ORIGINAL ARTICLE

Study of the Main Quality Properties of Banana, Orinoco Variety, Stored at Room Temperature

Estudio de las principales propiedades de calidad del plátano, variedad Orinoco, almacenado a temperatura ambiente

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ABSTRACT: Agricultural products require high quality, conditioned by their physical, chemical and mechanical properties, which are closely related to post-harvest handling and they influence the decision-making and the consumer´s preference. Hence, the interest of the research was to study the main quality properties of banana, Orinoco variety, stored at room temperature. For this, it was necessary to store 42 fruits at room temperature, dividing them into three groups of the same quantity for different types of packaging (wooden box, cardboard and bulk, taking the latter as a control). The properties (weight loss, firmness, pH, contents soluble solids) were evaluated daily during a five-day investigation period and subsequently processed using statistical tools. Characterization of this crop stored at room temperature was obtained in three forms of packaging. The properties evaluated obey a pattern of temporal variability distributed in three periods corresponding to the initial day, between two and three days and between four and five days of storage of the fruit. The best packaging was in cardboard boxes, showing minor changes in each of the properties, where the values of Pp in the five days of the experiment had maximum values of 16.76 g and on average 3.35 g per day. The models obtained for each determined and predicted property are adjusted to second order polynomials, where statistics are obtained that show the credibility of the results, which facilitates the planning of the post-harvest stage by producers and marketers.

Keywords: weight loss, firmness, pH, soluble solids, postharvest.

RESUMEN: Los productos agroalimentarios requieren de una alta calidad, condicionada por sus propiedades físicas, químicas y mecánicas, que están estrechamente relacionados a los manejos postcosecha, e infiere en la toma de decisiones. De ahí el interés de la investigación de *estudiar las principales propiedades de calidad del plátano variedad Orinoco, almacenado a temperatura ambiente.* Para ello fue necesario almacenar a temperatura ambiente 42 frutos, dividiendo en tres grupos de igual cantidad para distintos tipos de embalaje (caja de madera, cartón y a granel, tomando este último como testigo. Las propiedades (Pérdida de peso, Firmeza, pH, Contenidos de Sólidos Solubles) fueron evaluadas diariamente durante un periodo de investigación de cinco días y posteriormente procesados empleando herramientas estadísticas. Se obtuvo una caracterización de este cultivo almacenado a temperatura ambiente, en tres formas de embalaje. Las propiedades evaluadas obedecen a un patrón de variabilidad temporal distribuido en tres períodos correspondientes al día inicial, entre dos y tres días y entre los cuatro y cinco días de almacenamiento de la fruta. El mejor embalaje fue en cajas de cartón, mostrando menores cambios en cada una de las propiedades, donde los valores de Pp en los cinco días de experimento con valores máximos de 16,76 g y como promedio 3,35 g por día. Los modelos obtenidos para cada propiedad determinada y predicha se ajustan a polinomios de segundo orden, donde se obtienen estadígrafos que manifiestan la credibilidad de lo obtenido, lo que facilita la planificación de la etapa poscosecha por productores y comercializadores

***Palabras clave*:** pérdida de peso, firmeza, pH, sólidos solubles, poscosecha.

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INTRODUCTION

World agriculture is currently immersed in facing great challenges, including producing sufficient amounts of food for the population at all times of the year. In turn, it is essential guaranteeing that these have the optimum quality for their consumption as fresh and natural fruit, even after having been stored for long periods. For this reason, it is necessary to know the main properties of the fruits as well as to be able to predict in real time the changes that usually occur in these foods during storage (Tain, 2010).

The crop under study is highly coveted for its antioxidant properties and the large amount of vitamins it provides to humans, which is why the objective of the research is focused on determining the main quality properties of bananas, the Orinoco variety, stored at room temperature. atmosphere. Together with resorting to the use of novel statistical-mathematical methods that offer the search for the most effective and rapid response to all the physical, chemical and organoleptic changes that agricultural products usually experience.

In addition, by obtaining the data it will be possible to describe and predict the behavior of a phenomenon that varies over time, showing significant results of the existing trend between successive observations for a period of optimal quality for consumption as fresh fruit, which are adjusted each one of the properties to a predictive statistical model of the transformation carried out by the plantain during its storage at room temperature, as referred to in previous investigations but with other crops (Hannan, 1963; Gómez y Maravall, 1994; Coutin, 2001; Girona, 2001; Hernández y García, 2002; Santana, 2006).

MATERIALS AND METHODS

The The fruits were obtained in areas of the Ho Chi Minh Military Company of Various Crops, which is located within the Havana-Matanzas Plain. For the selection of the samples, the provisions of the FAO-182, 1993 standard adjusted to the USDA standard were followed and it was carried out by a panel of experts, using as common criteria, size, color, firmness to the touch and that the fruit be free from damage. Once the initial sample was formed, they were carefully placed in a horizontal position in a single layer, in both types of boxes (cardboard and wood) with holes to guarantee homogeneity between indoor and outdoor temperatures, until each property was determined as:

Length (cm): measuring the length of the fruit, from the outer curvature of the individual finger with a tape from the distal end to the proximal end (Figure 1), where the pulp is considered to end. (Thompson, 1998). Figure 1.

Circumference (cm): measuring the individual fruit with a tape at its widest point and turning according to its shape, as shown in Figure 2 (Martínez, 2003; Martínez et al., 2017).

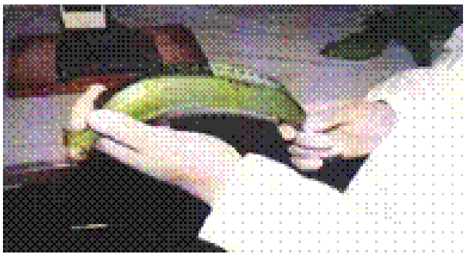

FIGURE 1. Determination of the length of the banana. Source: postharvestbook**.**

FIGURE 2. Determination of the circumference of the banana.

Volume of the fruit (cm ^{3}): weighing the fruit on an electronic scale the container with water, immerse the fruit while the container is still on the scale. The difference in grams between the two weights is equal to the **volume** of the fruit (cm^3).

Fruit density: it is obtained by expression 1, where the weight of the fruit in air is divided by its volume (Kushman et al., 1966).

$$[\delta] = \frac{P}{V}, \frac{N}{m^3} \quad (1)$$

Soluble solids content (SSC): it is determined with a refractometer (Figure 3) in which the demarcation line between these two portions crosses the vertical scale, giving the ºBrix reading according to Dadzie& Orchard (1997) and Martínez (2003).

The point, estimated from SST.

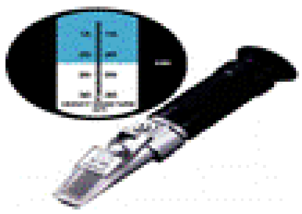

FIGURE 3. Hand refractometer.

pH:.To measure this property a digital pH meter was used.(Figure 4).

The mass was determined by weighing each fruit on an electronic scale model LG-1001[a] from 0 to 1000 g/0.1 g. Based on these values, weight loss was estimated during the days corresponding to the experiment.

Firmness: This is considered the property of this nature that best illustrates the quality of fruits and vegetables (Buitrago et al., 2004). This is the way to evaluate the resistance to compression, for this the digital durometer, Model CEMA-C08 of national manufacturing was used. Magness-Taylor principle, 0 to 1000 (kgf/cm^2) / 0.01 (kgf/cm^2) of appreciation was considered while measuring in three points of the equator, separated at approximately 120º from each other. According to Hernández & García (2002) and Hernández (2009), this test was carried out without removing the skin from the fruits.

The compression test was carried out according to the criterion recommended by Hernández and García (2002). It implies compressing a fruit without destroying it up to 5 % of its diameter. It was applied to all fruits individually on three points along the equator approximately 120 ºfrom each other, perpendicular to the axis of the peduncle, using parallel and averaged plates (Yirat et al., 2009; Tain, 2010; Monzón et al., 2015). (Figure 5)

FIGURE 4. Digital pH meter

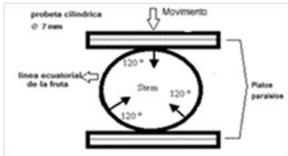

FIGURE 5. Compression test principle Magness-Taylor

Methodology for Information Processing

Within the investigation carried out as part of the analysis and processing of the information, an exploratory analysis of the data belonging to each property was carried out, determining in each case the behavior of the arithmetic mean (x), by means of expression 2.

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (2)$$

A Linear Regression (LR) analysis was then carried out, this statistical procedure creates a plot of each property over time of investigation, based on the statement of the study variables, to fit a curve by selecting a closer approximation to the dependency between both declared variables.

ANALYSIS AND DISCUSSION

The research sample is part of the same group (cluster) selected based on the criteria referred to above, which requires fruits with physiological ripeness of an intense green and uniform color. It had nine hands and each of these had an average of 12-14 fingers for a total of 127 fruits. All were separated manually and individually, guaranteeing that they were free of physical or mechanical damage. The final sample was randomly selected, from nine hands; only three were analyzed, giving 42 bananas to be characterized.

In order to achieve the objective of the investigation, it was necessary to use three types of packaging (wood, cardboard and in bulk) forming three groups (A, B and C, respectively) with a total of 14 fruits each, of Orinoco variety, all located in a single layer and subjected to the same storage conditions.

To determine each of the physical, chemical and mechanical properties, the methodology proposed by Martínez et al. (2017) was followed, where the bananas need to be separated and identified, having a number corresponding to the hand and place to be packed in. All the groups were stored during the same period of five days, with an average relative humidity of 81 % and the average daily temperature ranged between 24-26 °C. Fruits did not received any sanitary or industrial treatment during the research period, obtaining accurate values of each property to be determined.

During the five days that the plantain trial lasted, variety Orinoco, with group A, the total mass loss was 21.93 g and an average of 4.38 g per day (Table 1).

However, the trend of mass losses (Pm) is increasing, which is consistent with the nature of what is analyzed, where changes occur and, therefore, are highlighted during the final phase of storage at room temperature. with this type of packaging, where its material is much more resistant and thick, which makes it difficult to exchange with the environment. Given that mass losses are cumulative, it is logical to think that as the storage period increased, there was a greater weight loss, which is also modeled by the effect, among others, of storage temperature and relative humidity. Significant changes can also be seen in the other properties where the same process underlies and cracks the firmness of the fruit, both under compression (Fc) and punching (Fp), reaching values up to 10.00 and 0.40 kgf on the fifth day. /m2, respectively.

In the specific case of storage at room temperature, but in cardboard boxes (group B), the Pp values in the five days of the experiment reached maximum values of 16.76 g and an average of 3.35 g per day. In the case of pH, it had significant changes in the first two days of storage, being from the third day where it reaches its stability (with minor changes in its value) as shown in Table 2.

The results obtained in each property evaluated in group C (control) show greater change compared to the other groups (A and B), the total Pp was 23.02 g, losing 5.76 g per day. Something similar occurs in two other physical properties, since the length decreases constantly from the first day of its storage, as well as the circumference of the fruit, where it is more significant since the third day. For this same period mentioned above (third day), the Fc and Fp showed significant differences. However, the pH maintained a constant increase in the first days, it was different for SSC which had a value of 8.20 (Table 3) and was the highest for the three cases until reaching a slight stability for the fourth day, which is a response structured by the characteristics of the crop under study.

The trend of mass losses is increasing, in such a way that, even after harvesting, the product continues to lose water to the atmosphere, just as it did before harvesting; This is due to a physical process called transpiration, which takes place in the study fruit regardless of the presence or absence of the plant. Then, if we wanted to prolong the postharvest life of any fresh product, it follows that we must try to control the respiration and transpiration processes. There are differences; for the days after the loss is minimal.

The evaluation of the firmness was taken into account for both forms (compression and punching) because it is the property that best describes the quality of a crop and that always shows a decreasing trend with the days of storage. This is due to several changes that naturally accompany ripeness in most fruits, including changes in texture and reduced firmness. With senescence, phenomena such as wall degradation, enzymatic activation, increased membrane permeability, among others, cause a decrease in the firmness of the fruit walls, making it less resistant to compression and punching.

Table 4 shows the statistical summary of the average values of each of the evaluated properties of the fruits stored at room temperature, during the days of experimentation. where a very similar quantitative behavior can be seen roughly between the groups previously declared, which could be caused by the climatic conditions of the place and the characteristics of the crop itself, which leads to emphasize that the packaging is a determining factor for the production processes postharvest.

In the (climacteric) banana, the ethylene that is produced in all plant tissues as a response to "stress" simply increases the rate of respiration and accelerates a ripening process already started by the fruit itself, which can be seen in the three groups (A, B and C).

The values of weight loss (Pp) for group B and C are lower in relation to those obtained in group A. However, the density is dependent on Pp. On the other hand, Fc and Fp show significant differences between the groups, it should be noted that SSC of group B is shown to be lower than the others (Table 5).

Based on all of the above, it can be inferred that the best storage method is the one used for group B,

TABLE 1. Mean values of the quality properties of group A

Day	δ (g/mm^3)	Pp (g)	L (cm)	C (cm)	pH	Fc (kgf/m^2)	Fp (kgf/m^2)	SSC (%°Brix)
1	0.95	217.99	19.42	17.11	6.32	125.00	2.50	4.00
2	0.89	207.66	19.42	17.11	5.03	76.00	1.85	5.00
3	1.10	201.28	19.20	16.22	4.84	22.00	1.05	5.60
4	1.13	196.32	18.60	15.90	4.60	20.00	0.45	6.50
5	1.51	189.68	18.55	15.60	4.59	10.00	0.40	8.00

TABLE 2. Mean values of the quality properties of group B

Day	δ (g/mm^3)	Pp (g)	L (cm)	C (cm)	pH	Fc (kgf/m^2)	Fp (kgf/m^2)	SSC (%°Brix)
1	0.95	208.20	18.49	16.93	6.32	125.00	2.50	4.00
2	0.99	200.98	18.49	16.93	6.00	85.00	2.00	4.60
3	1.14	194.80	18.45	16.18	5.60	40.00	1.20	5.00
4	1.17	188.62	18.30	15.93	5.20	38.00	1.04	6.00
5	1.55	185.26	18.28	15.60	5.00	20.00	0.50	6.80

TABLE 3. Mean values of the quality properties of group C.

Day	δ (g/mm^3)	Pp(g)	L (cm)	C (cm)	pH	Fc (kgf/m^2)	Fp (kgf/m^2)	SSC (%°Brix)
1	1.02	169.57	20.33	16.61	6.32	125.00	2.50	4.00
2	1.01	162.11	17.19	16.61	5.00	75.00	1.75	5.20
3	1.14	157.94	16.30	15.99	4.84	20.00	1.00	6.00
4	1.11	146.82	15.94	15.82	4.60	18.00	0.40	6.80
5	1.35	146.55	15.60	15.60	4.00	5.00	0.30	8.20

TABLE 4. Mean values of each of the properties evaluated by days of storage

Day	V(cm)	Pp (cm)	L (cm)	C(cm)	pH	Fc (kgf/cm²)	Fp (kgf/cm²)	°Brix cm
1	231.00	217.99	19.42	17.11	6.32	125.00	2.50	4.00
2	232.50	207.66	19.42	17.11	5.03	76.00	1.85	5.00
3	186.00	201.28	19.20	16.22	4.84	22.00	1.05	5.60
4	180.00	196.32	18.60	15.90	4.60	20.00	0.45	6.50
5	132.00	189.68	18.55	15.60	4.59	10.00	0.40	8.00

TABLE 5. Summary of the behavior of the properties during the storage period

	δ (g/mm³)	Pp (g)	L (cm)	C (cm)	pH	Fc (kgf/m²)	Fp (kgf/m²)	SSC (%°Brix)
A	1.12	202.59	19.04	16.39	5.0	50.60	1.15	5.82
B	1.16	197.65	18.40	16.31	5.6	61.60	1.45	5.28
C	1.13	156.60	17.07	16.12	4.9	48.60	1.19	6.04

which was stored in cardboard boxes, showing minor changes in each of the properties, where the Pp values in the five days of experiment. It reached a maximum Pp of 16.76 g and an average of 3.35 g per day, reaching maximum firmness values under both compression and punching up to 20.00 and 0.50 kgf/m^2, respectively. This allows a longer conservation time of the main quality properties and extends the useful life of the fruit. The results obtained in each property evaluated in group B (cardboard box) are lower in relation to the other two groups (A and C). Which can be seen in the specific case of Pp, its values did not have significant changes, the SSC (% °Brix) increased progressively with a standard deviation of ± 1.12, as in the case of pH with a standard deviation of ± 0.55, for the Fc variable this had a sudden change from the first to the third day.

Once the best method or mode of storage at room temperature was selected, a statistical tool was used to find a model that is capable of describing this ripening process, allowing its behavior to be predicted to facilitate commercialization decision-making. It showed that up to the third day the fruit could be consumed fresh, since it retains its quality properties.

Modeling of the Storage Process

The results obtained from the models adjusted to the different trends or temporal variations of mass loss, firmness, soluble solids content and pH, are shown for group B (cardboard box) during the five days of storage (Figures 6; 7; 8; 9 and 10 and Table 6).

Figures 6 and 7 show the average values of Pp and pH obtained during the storage period, with models fitted to second-order polynomials and quadratic correlation coefficients of 0.998 5 and 0.993 3, respectively; with high prediction of its values, with respect to the measured ones

The average firmness values for Fc and Fp (Figures 8 and 9) with models also fitted to second-order polynomials and quadratic correlation coefficients in the expected intervals of 0.998 5 and

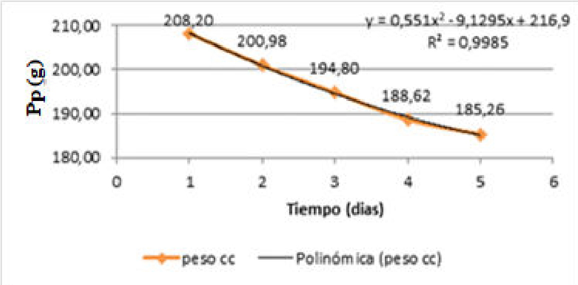

FIGURE 6. Mean and predicted values Pp, during the storage period.

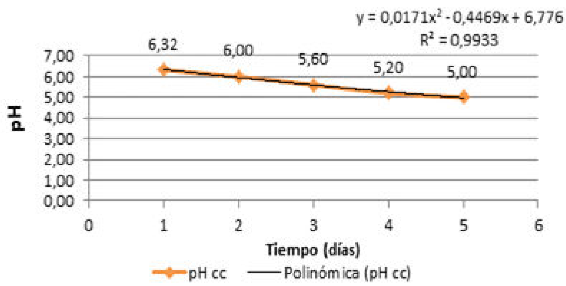

FIGURE 7. Mean and predicted values of pH.

0.993 3, respectively; very similar to each other, since it is the same property but under different circumstances it is within the expected range.

The third and fourth days showed greater changes in these parameters, due to the optimal physiological maturity obtained within a normal distribution with quality, since after this period the fruits begin to show perceptible and degradable physiological damage for commercialization.

The average values of the °Brix percentage (Figure 10) demonstrate the similarity of equal conditions as the other properties described above for the same selected group, but with fewer fluctuations within the adjustment model and whose values increase with the passage of time. Until its senescence. Each property is on the rise due to the expulsion of ethylene from the fruit, which worsens from the third day where it still has optimal conditions for consumption as fresh fruit without any damage; After this time, they begin to show physiological changes that can be extremely important when making decisions by different providers and consumers.

All the trends described by the models after five days of storage are considered adequate and are in consequence of the irreversible physiological changes that occur in the fruit. The temporal variations of the weight loss during the days of storage evaluated show a second-order polynomial trend, where statistical values such as R2 are reached, indicating that the adjusted model is capable of explaining up to 99% of the temporal variability for the case of weight loss, soluble solids content and pH and 97% for Fc and Fp. This model presents a typical error of 1.2, 0.57, 0.22, respectively, which is why it is considered favorable for accurately describing the storage process of banana, Orinoco variety, at room temperature (Table 6).

CONCLUSIONS

- The main physical, chemical and mechanical properties of banana, Orinoco variety, stored in three types of packaging for five days at room temperature were characterized. Weight loss, firmness, pH and soluble solids content were quantified during three periods that correspond to the initial day and between two and five days of fruit storage and it was shown that the most acute degradation of the fruit occurs in the third day.
- The best storage method corresponds to group B (cardboard boxes), which showed fewer changes in each property and maximum values of Pp of 16.76 g with average of 3 .35g per day, in the five days of the experiment.
- The values of firmness and pH of banana, Orinoco variety, are temporally correlated with each other, this dependence was of the order of three days and changes in one of them will have associated consequences on the second property.
- The models obtained for each determined and predicted property describe an adjustment model with second-order polynomials, and high values of the quadratic correlation coefficients, which facilitates the planning of the postharvest stage by producers and marketers.

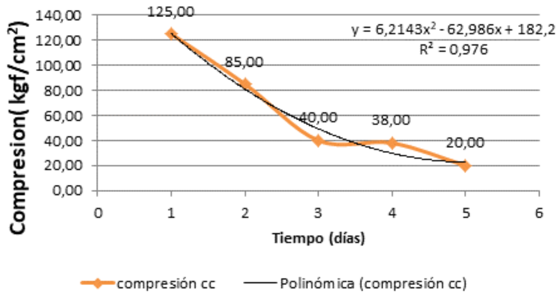

FIGURE 8. Mean and predicted values of compressive force.

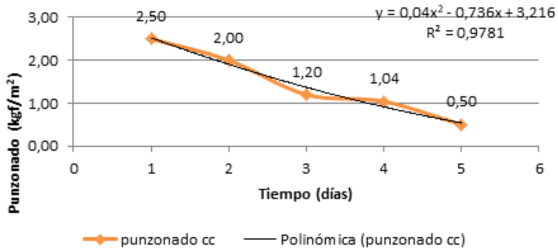

FIGURE 9. Mean and predicted values of punching force.

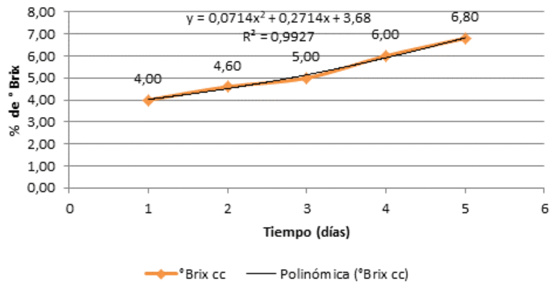

FIGURE 10. Average values of °Brix percentage

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TABLE 6. Models adjusted to the experimental values of each property

Property	Model	R^2	Typical error
Pp	$Pp = 0.551x^2 - 9.1295x + 216.9$	0.9985	1.2
Fc	$Fc = 6.2143x^2 - 62.986x + 182.2$	0.976	18.36
Fp	$Fp = 0.04x^2 - 0.736x + 3.216$	0.9781	0.17
SSC	$SSC = 0.0714x^2 + 0.2714x + 3.68$	0.9927	0.57
PH	$PH = 0.0171x^2 - 0.4469x + 6.776$	0.9933	0.22

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