Escuela Agrícola Panamericana, Zamorano

Food Science and Technology Department

Food Science and Technology Major

Senior Research Project

Evaluation of Plantain Peel Flour (*Musa paradisiaca* (L.) AAB cv. Curare enano) as a Sustainable Source of Dietary Fiber in the Elaboration of Cooked Pork and Beef Sausages

Presented by

Ana Fabiola Castillo Lanza

Andrea Gissell Soler Sánchez

Advisors:

Adela Acosta, D.Sc.

Sandra Espinoza, M.Sc.

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Authorities

TANYA MÜLLER GARCÍA

President

ANA M. MAIER ACOSTA

Vice President and Academic Dean

ADELA M. ACOSTA MARCHETTI

Head of Food Science and Technology Department

HUGO ZAVALA MEMBREÑO

General Secretary

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Abstract

Currently, consumers are in search for food that provides good sensory experience, nutritional benefit, and aid health. The plantain industry has an enormous output of discarded peel that usually ends as animal feed or deposited in landfills without considering its nutritional characteristics. The main purpose of this research was to evaluate the elaboration of Plantain Peel Flour (PPF) as a source of dietary fiber in the production of cooked sausages. In the first phase, plantain peel flour was processed and its nutritional composition and the presence of *Salmonella, Escherichia coli,* molds, and yeast evaluated. The amount of dietary fiber present was determined to be 26.13 ± 1.42%. In the second phase, the cooked sausages were prepared in the Meat Plant Zamorano with three different formulations, in which potato starch (PS) and water was replace by PPF in this manner: T1:3.50% PPF 8% water added (WA), T2:6.32% PPF 5.28% WA, and T3:9.02% PPF 2.48% WA; being the plant's standard cooked sausage, the control. Total coliforms and aerobic mesophilic bacteria were under the limit of regulations. A Complete Randomized Blocks Design was used for the sensory evaluations, it showed that the consumers preferred the plant's cooked sausage over the other treatments. The physicochemical properties like pH, texture profile and color were different between the plant´s cooked sausage compared to the treatments with addition of PPF. T3 had 1.58 ± 0.14% of dietary fiber, considered a source of it. Further studies on meat replacement for PPF in the cooked sausages is proposed.

Keywords: coliform bacteria, diet, E*scherichia coli*, filler, formulations, molds, pulp, *Salmonella,* and yeast.

Resumen

Actualmente, los consumidores buscan alimentos que ofrezcan una buena experiencia sensorial, aporten beneficios nutricionales y ayuden a la salud. La industria del plátano genera altas cantidades de cáscara, que generalmente termina como alimento para animales o se desecha, sin considerar su aporte nutricional. El objetivo principal de esta investigación fue evaluar la elaboración de Harina de Cáscara de Plátano (HCP) como fuente de fibra dietética para los chorizos parrilleros. En la primera fase, se procesó HCP y se evaluó su composición nutricional y la presencia de *Salmonella* spp*, Escherichia coli*, mohos y levaduras. Se determinó que la cantidad de fibra dietética presente era de 26.13 ± 1.42%. En la segunda fase, se prepararon los chorizos parrilleros con tres formulaciones diferentes, en las que se sustituyó el almidón de papa (AP) y el agua por HCP de esta manera T1:3.5% HCP 8% agua añadida (AA), T2:6.32% HCP 5.28% AA y T3:9.02% HCP 2.48% AA; siendo el control un chorizo estándar de la planta. Los coliformes totales y bacterias mesófilas aerobias estaban por debajo del límite de la normativa. Se realizó un diseño de bloques completamente al azar, el cual mostró que los consumidores prefirieron el control sobre los otros tratamientos. Las propiedades fisicoquímicas (pH, perfil de textura y color) fueron diferentes entre el control y el resto de los tratamientos. El T3 se considera una fuente de fibra dietética con un contenido de 1.58 ± 0.13%. Se proponen más estudios sobre la sustitución de la carne por HCP en los chorizos parrilleros.

Palabras clave: bacterias coliformes, dieta, Escherichia coli, formulaciones, levadura, mohos, pulpa, relleno y Salmonella. .

Introduction

Currently, in urban, developed cities, incidence of cardiovascular disease has continually increased (WHO 2022). As a result, individuals have changed their lifestyle, integrating nutritious foods as part of the diet, which allows improvements in their health and well-being. The idea is to promote a better diet with high consumption of nutritional values like protein, vitamins, minerals, carbohydrates, and dietary fiber. Furthermore, human nutrition goes along with the dietary patterns that comes from cultural, economic, and geographic availability (Maya Vadiveloo et al. 2019). According to USDA and HHS (2020) in U.S. more than 90 percent of women and 97 percent of men do not meet recommended intakes for dietary fiber.

Traditional sausages, which are usually fabricated with minced pork and beef meat and pork fat, mixed with spices, and food additives, are part of a daily diet and are well known for their source of protein (Lonergan et al. 2019). Pork and beef cooked sausages provide 16 - 24 g of protein in each 100 g serving according to the INCAP and OPS (2018), it has approximately 16.60 g of protein. Also, USDA (2019), established that cooked sausage contains approximately 19.3 g of protein. The Recommended Dietary Allowance (RDA) for daily consumption of protein needed to maintain the health of 97 to 98 percent of individuals, is 46 grams of protein for women and 56 grams for men (Sandi Busch 2018). Nevertheless, one of the biggest nutritional deficient in cooked sausages is the lack of dietary fiber. In consequence, another type of food sources that supplies dietary fiber is needed to maintain their fiber daily recommendation, when consuming cooked pork and beef sausages.

Dietary fiber is derived from plant material and it is composed mainly from non-starch carbohydrates and lignin, which are not digestible in the small intestine due to enzymes that mammals are not capable of hydrolyzing (Turner and Lupton 2011). On the other hand, dietary fiber absorbs water and increases volume, which helps reduce feces transit through the intestines, reducing constipation and aiding in bowel movement regularity. In addition, they have different functional properties: increasing water holding capacity, aiding in texture, having a stabilizing effect, and oil

stability, which are physicochemical properties of importance in food (Ahmad et al. 2020). They have been different studies on dietary fiber related to human health concluding that the increase of its daily consumption reduces the risk of cardiovascular diseases like diabetes and cancer (Pereira et al. 2004; Threapleton et al. 2013; McRae 2017) .The daily recommendation according to the FDA is 28 g per day, based on a 2000 calorie daily diet (FDA 2010). According to the Central American Technical regulations (MINECO et al. 2009), 3 g dietary fiber in per 100 g of food, 1.5 g per 100 kcal or per portion of food, allow it to be considered source of dietary fiber like.

Recently, food waste is one the major problems that cause concern to many companies, industries, governments, and consumers. Inefficient and improper disposal of solid wastes creates serious hazards to human population, including pollution of air and water resources, interfering with life and development (Okorie et al. 2015). One of the biggest sources of food waste is the food industrial processing, generated by-products that were part of the initial mass of fruits (Gowman et al. 2019). The food industry needs to find processes that can be applied for increasing their value and benefited from their physicochemical properties like fiber, protein, vitamins, and minerals. Vast research has been directed in this goal, especially with focus on fruit peels, for example grape, apple, banana, and coconut peels used for creating green composites, films, bioplastics, or flour to be used as ingredient in another food product (Mohd Basri et al. 2021).

Fruit and vegetable peels can be used as a low-caloric functional ingredient combined with other products for food dietary fiber enrichment. Food processing industries can take advantage of this coproduct to develop new products with sustainable materials and reducing the amount of global waste present currently, also known as upcycle which Merriam-Webster (2022), defines to recycle (something) in such a way that the resulting product is of a higher value than the original item. Tropical fruit peels like rambutan, durian, santol and mango have a high content of dietary fiber (around 52-84 g) (Wanlapa et al. 2015).

Plantain is a crop originated in South India and introduced in Southeast Africa. It is a crop that needs tropical and sub-tropical climates since it requires temperatures of 30 °C and relative humidity of 90 - 95%. Its cultivation around 52 countries worldwide is about 12.5 million acres (Ajayi and Ekunwe 2010). According to studies, plantain peel has a high fiber content, and it can help reduce cholesterol levels, blood sugar, helps relieve constipation and thus the prevention of colon cancer. Besides, it has vitamins and minerals that can help consumers reach out their daily necessary consumption (Okareh et al. 2015). Moreover (Rosero Chasoy and Serna Cock 2017) used plantain peel flour as a binder in a frankfurter-type sausage in which they evaluated five formulations for comparing water retention, emulsifying stability, and pH as physical properties of their interested.

Therefore, the objectives of this study were to produce and characterize plantain peel flour (*Musa paradisiaca* (L.) AAB cv. Curare enano) as a sustainable source of dietary fiber. Secondly, to evaluate the consumers sensory acceptance of the addition of plantain peel flour in pork and beef cooked sausages. Lastly, to evaluate the effect of the addition of plantain peel flour over the microbiological and physicochemical characteristics of cooked pork and beef sausages.

Materials and Methods

Experiment Location

The research was conducted at the Escuela Agrícola Panamericana, Zamorano, Honduras. The banana peel flour (*Musa paradisiaca* (L.) AAB cv. Curare enano) was made at the Food Innovation Plant. Additionally, chemical evaluations at the Zamorano Food Analysis Laboratory and microbiological analyses at the Zamorano Food Microbiology Laboratory. The preparation of the cooked sausages with the addition of different amounts of plantain peel flour was carried out at Zamorano's Meat Plant. For the final product microbiological evaluations were carried out at the Zamorano Food Microbiology Laboratory, physicochemical analysis at the Zamorano Food Analysis Laboratory, as well as preference and acceptance sensory studies in the Sensory Analytical Laboratory. The facilities are located at 30 km. East of Tegucigalpa, on the highway to Danlí, Valle del Yeguare, Municipality of San Antonio de Oriente, Francisco Morazán, Honduras.

Materials

The raw material used was plantain peel ("*Musa paradisiaca* (L.) AAB cv. Curare enano"), which was collected from waste generated by the students dining room, Doris Stone, at Zamorano as shown on Appendix A. The parameters used to determine the maturity scale are indicated in Figure 1. In addition, citric acid was acquired from the Fruit and Vegetable Processing Plant of Zamorano and sodium hypochlorite from the Food Innovation Plant. As well as napkins, disposable plastic plates, disposable plastic cups and soda crackers from the convenience store placed at Zamorano. In addition, the meat ingredients, spices, and additives were obtained from the Meat Plant of Zamorano, Honduras. Furthermore, the equipment used during the research is shown on Table 1.

Figure 1

Plantain Maturity Scale.

Note. Source (Agama-Acevedo et al. 2015)

Table 1

Equipment used.

Equipment	Brand
Distillation for protein analyses	FOSS Kjeltec° 8200
Digestion	FOSS Tecator® D 20
Convection oven	Fisher Scientific 750 F
Muffle	“SYBRON Thermolyne
pH meter	STARTER 2100
Brookfield Texturometer	Instron CT3
Analytical balance	Adventurer
Food dehydrator	Excalibur 300 series
Precision balance	METTLER TOLEDO
Electronic balance	OHAUS
Vacuum Stuffer	Frey Konti-C120
Oven	Enviro-Pak
Automatic meat mincer	Thompson Meat Machinery

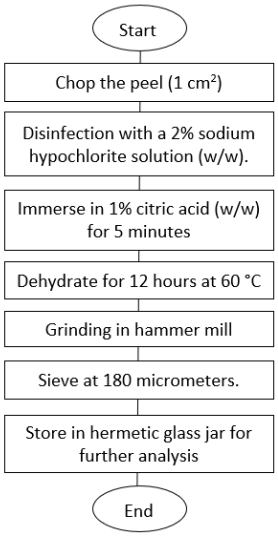
Phase 1. Elaboration and Evaluation of Plantain Peel Flour

Elaboration of Plantain Peel Flour

Plantain peel of the variety "Curare enano" obtained from the student dining room Doris Stone of Zamorano, which were purchased from an external supplier, was used. The plantain peel flour was elaborated in the Food Innovation Plant, following the procedure described by (Anchundia et al. 2016) (Figure 2). First, the peel was cut in 1 cm^2, then washed and disinfected with sodium hypochlorite at 2% (w/w) for 10 seconds and washed with water. Afterwards, they were submerged in a citric acid solution of 1% (w/w) for 5 minutes and them, they were washed and drained. Subsequently, they were dehydrated using the equipment (Excalibur 3000 series) during 12 hours at 60 °C, with a final moisture of 7%. Lastly, it was ground with a mill 180 mesh and stored in hermetic glass jars which were previously disinfected. The process was done at low relative humidity (less than 50%) and without sun exposition to avoid physical changes, this process was repeated three times on different days to produce three lots of flour.

Figure 2

Plantain Peel Flour Elaboration Process



Note. Source (Anchundia et al. 2016)

Microbiological Analysis.

Escherichia coli Analysis.

The process followed for evaluating Escherichia coli was indicated by the Microbiology Laboratory Zamorano. It began with taking a sterile plastic bag and u weighting 10 grams of each plantain peel flour (in this case we made three repetitions). Add up 90 mL of peptone water for each bag using a total of 270 mL. Secondly, we processed on the stomacher for around one minute. Taking pipettes, which were previously sterile, 1 mL from the first bag was taken and added to the petri plate, repeating the same process two times more. Lastly, for the Escherichia coli petri plates, 20 mL of MUG was added, first 15 mL and moved in small circles until the agar was homogenized later, the second layer was of 5 mL. for Escherichia coli at 35 °C for 24 hours.

Yeast and Molds Analysis.

The process followed for evaluating yeast and molds was followed by the Microbiology Laboratory Zamorano. For the evaluation of yeast and molds, 2 mL were taken from the bags already prepared with 10 grams of sample and peptone water processed in the stomacher. One mL of each bag was transferred to the petri plate and the other was placed on test tubes with buffer phosphate which were homogenized. Afterwards, 2 mL from the test tube were taken, 1 mL used for yeast and molds which it was added on the petri plate and 1mL for the second dilution and homogenized. Later, 2 mL were transferred from the test tube, 1 mL for yeast and molds which it was added on the petri plate and 1 mL for the third dilution and homogenized. For yeast and molds analysis, 15 mL of Rose Bengal Chloramphenicol Agar (RBCA) was used for each petri plate, being a total of 135 mL. Each petri plates were incubated (in different equipment), for yeast and molds, at 25 °C for 48 hours.

Salmonella spp. Analysis. The following process was followed by the Microbiology Laboratory Zamorano, and it was divided in several days.

- ***Day 1 Pre-enrichment.*** The followed process for *Salmonella* spp. started with weighting 25 grams of the sample (in this case the flour) and adding 225 mL of peptone water. This bag was homogenized thereafter, resting for 60 minutes at room temperature, and incubating at 35 °C for 24 hours.
- ***Day 2 Selective enrichment in broths.*** In a test tube with 10 ml of Rappaport-Vassiliadis broth 0.1 ml of the bag sample was added and 1ml of the sample evaluated was added in a test tube with 10ml of tetrathionate broth. Both test tubes were incubated, 42 °C and 35°C for 24 hours, for Rappaport-Vassiliadis and tetrathionate broth, respectively.
- *Day 3 Differential isolation in agar.* Both test tubes were homogenized with a peristaltic homogenizer, a microbiological loop was taken and introduced in the test tube, then a Frobisher technique with surface plate method was done in petri plates that had each one agar XLD (Xylose- Lysine Deoxycholate Agar), HE (Hektoen Enteric Agar) and BS (Bismult Sulfite Agar), respectively. Each incubated at 35 °C. This process was repeated for both test tubes.
- ***Day 4 Biochemicals test.*** To detect suspicious colonies from the petri plates, three test tubes for each petri plate were taken. This test tubes had triple sugar iron agar, lysine iron agar and urea broth, and added to each of this test tubes. They were incubated at 35 °C for 24 hours.
- ***Day 5.*** Finally, these test tubes were evaluated and compared according to the table of biochemical reactions of *Salmonella* spp. *(NOM-114-SSA1-11194 1995).*

Chemical Analysis.

Moisture Content

The moisture content of the flour was determined using the method established by AOAC 950.46B. To perform this procedure, porcelain crucibles at 102 °C were pre-set in the convection oven overnight, then cooled in a desiccator at room temperature for one hour and the crucible weight was recorded. Then, 3.0000 ± 0.0050 g of the samples were added in duplicate to the crucibles. The crucibles were introduced into the convection furnace at 100 - 102 °C for 18 hours. Subsequently, the crucibles were cooled with the flour in the desiccator for 30 minutes. Finally, the weight of the dry sample was recorded.

Ashes Analysis.

According to method AOAC 923.03, 3.000 ± 0.005 g of homogenized sample was weighed in each crucible, in duplicate, then incinerated in the muffle at 550 °C for 5 hours, obtaining a light grey color sample. The crucibles were cooled in the desiccator and the sample was weighed at room temperature.

Crude Protein Analysis.

Using the AOAC method 2001.11, the analysis was performed weighing 1.000 ± 0.005 g of sample on waxed paper, then introduced into the digestion tube together with two Kjeltabs and 12 mL of H_2SO_4 (sulfuric acid) with a pipette. Subsequently, two tubes were filled with 0.100 ± 0.005 g ammonium sulphate on waxed paper, while the other two tubes were filled with 0.300 ± 0.005 g acetanilide on waxed paper. The digestion tube with the sample was placed in the FOSS Tecator®digester D 20. After 12 hours. the ammonium was distilled in the FOSS Kjeltec® 8200 distiller. Finally, the titration with hydrochloric acid at 0.1 M was performed, the data obtained were expressed in g/100g.

Dietary Fiber Analysis AOAC 985.29.

***Gooch Filter - Crucible*.** This porcelain crucible was washed and heated for 1 hour in the muffle at 525 °C. Later, they were washed with deionized water and added 0.05 g of celite. Then, these porcelain crucibles were set a night in the convection oven at 105 °C. Finally, they were placed in the desiccator for one hour and weighted with the analytical balance.

Enzymatic Digestion. it was made a total content analysis to the plantain peel flour considered source of dietary fiber according to the method AOAC 985.19. It was weighted 1 ± 0.005 g of the sample using Berzelius´ beaker of 600 mL. Then, it was added 50 mL of phosphate for a giving solution of pH 6.0 on each beaker, and it was mixed up with a magnetic stirring bar. In addition, it was added 100 µl of α-amylase solution and mixed. Later, the beakers were covered up with aluminum foil and incubated on water bath at 95 °C for 15 minutes, the time started when the temperature inside the beakers were at 95 °C. After, the content inside the beakers were mixed up for 5 minutes and removed from the water bath letting them cool to room temperature. Subsequently, it was added 10 mL of NaOH (sodium hydroxide) at 0.275 M and adjust the pH solution to 7.5. Next, to the sample it was added 100 µl of α-protease, for an incubation on water bath at 60°C for 30 minutes, moreover, cooled to room temperature. In addition, it was added 10 mL of HCL (hydrochloric acid) solution at 0.325 M and adjust the pH at 4.0 - 4.6. Thirdly, added 100 µl of α-amyloglucosidase and incubated at 60 °C for 30 minutes. Lastly, for the enzymatic digestion it was added 280 mL of ethanol at 95% preheated at 60 °C, removed the samples from water bath and cool down the samples to room temperature for approximately one hour.

Filtration. This was the last step for measuring dietary fiber. First, it was used Buchner flask, rubber bung, porcelain Buchner funnel and a suction pump with a rubber tubing to make the suction filtration. In this case it was placed the porcelain crucible over the porcelain Buchner funnel adding ethanol at 78% to the celite. After, the content of the beaker was added and then, washed with

ethanol at 95% and acetone. These porcelain crucibles were placed in the convection oven for 24 hours. Finally, the crucibles were placed in the desiccator for one hour and weighted.

Hydrogen Potential (pH) Electrochemical Method.

The electrochemical method was used with a pH meter. In this research the pH of the cooked sausages was measured by three repetitions. It was used the relation 1:10, meaning 1 g of the sample and 10 mL of deionized water. The beaker was wave with an electromagnetic equipment and a magnetic stirring bar for an accurate data.

Arithmetical Mean of Plantain Peel Flour.

An arithmetic mean of the chemical analyses (moisture, ash, crude protein, and dietary fiber) was performed to standardize the samples and estimate the coefficient of variation, this is due to the fact there were evaluated different plantain bunches (*Musa paradisiaca)*.

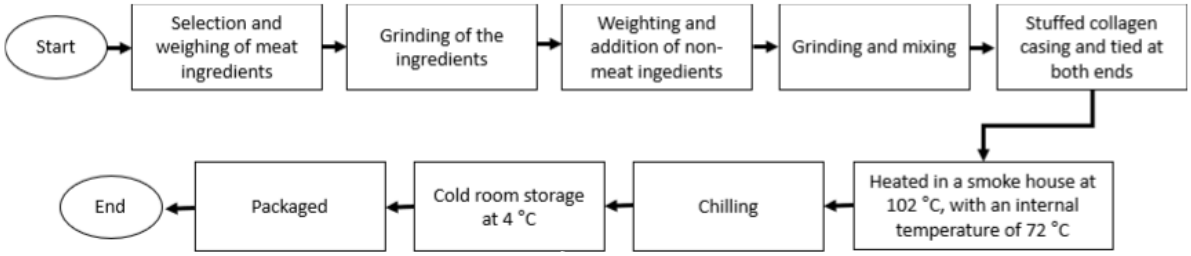
Phase II: Characterization and Evaluation of The Cooked Sausages with Plantain Peel Flour

The characterization of the cooked sausages with plantain peel flour was following the process described by Pineda Cuellar (2009). The flow process used (Figure 3) and the formulation were from the Meat Plant located in Escuela Agricola Panamericana, Zamorano (Table 2). This table was modified according to the treatments used in this research, leaving a control formulation and three with substitution of potatoes' starch with plantain peel flour treatment: one contains 31.11 g of flour per batch of 889 g, treatment; two had 56.2 4 g of flour per batch of 889 g, and the third treatment, considered being source of dietary fiber, contained a total of 80.24 g of flour per batch of 889 g. Subsequently, for the preparation of the treatments, it was used meat ingredients in this case pork (20, 50, and 95% of fat) and beef (10 and 40% of fat) trimmings, which were grounded and mix with additives, preservatives (sodium nitrite, sodium lactate, and sodium erythorbate), and the plantain peel flour. According to the final formula, T1 1: 3.5% Plantain Peel Flour (PPF) and 8% water added (WA), T2 2: 6.32% PPF and 5.28% WA, and T3: 9.02% PPF and 2.48% WA; being the normal cooked sausage, the control. Finally, the product received thermal treatment in an oven until they reached an

internal temperature of 72 °C and subsequently stored 4 °C in the cold room of the Meat Plant Zamorano.

Figure 3

Preparation of Cooked Sausages with Fiber Content.



Note. Source (Pineda Cuellar 2009)

Table 2

Sausages Formulation.

Ingredient (g)	Plantain Peel Flour (PPF)			
	Control (0% of PPF)	T1 (3.50%)	T2 (6.32%)	T3 (9.02%)
Beef and pork	662.74	662.74	662.74	662.74
Potato starch	31.12	---	---	---
Water	71.12	71.12	46	22
Ice	71.12	71.12	71.12	71.12
Condiments	52.68	52.68	52.68	52.68
PPF	---	31.116	56.24	80.24
Total lot	888.78	888.78	888.78	888.78

Note. Control: 3.5% potato starch (PS) 8% water added (WA), T1: 3.5% Plantain Peel Flour (PPF) 8% AW, T2: 6.32% PPF 5.28% AW, T3:9.02% PPF 2.48% WA.

Microbiological Analysis

Aerobic Mesophiles.

According to the Peruvian Ministry of Health (MINSA 2010) the maximum content for meat products in this case ready-to-eat, the microbiological criteria for aerobic mesophilic bacteria is 10000 UFC/g. Therefore, for this analysis it was weighted 10 grams of each cooked sausage and it was added 90 mL of peptone water. The sample were homogenized in a stomacher. Transferring 2 mL, one for the dilution $10^{-1}$and 1 mL for the test tube with phosphate buffer. This was repeated for dilution $10^{-2}$and 10^{-3}. Lastly, 15 mL of agar standard count was added and incubated for 48 hours at 35 °C.

Total Coliforms.

According to the Central American Technical Regulations (MINECO et al. 2009), also known as "RTCA" as the microbiological criteria is determined at < 10 UFC/g. For this analysis, 10 g of each sample were weighed, and 90 mL of peptone water added, homogenized the sample in the stomacher. Secondly, it was taken 1 mL for the dilution $10^{-1}$and added to each petri plate filling with the sample. The normal cooked sausage and the three treatments of cooked sausages combined with the plantain peel flour were evaluated. Then, each petri plated was filled with 15 mL of Violet Red Bile Agar (VRB), and later added 5 mL to each one. Lastly, they were incubated at 35 °C for 24 hours.

Physicochemical Analysis for the Cooked Sausages

Hydrogen Potential (pH) Electrochemical method.

The electrochemical method was used with a pH meter. In this research the pH of the cooked sausages was measured by three repetitions. It was used the relation 1:10, meaning 1 g of the sample and 10 mL of deionized water. The beaker was wave with an electromagnetic equipment and a magnetic stirring bar for an accurate data. Also, it was measured the pH of the plantain peel flour to understand how it could influence the sausages as shown on the Appendix C.

Hardness.

Cooked sausages were evaluated using the equipment Brookfield CT3/Instron by the method of ASTM E83 using the probe TA-SBA with a velocity of 4 mm/s and activation charge of 0.067 N. For the physical analysis the collagen casing was removed from the cooked sausage. Subsequently, the samples were cut with the dimensions 20 x 15 x 10 mm. It was taken the hardness of the normal cooked sausage and the sausage with PPF, repeating this process three times for an accurate average. The results were expressed in N (Newton).

Cooking Yield.

It was measured the weight of the raw sausages. Later, they were cooked until having an internal temperature of 72 °C. Lastly, the cooked sausages were cooled and weighted. This process was repeated three times for an accurate value, following Equation 1 (Loú 2016).

$$Cooking\ yield = \frac{Weight\ of\ cooked\ grilled\ sausages\ (g)}{Weight\ of\ raw\ grilled\ sausages\ (g)} \times\ 100 \quad [1]$$

Color.

Colored was evaluated following the description of LAA-I210-10 and the equipment Color Flex Hunter Lab, for each sample. This equipment measures the clarity or intensity of the sausages color. According to the color scale of L* a* b*; where L scale: measures the clarity with a scale of 0 up to 100, being a low number (0 - 50) indicates dark and a high number (51 - 100) indicates light. A scale: measures the intensity of the colors green and red, where negative values mean green color and positive red. B scale: measures colors yellow and blue, from a scale where positive value means yellow and negative values blue.

Sensory Analysis

On the Sensory Analysis Laboratory Zamorano the normal cooked and the sausages with addition of PPF were evaluated with an acceptance and preference test using 100 untrained panel. It was indicated the level of acceptance or rejection of the attributes like appearance, color, texture,

taste, odor, and general acceptance. Using a 9-point hedonic scale it was measured the acceptance of each attribute in which 1 means: dislike extremely, 5: neither like nor dislike, and 9: like extremely. The preference of the four treatments was indicating in order from 1 up to 4, in which 4 means: least preferred and 1: most preferred.

Experimental Design

Four treatments were evaluated with 3 replicates were established in the experiment for a total of twelve experimental units in a Completely Randomized Design (CRD) for the microbiological and physicochemical characteristics, through an analysis of variance using the program "Statistical Analysis System" (SAS version 9.4), with a significant difference of ($P \leq 0.05$). with a DUNCAN mean separation method. In addition, for the evaluation of preference (ranking) test it was used the Kramer (Basker) rank sum test. Subsequently, the acceptance test was analyzed with a complete randomized blocks design (RCBD) including the attributes of appearance, color, texture, taste, odor, juiciness, and general acceptance with a correlation analysis and a significant difference < 0.05.

Phase III: Characterization of the source of dietary fiber sausage

Proximate Complete Analysis

An analysis to the treatment of source of dietary fiber from the cooked sausage, evaluating the total amount of ashes according to the (AOAC 923.03), crude protein (AOAC 2001.11), crude fat (AOAC 991.26), moisture content (AOAC 950.46B) and dietary fiber with (AOAC 962.09) by duplicate.

Arithmetic Mean

The proximate complete analysis was evaluated with an arithmetic average with the objective of standardizing the samples including the coefficient of variation.

Dietary Fiber Analysis AOAC 985.29

The defatting process was done placing 6 grams the sample in a porcelain crucible for 18 hours in the convection oven. A funnel, filters, and an Erlenmeyer flask were used for defatting the cooked sausages samples with 30 mL of hexane. Lastly, the sample was placed in the convection oven for one hour and placed in the desiccator. This process was repeated.

***Gooch filter - Crucible*.**

This porcelain crucible was washed and heated for 1 hour in the muffle at 525 °C. Later, they were washed with deionized water and added 0.05 g of celite. Then, these porcelain crucibles were set a night in the convection oven at 105 °C. Finally, they were placed in the desiccator for one hour and weighted with the analytical balance.

Enzymatic Digestion.

It was made a total content analysis to the cooked sausage considered source of dietary fiber according to the method AOAC 985.19. It was weighted 1 ± 0.005 g of the sample using Berzelius´ beaker of 600 mL. Then, it was added 50 mL of phosphate for a giving solution of pH 6.0 on each beaker, and it was mixed up with a magnetic stirring bar. In addition, it was added 100 µl of α-amylase solution and mixed. Later, the beakers were covered up with aluminum foil and incubated on water bath at 95 °C for 15 minutes, the time started when the temperature inside the beakers were at 95°C. After, the content inside the beakers were mixed up for 5 minutes and removed from the water bath letting them cool to room temperature. Subsequently, it was added 10 mL of NaOH (sodium hydroxide) at 0.275 M and adjust the pH solution to 7.5. Next, to the sample it was added 100 µl of α-protease, for an incubation on water bath at 60 °C for 30 minutes, moreover, cooled to room temperature. In addition, it was added 10 mL of HCL (hydrochloric acid) solution at 0.325 M and adjust the pH at 4.0-4.6. Thirdly, added 100 µl of α-amyloglucosidase and incubated at 60 °C for 30 minutes. Lastly, for the enzymatic digestion it was added 280 mL of ethanol at 95% preheated at 60 °C, removed

the samples from water bath and cool down the samples to room temperature for approximately one hour.

Filtration.

This was the last step for measuring dietary fiber. First, it was used Buchner flask, rubber bung, porcelain Buchner funnel and a suction pump with a rubber tubing to make the suction filtration. In this case it was placed the porcelain crucible over the porcelain Buchner funnel adding ethanol at 78% to the celite. After, the content of the beaker was added and then, washed with ethanol at 95% and acetone. These porcelain crucibles were placed in the convection oven for 24 hours. Finally, the crucibles were placed in the desiccator for one hour and weighted.

Results and Discussion

Phase 1. Evaluation of Plantain Peel Flour Microbiology and Physicochemical Characteristics

Microbiology Analysis

The total amount of *Escherichia coli*, yeast and molds count of the Plantain Peel Flour (PPF) evaluated during the analysis show a consistent tendency, the results were under the limit being a count per plate of zero in all of the dilutions for *Escherichia coli*, yeast, and molds and absence of *Salmonella* spp, in the three repetitions the value was constant. Therefore, the sanitazion process, manipulation and temperature for PPF was ideal for the optimal microbiological results. This agrees with the results compared to Gomes et al. (2016), and Oloyede et al. (2013), were there was not a difference observed for the microbiological analysis on plantain peel flour.

Physicochemical Characteristics

Physicochemical characteristics in the development of new products, helps understand the importance and the properties from the food. It was obtained from 3.27 kg of plantain peel an amount of 0.50 kg of flour, representing a 15% of yield, this is due to the process of dehydration and grinding. As it is shown on Table 3, plantain peels in the green stage presented a moisture content of 7.39 ± 0.35 (g/100g), this could be due to the amount lost in the previous dehydration process. Moreover, the ash content was 0.19 ± 0.46 (g/100g), as stated by Okareh et al. (2015), the high values of ashes indicates high content of minerals. This agree with McClements (2005), who mentions that the amount of inorganic components available on the plantain peel could be Ca,Na, K and Cl. Furthermore, the amount crude protein was 7.12 ± 0.20 (g/100 g). Protein is an essential component of diet need for survival of human being their basic function is to supply the required amino acids. Also, the quantity of dietary fiber 26.13 ± 1.42 (g/100 g) shows that plantain peel can be used as a good source of dietary fiber for foods according to the Appendix D of the Central American Technical Regulation. This related to the study obtained by Agama-Acevedo and collaborators (2015), where the moisture

content was of 57.8 ± 2.0 (g/kg), protein 102.9 ± 0.9 (g/kg), ash 127 ± 1.0 (g/kg), soluble dietary fiber 73 ± 7.0 (g/kg), and insoluble dietary fiber 303.4 ± 12 (g/kg).

Table 3

Chemical Content of Plantain Peel Flour.

Sample	Moisture (%) Mean ± SD	Ashes (%) Mean ± SD	Crude protein (%) Mean ± SD	Dietary fiber (%) Mean ± SD
Plantain peel flour	7.39 ± 0.35	10.19 ± 0.46	7.12 ± 0.20	26.13 ± 1.42
% CV	4.68	4.47	2.81	5.02

Note. Standard Deviation (SD). Coefficient of Variation (%CV). [a] Mean of triplicate

Phase 2. Microbiology, Sensory and Physicochemical Characteristics Evaluation

Microbiology Analysis

In this microbiology analysis after the process made for the cooked sausages in the Meat Plant Zamorano as shown in the Appendix E, it was evaluated the presence of total coliforms in the sausages as an indicator of safety.

The mesophilic aerobic bacteria count showed no significant difference between all treatments ($P > 0.05$) that comply with the one established by MINSA (2010). Low counts were obtained due to a good manufacturing process, safety handling of the product after cooking and optimal conditions in storage with a temperature of 2 to 4 °C. The results expressed on Table 4 agree with Alves et al. (2016), and Wang L et al. (2019), were there was no difference on the sausages with the addition of fiber flour. The images of the results are shown in the Appendix F.

Table 4

Aerobic Mesophiles Results.

Treatments	Log^{NS} (CFU/g) Mean ± SD
C: 3.5% PS	1.86 ± 0.02
T1: 3.5% PPF	1.53 ± 0.17
T2: 6.3% PPF	1.46 ± 0.12
T3: 9% PPF	1.42 ± 0.32
P	> 0.05
%CV	14.59

Note. Aerobic mesophiles (AM). % CV: Coefficient of Variation. SD: Standard Deviation. NS: no significant difference (> 0.05). Control: 8% water added (WA), T1: 8% AW, T2: 5.28% AW, T3: 2.48% WA. PPF: Plantain peel flour. PS: Potato starch.

Sensory Evaluation

The average results of the sensory characteristics can be seen on Table 5. It was used a hedonic scale of 9 points, where one is considered: " disliked extremely " and 9 indicates: “like extremely" as shown on the Appendix G. Significant statistical differences were found between control and three different formulations in the seven parameters evaluated ($P \leq 0.05$). The control treatment (3.5% potato starch and 8% water added) obtained the best score in each of the attributes: appearance, color, odor, taste, juiciness, texture, and general acceptance.

Appearance.

According to Table 5 the control was the most accepted, in contrast, the least accepted was the Treatment 3 (T3) with 9.02% of plantain peel flour (PPF). This is related to the fact that consumers are accustomed to normal cooked sausages, unlike from the formulation with substitution of PPF. This goes according to the results of Mohd Zaini et al. (2021), were there evaluation in appearance show a preference on normal cooked sausages compared to dietary fiber ones. The appearance was affected due to the content added of plantain peel flour, this caused a darker tone compared to the treatments with least addition.

Color.

As reported on Table 5, the control formulation had the highest acceptance score for color, since it had significant statistical differences ($P \leq 0.05$) compare with the formulations in which potato starch was substituted in different proportions respectively, Treatment 2 (T2) and 3 (T3) did not present significant differences ($P > 0.05$), which were the least accepted, compared to the Treatment 1 (T1). These results were obtained since consumers are accustomed to a certain type of color in these products, unlike products with different color like the PPF cooked sausages (Kuznetsova et al. 2014).

Odor.

The control showed the highest acceptance, nevertheless, Treatments 2 (T2) and 3 (T3) did not have significant differences between them also, which were the least accepted, compare with

Treatment 1 (T1). Table 5 shows the letters that indicates significant differences. The variation of the smell perceived by consumers is related to the volatile compounds present in the plantain peel flour (Bugaud and Alter 2016).

Taste.

As reported by Herrera Úbeda (2016), taste is strictly defined as the tongue´s response to non-volatile soluble materials. As reported on Table 6 the control was the most accepted, although between the treatments with addition of plantain peel flour did not show significant differences. This is in accordance with the study conducted by Talukder (2015), where the sensory panel did not present significant differences of the beef taste with the addition at the different added fiber levels.

Juiciness.

Juiciness is an important factor in the quality of meat, the main factor determining juiciness is the end-point temperature, the higher the end-point temperature, the higher is the cooking loss and the lower the juiciness (Aaslyng 2009). Moreover, texture characteristics includes juiciness, tenderness, and chewiness. The control had the highest acceptance, and the lowest acceptance was the treatment with the addition of 9.02% of plantain flour according to Table 6, this because the amount of added water decreased from 8 to 2%, which significantly affected the perception of juiciness of the products.

Texture.

Texture is a fundamental property to establish consumer preference, include sensations such as softness, granularity, roughness, among others. As seen in Table 6, the control was the most accepted and the least accepted was the Treatment 3 (T3) with 9.02% of Plantain Peel Flour (PPF). Moreover, between Treatments 1 (T1) and 2 (T2) there was not a significant difference. In consequence, the results of T3 with a high content of PPF and less amount of water caused a harder texture sensation. The results concur with Talukder (2015), in which the evaluation of sausages with

dietary fiber were perceived as having more hardness, grainy and less juicy texture than those without fiber.

General Acceptability.

A common way to assess acceptability is through hedonic scales where the participants indicate how much they like or dislike the samples in terms of a specific sensory property (Fiorentini et al. 2020). On Table 6 it shows that the treatment that presented a greater general acceptance was the control, considering that in the seven aspects evaluated it also had a significant difference compared to the formulations with the addition of plantain peel flour. On the other hand, the treatment with a lower general acceptance was Treatment 3 (T3), likewise it was less accepted in the attributes of appearance, smell, flavor, juiciness, and color.

Table 5

Sensory Test of Appearance, Color, and Odor Acceptance.

Treatments	Appearance Media ± SD	Color Media ± SD	Odor Media ± SD
C: 3.5% PS	7.27± 1.48[a]	7.14 ± 1.69[a]	7.00 ± 1.82[a]
T1: 3.5% PPF	6.18 ± 1.86[b]	6.10 ± 1.96[b]	6.19 ± 1.81[b]
T2: 6.3% PPF	5.76 ± 1.94[c]	5.68 ± 1.90[c]	5.81 ± 1.96[c]
T3: 9% PPF	4.93 ± 2.20[d]	5.05 ± 2.19[c]	5.55 ± 1.84[c]
P	≤ 0.05	≤ 0.05	≤ 0.05
% CV	35.13	24.62	22.81

Note. % CV: Coefficient of Variation. SD: Standard Deviation. Letter from A-D: different small case letters in each column indicate significant differences between the treatments evaluated (P ≤ 0.05). 9-point hedonic scale: 1: “dislike extremely”, 4: “dislike slightly”, 5: “neither like or dislike”, 6: “like slightly” and 9: “like extremely”. PS: Potato starch. PPF: Plantain peel flour. Control: 8% water added (WA), T1: 8% WA, T2: 5.28% WA, T3: 2.48% WA.

Table 6

Sensory Test of Taste, Juiciness, Texture and General Acceptance

Treatments	Taste Media ± SD	Juiciness Media ± SD	Texture Media ± SD	General acceptance Media ± SD
C: 3.5% PS	7.54 ± 1.41[a]	7.34 ± 1.62[a]	7.27 ± 1.51[a]	7.48 ± 1.47[a]
T1: 3.5% PPF	6.12 ± 2.20 [b]	6.63 ± 1.88[b]	6.62 ± 1.78[b]	6.35 ± 1.88[b]
T2: 6.3% PPF	5.96 ± 1.93[b]	6.13 ± 1.76[c]	6.35 ± 1.74[b]	6.05 ± 1.75[bc]
T3: 9% PPF	5.73 ± 2.01[b]	5.58 ± 2.10[d]	5.82 ± 1.85[c]	5.77 ± 1.90[c]
P	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05
% CV	23.22	23.04	20.63	20.27

Note. % CV: Coefficient of Variation. SD: Standard Deviation. Letter from A-D: Same as Table 5a evaluated (P ≤ 0.05). 9-point hedonic scale: 1: "dislike extremely", 4: "dislike slightly", 5: "neither like or dislike", 6: "like slightly" and 9: "like extremely". PS: Potato Starch. PPF: Plantain Peel Flour. Control: 8% water added (WA), T1: 8% WA, T2: 5.28% WA, T3: 2.48% WA.

Preference Analysis.

Sensory Test of Preference for Ordering (Basker and Kramer Tests). Basker and Kramer tests are useful to understand which product overall evaluated is preferred by different panelist used as nonparametric test (Liria 2007) as shown on the Appendix G. In this evaluation as shown on Table 6, it was divided in the categories which specifies each treatment and the sum of each panelist. The orders scale from the sensory panel was listed from the most to the least preferred of the pork and beef cooked sausages. Furthermore, the Table 6 shows the results of the Basker Test where it presents the control as the most preferred over the other treatments given an absolute value of (v> 46.9) compared with the critical value for 100 panelists.

However, the treatments with PPF (T1, T2 and T3) were with a final absolute value ≤ 46.9. On the other hand, The Kramer test compared the sum of the total preference of each product, and it affirms that they were not a significant difference between the treatments. Nevertheless, there is a significant difference between control with the others evaluated in the preference test.

Based on the results gathered, since there was no significant difference between the treatments with the addition of plantain peel flour, the treatment with 9.02% of plantain peel flour and 2.48% of added water, which is considered source of dietary fiber, was selected to evaluate its chemical characteristics. Kramer Tests.

Table 7

*Kramer Tests.*7

Categories		C: 3.5% PS	T1: 3.5% PPF	T2: 6.3% PPF	T3: 9% PPF
	Sum	151	258	278	303
C: 3.5% PS	151	0	107	127	152
T1: 3.5% PPF	258	-107	0	20	45
T2: 6.3% PPF	278	-127	-20	0	25
T3: 9% PPF	303	-152	-45	-25	0

Note. PS: Potato Starch. PPF: Plantain Peel Flour. Control: 8% water added (WA), T1: 8% WA, T2: 5.28% WA, T3: 2.48% WA. Critical value: 46.9 per 100 panelists.

Correlation Analysis.

As observed in Table 7 there is a positive correlation between the treatments with la general acceptance in a significant level (< 0.00001). Therefore, the seven evaluated attributes help determined the general acceptance of the product, nevertheless, some attributes differ because they have a high (≥ 0.80), medium (0.50 - 0.79) and low (≤ 0.49) correlation. In the control treatment, the appearance, color, odor, and juiciness had a medium correlation, while flavor and texture stand out for its high correlation. The formulation 3.5% of plantain peel flour (T1), and 9.02% of plantain peel flour and 2.48% of water added (T2), its correlation in appearance, and odr is medium. While the attributes of color, flavor, juiciness, and texture had a high correlation. The formulation with 6.32% of plantain peel flour and 5.28% of water added had a medium correlation on appearance, color, and odor. Although, in flavor, juiciness, and texture.

In general, color, flavor, juiciness, and texture are the attributes that most affected the general acceptance since they oscillated between a medium and high correlation.

Table 88

Correlation Analysis Results of each Attribute with The General Acceptance of each Cooked Sausage using Phase 2 Treatments.

Treatment	Correlation					
	Appearance	Color	Odor	Flavor	Juiciness	Texture
Control	0.50	0.60	0.51	0.70	0.60	0.73
	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
T1	0.69	0.71	0.68	0.89	0.83	0.76
	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
T2	0.64	0.62	0.66	0.84	0.81	0.79
	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
T3	0.66	0.72	0.69	0.81	0.72	0.79
	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note. Control: 3.5% Potato starch 8% water added (WA), T1: 3.5% Plantain peel flour (PPF) 8% WA, T2: 6.3% PPF 5.28% WA, T3: 9% PPF 2.48% WA.

Physicochemical Characteristics

The colours of the food are amongst the first sensory stimuli to be noticed when eating food (Spence 2015). This analysis was evaluated with the Hunter colorimeter with scale L,a,b which is a scale based on the Opponent-Color Theory, compared to the receptors in the human eye . Following the Table 8, the treatments evaluated in the scale of L where all under a dark scale, from 0 - 50 nevertheless, they were a significant differences ($P \leq 0.05$) between the control and the other three treatments. Nevertheless, there is not a significant difference ($P > 0.05$) between the three treatments with plantain peel flour.Moreover, Flores Hernández (2016) had a result in the scale of L with a mean of 41.29 less than the results found according to in his evaluation at day 1, this is due to the type of flour he used compared to plantain peel flour.

Consequently, the scale a where a positive number indicates red and negative number indicates green, the results given show a significant difference ($P \leq 0.05$) between the control and treatment one (T1) compared to T2 and T3. Also, Suman and Joseph (2013), mentioned that myoglobin has the characteristic to give a red color to the meat, the quantity in each treatment compared to the control can be due to the plantain peel flour added in the formulation.

Lastly, the scale b where it determines a positive value as yellow and a negative number indicates blue, all of the treatments where in the yellowness scale with a significant difference (P ≤ 0.05) between the control with a value of 18.38 ± 1.025 and the treatments. However, the treatments (T1, T2, and T3) did not show a signficant difference between them with the addition of plantain peel flour. This results where similar to the results by Mehta et al. (2015), where it was evaluated a scale of color with the control compared to products with dietary fiber.

Table 99

Scale of Color L, a, b of Cooked Pork and Beef Sausages.

Treatments	Scale L Mean ± SD	Scale a Mean ± SD	Scale b Mean ± SD
C: 3.5% PS	49.93 ± 1.01[a]	17.91 ± 0.69[a]	18.38 ± 1.02[a]
T1. 3.5% PPF	37.94 ± 0.35[b]	16.63 ± 0.44[a]	6.47 ± 0.88[b]
T2: 6.3% PPF	38.54 ± 0.09[b]	11.30 ± 1.45[b]	6.83 ± 0.24[b]
T3: 9% PPF	38.74 ± 0.45[b]	9.46 ± 0.24[b]	7.64 ± 0.40[b]
P	≤ 0.05	≤ 0.05	≤ 0.05
%CV	1.29	8.76	8.53

Note. % CV: Coefficient of Variation. SD: Standard Deviation. L*: luminosity with a scale 0: dark 100: light, a*: scale from green to red from - value: green to + value: red, b*: scale from blue to yellow, - value: blue to + value: yellow. PS: Potato starch. PPF: Plantain peel flour. Control: 8% water added (WA), T1: 8% WA, T2: 5.28% WA, T3: 2.48% WA. P ≤ 0.05: Significant difference. Legend for signicant differences was not included

Food texture is a physical property of food arising from the structural constituents and textural properties are related to the deformation, disintegration, and the flow of a food under force, which is a branch of rheology (Giese 2003). Chewiness is the result from the multiplication between hardness, cohesiveness, and springiness mention by Salazar et al. (2021). Also, is considered the chewing time of the sample before swallowing it (Puma Isuiza and Núñez Saavedra 2018). Therefore, on Table 9 the results show a higher chewing value of 4.746 N in the treatment three (T3), this could be due to the fiber content. The results agree with Kim JHwan et al. (2012). who mentions that dietary fiber has a strong chewiness. In addition, the results were similar to the ones obtained by Dhingra et al. (2012), who mentions that their sample with high content of dietary fiber were harder and chewier than the

control. Nevertheless, treatment one (T1) and two (T2) with the addition of plantain peel flour did not show a significant difference ($P > 0.05$) but, the control showed the least value of chewing (1.310 N).

On the other hand, cohesiveness is the degree in which the mass remains together after chewing and it measures the internal bonds keeping the product intact this goes according to Puma Isuiza and Núñez Saavedra (2018). Moreover, lignin which is part of the components of plantain peel flour exhibited a strong correlation with cohesiveness.

As it can be seen on Table 9, cohesiveness on Treatment 3 (T3) was higher (0.273) this could be due to the addition of plantain peel flour. Nevertheless, Treatment 1 (T1) and 2 (T2) did not show significant difference ($P > 0.05$) and the control had the lower value of cohesiveness 0.076.

Hardness is the maximum load reached during the first deformation cycle according to Paredes et al. (2022). Based on Table 9, all the treatments show a significant difference ($P \leq 0.05$), and a significant analysis between the control and treatment one (T1). Nevertheless, treatment one (T1) and two (T2) had similar results in hardness, which were not significant ($P > 0.05$). Finally, treatment three (T3) show a higher result in the hardness characteristic, this treatment had a total of 9.02% of plantain peel flour.

According to Flores Hernández (2016), there exist a relation between the amount of dietary fiber added to a sausage, causing an increase on hardness. Based on Table 9 comparing the hardness of the control (6.675 N) and treatment one (T1) (8.697 N) did not show a significant difference ($P > 0.05$). As well as the treatments one (T1) and two (T2) did not show significant difference ($P > 0.05$). In contrast, treatment three (T3) had a higher content of fiber (1.57g) and value (15.215 N) of hardness.

Table 1010

Physicochemical Characteristics of The Treatments.

Treatments	Chewiness (N) Mean ± SD	Cohesiveness Mean ± SD	Hardness (N) Mean ± SD
C: 3.5% PS	1.31 ± 0.04^{c}	0.07 ± 0.04^{c}	6.67 ± 0.34^{c}
T1. 3.5% PPF	2.90 ± 0.04^{b}	0.14 ± 0.01^{b}	8.66 ± 0.65^{bc}
T2: 6.3% PPF	2.94 ± 0.04^{b}	0.15 ± 0.01^{b}	11.12 ± 0.96^{b}
T3: 9% PPF	4.74 ± 0.20^{a}	0.27 ± 0.02^{a}	15.85 ± 0.96^{a}
%CV	4.75	6.72	6.87

Note. Standard Deviation (SD), Coefficient of Variation (CV%, Letter N: Newtons. Letter a-c: Same as in table 5a means significant difference between treatments. $P < 0.05$: meaning there was significant difference in all the treatments evaluated. PS: Potato Starch. PPF: Plantain Peel Flour. Control: 8% water added (WA), T1: 8% WA, T2: 5.28% WA, T3: 2.48% WA.

Cooking yield was evaluated with the weight of cooked sausages and the raw sausages. Following Table 10, the Treatment 2 (T2) had the highest cooking yield (91.920%) among the others. In addition, between Treatment 3 (T3) and the control had the intermedium values and did not show significant difference ($P > 0.05$). Lastly, Treatment 1 (T1) showed the least cooking yield value (87.680%). According to the results, the control compared to Treatment 1 (T1) showed a significant difference ($P \leq 0.05$), this means there was a loss of product in the cooking process. Additionally, Treatment 3 (T3) did not have a significant difference ($P > 0.05$) compared with the control. Nevertheless, Treatment 3 (T3) showed a significant difference ($P \leq 0.05$) with the treatment 2 (T2). Therefore, according to Rosero Chasoy and Serna Cock (2017), sausages containing 50% of PPF, could physically trap water however, the increase in PPF concentration and the not proportional amount of water, will probably be due to an alteration the balance of hydrophilic-hydrophobic proteins between meat and PPF. Moreover, Rosero Chasoy and Serna Cock (2017), mentions that the water holding capacity of the PPF is mainly due by the presence of amino acids which had hydrophilic characteristics.

On the other hand, the evaluation of Hydrogen potential (pH) is the measure the concentration of hydrogen ions. The difference between the treatments is by the effect of the addition to cooked sausages with the plantain peel flour added as a substitution of potatoes' starch, the pH

values concur with Rosero Chasoy and Serna Cock (2017), when they substituted with plantain peel flour in sausages. The Table 10, show the pH value of the cooked sausages has a value of 7.27 is neutral in the control. Nonetheless, all three treatments show a result of slightly acidic value below the 7, from a scale of 0-14 for pH.

Table 11

Cooking Yield and pH Evaluation of The Treatments

Analysis	Treatments				
	C: 3.5% PS	T1. 3.5% PPF	T2: 6.3% PPF	T3: 9% PPF	%CV
C.Y. (Mean) ± SD	89.28 ± 4.49[b]	87.68 ± 4.64[c]	91.92 ± 5.44[a]	89.64 ± 3.09[b]	0.59
pH (Mean) ± SD	7.27 ± 0.00[a]	6.66 ± 0.01[b]	6.63 ±0.01[c]	6.43 ± 0.01[d]	0.19

Note. Standard Deviation (SD), Coefficient of Variation (CV%, pH: hydrogen potential. Letter a-c: Same as in table 5a treatments. C.Y: Cooking Yield. PS: Potato Starch. PPF: Plantain Peel Flour. Control: 8% water added (WA), T1: 8% WA, T2: 5.28% WA, T3: 2.48% WA.

Phase 3. Proximal Composition to The Source of Dietary Fiber Cooked Sausages

The proximal composition was made to Treatment 3 (T3), which is considered "source of dietary fiber". According to the Appendix D in the Central American Technical Regulation, also known as "RTCA," defines source of fiber a product with 3 g for 100 g of food, 1.5 g for 100 kcal or per portion of food. In this case it was defined as 1.5 g per portion of cooked sausage.

The moisture content (55.469%) presented on Table 11 concurs with the values obtained by Salazar et al. (2021), who evaluated the moisture content in fiber sausages giving a moisture content of 56.77%. At the same time, according to Table 11 the ashes content (10.64%), has a relation with the amount found in the plantain peel flour and the ingredients that were added to the sausage formulation. This result was higher compared to Flores Hernández (2016), where he found 6% of ashes due to the ingredients that were evaluated.

Furthermore, the content of protein is found concur Salazar et al. (2021), when they substitute also with flour the sausages. In the results it was found there is a slight amount higher

compared to the nutritional labeling of cooked sausages, this is due to the amount added of plantain peel flour in this treatment, giving approximate amount of 0.48g protein per portion.

Moreover, the content of crude fat (20.17%) of the Treatment 3 (T3) was like the control, according to the nutritional labeling of cooked sausage Zamorano this is due to the amount of fat was maintain in the sausage formulation. In addition, according to the USDA (2020), there is not a fat limitation for this product.

Lastly, the dietary fiber analysis evaluated to the Treatment 4 (T3) of cooked sausages, is defined as a source of dietary fiber according to the RTCA which defines that source of fiber can be from 1.5 g per portion of the food. In the study following Table 11 it was found a value of 1.56% which affirms the aforementioned.

Table 12

Proximate Analysis to The Source of Dietary Fiber on Cooked Sausages.

Sample	Moisture (%) Media ± SD	Ashes (%) Media ± SD	Crude Protein (%) Media ± SD	Crude fat (%) Media ± SD	Dietary fiber (%) Media ± SD
T3: 9% PPF	55.46 ± 4.04	10.64 ± 0.76	10.52 ± 0.20	20.17 ± 1.35	1.57 ± 0.13
% CV	7.28	7.21	1.92	6.67	3.79

Note. Standard Deviation (SD), Coefficient of Variation (CV%), T3: 9.02% of plantain peel flour with 1.5 g of dietary fiber per portion.

Conclusions

Plantain peel flour provide dietary fiber to cooked sausages, the treatment with the highest addition of plantain peel flour (9.02%) can be considered a source of dietary fiber according to Appendix D of the RTCA 67.01.07:10.

The addition of plantain peel flour indistinctive of the amount, decreased the panelists' acceptance of the sensory attributes of the cooked sausage. Within the treatments that contained plantain peel flour, only taste was not affected by the quantity added.

The microbiological counts of the treatments with plantain peel flour were found below the limit established by MINSA (Peruvian Ministry of Health). The higher the percentage of dietary fiber content, the higher texture profile of the cooked sausages. Plantain peel flour increased the dietary fiber content of cooked sausages and according to RTCA (2012) Treatment 3 (T3) contained 1.56% of plantain peel flour and can be considered a source of dietary fiber.

Recommendations

Try a formulation for cooked sausage in which it is maintained the amount of water and reduce the meat, this will help maintaining the juiciness of the sausage and increase its sustainability.

Perform a vitamin, mineral, phenolic, and flavonoids analysis to the plantain peel flour for further investigations.

Identify the amino acids presented on the plantain peel flour.

Evaluate the calories of the formulation with the addition of plantain peel flour to the sausages and perform a nutritional labeling.

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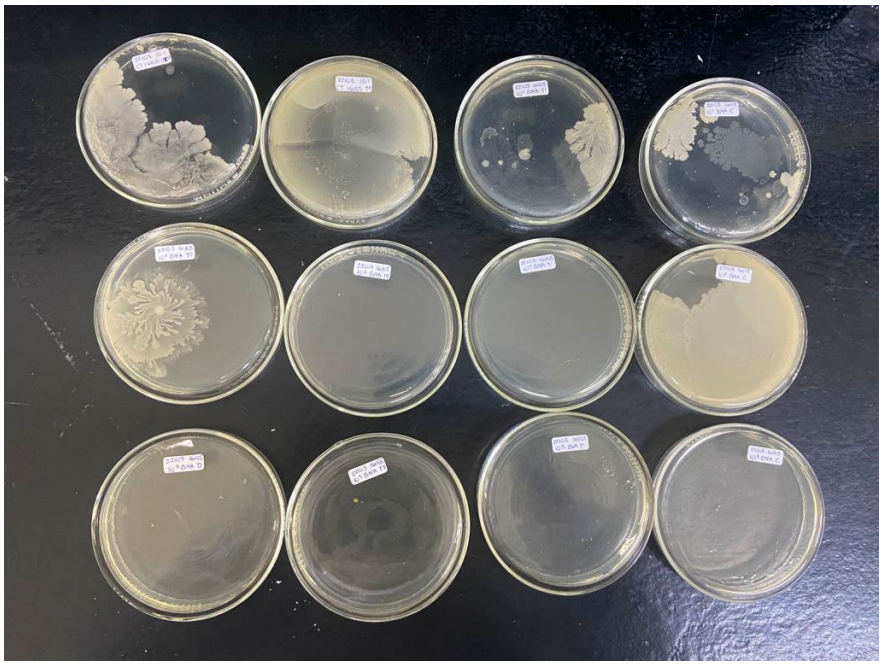
Appendices

Appendix A

Plantain Peel for the Phase.

Appendix B

Aerobic Mesophilic Bacteria Images by The Empty Plate Method.



Appendix C

Hydrogen Potential of Plantain Peel Flour.

Sample	pH Media ± SD
Plantain flour	5.66 ± 0.01
% CV	0.17

Note. Standard Deviation (SD), Coefficient of Variation (%CV). pH: hydrogen potential.

Appendix D

Central American Technical Regulation.

COMPONENTE	DECLARACIÓN DE PROPIEDADES	CONDICIONES
Energía	Exento, libre, sin, cero	No contiene más de 21 kJ (5 Kcal) por porción ó por 100 g ó 100 mL
	Bajo, baja fuente de	No contiene mas de 170 kJ (40 Kcal) por porción o por 100 g o 100 mL
	Ligero, liviano, reducido, menos, Light, lite	Contiene al menos un 25% menos de energía por porción o por 100 g o 100 mL con respecto al alimento de referencia. El alimento de referencia no debe ser bajo en energía
Grasa	Exento, libre, sin, cero	Contiene no más de 0,5 g por porción o por 100 g o 100 ml
	Bajo	Contiene no mas de 3 g por porción o por 100 g o 100 mL
	Ligero, liviano, reducido, menos, Light, lite	Contiene al menos un 25% menos de grasa por porción o por 100 g ó 100 mL, con respecto al alimento de referencia. El alimento de referencia no debe ser bajo en grasa.
Grasas Saturadas	Exento, libre, sin, cero	Contiene no más de 0,5 g de grasa saturada y menos de 0,5 gramos de ácidos grasos trans por porción o por 100 g o 100 mL.
	Bajo	Contiene no más de 1.0 g por porción o por 100 g o 100 mL y la grasa saturada no aporta más del 15% de la energía
	Ligero, liviano, reducido, menos, Light, lite	Contiene al menos un 25% menos de grasa saturada por porción o por 100 g o 100 mL, con respecto al alimento de referencia. El alimento de referencia no debe ser bajo en grasa saturada.
Colesterol	Exento, libre, sin, cero	Contiene no más de 2 mg por porción o por 100 g o 100 ml y contiene 2 g o menos de grasa saturada por poción o por 100 g o 100 mL
	Bajo	Contiene no más de 20 mg por porción por 100 g o 100 mL y contiene 2 gr o menos de grasa saturada por porción o por 100 g o 100 mL

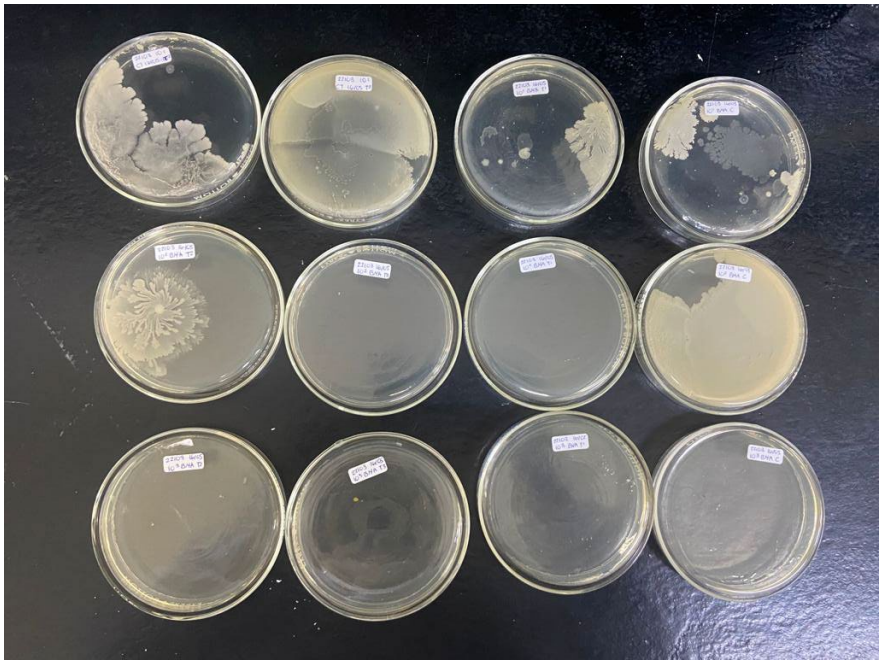
	Ligero, liviano, reducido, menos, Light, lite	Contiene al menos un 25% menos de colesterol por porción o por 100 g o 100 mL, con respecto al alimento de referencia. El alimento de referencia no debe ser bajo en colesterol. Contiene 2 g o menos de grasa saturada por porción o por 100 g o 100 mL
Azucares	Exento, libre, sin, cero	Contiene no más de 0,5 g por porción por 100 g o 100 mL
	"Sin azúcar agregado" y "Sin adición de azucares"	Declaraciones permitidas si no se ha adicionado durante el procesamiento, azúcar o ingredientes que contengan azúcar. Se declara si el alimento no es bajo o reducido en energía
	Ligero, liviano, reducido, menos, Light, lite	Contiene al menos un 25% menos de azúcar por porción o por 100 g o 100 mL, con respecto al alimento de referencia
Sodio	Exento, libre, sin , cero	Contiene no más de 5 mg por porción o por 100 g o 100 mL
	Bajo	Contiene no más de 140 mg por porción, por 100 g o 100 mL
	Muy Bajo	Contiene no más de 35 mg por porción, por 100 g o 100 mL
	Ligero, liviano, reducido, menos, Light, lite	Contiene al menos un 25% menos de sodio por Porción o por 100 g o 100 mL, con respecto al alimento de referencia
Proteína	Alto, buena fuente, rico en, excelente fuente	Contiene dos veces los valores para fuente
Vitaminas y Minerales		
Fibra		6 g por 100 g o 3 g por 100 Kcal
Proteína	Fuente, adicionado, enriquecido, fortificado	Contiene no menos de 10% del VRN por 100 g o contiene no menos de 5% del VRN por 100 ml o contiene no menos del 5% del VRN por 100 Kcal, o contiene no menos del 10% del VRN por Porción del alimento
Vitaminas y Minerales		Contiene no menos de 15% de VRN por 100 g (sólidos) 7,5% de VRN por 100 ml (líquidos ó 5% de VRN por 100 Kcal (12% de VRN por 1 MJ) ó 10% de VRN por porción de alimento
Fibra		Contiene no menos de 3 g por 100 g o 1.5 g por 100 Kcal o por porción del alimento
Vitaminas y Minerales	Mas, extra	Contiene al menos una diferencia en el valor de referencia de los nutrientes (VRN o VD) del 10% con respecto al alimento de referencia. Debe existir una diferencia absoluta mínima en el contenido de nutrientes equivalente a la cifra que se define para la

Appendix E

Treatments of Cooked Sausages before Cooking in the Oven at 102 °C.

Appendix F

Aerobic Mesophilic Bacteria Images by The Empty Plate Method.



Appendix G

Sensory Acceptance and Preference Evaluation Form.

Boleta de evaluación sensorial

Prueba de aceptación y preferencia de chorizos parrilleros con adición de harina de cáscara de plátano

Nombre: _____ Género F: M:

Año de estudio: _____ ¿Consume productos cárnicos? SI___ No___

Nacionalidad: _____ Fecha: _____

Instrucciones: Se le presentarán 4 muestras de chorizo, sírvase a evaluar cada muestra de izquierda a derecha, antes y después de cada muestra debe tomar un sorbo de agua y galleta salada para limpiar su paladar. Indique el grado en que le gusta o disgusta los atributos de cada muestra de acuerdo con los puntajes del cuadro No.1 anotando sus respuestas en el cuadro No.2.

Cuadro#1. Escala hedónica

1	2	3	4	5	6	7	8	9
Me disgusta extremadamente	Me disgusta mucho	Me disgusta moderadamente	Me disgusta un poco	Ni me gusta ni me disgusta	Me gusta un poco	Me gusta moderadamente	Me gusta mucho	Me gusta extremadamente

Cuadro#2. Atributos por evaluar

Atributos	**Código: _____**	**Código: _____**	**Código: _____**	**Código: _____**
Apariencia				
Color				
Olor				
Sabor				
Jugosidad				
Textura				
Aceptación general				

Comentarios y observaciones:

_____

_____

Preferencia por Ordenamiento: De las cuatro muestras presentadas, organícelas de acuerdo con su nivel de preferencia en una escala del 1 al 4. En donde (1) corresponde a la muestra más preferida y (4) a la muestra menos preferida

Preferencia	**Código**
1 (Más preferida)	
2	
3	
4 (Menos preferida)	

Justificación de su elección:

_____

Appendix H

Basker and Kramer Test Table "Critical Value of Difference between Sum of Categories.

Número de panelistas	Número de productos								
	2	3	4	5	6	7	8	9	10
20	8.8	14.8	21.0	27.3	33.7	40.3	47	53.7	60.6
21	9.0	15.2	21.5	28.0	34.6	41.3	48.1	55.1	62.1
22	9.2	15.5	22.0	28.6	35.4	42.3	49.2	56.4	63.5
23	9.4	15.9	22.5	29.3	36.2	43.2	50.3	57.6	65.0
24	9.6	16.2	23.0	29.3	36.9	44.1	51.4	58.9	66.4
25	9.8	16.6	23.5	29.9	37.7	45.0	52.5	60.1	67.7
26	10.0	16.9	23.9	30.5	38.4	45.9	53.5	61.3	69.1
27	10.2	17.2	24.4	31.1	39.2	46.8	54.6	62.4	70.4
28	10.4	17.5	24.8	31.7	39.9	47.7	55.6	63.6	71.7
29	10.6	17.8	25.3	32.3	40.6	48.5	56.5	64.7	72.9
30	10.7	18.2	25.7	32.8	41.3	49.3	57.5	65.8	74.2
31	10.9	18.5	26.1	33.4	42.0	50.2	59.4	66.9	75.4
32	11.1	18.7	26.5	34.0	42.6	51.0	60.3	60.3	76.6
33	11.3	19.0	26.9	35.0	43.3	51.7	61.2	69.0	77.8
34	11.4	19.3	27.3	35.6	44.0	52.5	62.1	70.1	79.0
35	11.6	19.6	27.7	36.1	44.6	53.3	63	71.1	80.1
36	11.8	19.9	28.1	36.6	45.2	54.0	63.9	72.1	81.3
37	11.9	20.2	28.5	37.1	45.9	54.8	64.7	73.1	82.4
38	12.1	20.4	28.9	37.6	46.5	55.5	67.2	74.1	83.5
39	12.2	20.7	29.3	38.1	47.1	56.3	65.6	75.0	84.6
40	12.4	21.0	29.7	38.6	47.7	57.0	66.4	76.0	85.7
41	12.6	21.2	30.0	39.1	48.3	57.7	67.2	76.9	86.7
42	12.7	21.5	30.4	39.5	48.9	58.4	68	77.9	87.8
43	12.9	21.7	30.8	40.0	49.4	59.1	68.8	78.8	88.8
44	13.0	22.0	31.1	40.5	50.0	59.8	69.6	79.7	89.9
45	13.1	22.2	31.5	40.9	50.6	60.4	70.4	80.6	90.9
46	13.3	22.5	31.8	41.4	51.1	61.1	71.2	81.5	91.9
47	13.4	22.7	32.2	41.8	51.7	61.8	72	82.4	92.1
48	13.6	23.0	32.5	42.3	52.2	62.4	72.7	83.2	93.8
49	13.7	23.2	32.8	42.7	52.8	63.1	73.5	84.1	94.8
50	13.9	23.4	33.2	43.1	53.3	63.7	74.2	85.0	95.8
55	14.5	24.6	34.8	45.2	55.9	66.8	77.9	89.1	100.5
60	15.2	25.7	36.3	47.3	58.4	69.8	81.3	93.1	104.9
65	15.8	26.7	37.8	49.2	60.8	72.6	84.6	96.9	109.2
70	16.4	27.7	39.2	51.0	63.1	75.4	87.8	100.5	113.3
80	17.5	29.6	42.0	54.6	67.4	80.6	93.9	107.5	121.2
90	18.6	31.4	44.5	57.9	71.5	85.5	99.6	114.0	128.5
100	19.6	33.1	46.9	61.0	75.4	90.1	105	120.1	135.5
110	20.6	34.8	49.2	64.0	79.1	94.5	110.1	126.0	142.1
120	21.5	36.3	51.4	66.8	82.6	98.7	115	131.6	148.4