XP 504 with capacity for 520 g; color was determined with a Hunter LAB model DP-9000 colorimeter in the Lab for Quality Control of Casa Luker company; variables L, a*, b*, tint (Equation 1), chroma (Equation 2) and ΔE (Equation 3) were calculated as well. Firmness was determined with a penetrometer using a universal type texturometer EZTest Shimadzu table, with cells of 500 N. In pulp there were measured the chemical parameters of: acidity expressed as malic acid percentage according to the adapted method 942.05/90 of the AOAC; soluble solids (°brix) with a refractometer with scale from 0 to 30% corrected by temperature and acidity according to the Equation 4 (Icontec-NTC 4086, 1996); starch content by the Antrona modified method (AOAC 2002.02/90); pH by the AOAC 981.12/90 method; maturation index and °brix/acidity ratio; Ca and Fe by atomic absorption with a Varian Spectra AA 220 spectrophotometer; P by colorimetric method (stannous chloride) (Ferrer, 1993; Monsalve, 2001); humidity in oven (AOAC 930.15/90); respiration intensity with the Pettenkofer respiration apparatus based on the principle of CO_2 recollection in the barium hydroxide respiration process and later titration (Equation 5) (Mejía and León, 2002); ethylene production rate by gas chromatography with a Hewlett Packard 5890 series II chromatographer with fire ionization detector (FID), HP 5 column, nitrogen as carrying gas, 8.51 psi pressure, 3.7 ml/min flux, injection and detector temperature 50 °C. For the study it was used a longitudinal repeated measures design, balanced, with a three-level factor. Evaluated factor was harvesting time and the response variables were the physicochemical parameters. For data analysis it was used Anova with repeated measurements and 5% significance using the free software R (R development Core Team 2011).

$$Tint = Tan^{-1}\left(\frac{b}{a}\right) \quad \textbf{Eq. 1}$$

$$Chroma = \sqrt{a^{-2} + b^{-2}} \quad \textbf{Eq. 2}$$

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad \textbf{Eq. 3}$$

$$Corrected\ S.T = 0.194 * A + S.S.T \quad \textbf{Eq. 4}$$

where,
a = interval of colors between green (-) and red (+),
b = interval of colors between blue (+) and yellow (-),
ΔE = total change of color.
L = luminosity (0 = black, 100 = white)
A is the malic acid percentage and S.S.T. are the total soluble solids.

$$IR = \frac{(Vb\text{-}Vm)xNx22}{Wxt} \quad \textbf{Eq. 5}$$

where,
IR = Intensity of respiration,
Vb = Volume of acid in ml, used to titrate the blank,
Vm = Volume of acid in ml, used to titrate the sample,
N = Normality of the acid,
22 = meq weight of the CO_2 in mg,
W = Sample weight in kg,
t = Time in hours of continuous flux of air through the system.

Results and discussion

Physical characteristics

Composition and physical appearance of the Dominico Hartón plantain at the harvesting time changed with age from the beginning of flowering. Physical parameters (Figure 1) show that fruit weight increases while fruit filling. In the rainy season this parameter is completed at the week 18, with an average value of 45 g and an increase in weight between the weeks 14 and 16 of 30.5%, this agrees with the findings of Arrieta *et al.* (2006). This increment coincides with the increases in fruit

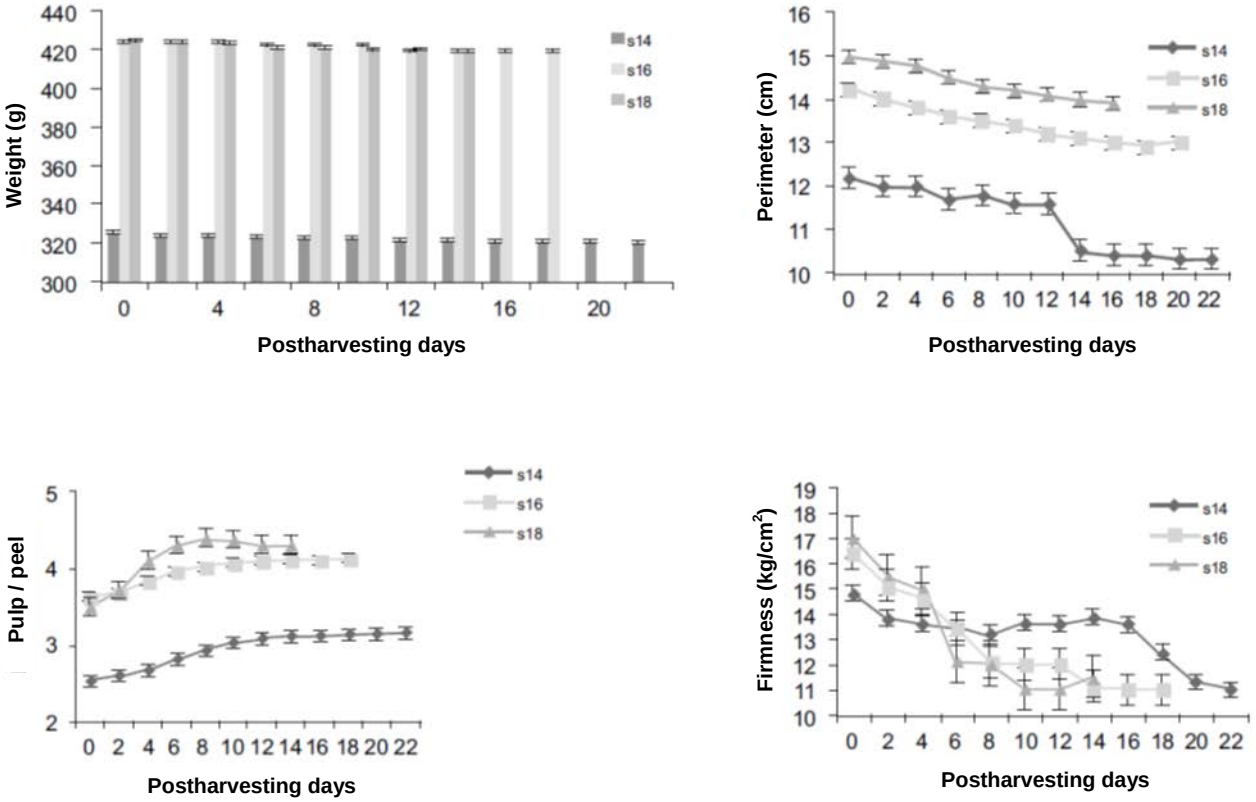

Figure 1. Physical parameters of Dominico Hartón plantain fruits at different postharvesting ages.

perimeter, thus the ratio pulp/peel did not significantly changed after the week 16. These results are caused by a larger amount of photoassimilates as a consequence of a higher solar radiation in the fruits after the week 18. During the ripening process, between the harvesting day and day 14 postharvest, fruit weight was reduced 29.75 g, equivalent to 7%, which is a variation directly correlated with harvesting age. Similarly, perimeter was reduced as consequence of humidity and volatile compound losses by respiration and transpiration, mainly in the peel. The pulp/peel ratio increased till maturity, from 3.5 to 4.38 for fruits of 18 weeks, 3.61 to 4.1 for fruits of 16 weeks and, 2.53 to 3.1 for fruits of 14 weeks. Fruit firmness (kg/cm^2) increased with the harvesting age, being 14.8 at 14 weeks, 16.4 at 16 weeks and 17 at 18 weeks at the harvesting time, however, it was reduced with ripening time being softer the filler fruits.

Tint was between -61.46 and 86.74 and chroma was between 28.71 and 28.83 ($P < 0.05$) (Table 1) and with a more intense green color in older harvesting time plantains, a darker green for the higher chroma values; evolution of the yellow color taken from the b* parameter is proportional to the total color change or ΔE parameter. In Table 1 are displayed increments ($P < 0.05$) in color on the harvested samples at 16 and 18 weeks, but not in the harvest at 14 weeks when they have not reached a pure yellow color and then they turn dark. Time to reach the yellow color in the fruits harvested at 18 and 16 weeks was 9 and 14 days, respectively, which agrees with the findings of Barrera *et al.* (2010) and Arcila (2002); contrarily, fruits harvested at 14 weeks acquire a hard consistency and brownish color 21 days after harvesting.

Chemical and physiological characteristics

In Figure 2 are displayed the chemical properties of the fruit. At harvesting time humidity had an average value of 60.2% for fruits at the three harvesting ages. On wet basis, losses were higher on 18 weeks fruits because

Table 1. Color parameter values in Dominico Hartón plantain.

Post-harvesting days	Weeks to flowering								
	14	16	18	14	16	18	14	16	18
	Tint			Chroma			ΔE		
0	-61.46	-61.55	-61.65	26.31	28.71	28.83	1.7843	3.3536	4.3721
2	-63.99	-64.23	-65.15	25.43	29.85	31.8	1.4603	2.1394	3.3644
4	-66.54	-68.63	-69.84	24.85	29.71	32.14	2.3939	2.1394	2.8188
6	-65.4	-74.45	-75.43	26.19	27.74	33.87	1.6366	2.879	5.6564
F	-69.19	-75.92	-82.13	28.52	28.48	37.11	1.8467	2.4441	3.1324
10	-69.F9	-80.61	-82.03	31.41	25.78	35.21	1.9311	3.3601	8.3601
12	-71.93	-79.12	-82.04	34.01	25.73	27.32	1.2786	5.2326	0.9987
14	-75.34	86.74	78.33	27.52	24.46	27.45	2.4516	8.5534	—
16	84.67	82.82	78.32	27.30	24.45	—	4.0611	0.616	—
18	82.17	78.65	—	27.33	25.35	—	2.0142	—	—
20	78.68	78.56	—	27.11		—	2.9194	—	—
22	78.61	—	—	27.18		—	—	—	—

they have a larger area for mass transference. These losses were, respectively, 20.3%, 6.7% and 5.02% in the 18, 16 and 14 weeks fruits. Starch content (%DW) increased with harvesting age, being 56.5, 67 and 74.8 for 18, 16 and 14 weeks fruits, respectively, which agrees with an increase in consistency. During ripening, starch was reduced approximately 7%, 15% and 32% for 14, 16 and 18 weeks fruits due to hydrolysis of simple sugars. Arrieta *et al.* (2006) and Barrera *et al.* (2009) state that °brix and acidity increase till fruit reaches the climaterium. Arcila (2002) found that the acidity increment is lower in fruits at younger harvesting age, and that is the reason why, although they reach similar °brix, they have larger °brix/acidity ratios. pH tended to stabilize after whole fruit ripening. Average concentrations of Fe, Ca and P were, respectively, 39 ppm, 15 ppm and 34 ppm, without variation as results of the harvesting age or during postharvest.

Maximum respiration and ethylene production rates happened at 18, 11 and 6 days for fruits harvested at 14, 16 and 18 weeks, respectively (Figure 3), which agrees with the results of Cayón *et al.* (2000) and Azcón-Bieto and Talón (2008).

In summary, the weeks to harvest variable had a significant effect for the pulp/peel, humidity, respiration and ethylene production rates, and color parameters. pH and firmness variables were independent of the harvesting age and dependent of the postharvesting time ($P < 0.05$). Weight variable was dependent of the harvesting age, but not of the time during postharvest.

Conclusions

- Physical characteristics and chemical composition of the clon Dominico Hartón plantain fruits varied according to the harvesting age. After 16 weeks weight and pulp/peel ratio changed although it was not significant; with harvesting age there is an improvement on the physical appearance of the fruit.
- Carbon dioxide and ethylene production rates were proportional to the harvesting age and increased till climaterium, from

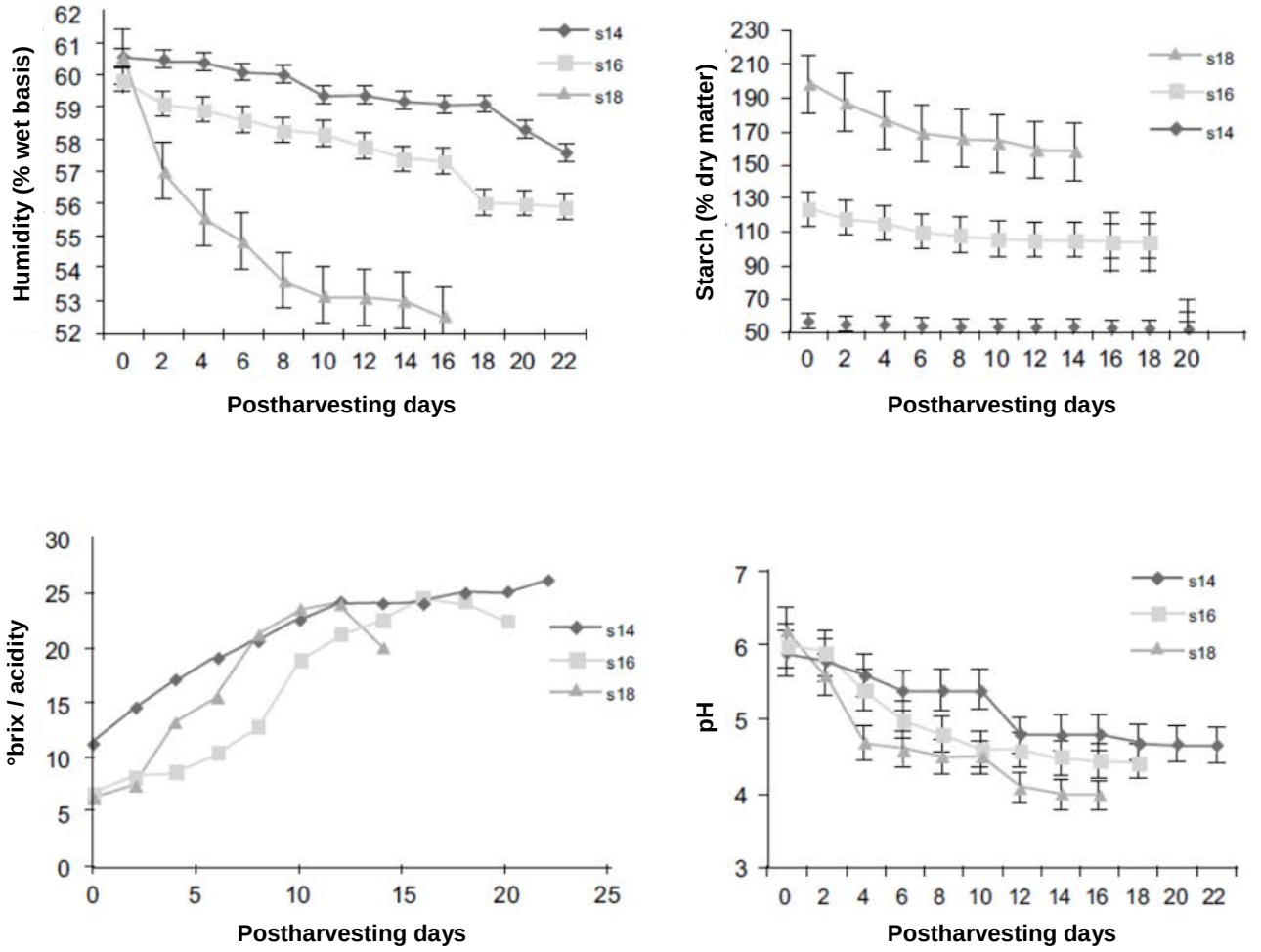

Figure 2. Chemical parameters of Dominico Hartón plantain fruits at different postharvesting ages.

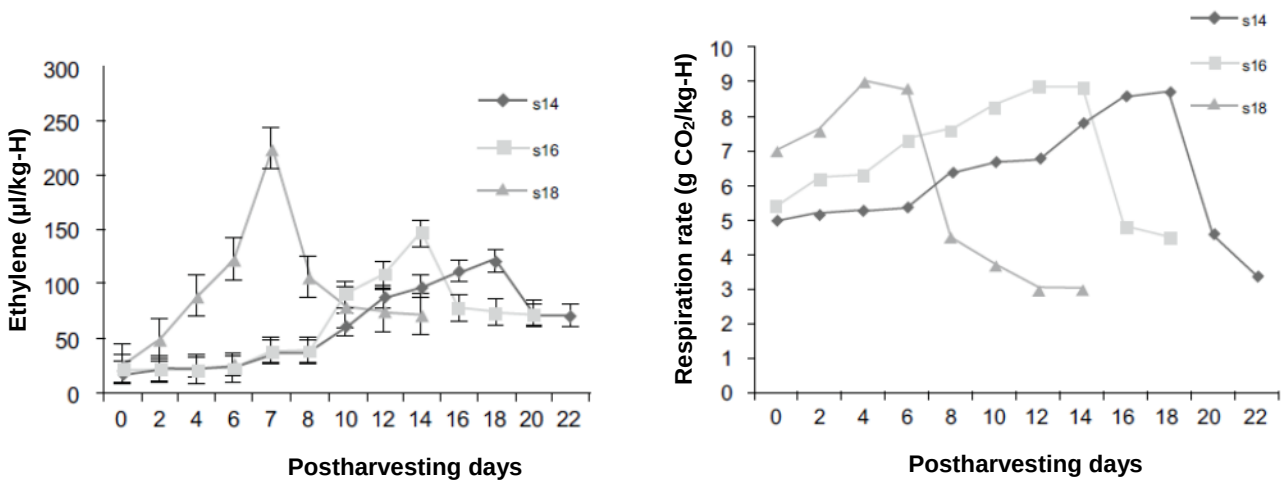

Figure 3. Physiological parameters of Dominico Hartón plantain fruits at different postharvesting ages.

that stage they were reduced till senescence.

- 18 week old fruits displayed higher starch content at the green state and there was no correlation between harvesting age and Fe, Ca and P content.
- Harvested fruits at 14 weeks did not ripened satisfactorily and their appearance, color and firmness were not suitable for marketing, additionally, they showed low pulp and peel yield and lower starch content.
- The best harvesting age was 16 weeks, age at which a later weight increment is not relevant for a longer harvesting time. At this age, the °brix/acidity ratio and starch content are comparable with fruits harvested at 18 weeks, appearance is acceptable and green shelf life is suitable for national markets.

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