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PHYSICOCHEMICAL CHARACTERIZATION AND SENSORY EVALUATION OF BANANA PULP (*Musa paradisiaca*) DEHYDRATED IN SHEETS

Jennifer Katiusca Castro, Néstor Enrique Cerquera and Eduardo Pastrana-Bonilla
Universidad Surcolombiana, Avenida Pastrana -Cra. 1, Neiva, Huila, Colombia
E-Mail: Jenniferkatiusca.castro@usco.edu.co

ABSTRACT

The present work deals with the characterization of banana pulp (*Musa paradisiaca*) dehydrated in sheets and its further sensory evaluation. For the drying tests, a static type equipment was used, and the fresh and dehydrated banana pulp was characterized taking into account its moisture content, soluble solids, pH, acidity and proximal analysis. The conservation parameters of the dehydrated pulp were satisfactory, which are favored by the low water activity reached in the dehydrated product; the sensorial analysis showed that temperature and speed of the drying air exert a big influence in the quality factor called "Appearance and Color".

Keywords: sensorial analysis, pulps, sheets, dehydration pulps.

1. INTRODUCTION

Bananas are one of the most important agricultural products for Colombia. According to FAOSTAT (2016), world banana production in 2013 was close to 108 million tons, with the largest producers being India (25.67 %), China (11.52 %), Mainland China (11.24%), the Philippines (8.05%), and Dominican Republic (5.58%). Colombian production is about 1.95% of world production of bananas.

In the year 2015 Colombia had 80,839 hectares cultivated in bananas, for an annual production of 2'098.065 metric tons (FAOSTAT, 2016); Of the cultivated area, 47,407 hectares are located in the departments of Antioquia, Magdalena and La Guajira, which are the largest producing areas of the country (AUGURA, 2016). Colombian bananas, whose exports are mainly to the European Union and the United States, produced 94 million boxes in 2015 (AUGURA, 2016). However, postharvest losses and the emergence of new markets for processed products make it convenient to introduce technologies and processes that allow their most efficient use.

The pulping and subsequent dehydration of the banana pulp is an alternative for the use of this fruit, which deteriorates rapidly after harvest, seeking to preserve the quality of the pulp and adding value to this product. In recent years, the Colombian fruit sector has grown unusually, mainly due to the industrialization of fruits and the growing demand for natural products such as fruit pulps, pulp preparations and nectars (Cerquera, 2006). Fruit pulps are marketed fresh, under refrigeration and / or frozen, concentrated or dehydrated.

Dehydration is one of the oldest techniques used to reduce post-harvest losses of agricultural products by reducing the moisture content of the agricultural products with the corresponding reduction of water activity. Within the techniques of drying or dehydration can be mentioned the processes of drying by natural convection, generally realized in stoves, by forced convection with different types of dryers and, by vacuum, which are applied to a great variety of agricultural products, such as grains, fruits and vegetables (Park, Yado and Brod, 2001; Arévalo-Pinedo and Murr, 2005; Leite, Mancini And Borges, 2007; Parra-Coronado, Roa-Mejia and Oliveros-Tascon, 2008; Corrêa Cacciatore, Silva and Arakaki, 2008; Corrêa, Pereira, Vieira and Hubinger, 2010; Borges Mancini, Corrêa and Nascimento, 2008; Borges, Mancini , Corrêa and Leite, 2011).

During the drying process, a reduction in product dimensions can be observed, this due to changes in the microstructure of the fresh tissue, promoted by thermal stress and mainly by the removal of moisture (Lewicki and Pawlak, 2003; Demirel and Turhan, 2003). Kingsley, Meena, Jain and Singh, 2007; Borges *et al*., 2008). This phenomenon, known as shrinkage or contraction, has been discussed in several research studies, with different behavior for each type of food studied, for each geometry and for each drying system, but in general terms the volume of the product evolves in the same way as the moisture content does. (Talla, Puiggali, Jomaa and Jannot, 2004; Kingsly*et al*., 2007; Borges *et al*., 2008).

Drying of bananas using different methods, such as solar drying (Smitabhindu, Janjai and Chankong, 2008), vacuum drying (Swasdisevi, Devahastin, Sa-Adchom and Soponronnarit, 2009), foam mat drying (Thuwapanichayanan, Prachayawarakorn and Soponronnarit, 2008), spray drying (Evelin, Jacob and Vijayanand, 2007), among others, have been reported. Drying with hot air is the most common technique used to preserve banana (Queiroz and Nebra, 2001; Demirel and Turhan, 2003; Karim and Hawlader, 2005; Nguyen and Price, 2007).

Dehydration techniques using low temperatures are of static type and they use forced air or vacuum heaters. Direct contact dehydration systems are also used, such as high temperature rolling equipment with continuous operation. However, this procedure greatly affects the nutritional content and organoleptic and

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functional characteristics of the pulps (Barbosa and Vega, 2000).

Colombia has a great export potential for its production of tropical fruits, which are sought after abroad. In particular, the market for "rolled dehydrated pulps" is a niche that is not yet being covered by other countries because it is a relatively recent development, whose target market are countries such as Germany, the United States, Canada and alternatively to Spain, Japan and the Andean Community. Obtaining products that retain their nutritional content and organoleptic properties mean that researches on shelf-life are based on ensuring that all parameters are within permissible limits.

Within the techniques, for food evaluation and analysis, it is found the sensory evaluation that is as relevant as the chemical, physical and microbiological characterization. These sensory evaluation techniques are as scientific as those of other types of analysis, since they are validated by means of statistics, physiology, and psychology among others. (Anzaldúa, 1994). For this reason, the objective of the present work was to characterize physicochemically and to evaluate sensorially the dehydrated banana pulps in sheet, obtained under different temperatures and drying air speeds.

2. MATERIALS AND METHODS

2.1 Raw material

Pulps were obtained from bananas (*Musa paradisiaca*) in good quality state, in maturity stages 4 and 5 according to the color table for banana skin reported by Dadzie and Orchard (1997). The banana pulp was mixed with orange pulp (*Citrus sinensis*) in proportion of three (3) parts of banana pulp for one (1) part of orange pulp. The addition of orange pulp to banana had the objective of reducing browning by increasing the amount of citric acid present and the consequent reduction of pH. The pulp of the selected fruits was obtained, preserved and dehydrated in the facilities of the Pilot Plant of the Institute of Food Science and Technology (ICTA) of the National University of Colombia - Bogotá.

In order to dry the pulps, it was used an equipment that was constructed taking into account the recommendations given by Perry, Green and Maloney (1997), with drying air speed between 120 and 300 m^3 min^{-1}, in order to improve the coefficient of heat transfer and to eliminate pockets of stagnant air. Additionally, it was taken into account that the trays were metallic in order to improve heat transfer, as well as that the free space between trays was greater than 38 mm.

2.2 Physicochemical characterization of fresh pulps

The characterization of the fresh banana pulp was made prior to drying tests. To do this, three replicates, 10 fruits each, were analyzed to determine the moisture content using a vacuum oven and applying AOAC OM934.06, Association of Official Analytical Chemists (AOAC) (1998). Titratable acidity was determined by titration according to AOAC OM942.15, the determination of soluble solids was performed using a Kikuchi refractometer with a scale of 0 - 30 ºBrix ± 0.2 ºBrix; pH was determined using the Pearson's modified method (1993).

2.3 Obtention of dehydrated banana pulps in sheet

Pulp dehydration was performed under the following static-layer drying conditions: temperature of 50 °C and 65 °C, in combination with three hot air speeds: 178.3 m min^{-1} (Air flow of 0.151 m^3 s^{-1}), 206.1 m min^{-1} (0.175 m^3 s^{-1}) and 234.1 m min^{-1} (0.198 m^3 s^{-1}); Six treatments with two replicates each were performed , for a total of twelve trials, according to a completely randomized experimental design with a factorial arrangement. Approximately 500 g of pulp were placed in each of the trays, previously coated with stretch film, in order to easily remove the product once dehydrated.

In each test, four trays were simultaneously dehydrated, taking the weight of two trays each hour, until the weight corresponding to a final moisture content of 11 % wet basis (mw) (0.123 dry basis (md)) was obtained.

2.4 Physicochemical characterization of dehydrated pulps in sheet

The moisture content of the dehydrated pulp was determined using a vacuum oven (AOAC standard OM934.06); the water activity was determined directly with the Novasina BSK equipment, for the titratable acidity the AOAC OM942.15 protocol was applied, pH was determined using the modified method of Pearson (1993) and a micrometer was used to determine the thickness of the fruit sheet.

2.5 Proximal analysis of the dehydrated pulps in sheet

Proximal analysis of the fresh and dehydrated pulps were made in order to determine: moisture (AOAC OM934.06), fat (AOAC OM920.39), crude fiber (AOAC OM96209), protein (AOAC OM954.01), minerals (AOAC OM942.05), and carbohydrates (by calculation the difference), calculation and kcal in 100 g using the indirect calculation Factor Atwater.

2.6 Sensory analysis

The sensorial evaluation of the dehydrated pulps was carried out applying a scale and descriptive test, with the aid of the sensory panel composed of six (6) trained judges. The samples were obtained from the treatments at the drying temperatures of 50 ºC and 65 ºC for the three airflows used, for a total of six treatments, in order to be able to compare the results for these conditions. Samples were randomly coded and served at room temperature. In the instruments used for the sensory evaluation, the information corresponding to the description of the composite scale was recorded for the qualification of the quality factors of the dehydrated banana pulp in sheet, as shown in Table-1.

The data obtained in the sensory tests were subjected to a variance analysis, applying a bifactorial design (Factor 1: Temperature (°C) and Factor 2: Air Speed (m min^{-1}) with a 2x3 factorial structure composed of six replicates. Subsequently, a multiple comparison was

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performed to establish significant minimum differences between the quality factors evaluated by the judges using a Tukey significance test with a significance level of 5 % in all cases.

Table-1. Description of quality factors for sensory evaluation of dehydrated banana pulp in sheet

Appearance and color
(7 a 5) Characteristic color of the fruit, bright yellow, natural, absence of foreign matter, homogeneous, with little brown dots, complete uniform edges.
(4 a 3) Slightly dark, opaque, inhomogeneous, with bubbles
(2 a 0) Non characteristic color, brown, brown, artificial, with skin residues, black particles or strange to the fruit.
Aroma and taste
(7 a 5) Characteristic to banana, good acid sweet balance
(4 a 3) Very sweet or sour, tasteless, residual taste, metallic.
(2 a 0) Non characteristic, caramel like, burnt, astringent, moldy, bitter.
Texture
(6 a 5) Soft, gummy, chewable.
(4 a 3) Very hard, rubbery, sticky, leathery
(2 a 0) Dry, rough, grainy, sandy.

3. RESULTS AND DISCUSSIONS

3.1 Characterization of fresh banana pulp

The average characteristics of fresh banana / orange pulps, hereinafter referred to as banana pulp, used in the drying tests, are presented in Table-2. The moisture content values (79.9 % mw) are found within the values reported by Nguyen and Price (2007) (74.4 % mw) and Karim and Hawlader (2005) (80 % mw). The density value of the pulp (1.05 g cm^{-3}) is close to that reported by Karim and Hawlader (2005) which is 0.98 g cm^{-3}. The pH value (4.10) is close to that reported by Muriel (2013) (4.21); Soluble solids (18.5 ° Brix) are close to those reported by Muriel (2013) (23.3 ° Brix); the value of acidity (0.62 %) is close to that reported by Muriel (2013) (0.74 %)

Table-2. Physicochemical parameters of fresh banana pulp.

Parameter	Banana/Orange
Pulp yield (%)	52,00
Pulp water (% Mw)	79,90
Density (g.cm^{-3})	1,05
pH	4,10
Soluble Solids (ºBrix)	18,50
Acidity (% Citric Acid)	0,62

The proximal analysis of fresh banana pulps presented average values of 0.0 % fat content, close to that reported by Tonna, Afam and Godwin, 2013 (0.2 %) and Aurore Parfait and Fahrasmane, 2009 (0.3 %); Carbohydrates 19.3 %, close to that reported by Tonna*etal*, 2013 (22.2 %), and Aurore *et al*., 2009 (21.8%) and the Colombian Family Welfare Institute (ICBF) 2005 (20 ,5 %); Minerals 0.5 %, crude fiber 0.45 %, and energy 77.2 kcal (100 g) $^{-1}$.

3.2. Characterization of the dehydrated pulp.

The pH of the dehydrated pulp presented a similar value to the fresh pulp, while the titratable acidity presented a 530 % increase with respect to the acidity of the fresh pulp, with a value of 3,287 and a typical error of 0.067. The water activity of the dehydrated pulp presented an average value of 0.484 with a typical error of 0.008, varying between 0.40 and 0.60, which allows to consider that the dehydrated banana obtained with this procedure has a good "in shelf" conservation behavior and very low probability of being attacked by pathogenic microorganisms.

The sheets of the dehydrated pulps had an average thickness of 1.7 mm, the initial thickness of the fresh pulp being approximately 10 mm, with an 83 % reduction in the thickness of the banana pulp sheet, which is in agreement with the results obtained by different authors for hot-air drying of bananas (Queiroz and Nebra, 2001; Talla *et al*., 2004; Demirel and Turhan, 2003). The yields obtained for dehydrated banana were 22.3 % with respect to the fresh pulp and 11.2 % with respect to the fresh product including the peel.

The proximal analysis of the dehydrated banana pulps had an average moisture content of 9.4 % mw (0.104 md) with a maximum value of 10.1 % mw (0.112 md), 0.0 % fat, crude fiber 1, 8 %, protein 4.0 %, minerals 3.6 %, carbohydrates 81.2 % and 341 kcal (100 g) $^{-1}$. As can be seen, the final moisture content is below 12 % mw (0.136 md), which corresponds to the expected moisture content that guarantees the product's stability under prolonged storage. On the other hand, an increase in the content of crude fiber, proteins, minerals and carbohydrates was

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observed due to the concentration of total soluble solids, resulting in a product with higher caloric content, this behavior resulting in the increase of the constituents due to the reduction of the water content agrees with the reported by Aurore *et al*., 2009.

3.4 Sensory analysis of dehydrated pulps.

The consolidated information, derived from the rating instruments used by the judges of the sensory panel, is presented in Table-3 and Table-4.

Table-3. Consolidated judges' qualifications to the quality factors of banana pulp dehydrated in sheets at 50 °C

Treatment	**T1V1**						**T1V2**						**T1V3**					
Judge	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Appearance and Color	4	1	3	4	3	2	4	2	4	4	5	5	4	2	4	4	4	3
Aroma y Flavor	4	6	5	5	5	3	5	5	5	5	4	2	5	6.5	4	5	6	2
Texture	4	4	5	4	3	3	4	4	3	3	4	3	6	6	5	5	5	3

Where:
T1V1: banana pulp dehydrated at 50 °C and 178.3 m min^{-1}
T1V2: banana pulp dehydrated at 50 °C and 206.1 m min^{-1}
T1V3: banana pulp dehydrated at 50 °C and 234.1 m min^{-1}

Table-4. Consolidated judges' ratings on the quality factors of dehydrated banana pulp in sheet at 65 °C.

Treatment	**T2V1**						**T2V2**						**T2V3**					
Judge	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Appearance	4	1	3	5	5	4	6	4.5	5	6	5	6	5	3.5	4	4	5	5
Aroma y Flavor	4	5	3	4	4	2	5	4	4	4	4	5	4	5	3	5	4	3
Texture	4	6	5	5	4	4	5	4	3	3	3	5	5	5.5	5	5	3	4

Where:
T2V1: banana pulp dehydrated at 65 °C and 178.3 m min^{-1}
T2V2: banana pulp dehydrated at 65 °C and 206.1 m min^{-1}
T2V3: banana pulp dehydrated at 65 °C and 234.1 m min^{-1}

In the analysis of variance, Table-5, it can be seen that the dehydrated pulps in sheets have significant differences that indicate that the temperatures and speeds used exert a sensorial influence that can be perceived in the evaluation of the factor "Appearance and color".

Table-5. Appearance and color.

Source of variation	**SS**	**DF**	**MS**	**F**	**P**	**Ft**
Temperature	10,03	1	10,03	9,38	0,0046	4,17
Air speed	12,76	2	6,38	5,97	0,0066	3,32
Interaction	0,60	2	0,30	0,28	0,7583	3,32
Error	32,08	30	1,07	-	-	-
Total	55,47	35	-	-	-	-

The "Aroma and Flavor" factor does not have statistically significant differences, as shown in Table-6; in other words, the evaluating judges considered that the two factors did not alter the characteristic flavor of the fruit, having a good acidity-sweetness balance, making impossible to perceive the changes in this parameter for the different treatments studied in this research work.

Table-6. Aroma and flavor.

Source of variation	**SS**	**DF**	**MS**	**F**	**P**	**Ft**
Temperature	3,06	1	3,06	2,54	0,1217	4,17
Air speed	0,29	2	0,15	0,12	0,8866	3,32
Interaction	1,63	2	0,81	0,67	0,5176	3,32
Error	36,21	30	1,21	-	-	-
Total	41,19	35	-	-	-	-

Table-7 shows that the degree of acceptance by the judges considers a variation in the qualification of the factor "Texture". It can be observed that the drying rates reflect a statistically significant differentiation effect between the treatments. This factor does not present significant differences with respect to the dehydration temperatures of the pulps.

Table-7. Texture

Source of variation	SS	DF	MS	F	P	Ft
Temperature	0,56	1	0,56	0,74	0,3955	4,17
Air Speed	7,60	2	3,80	5,02	0,0132	3,32
Interaction	2,38	2	1,19	1,57	0,2249	3,32
Error	22,71	30	0,76	-	-	-
Total	33,24	35	-	-	-	-

Table-8 shows the consolidated analysis of variance (ANOVA) and the Tukey significance test. The different superscripts in the values of each cell indicate statistically significant differences for a probability P <0.05 with values of Mean ± standard deviation (n = 6).

Table-8. Consolidated ANOVA and Tukey 5 % N.S.

	V1	V2	V3
T1	$2{,}83 \pm 1{,}17^{b}$	$4{,}00 \pm 1{,}10^{ab}$	$3{,}50 \pm 0{,}70^{b}$
T2	$3{,}67 \pm 1{,}51^{ab}$	$5{,}42 \pm 0{,}67^{a}$	$4{,}42 \pm 0{,}67^{ab}$

According to this, for the "Appearance and color" quality factor, the dehydrated banana at 65 °C, with a speed of 206.1 m min-^{1} is the treatment with the highest degree of acceptability with the highest score by the evaluation panel. Likewise, with two other speeds 178.3 m min-^{1} and 234.1 m min-^{1} when a temperature of 50 °C was used, there were found statistically significant differences, but their means indicate lower ratings, with very low acceptance by the judges, therefore these two treatments are not recommended. The remaining treatments did not have statistically significant differences.

CONCLUSIONS

a) The behavior of the obtained products in terms of their conservation parameters was satisfactory. The water activity found in the dehydrated product allows to predict a good shelf-life and behavior, and very low probability of being attacked of pathogenic microorganisms.
b) The temperatures and air speeds used exert a sensorial influence that can be perceived in the evaluation of the factor "Appearance and color". For the other two quality factors evaluated by the judges, there were no statistically significant differences. In this sense, the treatment that has the highest degree of acceptability by the panel of evaluators was that of dehydrated banana pulps at 65 °C, with a speed of 206.1 m min-^{1}.

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