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Efecto de la harina de cáscara de plátano (*Musa paradisiaca* L. cv. Dominico Harton) como ligador en salchichas tipo frankfurter

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Abstract

Agroindustrial residues such as plantain (*Musa paradisiaca* L. cv. Dominico Harton) peel have functional properties, which made them suitable for use as a food ingredient. The aim of this research was to evaluate plantain peel flour (PPF) as a binder in the production of frankfurter- type sausage. Five formulations were prepared in which wheat flour (WF) was replaced by PPF as follows: 25%, 50%, 70% and 100%, respectively. Once the sausages are obtained, water retention capacity (WRC), emulsifying stability (E_S), and pH, were evaluated. When comparing treatments with the control sample, it was found that replacing up to 50% of WF by PPF, significantly increased WRC by 7.5%. When replacing 25%, Es, there were no statistically significant changes among treatments. When replacing 100%, the product pH, was significantly decreased. The results indicated, the sausages made with 50% of PPF, retained the formulation water, which is PPF has potential for this type of sausage manufacture. PPF could replace WF up to 25% in the frankfurter formulation, without affecting E_S and pH and favoring WRC.

Keywords: Agroindustrial residues, meat emulsion, physicochemical properties.

Resumen

Los residuos agroindustriales como la cáscara de plátano (*Musa paradisiaca* L. cv. Dominico Harton), presentan propiedades funcionales que los hacen aptos para uso como ingrediente alimentario. El objetivo de la presente investigación fue evaluar la harina de cáscara de plátano (HCP) como ligador en la elaboración de salchichas tipo frankfurter. Se elaboraron cinco formulaciones en la que se sustituyó harina de trigo (HT) por HCP, en las siguientes concentraciones, 25%, 50%, 70% y 100%, respectivamente. Obtenidas las salchichas, se evaluó la capacidad de retención de agua (CRA), estabilidad emulsificante (Ee), y pH. Al comparar los tratamientos con la muestra control se encontró que al reemplazar hasta el 50% de HT por HCP se incrementó significativamente la CRA en 7.5%. Al reemplazar 25%, Ee, no se presentaron cambios estadísticamente significativos entre los tratamientos. Al reemplazar el 100%, se disminuyó el pH del producto en forma significativa. Los resultados indicaron que las salchichas elaboradas con 50% de HCP retienen el agua propia de la formulación, por lo cual la HCP tiene potencial para la fabricación de este tipo de salchichas. La HCP podría reemplazar hasta en 25% la HT en la formulación de salchichas tipo frankfurter, sin afectar la Ee y el pH, y favoreciendo la CRA.

Palabras clave: Emulsión cárnica, Propiedades fisicoquímicas, Residuos agroindustriales.

Introduction

Meat sausages represented, on average, 16% of food purchases in the family basket. Its growing demand in industrialized and developing countries, has stimulated the formulation of new products with high nutritional value and technological and functional properties (Pacheco-Pérez, Sepúlveda-Valencia & Restrepo-Molina, 2011). New meat formulations, require processing industries to implement new technologies, new ingredients addition, or the existing replacement (Savadkoohi, Hoogenkamp, Shamsi, & Farahnaky, 2014). Among the non-meat ingredients added to the sausage formulation, are cereals such as wheat flour and legumes such as soybean (*Glycine max* (L.) Merr.), bean (*Phaseolus vulgaris* L.) and chickpea (*Cicer arietinum* L.), which are widely used as binders or extenders because of their ability to increase water and fat retention (Kurt & Kilinççeker, 2009). At the same time, these ingredients are intended to replace the preservatives addition and synthetic antioxidants such as nitrites, which react under appropriate conditions of temperature and pH in nitrosamines and other toxic substances that may be carcinogenic (Pinzón-Zárate, Hleap-Zapata, & Ordóñez-Santos, 2015).

Plantain peel is one of the plantain-based snack industry residues, and for each hectare of plantain cultivation, about 220 tones of plantain residues, are generated (Reddy *et al.*, 2003). This type of agricultural residues, has become a problem for industries, because they have limited space for final disposal (Bernardino-Nicanor *et al.*, 2006), whereby, are discarded without any pre-treatment, near water sources and roads, causing environmental problems such as pest spread, bad odors, soil and water pollution (Reddy *et al.*, 2003; Serna-Cock, & Torres-Leòn, 2014).

Arun *et al.* (2015), report on plantain cv. Nendran peel flour, cultivated in India, 5.89 % of protein, 5.12 % of fat, 7.83 % of ash, 11.03 % of carbohydrate, which are values according to the state of maturity, cultivar, soil fertilization and weather conditions, in which the fruit is harvested. Likewise, Arun *et al.* (2015), announces that the plantain peel contains vitamins as follows: ascorbic acid (0.08 mg.100 g^{-1}), riboflavin (0.065 mg.100 g^{-1}), niacin (0.12 mg. 100 g^{-1}) and folic acid (33.12 mg.100 g^{-1}). These micronutrients facilitate the metabolism of other nutrients and maintain various physiological processes, which are vital for all living-active cells and the absence, brings severe clinical pictures. In turn, the presence of these vitamins in plantain peel, postulated as a natural antioxidant. It should also be mentioned that plantain peel has potassium (35.61 mg.100 g^{-1}), which is the most abundant element, followed by calcium (28.63 mg.100 g^{-1}), sodium (14.49 mg.100 g^{-1}) and iron (6.96 mg.100 g^{-1}) (Happi-Emaga *et al.*, 2007). Like vitamins, minerals are essential nutrients for the proper functioning of human body and their lack, can cause serious health problems.

On the other hand, Agama-Acevedo *et al.* (2016), report the plantain peel flour have a contents of total phenols of 7.71 mg EAG.g^{-1}, mainly flavonoid type, which increase as ripening fruit. The phenol compounds, present in the plantain peel, are responsible for the high antioxidant activity (84.73 µmol Trolox eq. g^{-1}). The phenolic compounds presence in plantain peel, Makes it possible to use as a natural antioxidant to reduce the implementation of synthetic antioxidants as butylated hydroxytoluene (BHT) and butylated hydroanisole (BHA), commonly used in processed foods, which have been registered as carcinogens and toxic (Anyasi *et al.*, 2015 & Ajila *et al.*, 2010). likewise, Happi-Emaga *et al.* (2007), report in their studies, the plantain peel contains between 40-50% of total dietary fiber, which promotes benefits in the physiological processes, including laxative effect, decrease of blood cholesterol and reduction of blood glucose.

Even the plantain peel has been used by some researchers in the heavy metals adsorption, biomass production, antioxidant source and production of cellulose nano-fibers, and recently, in cookies preparation for its antioxidant capacity and dietary fiber content (Agama-Acevedo *et al.*, 2016). To date, the inclusion of this residue in the manufacture of meat sausages has not been reported. Therefore, the aim of this research was to partially substitute, in the formulation of frankfurter-type sausage, wheat flour as conventional binder by plantain peel flour and evaluate its water retention capacity, emulsifying capacity and pH.

Materials and methods

Preparation of plantain peel flour (PPF)

Plantain (*Musa paradisiaca* L. cv. Dominico Harton), was acquired in the local market of Palmira-Valle del Cauca, Colombia, guaranteeing that all fruits come from the same crop and have the same ripening stage. The fruits were washed and disinfected with hypochlorite at 100 ppm for 10 min (Djioua *et al.*, 2009). Plantains were peeled with a stainless steel knife. The shells were split into approximately 2 × 2 pieces and dried by freeze-drying under vacuum pressure of 0.120 mBar, and condenser temperature of -40° C for 24 hours. Alternatively, dried material was blade milled (IKA® Labortechnik M20, China). The milled material, was passed through a 250 µm sieve in a Rotap (Tyler®) during 15 min. Plantain peel flour (PPF), packed in a 4 gauge plastic bag and sealed under vacuum at -0.8 psi. Subsequently, plastic bags were stored at 5° C for further use.

Elaboration of sausage

For sausages elaboration, were used cuts of pork shoulder with little connective tissue. The meat is sliced with stainless steel knife, in small fractions and introduced into a mill (Torrey®. M-12-FS, Mexico). With the aim to obtain a meat emulsion, The milled meat went to the crushing process (SHARFEN® TC-1, Germany), in this stage, milled meat, fat, and other ingredients described in Table 1, were added.

Table 1. Ingredients in the formulation of frankfurter type sausages

Sausages formulation					
Ingredient (g)	[a] **Plantain peel flour (PPF)**				
	0.0%	25%	50%	75%	100%
Pig leg	1000	1000	1000	1000	1000
Nitrite salt [b]	6.8	6.8	6.8	6.8	6.8
Fat	120	120	120	120	120
Water	250	250	250	250	250
Spices	71	71	71	71	71
Wheat flour	100	75	50	25	--
Plantain peel flour (PPF) [a]	---	25	50	75	100
Total lot	1.55 kg	1.55 kg	1.55 kg	1.55 kg	1.55 kg

[a] Plantain peel flour (PPF) (% in wet weight of wheat flour)

[b] Nitrite salt =99.4 g of sodium chloride, 0.6 g of sodium nitrite

The emulsion temperature in the cutter was maintained below 10° C. Finally, Wheat flour (WF) was added and plantain peel flour (PPF) in different concentrations depending on the treatment (Table 1). The HT used in the control formulation, was partially replaced by HCP as follows: 25%, 50%, 75% and 100% concentrantions, respectively. The meat emulsion was passed to the hydraulic inlay equipment (Javar® EM 30, Colombia), where synthetic casing was used (Amicel) 23 mm in diameter. The sausages baking was carried out manually at a length of 7 cm using yarn. The sausages cooking was carried out up to a temperature in the center of 75° C. The temperature control was carried out with a punch thermometer Checktemp® (HI 9850, England). Once the temperature was reached, the sausages were immersed in a cold water bath with crushed ice at 4° C for 10 min. The sausages were packed in 4-gauge plastic bags and sealed under vacuum at -0.8 psi. Sausages were stored at 4° C for 48 hours before being analyzed.

Water retention capacity

Water retention capacity (WRC) in the sausage, was determined according to what was reported by Dzudie *et al.* (2002). A sample of approximately 0.5 g was deposited on a grade 1 filter paper and pressed among two plexiglass plates for 20 min under 1 kg of weight. The area of the pressed flesh and juice propagation, were determined by the software Imagej, (Imagen j® 1.40 g, Wayne Rasband, National Institutes of Health, USA). WRC, was calculated according to the established in Equations 1 and 2.

Free water = (Total surface area – meat film area) × (61.10) × 100 / Total moisture of the meat sample (mg)

Equation 1

WRC (%) = 100 – free water (%) Equation 2

Emulsifying stability (Es)

Emulsifying stability (Es), was determined in the meat emulsion. For this purpose, approximately 30 g of mass, was extracted from the cutter and deposited in Petri dishes for further analysis. In pre-weighed 15 ml falcon tubes, 8 g of meat emulsion was deposited and placed in a plastic grid. The tubes were heated for 30 min in a water bath at an average temperature of 75 ± 1° C (Choe *et al.*, 2013). Subsequently, the tubes were centrifuged at 895 g for 5 min at 25° C, and the lipid layer detached from the mass (Yasumatsu, Sawada, & Moritaka, 1972). Es, was calculated by Equation 3.

% Es = Meat emulsion weight in the tuve after draining lipid layer × 100 / meat emulsion weight in the tube before heating

Equation 3

pH determination

The pH was measured by making a 10% (w / v) solution with distilled water, followed by homogenizing solution in a blender (1 min at 1900 rpm), the pH was determined by means of a pHmeter (Mettler Toledo, Switzerland) (Dzudie *et al.*, 2002).

Statistic analysis

To study the effect of HT partial replacement by HCP within the formulation of frankfurter type sausages, we used a random mix design with two replicates (n = 2). In each replicate, the response variables, water retention capacity, emulsifying stability and pH, were evaluated in triplicate. To determine the difference among treatments (Table 1), ANOVA was used at a confidence level of 95% ($p \leq 0.05$). The means comparison was used to determine significance in each treatment by the Tukey test using the software Minitab version 17®. Data performed in the figures are expressed in mean values ± standard deviation.

Results and discussion

Water retention capacity

The substitution effect of WF by PPF in the WRC of the frankfurter-type sausage is shown in Figure 1a.

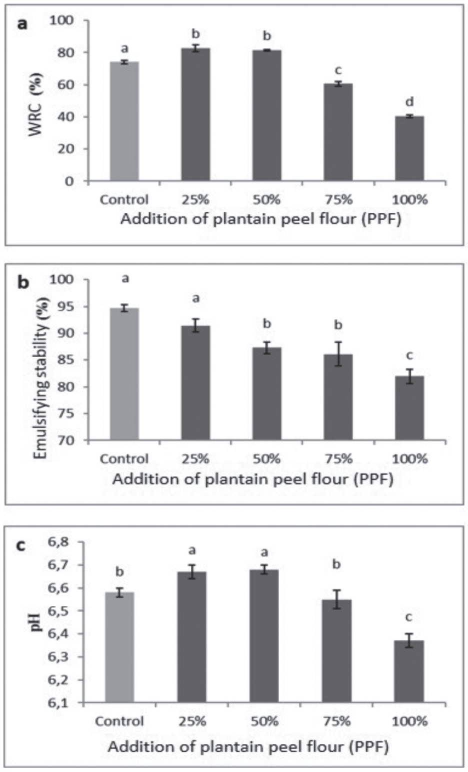

Figure 1. Addition effect of the plantain peel flour (PPF) on water retention capacity (a), emulsifying stability (b) and pH (c) in Frankfurter-type sausages.

Data with different letters for each column represent significant difference ($p<0.05$).

There were statistically significant differences among treatments. Subsequently, the increasing PPF concentration up to 50%, causes a significant increase of 7.5% in the WRC, compared to control. However, it was evidenced that, when this concentration is exceeded, WRC decreased significantly ($p < 0.05$), in 14% for sausages which containing 75% of PPF (compared to control treatment), and 34%, by completely replacing WF.

The results indicate that WRC is favored by replacing up to 50% of the WF content used in the frankfurter-type sausage formulation. WRC is the retained moisture rate in the simple, compared to the initial moisture content, after the samples have been subjected to a mechanical force, therefore, the higher percentage of water released when applying any type of mechanical stress, less moisture will have the sample, which leads to dehydration and loss of product weight with consequent loss of quality. In the case of meat products, the ability to retain water before and after cooking is an important factor because of this variable depends on two factors as follows: the loss of product quality and hence its shelf life and economic profit margin for the manufacturer (Savadkoohi *et al.*, 2014).

Dzudie *et al.* (2002), reported a significant increase ($p<0.05$) 0f 14% in WRC of beef sausages by substituting 10% wet weight of meat for common bean meal, which classifies common bean flour as an excellent non-meat ingredient for use as an extender. On the other hand, Savadkoohi *et al.* (2014), obtained a significant increase ($p<0.05$) of 5.22% in WRC in frankfurter type sausage, by introducing 7% of the total weight sausage, for tomato bagasse. The previous value was lower than obtained in the present study with PPF, since PPF represented 6.45% of the total weight sausages. It could be thought the WRC of the PPF is mainly due to the presence in the plantain peel of the following amino acids: threonine (123.5 $mg.g^{-1}$), valine (116.4 mg. g^{-1}), methionine plus cysteine (108.6 mg. g^{-1}) and isoleucine (101.4 mg. g^{-1}), which are in greater concentration, and their quantity depends on the cultivar and crop geographical conditions (Happi-Emaga *et al.*, 2007).

In addition, these amino acids have a hydrophilic character and therefore, sausages containing 50% of PPF, which could physically trap more water. However, the increase in PPF concentration, was not proportional in the water retention of the final product, and this was probably due to an alteration in the balance of hydrophilic-hydrophobic proteins between meat and PPF. Undoubtedly, PPF presents better WRC compared to tomato bagasse.

Emulsifying stability (Es)

In meat sausages, emulsifying stability (Es) is an important factor in the heat treatment stage. From this parameter, depends the yield and profit margin for the product, therefore, it is sought the Es values are equal to or greater than the control treatment. The mean Es values in the sausage dough, can be seen in Figure 1b. There were no statistically significant differences among control and the simple, which were contain 25% of PPF. However, the other treatments, had a significant reduction ($p < 0.05$), compared to control sample. Therefore, it is possible to replace 25% of WF by PPF without significantly affecting Es.

The decrease in Es shown in Figure 1b, is due to the increase in the fat content exuded by the meat mass during the protein coagulation in the heat treatment. The fat exudation and the consequent Es decrease in formulations with percentages higher than 25% of PPF, is due to the difference in protein content among two flours (8.1% dry protein for PPF, compared to WF, which were contain 13.74% of protein on a dry basis). It should be added the functional properties of proteins such as Es, are affected by their water solubility and hydrodynamic properties (Àlvarez *et al.*, 2011). Another parameter that influenced the emulsifying stability in samples that exceeded 25% of PPF, is the meat viscosity of the meat mass at the moment of being hit in the cutter. Wheat fiber addition has been reported to increase viscosity, bringing with it higher Es in meat mass, in consciousness, wheat fiber is a viable option for the non-canned meat product industry. Choe *et al.* (2013), found a significant reduction in the meat mass exudates during the heat treatment, incorporating a mixture of wheat fiber and pork skin, and an increased stability of meat emulsion. In turn, they stated that to increase and stabilize the emulsion. The protein molecules of the meat product, must encapsulate the fat globules and gel the water present in the formulation.

pH

The pH values are presented in Figure 1c. A pH range is observed between 6.58 for the control sample and 6.37 when replacing 100% of the WF. In addition to 50% of PPF, a significantly pH increased value in the sausages was performed, compared to the control sample. The addition of 75 and 100% PPF produced a decrease in pH values. The sample which did not contain WF had the lowest pH value and this is explained by the fact PPF has an acidic pH value of 5.33, compared to the WF having pH close to the neutrality (6.56-6.83)(Alkarkhi *et al.*, 2011). In addition, is explained due to the amount of exudates was higher than the other concentrations. In contrast, the increase in pH simple values containing 25% and 50% of PPF and is due to the fact they had higher amounts of retained water, and therefore, a higher concentration of basic dissolved substances such as the nitrate salts and sodium chloride. Taking into account that pH is a logarithmic value, small differences among pH are large variations in the hydrogen ions concentration. pH is considered one of the intrinsic factors that directly affects microbial growth and it can be stated the pH values for both, control and treatments, have a high risk of bacteria, yeasts and molds growth (Arief *et al.*, 2014). Because of the above mentioned, it is ideal to obtain pH values below 4.5 to inhibit the toxins formation, e.g., *Clostridium botullinum*, and limit the growth of pathogenic microorganisms such as *E. coli* and *Salmonella*. In the case of frankfurter sausages, they have an average pH range of 6.30-6.48, which makes them susceptible to microbiological modifications capable of altering the chemical composition of sausages. In order to avoid this, the use of preservatives must be guaranteed in the formulation and during all stages of the process, water activity, potential rust reduction must be controlled among other aspects, in order to generate a barrier technology, which guarantees the safety of the final product (Arief *et al.*, 2014).

The results of this research are in accordance with those reported by *Choe et al.* (2013), who observed a significant increase in pH values when adding a mixture of wheat fiber and pork skin to frankfurter type sausages. Similarly, *Dzudie et al.* (2002), found an increased pH in frankfurter type sausages by adding bean flour as meat extender.

In general, pH value of the final product, depends on the meat and additives, and these, can affect the quality of the product, including water retention, freshness, color and texture of the final product at the time of storage (Jin *et al.*, 2016).

Conclusion

In the sausages elaboration, by replacing wheat flour (WF) with plantain peel flour (PPF) up to 50%, there is a significant increase in the water retention capacity of 7.5%, this property is a functional property of great importance, since on this depends the margin of economic profit in the meat processing. In addition, it was observed the 25% substitution of WF, did not significantly affect the emulsifying stability of the meat mass. With respect to pH, there were significant variations in the evaluated treatments. In order to replace the wheat flour, which is considered a conventional binder in the processing of processed meat, by another non-conventional compound, it must be ensured the non-conventional element have a high water retention capacity and high emulsifying stability. Given these concerns, it can be concluded that plantain peel flour (PPF) can be used as an unconventional binder at a concentration of 25% based on the total wheat flour (WF) used in frankfurter-type sausage production.

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