Phenolic compounds from the peel of Musa cavendish, Musa acuminata and Musa cavandanaish

Espinosa, Alfredo [1]; Santacruz, Stalin [1,2]

[1]*Universidad San Francisco de Quito. Cumbayá, Diego de Robles y Vía Interoceánica, Quito, Ecuador. P.O. Box 17-1200-841*
[2]*Universidad Laica Eloy Alfaro de Manabí. Avenida circunvalación, Manta, Ecuador. P.O. Box 13-05-2732*

Abstract: Ecuador, one of the big banana exporters, produces approximately 240 000 tons of fruit that are not exported. This by-product generates a serious environmental problem due to its high organic load. Banana peel is a source of antioxidant compounds such as phenolic compounds. These compounds have anti-cancer, anti-aging and anti-inflammatory properties, and therefore their importance in human health. However there are no studies of the content of phenolic compounds in varieties of banana. The aim of this study was to quantitatively determine the content of phenolic compounds and tannins in the peel of *Musa cavendish*, *Musa acuminata* and *Musa cavandanaish* during the fruit ripening process. The quantification of phenolic compounds and tannins was done with a spectrophotometer after an ethanol extraction and was expressed as gallic acid equivalents (GAE) and tannic acid equivalents (TAE) respectively. The results showed that the highest content of phenolic compounds and tannins was 6 411 mg/100 g peel (dry basis) and 1 056 mg/100 g peel (d.b.) respectively. The results correspond to the peel of *Musa cavendish* after two days of being cut. Additionally, it was found that the ripening process leads to a reduction of phenolic compounds (GAE) and tannins (TAE). The three varieties of banana are a good source of phenolic compounds and tannins in the early stages of organoleptic maturity.

Keywords: plantain, phenols, gallic acid, tannic acid, banana peel.

Compuestos fenólicos a partir de la corteza de Musa cavendish, Musa acuminata y Musa cavandanaish

Resumen: Ecuador, uno de los grandes exportadores de banano, produce aproximadamente 240 000 toneladas de fruta que no se exportan. Este subproducto genera un grave problema ambiental debido a su alta carga orgánica. La corteza de plátano es una fuente de compuestos antioxidantes tales como compuestos fenólicos. Estos compuestos tienen propiedades anticancerígenas, anti-envejecimiento y anti-inflamatorias, y por ello su importancia en la salud humana. Sin embargo, no hay estudios sobre el contenido de compuestos fenólicos en las variedades de plátano. El objetivo de este estudio fue determinar cuantitativamente el contenido de compuestos fenólicos y taninos en la corteza de *Musa cavendish*, *Musa acuminata* y *Musa cavandanaish* durante el proceso de maduración de la fruta. La cuantificación de los compuestos fenólicos y taninos se realizó con un espectrofotómetro después de una extracción con etanol y se expresó como equivalentes de ácido gálico (GAE) y equivalentes de ácido tánico (TAE) respectivamente. Los resultados mostraron que el mayor contenido de compuestos fenólicos y taninos era 6411 mg / 100 g corteza (base seca) y 1056 mg / 100 g corteza (b.s.), respectivamente. Los resultados corresponden a la corteza de *Musa cavendish* después de dos días de haber sido cortado. Adicionalmente, se encontró que el proceso de maduración lleva a una reducción de compuestos fenólicos (GAE) y taninos (TAE). Las tres variedades de plátano son una buena fuente de compuestos fenólicos y taninos en las primeras etapas de la madurez organoléptica.

Palabras clave: plátano, fenoles, ácido gálico, ácido tánico, corteza de plátano.

1. INTRODUCTION

Banana is Ecuador's second largest export after oil. Exports grew from 1.3 million tons in 2007 to 2 million tons in 2012. In 2010, the Ecuadorian banana industry exported the equivalent of 32% of world trade in bananas. The massive production leads to a big quantity of bananas which is not exported, due to problems during harvest, transport or natural defects of the fruit. Paredes (2010) estimates that approximately 240 000 tons of Ecuadorian bananas are not exported every year. An important way to use such by-product has been as livestock food, especially for cattle. However, the majority is not properly managed and generates a serious environmental problem due to its high organic load (Intriago and Paz 2000) and air contamination due to the generation of methane gas.

stalin.santacruz@gmail.com
Received: 17/02/2016
Accepted: 22/09/2016
Published: 20/01/2017

Banana peel is a source of antioxidant compounds such as vitamin C, vitamin E, and phenolic compounds, which may offer great benefits to the consumer. Studies have confirmed that tannins present in bananas form insoluble complexes with proteins, among other compounds, leading to low digestibility of protein and therefore a low level of growth in animals (Calderón and Latorre 1999; Silanikove et al. 2001; Makkar 2003; Velásquez 2004). Several cultures have used banana leaves to relieve diabetes, diarrhea, heart and stomach problems (Mahmood et al., 2011). Kähkönen et al. (2011) showed the beneficial effect of phenolic compounds on human health, such as antimutagenic, anti-cancer, anti-aging, anti-inflammatory and antiviral among other properties. Epidemiological evidence has shown that regular consumption of fruits and vegetables provides enough amount of compounds that protect the immune system and help to prevent the development of coronary heart disease (Paladino and Zuritz 2011).

Studies on antioxidants have been conducted primarily with grapes (Meng et al. 2012; Dos Santos et al. 2014). However, there is a wide variety of fruits and vegetables that provide this type of beneficial components (Robbins 2003; Heim et al. 2002; Clifford 2000; Hollman and Arts 2000; Santos-Buelga and Scalbert 2000). Several ecuadorian fruits belonging to Anacardiaceae, Passifloraceae, Rosaceae and Solanaceae among other families have showed high levels of phenolic compounds (Vasco et al., 2008).

Phenols are associated with colour, sensory characteristics (flavour, astringency, hardness) and antioxidant properties of plant foods. In nature there are approximately 8000 phenolic compounds. The antioxidant activity of the different polyphenols depends of the structure and molecular weight among other factors. There are studies that identify the polyphenols present in the *Musa cavendish* variety (Mahmood et al., 2011). However there are no studies on the polyphenol content in other varieties of banana, neither a comparison of the type of polyphenols present in banana.
A study of the content of total phenolic compounds in banana peel may serve to reduce the impact of banana by-products to the environment. Therefore, the aim of this study is to compare the content of phenolic compounds, galllic acid and tannins from the peel of three varieties of banana, *Musa cavendish, Musa acuminata* and *Musa cavandanaish*, during fruit ripening.

2. MATERIALS AND METHODS

Musa cavendish, Musa acuminata and *Musa cavandaneish* samples were obtained in Santo Domingo de Los Colorados, Ecuador. Bananas were cut and stored in a room at 35 °C in the absence of light. Soluble solids (ºBrix) were measured with an ABBE refractometer (Fisher Scientific, USA) daily until the value began to decrease.

2.1 Determination of soluble solids

Banana pulp (30 g) was disintegrated in a mixer with 90 mL of distilled water for 2 minutes. Afterwards, the suspension was filtered (filter paper 7-12 µm particle retention, Macherey-Nagel, USA). The filtrate was examined with an ABBE refractometer (Fisher Scientific, USA) and °Brix reported.

2.2 Determination of total phenolic compounds extraction

The extraction was carried according to the method proposed by Slinkard and Singleton (1977). The peel was removed from the fruit and dried in an oven (Precision, USA) at 40 °C for 2 days. After drying, samples were milled (Toastmaster, China) to a particle size of approximately 170 µm. The powder sample (15 g) was dissolved in 150 mL of ethanol (95% v/v) and stirred for 24 h at 20ºC. Afterwards, the mixture was filtered and the filtrate was concentrated in a rotary evaporator (Buchi, Switzerland) until a dry residue was obtained.

The total phenolic compounds were determined according to the Folin-Ciocalteu method proposed by Slinkard and Singleton (1977). A dry residue previously obtained (0,1 g) was mixed with 5 mL of ethanol (95% v/v) and water to get a total volume of 100 mL (stock solution). The stock solution (0,4 mL) was mixed with 2 mL of Folin-Ciocalteu reagent and the mixture was allowed to stand for 5 min. Afterwards, 4 mL of sodium carbonate solution (5 %) were added to the mixture, and diluted to 25 mL with distilled water. The solution was left in darkness for 1 hour. The absorbance of the resulting solution was measured at 760 nm in a spectrophotometer (ThermoSpectronic, USA). Quantification of total phenolic compounds was done by using a calibration curve and gallic acid as standard.

All experiments were performed in triplicate and results were expressed in mg of GAE (gallic acid equivalent)/100 g peel (dry basis).

2.3 Determination of tannin content

Tannin content was performed according to the method proposed by Slinkard and Singleton (1977). A stock solution of tannic acid was prepared by dissolving 10 mg of tannic acid in 100 mL of distilled water. A proper amount of the stock solution was mixed with 1,25 mL of Folin-Ciocalteu reagent and 2,5 mL of sodium carbonate solution (5%). The resulting mixture was diluted to 25 mL with distilled water and the absorbance was measured after 30 minutes at 760 nm. A calibration curve in the range from 0 to 0,25 mg/mL of tannic acid was prepared using proper amounts of stock solution.

Samples were prepared by mixing 1 g of previously prepared powdered peel with 80 mL of distilled water. The mixture was boiled for 30 minutes. Afterwards, the mixture was cooled to 20 °C and the volume adjusted to 100 mL with distilled water. The resulting solution was filtered using filter paper (Macherey-Nagel, USA). An aliquot of 1 mL of filtrate was taken and treated in a similar way as the stock solution of tannic acid. The results were expressed in mg of TAE (tannic acid equivalent)/100 g of peel (d.b.). All experiments were performed in triplicate.

2.4 *Experimental Design*

A completely randomized design with a factorial arrangement 3^2 was used. The factors were the varieties of banana *(Musa cavendish, Musa acuminata, Musa cavandanaish)* and the number of days after cutting (bananas stored at 35 °C). Previous studies showed that °Brix did no increase after the 10th day of storage and therefore the days after cutting were 2, 6 and 10. All experiments were performed in triplicate.

The response variables were total soluble solids expressed as ºBrix, total phenolic content expressed in mg of GAE/100 g peel (d.b) and tannin content, expressed in mg of TAE/100 g peel (d.b.). The results of the response variables were analysed using analysis of variance (ANOVA) and mean separation test Tukey.

3. RESULTS AND DISCUSSION

Figure 1 shows the effect of maturation in GAE content of the three varieties of banana. In the case of *Musa cavendish* the largest decrease in the content of GAE occurred between the second and sixth day after cutting with values of 6411 and 2832 mg GAE/100 g peel (d.b.) respectively. In the case of varieties *Musa cavandanaish* and *Musa acuminata* the differences between the second and sixth day were smaller and the values varied between 2821 and 1622 mg GAE/100 g peel (d.b.). After the sixth day GAE content remained constant. Statistical analyses (data not shown) revealed that there was no difference on the GAE content among the three varieties for a fixed stage of maturity, except for *Musa cavendish* two days after cutting, which showed a statistical higher content compared to the other two banana varieties.

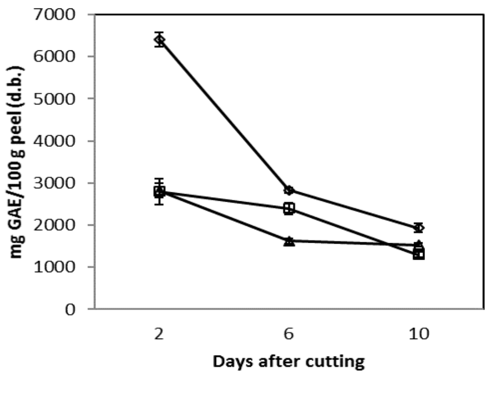

Figure 1. Total phenolic compounds content, mg GAE/100 g peel (d.b.), on three varieties of banana after cutting, stored at 35°C. *M. cavendish*, *M. acuminate*, *M. cavandanaish*

According to Canales (2009), the decrease of the content of phenolic compounds is due to the process of fruit ripening. During this stage an oxidation of phenolic compounds to quinones occurs. Mahmood et al. (2011) reported an average GAE content of 5830 mg/100 g sample for the variety of banana *Musa paradisiaca*. This value is similar to the average obtained on day 2 after cutting for *Musa cavendish* variety. However we must take into account that the study performed by Mahmood et al. (2011) was conducted on the flower of *Musa paradisiaca* plant and not in banana´s peel. Fariza et al. (2011) reported a maximum GAE value of 7640 mg/100 g sample (fresh basis) in the peel of banana (*Musa spp*.), which is similar to the maximum values found in the present study.

The content of polyphenols in *Musa cavendish* peel was similar to *Rubus glaucus* Benth (7300 mg/100 g sample, f.b.) and *V. floribundum* Kunth (3000 mg/100 g sample, f.b.) which are considered to have high levels of phenolic compounds (Vasco 2009). According to the obtained results, *Musa cavendish* peel could be a good source of polyphenols. However, to obtain larger quantities of polyphenols the extraction must be done before the fruit begins with the organoleptic maturation.

As shown in Figure 2, there was an increase in the content of soluble solids from day 2 until day 10, being *Musa acuminata* the variety which presented the highest value (33,03 °Brix) and was also statistically different than the others. This increase was due to the hydrolysis of starch into the fruit (Linaza 1976), resulting in the formation of sugars. The largest increase in sugar production occurred between day 2 and day 6 after cutting.
According to Arcila et al. (2002) the value of °Brix in the Dominico-Harton banana variety ranged between 6,2 and 32,2°Brix. These values are very similar to those found in the present study which varied between 4,33 and 33,03°Brix. Buitrago and Escobar (2009) showed that the total soluble solids content ranges from 17% on day 0 to 27% on day 20 of maturation at 20 °C. The difference in the content of soluble solids, particularly in the first few days of maturation may be due to a different variety of banana, the days of ripening and maturation conditions (Linaza 1976).

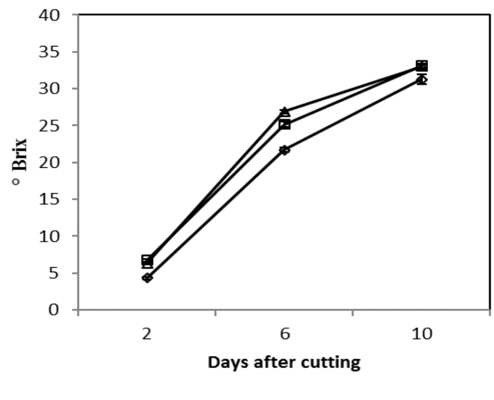

Figure 2. Soluble solids content (°Brix) on three varieties of banana after cutting, stored at 35ºC. . *M. Cavendish*, *M. acuminate*, *M. cavandanaish*

Figure 3 showed the effect of maturation on the TAE content of the three varieties of banana. The trend was similar for the three varieties. The decrease in TAE content was almost linear along the three maturation stages. Statistical analyses showed that *Musa cavandanaish* had the lowest content of TAE along the storage, which varied between 793 and 248 mg TAE/100 g peel (d.b.), and were also statistically different than the other two varieties.

Musa cavendish and *Musa acuminata* had the highest content of TAE on the second day after cutting, with values of 1056 and 1005 mg TAE/100 g peel (d.b.) respectively, which were also statistically different than the other variety.

A study performed by Mahmood et al. (2011) reported an average TAE content of 88,31 mg/100 g of peel (d.b.) from *Musa paradisiaca*. This value is much lower than the values found in the present study which range between 248 and 1056 mg TAE/100 g peel (d.b.) for the three varieties of banana. The study by Mahmood et al. (2011) focused on the plant of *Musa paradisiaca*, while the present study was focused on the peel of different varieties. Vipa and Chidchom (1994) reported the tannin content of the peel extracts from *Musa paradisiaca* at different stages of maturation. In ripening stage one, the tannin content was 5800 mg TAE/100 g peel (d.b.), whereas in the maturation stage six, tannin content was 1130 mg TAE/100 g peel (d.b.).

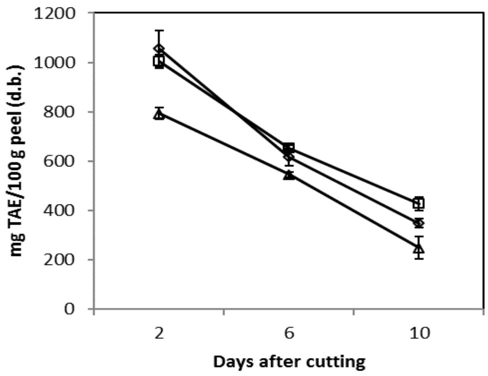

Figure 3. Total tannin content, mg TAE/100 g peel (d.b.), on three varieties of banana after cutting, stored at 35 ºC. —◇— *M. Cavendish*, —□— *M. acuminate*, —△— *M. cavandanaish*

The difference in the content of tannins may be due to different fruit varieties utilised and different maturation stages of the studies.

Musa cavendish, *Musa cavandanaish* and *Musa acuminata* peels had higher content of tannins than blackberry or grapes, which are good sources of these compounds and reported values of 209 mg/100 g (d.b.) and 154,5 mg/100 g (d.b.) respectively (Vasco 2009). The three varieties of banana peel could be a good source of tannins. An extraction with a high yield of tannin can be obtained before the fruit reaches organoleptic maturity.

4. CONCLUSION

The present work showed differences in the content of total phenolic compounds (GAE) and total tannins (TAE) between the three varieties of banana. *Musa cavendish* peel had the highest content of both compounds, which were lowered along the maturation stages. The three varieties of banana are a good source of phenolic compounds and tannins in the early stages of organoleptic maturity.

REFERENCES

Arcila, P., Giraldo, G., Celis, F., Duarte, J. (2002). *Cambios físicos y químicos durante la maduración del plátano dominico-hartón (Musa AAB Simmonds) en la región cafetera central colombiana*. In: Memorias XV reunión. Cartagena, Colombia. Asociación de Bananeros de Colombia AUGURA.

Buitrago, J., Escobar, A. (2009). *Aplicación de levadura Candida spp. Como una alternativa viable para la retardación en la pudrición del banano (Musa acuminata).* Bogotá, Colombia: Tesis Pontificia Universidad Javeriana.

Calderón, C., Latorre, S. (1999). *Evaluación fisiológica y nutricional del efecto de los taninos en los principales sorgos graníferos cultivados en Colombia.* Tibaitatá, Colombia: Corporación Colombiana de Investigación Agropecuaria – CORPOICA.

Canales, M. 2009. *Determinación de la concentración de polifenoles en frutos de ají (Capsicum annum).* Temuco, Chile: Tesis Universidad Católica de Temuco.

Clifford, M. (2000). Anthocyanins-nature, occurrence and dietary burden. *Journal of the Science of Food and Agriculture, 80*, 1063-1072.

Dos Santos Lima, M., De Souza, I., Toaldo, I., Correa, L., Camarao, A., Biasoto, T., Pereira, G., Bordignon-Luiz, M., Ninow, L. (2014). Phenolic compounds, organic acids and antioxidant activity of grape juices produced from new Brazilian varieties planted in the Northeast Region of Brazil. *Food Chemistry, 161*, 94-103

Fariza, S., N. Yusoff, I. Eldeen, E. Seow, A. Sajak, K. Leong Ooi. (2011). Correlation between total phenolic and mineral contents with antioxidant activity of eight Malaysian bananas (Musa sp.). *Journal of Food Composition and Analysis, 24*, 1-10

Heim, K.E., Tagliaferro, A.R. and Bobilya, D.J. (2002). Flavonoid antioxidants: Chemistry, metabolism and structure-activity relationships. *Journal of Nutritional Biochemistry, 13*, 572-584.

Hollman, P.C.H. and Arts, I.C.W. (2000). Flavonols, flavones and flavanols - nature, occurrence and dietary burden. *Journal of the Science of Food and Agriculture, 80*, 1081-1093.

Intriago, F., Paz, S. (2000). Ensilaje de cáscara de banano maduro con microorganismos eficaces como alternativa de suplemento para ganado bovino. Dissertation. Universidad Earth, Guácimo, Costa Rica.

Kähkönen, M., Hopia, A., Heinonen, M. (2011). Berry phenolics and their Antioxidant activity. *Journal of Agricultural and Food Chemistry, 49*, 4076 – 4082

Linaza, A. 1976. Quantitative evolution of sugars in bananas fruit ripening at normal to elevated temperatures. *Acta Horticulturae, 57*, 163-173

Mahmood A., Ngah, N., Omar, M. (2011). Phytochemicals constituent and antioxidant activities in musa x paradisiaca flower. *European Journal of Scientific Research, 66*, 331-318

Makkar, H.P. (2003). Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. *Small Ruminant Research, 49*, 241-256

Meng, J.F., Fang, Y.L., Qin, M.Y., Zhuang, X.F., Zhang, S.W. (2012). Varietal differences among the phenolic profiles and antioxidant properties of four cultivars of spine grape (Vitis davidii Foex) in Chongyi County (China*). Food Chemistry, 134*, 2049-2056

Paladino, S., Zuritz, C. (2011). Extracto de semillas de vid (Vitis vinifera L.) con actividad antioxidante: Eficiencia de diferentes solventes en el proceso de extracción. *Revista de la Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo. Mendoza, 43*, 187-199

Paredes, A. (2010). Obtención de enzimas celulasas a partir de hongos (Pleurotus ostreatus, Pleurotus pulmonarius y Lentinula edodes) utilizando como sustrato los residuos del cultivo del banano (Musa cavendish). Ambato, Ecuador: Tesis Universidad Técnica de Ambato.

Robbins, R.J. (2003). Phenolic acids in foods: An overview of analytical methodology. *Journal of Agricultural and Food Chemistry, 51,* 2866-2887.

Santos-Buelga, C. and Scalbert, A. (2000). Proanthocyanidins and tannin-like compounds - nature, occurrence, dietary intake and effects on nutrition and health. *Journal of the Science of Food and Agriculture, 80,* 1094-1117.

Silanikove, N., Perevolotsky, A., Provenza, F. (2001). Use of tannin-binding chemicals to assay for tannins and their negative postingestive effects in ruminants. *Animal Feed Science and Technology, 91*, 69-81

Slinkard, K., Singleton, V.L. (1977). Total phenol analyses: automation and comparison with manual methods. *American Journal of Enology and Viticulture, 28,* 49-55

Vasco, C. (2009). *Phenolic compounds in ecuadorian fruits*. Uppsala, Sweden: Tesis doctoral Swedish University of Agricultural Sciences.

Vasco, C., Ruales, J., Kamal-Eldin, A. (2008). Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. *Food Chemistry, 111*, 816-823.

Velásquez, A. (2004). Extracción de taninos presentes en el banano verde. *Revista Lasallista de Investigación, 2,* 8-14

Vipa S, Chidchom, H. (1994). Extraction of tannin from banana peel. *Kasetsart Journal, 28*, 578-586

Alfredo Espinosa Borrero. Nacido en Quito-Ecuador de profesión Ing. De Alimentos. Desde niño fue apasionado por la naturaleza, le gustaba mucho ir a la hacienda de su abuela a trabajar en el campo junto con los animales. Le gusta mucho practicar deporte en especial ciclismo de montaña, andinismo y natación. Luego de terminar sus estudios de la primaria y secundaria ingresó a la USFQ a la carrera de Ing. De Alimentos. Actuablemente se dedica a administrar una empresa familiar dedicada a la comercialización de instrumentos analíticos para laboratorios y también ofrecer el servicio de calibración bajo norma ISO 17025.

Stalin Santacruz. Graduado como Ingeniero Químico en la Escuela Poltécnica Nacional, luego de lo cual se desempeñó como asistente de investigación en el entonces Instituto de investigaciones Tecnológicas (actual DECAB). Realizó su maestría en la misma institución, y luego de ello trabajó como investigador en North East Wales Institute (UK). Seguidamente hizó sus estudios de doctorado en Swedish University of Agricultural Sciences, Suecia y en Lund University el postdoctorado. De regreso al Ecuador trabajó como docente en la Universidad San Francisco de Quito y actualmente labora como docente-investigador en la universidad Laica Eloy Alfaro de Manabí.