Advance Journal of Food Science and Technology 15(SPL): 166-178, 2018
DOI:10.19026/ajfst.15.5890
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: September 14, 2017 Accepted: November 17, 2017 Published: July 10, 2018

Research Article

Effect of Addition of Starch and Yam Flour on the Sensory and Instrumental Properties of Low Fat Sausages

[1]Ana L. Paternina, [3]Jairo G. Salcedo, [2]Pedro E. Romero and [2]Claudia D. Paula
[1]Departamento de Ciencias Agroalimentarias,
[2]Departamento de Ingeniería de Alimentos, Universidad de Córdoba, Ciénaga de Oro,
[3]Departamento de Ingeniería Agroindustrial, Universidad de Sucre, Sincelejo, Colombia

Abstract: This research evaluates the effect of the addition of yam flour and starches on the sensory and instrumental properties of low-fat sausages. A 3×5 factorial arrangement completely randomized was applied to sausages using the following factors: fatty mimetic (flour, native starch and pregelatinized starch) and fat substitution (0, 10, 20, 30 and 40%), evaluating their sensorial and instrumental properties with three replicates per treatment. By replacing 30 and 40% of the fat in the sausages, these were less bright and redder, while 10% of the fat replaced by native starch and pregelatinized, the values of luminosity increased ($p \leq 0.05$) with respect to the control treatment. By replacing 10 and 20% of fat with mimetics, an improvement in texture was observed, reducing the hardness between 10.23 and 25.86%. Sensory evaluation showed that this substitution did not cause any alteration in the acceptability of the sausages ($p \leq 0.05$) with respect to the control formulation, with the exception of those made with native starch at 20% substitution, which was less accepted in flavor. The substitution of 10 and 20% of fat for flour and pregelatinized starch are the most recommended in the production of sausages with better sensory acceptance, texture and luminosity.

Keywords: Acceptance, color, consumer, fat substitutes, hedonic scale, texture

INTRODUCTION

Sausages are widely accepted by consumers of all ages because of their excellent nutritional and sensory characteristics (Feng *et al*., 2013). One ingredient used in the formulation of these types of products that influences these characteristics is animal fat. This is used in proportions of 20 to 30% in traditional sausages around the world (Choe *et al*., 2013; Feng *et al*., 2013; Oliveira-Faria *et al*., 2015) and its main objective is to achieve the development of products with high technological and sensorial quality, but its consumption, due to the high contribution of Saturated Fatty Acids (SFA) (30 to 60 g/100 g), has been associated with the development of certain cardiovascular and chronic diseases such as obesity, cancer, hypertension and stroke (Zhang *et al*., 2010; Pacheco Perez *et al*., 2011; Rivera Ruiz, 2012), so consumers are interested in reducing dietary fat intake, focusing on the purchase of healthy products with high nutritional value added and sensorially acceptable (Pacheco Perez *et al*., 2011; Brewer, 2012; Feng *et al*., 2013).

As an alternative to reducing SFA, it has been suggested to partially replace animal fat with other ingredients that do not contribute calories or improve the fatty acid profile. Among the alternatives proposed, the substitution of part of the fat with water (Ahmed *et al*., 1990), vegetable oils (Salcedo-Sandoval *et al*., 2013; Cofrades *et al*., 2014), protein (Cengiz and Gokoglu, 2007; Yoo *et al*., 2007) and fiber (Campagnol *et al*., 2012; Tomaschunas *et al*., 2013), leading to healthier products, but some problems related to texture and sensory quality have been reported. In order to improve these properties, the use of carbohydrates as an excellent alternative due to their properties of water retention and gel formation has been indicated, which allows to be able to preserve certain organoleptic characteristics that can vary by the diminution of the fat, like the texture (Tokusoglu and Ünal, 2003; Mallika *et al*., 2009).

One of the most used industrial carbohydrates is starch, due to its economic benefits, high availability and wide applicability. Different studies show the potential of starches and flour rich in this polymer to be incorporated in low-fat meat products (Pietrasik and

Corresponding Author: Ana L. Paternina, Departamento de Ciencias Agroalimentarias, Universidad de Córdoba, Ciénaga de Oro, Colombia, Tel.: 3005167741

Janz, 2010; García *et al*., 2012; Feng *et al*., 2013; Bastos *et al*., 2014). For example, when using potato enzyme starch as a substitute for fat in sausages, no differences were observed in the texture profile and the Sensory properties with the control sample (Liu *et al*., 2008). When using modified cassava starches, there were no significant differences with the control sample regarding juiciness, oiliness, texture, taste and general acceptability up to 21 days of storage (Luo and Xu, 2011). When using flours in the elaboration of low-fat meat sausages, such as green banana in the shell, formulations with textural characteristics similar to the control have been found (Araya-Quesada *et al*., 2014).

Taking into account the wide applicability of starches due to the contribution of their techno-functional properties, they are subjected to modification processes, through physical, chemical, enzymatic or combined methods that enhance or provide an improvement in functionality, to resist the requirements of modern food processing, as well as to meet the demands of innovative and high quality food by the customer (Amani *et al*., 2005; Kaur *et al*., 2004). It has also been explored to obtain starches and flours from carbohydrate-rich tubers whose starches possess excellent techno-functional characteristics and ensure that products of excellent quality are obtained, as well as being able to diversify the sources of crops traditionally used to obtain these Such as maize, potato, wheat, rice and cassava, which are highly demanded in the food industry (Nguimbou *et al*., 2012; Torres Rapelo *et al*., 2013).

The starch obtained from yams has been reported as an alternative source to commercial starches because it has certain desirable techno-functional properties, among which is its great capacity to maintain its viscosity stable at high temperatures and low pH values (Alves *et al*., 2002), it has also been reported that it contains a low lipid content of less than 0.5% (Pacheco and Techeira, 2009). Similarly, it has been reported that the flour obtained from yams has low-fat content (between 0.37 and 0.45%) (Techeira *et al*., 2014) this characteristic that allows them to be used as a substitute for fat.

In this research, three modified starches were characterized in order to select among them the one that would present the best techno-functional properties to be used as a substitute for fat. Therefore, the aim of this study was to evaluate the effect of the addition of native starch, modified starch and yam flour on the sensory and instrumental properties of low-fat sausages, in order to obtain a product reduced in animal fat that can be accepted by the consumer.

MATERIALS AND METHODS

Raw materials: The plant material used in the research corresponds to the *Dioscorea rotundata* yam variety, supplied by local producers in the city of Sincelejo (Colombia). Beef and pork fat were obtained from a local supermarket in the city of Sincelejo (Colombia). The ingredients and additives used in the sausage manufacturing process were obtained from the input distributor TECNAS S.A.

Preparation of starches and yam flour: The production of starches and yam flour was carried out at the Unitary Operations Plant of the University of Sucre. For the extraction of the Native Starch (NS) of yam, continuous bubble equipment was used at pilot scale, designed to obtain starch and recovery of its mucilage, followed the methodology proposed by Salcedo *et al*. (2014).

The Pregelatinized Starch (PS) of yam was performed in a batch reactor, following the method set forth by Barragán-Viloria *et al*. (2016) with some modifications. A continuous stirring system was used and heating at 81°C for 10 min at 300 rpm. 0.5 mL of ethanol was added for each gram of starch while stirring for 1 h, then methanol, equivalent to one-third of the water in the suspension, was added with continuous stirring for 5 h. Finally, the samples were dried in a convective oven at 40°C for 24 h and ground until passing through a 100 mesh sieve.

Acetylated Starch (AS) was obtained following the method modified by Salcedo Mendoza *et al*. (2016a). For this a 4.5% starch slurry was prepared and stirred for 60 min at 30°C, 3.0 mL of acetic anhydride was added dropwise to the stirred suspension, maintaining the pH between 8.0-8.4 using 3.0 NaOH solution % (W/v). After completion of the reaction time, the suspension was adjusted to pH 4.5 with 0.4N HCl. The starch obtained was washed, dried in a convective oven at 40°C for 24 h and reduced in size until passed through a 100 mesh screen.

Enzymatic Starch (ES) was obtained by preparing an aqueous solution (120 mL) containing 20 g/L of starch and 315 μL of the hydrolyzing enzyme (commercial α-amylase). The solution was kept under stirring at a pH of 5.5 (0.1 mol/L citrate buffer). Reducing sugars were determined (Miller, 1959) to calculate the dextrose percent (DE). The reaction was stopped using hydrochloric acid (2 mol/L) to lower the pH to 1.5 over the course of 5 min and then using sodium hydroxide (2 mol/L) to raise the pH to 6. Finally, the Starch was allowed to settle, the supernatant was removed, dried in a convective oven at 40°C for 24ch, milled and the sample was passed through a 100 mesh screen. The enzymatic activity was determined following the method proposed by Matute *et al*. (2012).

The Flour (F) of yam was obtained following the method proposed by Pérez and Pacheco de Delahaye (2005), with some modifications. The tubers were washed with potable water to remove all soil and disinfected with a solution of 200 ppm of sodium hypochlorite for 10 min by immersion, then they were peeled, chopped and immersed in 0.1% citric acid solution and convectively dried 50°C for 12 h. Subsequently, they were subjected to a process of reduction of size up to 100 mesh.

Infrared spectroscopy with Fourier Transform (FT-IR): Infrared spectra of native starch pregelatinized starch and yam meal were obtained using a Fourier transform infrared spectrometer (Thermo scientific reference Nicolet iS5 Transmission iD1) in the region of 500 to 4000 cm^{-1}. The crystals were obtained by mixing 20 mg of starch with KBr in a ratio of 1: 5 (starch: KBr) and collecting thirty-two readings at a resolution of 4 cm^{-1} (Colussi *et al*., 2015).

Water Absorption Index (WAI), Water Solubility Index (WSI) and Swelling Power (SP): The method modified by Salcedo Mendoza *et al*. (2016b). For this process, 1 g of starch was deposited on a dry basis in a previously tared centrifuge tube. To this tube, 25 mL of distilled water was added, preheated to the evaluated temperatures (60, 70 and 80°C). The suspension was placed in a water bath according to the temperature under evaluation for 30 min and was shaken manually at 10 min of heating initiation. It was then centrifuged at 565 g for 15 min. The supernatant (soluble starch) was then extracted and the total volume determined. Subsequently, a 10 mL sample of the supernatant was deposited in a pre-weighed Petri dish and dried in an oven at 70°C for 16 h. The weight of the Petri dish was recorded with the soluble material and the centrifuge tube containing the gel (insoluble starch). The values of WAI, WSI and SP were estimated from Eq. (1), (2) and (3):

$$WAI = \frac{GelWeight(g)}{SampleWeight(g)} \quad (1)$$

$$WSI = \frac{SolubleWeight(g) x \frac{V}{10}}{Pesodelamuestra(g)} \quad (2)$$

$$SP = \frac{GelWeight\ (g)}{SampleWeight(g) - Solubleweight\ (g)} \quad (3)$$

Sausages formulation and processing: For the formulation of the sausages, among the modified starches the one that presented the highest values of WAI, SP and WSI at 60 and 70°C was selected, following the formula proposed by Paternina *et al*. (2016) with some modifications based on the Colombian Technical Norm of meat products (NTC 1325, 2008). Five formulations were made from five fatty substitutions by fatty mimetics (flour, native starch and modified starch) in a weight/weight ratio. The fat content replaced in the formulations, in percentages was 0, 10, 20, 30 and 40%, corresponding to 0, 2, 4, 6 and 8 g/100 g as shown in Table 1. To establish the level of fat to be replaced in the meat product, the fat content of commercial sausages was determined which included in its formula pig fat and the maximum value to be replaced by fat was determined by finding hardness values statistically equal to the control formulation.

Table 1: Formulation of sausages with different percentages of fat substitution

	Formulation (%)				
Ingredient	0	10	20	30	40
Beef	60	60	60	60	60
Pork fat	20	18	16	14	12
Fatty mimetic	0	2	4	6	8
Ice	20	20	20	20	20
Curing Salt[1]	1.5	1.5	1.5	1.5	1.5
Erythorbate	0.03	0.03	0.03	0.03	0.03
Phosphate	0.2	0.2	0.2	0.2	0.2
Universal Condiment	1	1	1	1	1
Spices Mixture[2]	0.71	0.71	0.71	0.71	0.71

[1]16% sodium nitrite and 94% sodium chloride; [2]Mixed spice powder: onion 0.3%, garlic 0.3%, pepper 0.01%, nutmeg 0.1%.

Meat emulsions were made from beef with a temperature of 4°C and a pH range of 5.8 to 6.4. Organoleptic characteristics such as color, odor and texture were evaluated on the obtained meat. Subsequently, the meat was cleaned by removing surface fat and connective tissue, then the fat and the meat were chopped forming cubes of approximately 5 cm in size, which were cured using curing salt (6% nitral). Subsequently, the chopped and cured meat and fat were put through to a fine grinding process, using a No. 22 JAVAR brand mill. The mixture of meat and additives was made in a JAVAR cutter with capacity for 5 L, the ingredients were added according to the following order: meat, ice, phosphate, erythorbate, condiments, spices, ice, fat, ice and fatty mimetic. After obtaining the emulsion, the different blends were filled into synthetic gut (19 gauge) using a FELSINEA stuffer, 12 cm portions were obtained and then scalded by immersion at 72°C for 30 min until the internal temperature of the product was reached (70°C), the samples were then cooled to room temperature and vacuum packaged, encoded and stored under refrigeration at 4°C.

Instrumental color measurement: Color analysis was carried out by determining the color coordinates of the CIELAB space (L*: brightness or clarity; a*: green red coordinate and b*: yellow-blue coordinate) and the illuminant D65 was used as a reference system. The measurements were made on a Colorflex EZ 45 colorimeter (HunterLab®), following the methodology used by Grigelmo-Miguel *et al*. (1999). The colorimeter was calibrated with a standard white plate (L* = 97.83; a* = -0.43 and b* = 1.98) before each series of measurements.

Instrumental measurement of sausage texture profile: A TX-T plus texturometer was used to determine the texture profile. For this, sausage samples with a length of 1.7 cm were used, which were placed horizontally and a 30% uniaxial compression was performed at a speed of 1 mm/s. A force of compression of 5 g was applied twice in succession on the samples, in order to simulate human chewing, where the force/time curve was obtained and the following parameters were calculated: hardness, cohesivity, adhesiveness, elasticity and chewability (Paternina *et al*., 2016).

Sensory evaluation: The acceptability of each one of the formulations was evaluated using a non-trained sensory panel composed of 50 habitual consumer sausage starters, which were verbally recruited. The sausages used were cut into 8 g slices, served at room temperature in white dishes coded with three-digit numbers at random; The tasters were asked to evaluate the appearance, color, smell, taste and texture, using a mixed structured hedonic scale of 9 points where one (1) is "extremely disagreeable and nine (9) Determined the intention to buy, using a 5-point scale, where one (1) means "I certainly would not buy" and five (5) means "I would certainly buy."

The sensory panel was performed in four sessions. On the first, the tasters were asked to evaluate the acceptability of the four samples formulated with the flour, on the second session, the ones that were made with the native starch, on the third session, they tasted those made with the pregelatinized starch and in the fourth session, the tasters evaluated the formulations that had the greater acceptance of the previous sessions. A control sample was included in each session.

Statistical analysis: A categorical multifactorial design was used for the statistical analysis of the techno-functional properties of the starches and the instrumental results of color and texture. The sample was taken as factors for the techno-functional properties in five levels (NS, PS, AS, ES and S) and the temperature in three levels (60, 70 and 80°C). In the instrumental properties of the sausages the Fatty Mimic (FM) in three levels (S, NS and PS) and the replacement of fat in five levels (0, 10, 20, 30 and 40%). The selection of the most accepted sausages was carried out through a sensorial analysis, through an experiment to a classification route, with a completely randomized block design, where the factor of study was the substitution of fat in five levels (0, 10, 20, 30 and 40%) for each type of fatty mimetic (flour, native starch and pregelatinized starch to determine any effect of the independent variables on the dependent variables, an Analysis of Variance (ANOVA) ($\alpha = 0.05$) was applied. To compare the obtained results a test of multiple ranges of comparison of means of Tukey was used. In all cases, three replications were performed for each treatment and the data were analyzed using the statistical package R 3.2.1 free version.

RESULTS AND DISCUSSION

Infrared spectroscopy with Fourier transform (FT-IR): Figure 1 shows the FT-IR spectra of starches and yam flour from the 500 cm^{-1} band to the 4000 cm^{-1} band. With the modifications applied to NS of the band corresponding to the hydroxyl groups -OH decreased from 3456 to 3443, 3417, 3385 cm^{-1} on PS, AS and ES respectively. This behavior may be due to modifications in the initial interactions of the hydroxyl groups within the NS allowing the establishment of new hydrogen bonding bridges with less steric hindrance (Mina *et al*., 2009). The absorbances between 2925 and 2930 cm^{-1} corresponding to the C-H extension vibrations, the band between 1640 and 1650 cm^{-1} corresponding to flexural vibrations of the O-H group (Sukhija *et al*., 2016) appear in the flour and in the Starches in study, observing a displacement of the band of 1645 to 1646 cm^{-1} for the AS and the ES and of 1648 cm^{-1} for the PS, due to the introduction of acetyl groups and to the hydrolysis of the granule during the enzymatic attack in the starch (Xu *et al*., 2005). The band 1418 cm^{-1}

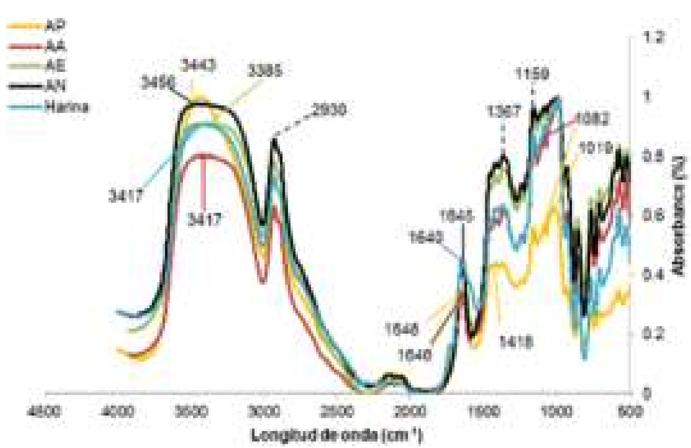

Fig. 1: Infrared spectroscopy with Fourier Transform (FT-IR) of starches and yam flour

Table 2: Techno-functional properties of starches and yam flour

Sample	Temperature 60°C	70°C	80°C
	WAI (g gel/g sample)		
NS	1.91±0.03 bB[2]	2.11±0.05 bB	8.33±0.27 aA
PS	6.33±0.15 bA	8.39±0.07 aA	8.69±0.59 aA
AS	1.84±0.01 bB	2.29±0.02 bB	6.17±0.38 aC
ES	1.85±0.05 bB	2.05±0.04 bB	6.91±0.80 aB
S	2.53±0.03 bB	2.56±0.05 bB	6.36±0.40 aBC
	SP (g gel/g sample)		
NS	1.91±0.03 bB	2.11±0.06 bB	8.52±0.28 aAB
PS	6.75±0.28 bA	8.97±0.07 aA	9.17±0.64 aA
AS	1.85±0.01 bB	2.30±0.03 bB	6.60±0.36 aC
ES	1.88±0.05 bB	2.08±0.04 bB	8.23±0.95 aB
S	2.65±0.04 bB	2.69±.10 bB	6.72±0.43 aC
	WSI (g soluble/g sample)		
NS	0.004±0.0005 bC	0.005±0.0005 bC	0.04±0.004 aD
PS	0.08±0.003 bA	0.10±0.005 aA	0.10±0.01 aC
AS	0.01±0.001 bBC	0.01±0.001 bBC	0.13±0.02 aB
ES	0.02±0.002 bB	0.03±0.002 bB	0.30±0.01 aA
S	0.09±0.005 aA	0.10±0.009 aA	0.11±0.003 aBC

[1]Promedium of three replicates±standard deviation; [2]Means with different letters in rows (lower case, temperature comparison) and columns (upper case, sample comparison) indicate significant differences ($p \leq 0.05$), according to the Tukey test.

assigned to C-H flexural vibrations appeared in the PS, while the other starches and the flour obtained the band 1367 cm^{-1}, this was attributed to the C-H group deformation. The peak 1159 cm^{-1} appeared in all the evaluated samples and is associated with vibrations of the bonds -C-O-C- in glucose, characteristic of a carbohydrate (López-Rubio *et al*., 2009). The band 1082 cm^{-1} corresponding to the C-O group stretching appears in the acetylated and pregelatinized starches. A new peak at 1019 cm^{-1} was evident on the PS, assigned to C-O-H deformation vibrations (Sukhija *et al*., 2016).

Water absorption Index (WAI), Water Solubility Index (WSI) and Swelling Power (SP): The interaction of the temperature and sample factors generated statistically significant changes ($p \leq 0.05$) in WAI, SP and WSI of starches and flour. Table 2 shows the values obtained from WAI, SP and WSI, observing that as the temperature gradually increases, there is also a gradual increase in these properties. These increases may be due to the progressive relaxation of the forces of intragranular bonds with the increase of temperature, thus facilitating the entry of the water molecules into the granule, causing an increase in size and therefore a greater swelling power (Techeira, 2008). This same behavior was reported by Chen *et al*. (2017) and Huang *et al*. (2016) in native and modified yam flour and starches.

On the other hand, significant differences ($p \leq 0.05$) between samples were evidenced for each temperature evaluated in the WAI, SP and WSI values. The greatest increase in WAI and SP at different temperatures was obtained with the PS, possibly due to the disorganization in the granule structure, presence of weaker intragranular forces and loss of crystallinity with the consequent decrease of the pastification temperature, which allows it to absorb large amounts of water, causing swelling and increasing its volume at lower temperatures (Hernández-Medina *et al*., 2008; Techeira, 2008). This behavior is characteristic of this type of sample as a consequence of the nature of the process to which it has been put through, since the thermal treatments used in the preparation of pregelatinized starches cause strong changes in the crystalline structure mainly at the level of the amorphous regions, generating a rupture of its intragranular forces, which leads to the beginning of the unfolding of the double-helix regions, causing a disorganization in the granule structure (González and Pérez, 2003; Rincón *et al*., 2007).

The values of WAI and SP at 60°C of flour and starches: native and enzymatic are within the range reported by Salcedo Mendoza *et al*. (2016b) for native and acetylated cassava and yam starches (1,862 at 5,219 g/g for WAI and 1,877 at 5.38 g/g for SP), while those from PS are superior. In addition, SP values of the PS at different temperatures are within the range reported by Huang *et al*. (2016) in native and modified starches by enzymatic hydrolysis and a crosslinked carboxymethylated dual of *Dioscorea opposita* (4.74 g/g to 13.58 g/g) for temperatures between 65 and 95°C.

As for the WSI, the highest value for NS, AS and ES was obtained at 80°C, on the flour, an increase was observed as well, although not significant, whereas for the PS the largest increase was a 70°C being equal to 80°C, since as the temperature increases the granule gelatinizes, causing the rupture of the intragranular molecular order and the release and solubilization of the amylose molecules in the dispersing medium; highlighting the highest values in the different temperatures evaluated with modified starches and flour, possibly associated with an intragranular structure weaker than the NS, which facilitates the leaching of the starchy material to the outside of the granule (Bello Pérez *et al.*, 2002). The WSI values of

Table 3: Average1 values of the color of the sausages

	Substitution (%)				
FM	Control[2]	10	20	30	40
			Parameter L*		
S	53.45±0.03 aA[3]	53.44±0.03 aC	53.33±0.05 aB	52.41±0.08 bB	51.39±0.07 cB
NS	53.47±0.01 cA	54.39±0.04 aB	53.80±0.05 bA	53.21±0.08 dA	53.19±0.08 dA
PS	53.45±0.04 bA	54.87±0.03 aA	51.44±0.08 cC	50.18±0.05 eC	50.48±0.05 dC
	Parameter a*				
S	11.40±0.03 dA	11.24±0.05 eC	12.26±0.02 cB	12.48±0.03 bB	14.50±0.01 aA
NS	11.40±0.02 dA	11.77±0.04 cB	12.03 ±0.008 bC	12.18±0.05 aC	12.23±0.04 aC
PS	11.40±0.02 dA	12.69±0.01 cA	12.67±0.01 cA	13.66±0.02 bA	13.91±0.06 aB
	Parameter b*				
S	14.24±0.15NS[4]	14.70±0.23NS	14.60±0.23NS	14.28±0.40NS	13.90±0.48NS
NS	14.69±0.24NS	15.05±0.34NS	14.59±0.11NS	14.51±0.21NS	13.65±0.10NS
PS	14.25±0.15NS	14.82±0.05NS	14.20±0.23NS	14.02±0.15NS	13.03±0.15NS

[1]Promedium of three replicates±standard deviation; [2]Control: 0% fat replacement; [3]Means with different letters in rows (Lower case letters, comparison between substitution and columns (Capital letters, comparison between FM) indicate significant differences (p≤0.05), according to the Tukey test; [4]NS: Not Significant

the NS, AS and ES were within the range reported by Salcedo Mendoza *et al*. (2016a, 2016b) for native and acetylated yam starches of the *Dioscorea alata* and *rotundata* varieties (0.001 to 0.015 g/g) and cassava (0.015 to 0.03 g/g), while those of the PS and flour were higher.

Taking into account that the PS has the capacity to absorb more water at temperatures of 60 and 70°C, it would be the most favorable starch for the development of low in fat meat emulsions, since it would allow, during the scalding of the products, to achieve The swelling and the absorption of water in sequence with the thermal changes and release of water by the proteins of the meat, favoring the texture of the products (Pietrasik and Janz, 2010). It is worth noting that WAI and SP of PS, the values are higher than those reported for native cassava starch (3.540 g/g for WAI and 3.387 g/g for SP) at 60°C (Salcedo Mendoza *et al*., 2016b). Of the flour, these values are not far off. Taking into account that cassava starch has great acceptance in the meat industry by favoring water retention, improving texture, wettability and imparting binding characteristics during the cooking process (Torres, 2012), it could be expected that when using flour And the PS of yam in meat products, these confer good water retention and desirable textural properties in the meat emulsions therefore the PS was selected among those modified for use with FM.

Instrumental color measurement: On Table 3, the values obtained from the chromaticity L*, a* and b* are shown. The interaction between the FM factors and the fat substitution used in the preparation of the emulsions generated statistically significant changes ($p\leq0.05$) in the parameters L* and a*, but not in b*. In the luminosity, significant differences ($p\leq0.05$) were found between the fat substitution percentages for each FM, obtaining the lowest values when replacing 30 and 40% fat. However, by replacing 10 and 20% of fat by NS and 10% by PS, the luminosity values increased in comparison to the control treatment, this was possibly influenced by the color of the starch gels. On the other hand, the lower values of luminosity detected in these formulations could be due to their lower fat content, since a reduction in fat level generally favors the appearance of darker colors (higher red values and values of), resulting from a reduction in the overall dispersion of light associated with fat dispersing properties (Pietrasik and Janz, 2010). A decrease in brightness was also evidenced in hamburger meat where green banana and oatmeal meal were used as fat substitutes (Bastos *et al*., 2014) and in chicken emulsions where green banana flour with peel was evaluated as a substitute for (Araya-Quesada *et al*., 2014), while using pigskin and amorphous cellulose as a fat substitute in meat products has shown an increase in brightness with respect to control (Oliveira-Faria *et al*., 2015).

The positive values of a*indicated a relative visual position towards the red color. Significant differences ($p\leq0.05$) were found between the substitutions for each FM, noting that, when replacing the fat with the fatty mimetics said color increased in relation to the control formulation, becoming redder, as the percentage of substitution of fat increased, except for those formulated with a 10% replacement fat per flour. Possibly the significant increase in redness values with the decrease in fat content is due to the higher exposure of the lean meat content (Crehan *et al*., 2000). A similar behavior was evidenced in chicken emulsions when replacing fat with green banana flour (Araya-Quesada *et al*., 2014), in hamburger meat when using green banana and oatmeal as fat substitutes (Bastos *et al*., 2014) and in fat-substituted sausages with rice starch and mixtures of starch with gum (Feng *et al*., 2013).

In addition, it was evidenced that for all substitutions except for the control, there were significant differences ($p\leq0.05$) between the GMs, in the chromaticity values L* and a*, with sausages formulated with NS to be more luminous and less dark than the (Bastos *et al*., 2004). The results of this study are presented in Table 1 and 2. A similar behavior was

Table 4: Average values1 of the texture profile of the sausages

	Substitution (%)				
FM	Control[2]	10	20	30	40
			Hardness (N)		
P	12.02±0.84 aA[3]	10.59±0.32 bA	10.79±0.15 bB	12.35±0.50 aB	12.70±0.30 aB
NS	12.18±0.14 bA	9.03±0.50 cB	11.97±0.28 bA	12.38±0.55 bB	14.37±0.33 aA
PS	12.06±0.20 bA	9.11±0.33 dB	10.76±0.27 cB	13.60±0.40 aA	13.37±0.21 aB
	Elasticity				
P	0.90±0.007 aA	0.91±0.006 aA	0.91±0.002 aAB	0.92±0.006 aA	0.92±0.005 aB
NS	0.91±0.008 bA	0.91±0.007 bA	0.90±0.006 bB	0.91±0.003 bB	0.93±0.005 aA
PS	0.90±0.008 bA	0.89±0.005 bB	0.91±0.004 aA	0.90±0.002 abB	0.90±0.003 abC
			Cohesivity		
P	0.77±0.019 aA	0.77±0.014 aA	0.76±0.006 aB	0.77±0.013 aAB	0.78±0.005 aA
NS	0.78±0.008 aA	0.79±0.011 aA	0.79±0.014 aA	0.75±0.019 bB	0.79±0.008 aA
PS	0.77±0.006 bA	0.79±0.008 abA	0.80±0.004 aA	0.78±0.019 abA	0.80±0.007 abA
	Masticability (Kg)				
P	8.44±0.46 aA	7.44±0.31 bA	7.40±0.06 bB	8.68±0.48 aB	9.08±0.24 aB
NS	8.60±0.24 bA	6.49±0.47 cAB	8.54±0.37 bA	8.40±0.29 bB	10.61±0.29 aA
PS	8.40±0.25 bA	6.41±0.21 cB	7.89±0.16 bB	9.52±0.09 aA	9.54±0.23 aB
	Adhesivity (Kg)				
P	-0.03±0.010NS[4]	-0.02±0.004NS	-0.03±0.003NS	-0.03±0.006NS	-0.04±0.002NS
NS	-0.03±0.009NS	-0.03±0.008NS	-0.03±0.003NS	-0.03±0.004NS	-0.03±0.004NS
PS	-0.03±0.008NS	-0.02±0.003NS	-0.03±0.003NS	-0.03±0.002NS	-0.02±0.001NS

[1]Promedium of three replicates±standard deviation; [2]Control: 0% fat replacement; [3]Means with different letters in rows (Lower case letters, comparison between substitution and columns (Capital letters, comparison between FM) indicate significant differences (p≤0.05), according to the Tukey test; [4]NS: Not Significant

observed by Bastos *et al*. (2014) when comparing the different flours used as fat mimetics on the production of hamburgers.

On the other hand, the main effect of the factors was significant (p≤0.05) on the blue-yellow chromaticity (b*). The positive values of b* indicated a tendency toward yellow. The highest values of b* were obtained by replacing 10% of the fat by the mimetics and the smaller ones by replacing it by 40%. These results agree with those reported by Araya-Quesada *et al*. (2014), Bastos *et al*. (2014) and Feng *et al*. (2013), who determined significant differences between the control and the fat-substituted meat products, resulting in the latter being less yellow. On the other hand, it was evidenced that when replacing the fat by the PS the sausages presented a less yellow hue than when using the flour and the NS, which could be related to it's greater potential to absorb moisture, generating a diluting effect on the chromaticity b* (Aleson-Carbonell *et al*., 2005).

Instrumental measurement of sausage texture profile: On Table 4, the results obtained from the texture profile are shown. There were statistically significant differences (p≤0.05) between the interaction of the factors under study for the parameters hardness, elasticity, cohesiveness and chewing, but not in the adhesiveness. As for the hardness, the results showed that when replacing 10 and 20% the fat per yam flour, hardness decreases in 11.89 and 10.23%, respectively, when compared with the control formulation; Similarly, by replacing it by PS in the same percentages, the hardness decreased by 24.46 and 10.77%, respectively and by replacing it by 10% by NS, it decreased by 25.86%, while by replacing 40% fat by NS Increased by 17.98% and by PS by 30 and 40% increased by 12.77 and 10.86%, respectively; since the decrease of the fat content in meat products affects the hardness, because the fat contributes succulence, juiciness and tenderness, in such a way that foods with low content of fat present a greater hardness (Brewer, 2012). A similar behavior was observed when preparing low-fat chicken meat emulsions with ratios of 22.5/2, 20/4 and 17.4/6% fat/banana flour, where the addition of 17.4/6% fat/flour increased the hardness of products with respect to control and to 22.5/2% decreased (Araya-Quesada *et al.*, 2014). Also, by increasing the addition of 3 to 6% inulin fiber gel in a low-fat emulsion paste the hardness increased by 25.30% (Álvarez and Barbut, 2013). On the other hand, the use of other fatty mimetics in meat products such as the combination of pork skin with amorphous cellulose (Oliveira-Faria *et al*., 2015) and wheat fiber (Choe *et al*., 2013) have increased the hardness of the products Between 3.84-51.31% and 25.06-64.86%, respectively, when compared to the control without fat replacement.

On the other hand, on the 30 and 40% substitutions the starches tended to generate a higher hardness than the flour, which may be related to the starch content, since this favors the formation of stronger structures, due to the swelling of the starches. Heat-starch granules embedded within the protein gel matrix (Carballo *et al*., 1995). This behavior was also evidenced by Pietrasik and Janz (2010) in a low-fat sausage type bologna, where the addition of pea starch generated a higher hardness than pea flour.

The replacement of the fat by the flour did not have a significant effect (p≥0.05) on the elasticity and the cohesiveness of the low fat sausages, being statistically equal to the control sample. These results are consistent

Table 5: Average results of the acceptance test of sausages formulated with fatty mimetics

Susbstitution (%)	Attributes					
	Appearance	Color	Smell	Flavor	Texture	Purchase intention
			Flour			
Control[1]	6.39 ab[2]	6.10 ab	6.26 ab	6.28 ab	6.19 a	3.53 ab
10	5.96 b	5.66 b	5.92 ab	5.46 b	5.84 a	3.08 bc
20	6.04 b	6.08 ab	5.88 b	5.70 b	5.64 a	2.90 c
30	6.28 ab	6.18 ab	6.56 a	5.86 ab	6.02 a	3.38 abc
40	6.80 a	6.60 a	6.56 a	6.58 a	6.24 a	3.94 a
NS						
Control	6.12 ab	5.60 bc	5.82 b	6.34 ab	6.26 a	3.44 b
10	6.66 a	6.14 ab	6.34 ab	7.02 a	6.02 a	3.86 a
20	5.74 b	5.44 c	5.80 b	5.44 c	5.82 a	3.16 c
30	6.60 a	6.70 a	6.52 a	6.86 ab	6.30 a	3.88 a
40	6.02 ab	5.56 bc	5.90 ab	6.10 bc	5.66 a	3.32 bc
PS						
Control	5.68 b	5.66 a	6.12 a	5.96 ab	5.76 ab	3.08 c
10	6.70 a	6.22 a	6.12 a	6.52 a	5.94 ab	3.86 a
20	6.64 a	6.32 a	6.28 a	6.66 a	6.04 a	3.86 a
30	6.52 a	6.14 a	5.92 a	5.62 b	5.66 ab	3.18 bc
40	6.40 ab	6.12 a	6.06 a	5.46 b	5.10 b	3.34 b

[1]Control: 0% fat substitution; [2]Means with different letters in columns indicate significant differences ($p \leq 0.05$), according to Tukey's test

with those reported by Araya-Quesada *et al*. (2014) in low-fat chicken meat emulsions. However, differences were found when replacing it with starches, observing that when replacing it with NS and PS by 40 and 20%, respectively, they increased the elasticity with respect to the control. Probably, these formulations increase the structural stability of the emulsion, improving the ability to maintain its shape when subjected to an effort. Also, it is evident that when replacing the fat with PS, it generates a lower elasticity than the NS and the flour, which may be due to the formation of stronger structures in the meat matrix (Carballo *et al*., 1995). In terms of cohesiveness, replacing 30% of the fat with NS decreased this compared to the other formulations, while replacing it with 20% per PS increased, with respect to the control, indicating less deformation due to the first compression cycle, possibly associated with greater strength among the internal links of the meat network (Albarracín *et al*., 2010). However, in the majority of substitutions evaluated, the flour tended to generate a lower cohesiveness than the NS and the PS, which may be due to its lower starch content (Carballo *et al*., 1995).

For masticability significant differences ($p \leq 0.05$) between each FM substitutions were found, noting that by replacing 10% fat for the mimetic, the chewiness of the sausages decreased in relation to the control formulation, whereas by substituting 40% by NS and 30 and 40% by PS, it increased. Also, there were significant differences ($p \leq 0.05$) between FM for each substitution evaluated except for the control. Starches tended to increase its chewiness when compared with flour, generating NS in substitutions 20 and 40% higher values and 30% on the PS, possibly because starches significantly influence the chewing ability and disintegration of the formulated gels (Araya-Quesada *et al*., 2014), noting that this feature intervenes directly in the fat content of food, as this improves mouthfeel and facilitates when chewing them (Totosaus and Pérez-Chabela, 2009).

The main effect of the factors under study was not significant ($p \geq 0.05$) on the adhesiveness of the sausages. These results are consistent with those reported by Araya-Quesada *et al*. (2014) in low-fat chicken meat emulsions.

Sensory evaluation: Fifty habitual consumers of sausages, evaluated the level of acceptance of low-fat sausages and control formulation (20% fat and 0% FM) according to the attributes of appearance, color, smell, taste and texture, also evaluated the intention of purchase, finding significant statistical differences ($p \leq 0.05$) for attributes of appearance, color, smell, taste and purchase intention when replacing fat with flour and NS, while replacing it with PS revealed significant statistical differences ($p \leq 0.05$) for attributes of appearance, taste, texture and purchase intention.

Table 5 shows the results of the sensory evaluation made by the tasters of the different sausages, using fat mimetics flour, NS and PS and the control formulation (20% fat and 0% flour). When replacing the fat with flour, it was observed that these in any of the evaluated parameters detected significant differences ($p \geq 0.05$) between the control sausage and the low-fat ones, although pig fat contributes significantly to the development of the flavor, The flavor profile, the appearance, the color and the texture of the sausage products (Tokusoglu and Ünal, 2003; Weiss *et al*., 2010; Gómez and Lorenzo, 2013). Similar results were evidenced by Pietrasik and Janz (2010) when comparing the acceptability judgments of the tasters of a low-fat bologna-type sausage with wheat flour, using the formulation 10% fat and 4% wheat flour and the control sample made with 22% fat.

However, among the sausages with different fat substitutions per flour, significant statistical differences were detected ($p \leq 0.05$). Regarding appearance, 84% of the tasters had a positive acceptance of the sausage with 40% of fat substitution, denoting a 50% between the "I slightly like it" and "I like it moderately" hedonic terms and was statistically equal to the control sausage already substituted with 30% of fat, rated by consumers with 62 and 54% respectively, among the same hedonic terms. The lowest acceptance of sausages for this attribute were those made with substitutions of 10 and 20%, rated by 30 and 34%, respectively, of the tasters in the term "I like it slightly", resulting statistically different ($p \leq 0.05$) to the sausage made with 40% of fat replacement.

As for the color attribute, 82% of consumers had a positive acceptance of the sausage made with 40% of fat substitution per flour, qualifying it 62% between the hedonic terms "I slightly like it" and "I like it moderately", being statistically equal ($p \geq 0.05$) to the control sausage and those formulated with substitutions of 20 and 30%, rated by consumers with 72, 48 and 58% respectively, among the same hedonic terms "I slightly like it" and "I like it moderately" and was statistically different ($p \leq 0.05$), to the sausage elaborated with 10% fat replacement qualified by the tasters with 60% between the hedonic terms "I'm Indifferent" and "I slightly like it", the latter being the one with less acceptance.

As for the smell, the sausages formulated with substitutions of 30 and 40% of fat per flour obtained the highest averages, being rated by the consumers between the hedonic terms "I slightly like it" and "I like it moderately", with percentages of 58 and 36% respectively, however the scent perceived by the tasters on these was statistically equal ($p \geq 0.05$) to that of the control sausage denoted with 64% between the hedonic terms "I slightly like it" and "I like it moderately" and the one made with 10% of fat replacement, rated 50% between the "I'm Indifferent" and "I slightly like it" hedonic terms, but they were different ($p \leq 0.05$) than the sausage made with 20% of fat substitution, obtaining the latter the lowest acceptance by the consumers, who denoted it with 44% between the hedonic terms "I'm Indifferent" and "I slightly like it".

As for the appearance attribute, the flavor perceived by the tasters of the sausage made with 40% of the substitution of fat by flour was statistically equal ($p \geq 0.05$) to the control sausage and the formulation with 30% of fat substitution, but different from sausages made with 10 and 20% substitutions, the latter being the least accepted, the consumers denominated them in the terms of "I'm Indifferent" and "I slightly like it" with ratings of 40 and 36% respectively. However, control sausages and manufactures with 30% and 40% of fat substitutions were rated by consumers among the hedonic terms "I slightly like it" and "I like it moderately" with percentages of 42, 46 and 42% respectively.

The tasters revealed that there were no significant statistical differences ($p \geq 0.05$) between the samples in terms of their texture, locating them according to the hedonic scale used, between the terms "I'm Indifferent" and "I like it moderately". Opposite results were reported by Bastos *et al*. (2014) who, when evaluating oatmeal and banana meal as fat substitutes in hamburgers, found that the tasters perceived differences in texture being more accepted those made with oatmeal, followed by that of banana and control.

Regarding the purchase intention, 70% of consumers stated their interest in acquiring the sausage made with 40% of substitution of fat per flour versus 10% of disinterest, being denoted by the term "I would probably buy it" The control sausage and the 30% fat substitution sausage were rated between the terms "I have doubts about whether I would buy it" and "I would probably buy it" and those with 10 and 20% fat substitutions were denoted in the term "I have doubts if I would buy it" 32 and 22% respectively.

In the results (Table 5) of the sensory evaluation emitted by the consumers of the different sausages using as yam FM, NS and the control formulation (20% fat and 0% NS), it was observed that the tasters perceived similar appearance and texture in the sausages where the fat was replaced by the NS with respect to the control. On the other hand, it was found that when substituting fat 30% for NS the sausages had a greater acceptance for the attributes of color and odor with respect to the control formulation and when replacing 20% the fat for NS they were less accepted as for the flavor that control, while with the other formulations the color, smell and perceived taste was similar to the control. Similar results were evidenced by Pietrasik and Janz (2010) when comparing the acceptability judgments issued by the tasters of a low-fat bologna-type sausage with native pea starch, using the formulation 10% fat and 4% starch with respect to the control sample, made with 22% of fat, where the consumers did not perceive differences in the appearance, the texture and the flavor between them.

However, the sausages made with 10 and 30% of fat replacement by NS were distinguished from the other formulations for the appearance attribute when obtaining the highest means, being statistically different ($p \leq 0.05$) to the sausage made with a replacement of 20 % and equal to the control and the one made with a substitution of 40%, where the sausages processed with substitutions 0 (control), 10, 30 and 40% were rated by consumers with 52%, 56%, 42% and 50%, respectively, between the hedonic terms "I slightly like it" and "I like it moderately", while the one made with a 20% replacement was denoted by 56% between "I'm Indifferent" and "I slightly like it".

As for color and smell, with a 30% substitution of fat by NS, the sausages had a positive acceptance of 82 and 78%, respectively by the consumers, who denoted it for color in 52% between the terms Hedonic "I slightly like it" and "I like it moderately", being statistically equal (p≥0.05) to the sausage made with 10% fat substitution, rated 42% among the same hedonic terms and was statistically different (p ≤ 0.05) to the other treatments.

I regard of the smell attribute, by replacing 10 and 30% of fat by NS the tasters define the sausages between the hedonic terms "I slightly like it" and "I like it moderately" with 56% and 46% of acceptability respectively and with the samples that have a 40% of fat replacement they define the samples between the terms "I'm Indifferent" and "I slightly like it" with a 60% of acceptability, among which the tasters did not reveal significant statistical differences (p≥0.05) among themselves, but between the ones that were elaborated with 30% of fat substitution in relation to the Control sample and the one produced with a replacement of 20%, were defined between the terms "I'm Indifferent" and "I slightly like it" with 56% and 44% of acceptability, respectively.

For the flavor, 86% of the consumers had a positive acceptance of the sausage where 10% fat was replaced by NS, qualifying it 32% in the hedonic term "I like moderately", being statistically equal (p≥0.05) to the control sausage already formulated with 30% replacement, denoted by the tasters between the hedonic terms "I like it slightly" and "I like moderately" with 30 and 36%, of acceptability, respectively and was statistically different (p≤0.05), to the sausages made with substitutions of 20 and 40%. When substituting 20% the fat for NS the sausage was less accepted, with a disinterest on the part of the tasters of 38%, who referred it (30%) between the hedonic terms "Indifferent" and "I like it slightly", however, was statistically equal (p≥0.05) to that produced with 40% fat replacement by NS (40%) referred to between the terms "I like it slightly" and "I like it moderately".

The tasters revealed that there are no significant statistical differences (p≥0.05) between the samples in terms of their texture, locating them according to the hedonic scale used between the terms "I'm Indifferent" and "I like it moderately".

Regarding the purchase intention, by replacing 10 and 30% of fat by NS, 70% of consumers stated their interest in acquiring the sausages being denoted by the term "I would probably buy it", for the other formulations they expressed the term "I have doubts if I would buy it", being the one made with a substitution of 20% of the fat that presented the most disinterest (32%).

In the results (Table 5) of the sensorial evaluation emitted by the consumers of the different sausages using as FM PS of yam, it was observed that the tasters did not detect significant differences (p≥0.05) in the attributes of color, smell, flavor and Texture between the control sausage and the low-fat sausages, while in the appearance itself, the sausages elaborated with substitutions of 10, 20 and 30% being more conspicuous in appearance than the control, being denoted by the tasters between the terms "I slightly like it" and "I like it moderately" with percentages of acceptance of 56, 58 and 36%, respectively, while the control was rated at 38% between the terms "I'm Indifferent" and "I slightly like it" and was equal to the one formulated with 40% of fat replacement accepted by 42% between the terms "I slightly like it" and "I like it moderately".

For the color and smell attributes, the tasters revealed that there are no significant statistical differences (p≥0.05) between the samples according to the hedonic scale used the terms "I'm Indifferent" and "I like it moderately".

In terms of taste, replacing 10% and 20% of fat by PS the sausages had greater acceptance according to the hedonic scale used between the hedonic terms "I slightly like it" and "I like it moderately", with percentages of acceptance of 48% for both formulations, this results were statistically different (p≤0.05) than those made with substitutions of 30 and 40% of fat denoted between the "I'm Indifferent" and "I slightly like it" hedonic terms with percentages of acceptance of 36% for both and all formulations were the same to the control sample denoted with a response of 26% with the hedonic term "I slightly like it".

For texture, by replacing fat by 20% by PS, 60% of consumers had a positive acceptance of the sausage, rating it 16% in the hedonic term "I like it slightly" and 30% in the term "I like it a lot ", being statistically equal (p≥0.05) to the control sausage and those formulated with substitutions of 10 and 30% of fat replacement, denoted by the tasters between the hedonic terms "I'm Indifferent "and" I like it slightly" with 34, 40 and 42% respectively and was statistically different (p≤0.05) to the sausage made with 40% of fat replacement by PS, obtaining the lowest acceptance with a disinterest by the tasters of 36%, who referred it (40%) Between the hedonic terms "I'm Indifferent" and "I like it slightly". Similar results were reported by Luo and Xu (2011), were a trained panel did not detect differences in taste and texture of the sausages were fat was replaced by modified cassava starches with respect to the control, observing higher but not significant scores, in the sausages of greater fatty content.

Regarding the intention to purchase, consumers stated their interest in purchasing sausages made with 10 and 20% fat substitutions per PS, being denoted by the term "I would probably buy it", for the other formulations, the tasters expressed the term "I have doubted if it would buy it", being the control sample the one that presented the most disinterest (36%) on the part of the tasters.

Table 6 shows the results of the sensory evaluation issued by fifty habitual sausage tasters, on the most widely accepted formulations using the different fatty mimetics, observing that consumers did not perceive statistical differences (p≥0.05) between the samples in

Table 6: Average results of acceptance test the most preferred sausages

Substitution (%)/FM	Appearance	Color	Smell	Flavor	Texture	Purchase intention
20/PS	6.74 a[1]	6.74 a	6.00 a	6.44 a	6.34 a	3.82 a
30/NS	6.80 a	6.78 a	6.22 a	6.42 a	6.22 a	3.48 b
40/S	6.98 a	6.92 a	6.30 a	6.80 a	6.36 a	3.88 a

[1]Means with different letters in columns indicate significant differences ($p \leq 0.05$), according to the Tukey test

terms of appearance, color, smell, taste and texture, placing them according to the hedonic scale used the terms "I like it slightly" and "I like moderately". Highlighting the positive acceptance they had of each parameter evaluated with ranges between 82-94%, 82-86%, 66-76%, 74-80% and 66-70% for appearance, color, smell, taste and texture, respectively, standing out the appearance, the color and the flavor with ranges greater than 70%, considered satisfactory results to be accepted by the consumers (Peuckert *et al*., 2010).

On the other hand, for the purchase intention, when substituting the fat 20% for PS and 40% for flour, there were no statistical differences ($p \geq 0.05$) between them, being located by the consumers in the hedonic term "Probably would buy" and by replacing 30% fat with NS, they expressed the term "I have doubts if i would buy".

CONCLUSION

The PS of yam was characterized by its high capacity to absorb water and its great swelling power desired characteristics in an FM. The flour and the PS of yam can be used in the production of sausages to replace the dorsal pig fat up to 20%, as it improves the texture of the products decreasing hardness and chewing and improves the color; Sensorially they do not present differences in the attributes of appearance, color, smell, flavor and texture with respect to the control formulation.

REFERENCES

Ahmed, P.O., M.F. Miller, C.E. Lyon, H.M. Vaughters and J.O. Reagan, 1990. Physical and sensory characteristics of low-fat fresh pork sausage processed with various levels of added water. J. Food Sci., 55(3): 625-628.

Aleson-Carbonell, L., J. Fernández-López, J.A. Pérez-Alvarez and V. Kuri, 2005. Characteristics of beef burger as influenced by various types of lemon albedo. Innov. Food Sci. Emerg., 6(2): 247-255.

Álvarez, D. and S. Barbut, 2013. Effect of inulin, β-glucan and their mixtures on emulsion stability, color and textural parameters of cooked meat batters. Meat Sci., 94(3): 320-327.

Alves, R.M., M.V. Grossmann, C. Ferrero, N.E. Zaritzky, M.N. Martino and M.R. Sierakoski, 2002. Chemical and functional characterization of products obtained from yam tubers. Starch, 54(10): 476-481.

Amani, N.G., A. Kamenan, A. Rolland-Sabaté and P. Colonna, 2005. Stability of yam starch gels during processing. Afr. J. Biotechnol., 4(1): 94-101.

Araya-Quesada, Y., A. Morales-Torres, L. Wexler and P. Vargas-Aguilar, 2014. Potencial tecnológico de harina de plátano verde con cáscara (Musa AAB) como sustituto de grasa para geles cárnicos. INNOTEC, 9: 50-60.

Barragán-Viloria, K., J. Salcedo-Mendoza and J. Figueroa-Flórez, 2016. Propiedades tecno-funcionales de almidón modificado de yuca (*Manihot esculenta* C.) por pregelatinización tipo batch. Agron. Colomb., 34(Supl.1): S317-S320.

Bastos, S.C., M.E. Pimenta, C.J. Pimenta, T.A. Reis, C.A. Nunes, A.C. Pinheiro, L.F. Fabrício and R.S. Leal, 2014. Alternative fat substitutes for beef burger: Technological and sensory characteristics. J. Food Sci. Tech., 51(9): 2046-2053.

Bello Pérez, L.A., S.M. Contreras Ramos, R.R. Manilla, J.S. Feria and A.J. Aparicio, 2002. Propiedades químicas y funcionales del almidón modificado de plátano *Musa paradisiaca* L. (VAR. MACHO). Agrociencia, 36(2): 169-180.

Brewer, M.S., 2012. Reducing the fat content in ground beef without sacrificing quality: A review. Meat Sci., 91(4): 385-395.

Campagnol, P.C., B.A. dos Santos, R. Wagner, N.N. Terra and M.A. Rodrigues Pollonio, 2012. Amorphous cellulose gel as a fat substitute in fermented sausages. Meat Sci., 90(1): 36-42.

Carballo, J., G. Barreto and F. Jiménez Colmenero, 1995. Starch and egg white influence on properties of bologna sausage as related to fat content. J. Food Sci., 60(4): 673-677.

Cengiz, E. and N. Gokoglu, 2007. Effects of fat reduction and fat replacer addition on some quality characteristics of frankfurter-type sausages. Int. J. Food Sci. Tech., 42(3): 366-372.

Chen, X., X. Li, X. Mao, H. Huang, T. Wang, Z. Qu, J. Miao and W. Gao, 2017. Effects of drying processes on starch-related physicochemical properties, bioactive components and antioxidant properties of yam flours. Food Chem., 224: 224-232.

Choe, J.H., H.Y. Kim, J.M. Lee, Y.J. Kim and C.J. Kim, 2013. Quality of frankfurter-type sausages with added pig skin and wheat fiber mixture as fat replacer. Meat Sci., 93(4): 849-854.

Cofrades, S., J.A. Santos-Lopez, M. Freire, J. Benedí, F.J. Sánchez-Muniz and F. Jiménez-Colmenero, 2014. Oxidative stability of meat systems made with W1/O/W2 emulsions prepared with hydroxytyrosol and chia oil as lipid phase. LWT-Food Sci. Technol., 59(2): 941-947.

Colussi, R., S.L.M. El Halal, V. Zanella Pinto, J. Bartz, L.C. Gutkoski, E. da Rosa Zavareze and A.R. Guerra Dias, 2015. Acetylation of rice starch in an aqueous medium for use in food. LWT-Food Sci. Technol., 62(2): 1076-1082.

Crehan, C.M., E. Hughes, D.J. Troy and D.J. Buckley, 2000. Effects of fat level and maltodextrin on the functional properties of frankfurters formulated with 5, 12 and 30% fat. Meat Sci., 55(4): 463-469.

Feng, T., R. Ye, H. Zhuang, Z. Rong, Z. Fang, Y. Wang, Z. Gu and Z. Jin, 2013. Physicochemical properties and sensory evaluation of Mesona blumes gum/rice starch mixed gels as fat-substitutes in Chinese Cantonese-style sausage. Food Res. Int., 50(1): 85-93.

García, O., J. Ruíz-Ramirez and I. Acevedo, 2012. Evaluación físico-química de carnes para hamburguesas bajas en grasas con inclusión de harina de quinchoncho (Cajanus cajan) como extensor. Rev. Cient., 22(6): 497-506.

Gómez, M. and J.M. Lorenzo, 2013. Effect of fat level on physicochemical, volatile compounds and sensory characteristics of dry-ripened "chorizo" from Celta pig breed. Meat Sci., 95(3): 658-666.

González, Z. and E. Pérez, 2003. Evaluación fisicoquímica y funcional de almidones de yuca (*Manihot esculenta* Cranz) pregelatinizados y calentados con microondas. Acta Cien. Venez., 54(2): 127-137.

Grigelmo-Miguel, N., M.I. Abadías-Serós and O. Martín-Belloso, 1999. Characterisation of low-fat high-dietary fibre frankfurters. Meat Sci., 52(3): 247-256.

Hernández-Medina, M., J.G. Torruco-Uco, L. Chel-Guerrero and D. Betancur-Ancona, 2008. Caracterización fisicoquímica de almidones de tubérculos cultivados en Yucatán, México. Food Sci. Technol., 28(3): 718-726.

Huang, H., Q. Jiang, Y. Chen, X. Li, X. Mao, X. Chen, L. Huang and W. Gao, 2016. Preparation, physico-chemical characterization and biological activities of two modified starches from yam (*Dioscorea Opposita* Thunb.). Food Hydrocolloid., 55: 244-253.

Kaur, L., N. Singh and J. Singh, 2004. Factors influencing the properties of hydroxypropylated potato starches. Carbohyd. Polym., 55(2): 211-223.

Liu, H., Y.L. Xiong, L. Jiang and B. Kong, 2008. Fat reduction in emulsion sausage using an enzyme-modified potato starch. J. Sci. Food Agr., 88(9): 1632-1637.

López-Rubio, A., J.M. Clarke, B. Scherer, D.L. Topping and E.P. Gilbert, 2009. Structural modifications of granular starch upon acylation with short-chain fatty acids. Food Hydrocolloid., 23(7): 1940-1946.

Luo, Z. and Z. Xu, 2011. Characteristics and application of enzyme-modified carboxymethyl starch in sausages. LWT-Food Sci. Technol., 44(10): 1993-1998.

Mallika, E.N., K. Prabhakar and P.M. Reddy, 2009. Low fat meat products – an overview. Vet. World, 2(9): 364-366.

Matute, L., A. Bertsch and I. Diaz, 2012. Evaluación de la actividad amilolítica de Aspergillus niger ANM-1 en fermentaciones en estado sólido y sumergido para la obtención y caracterización de aditivos enzimáticos. Rev. Fac. Agron., 38(1): 9-17.

Miller, G.L., 1959. Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal. Chem., 31(3): 426-428.

Mina, J.H., A. Valdez, P.J. Herrera-Franco and T. Toledano, 2009. Influencia del tiempo de almacenamiento en las propiedades estructurales de un almidón termoplástico de yuca (TPS). Ing. Compet., 11(2): 1-27.

Nguimbou, R.M., M. Himeda, Y.N. Njintang, N.L. Tatsadjieu, B. Facho, J. Scher and C.M.F. Mbofung, 2012. Comparative physicochemical, thermal and microstructural properties of starches from two underutilized taro ecotypes. Int. J. Biosci., 2(4): 64-74.

NTC 1325, 2008. Colombian Technical Standard on meat products, processed non-canned meat products. Bogotá, D.C., pp: 1-30.

Oliveira-Faria, M., T.M. Martins, A.G. da Cruz, B.A. dos Santos, M.A. Rodrigues Pollonio and P.C. Bastianello Campagnol, 2015. Properties of bologna-type sausages with pork back-fat replaced with pork skin and amorphous cellulose. Meat Sci., 104: 44-51.

Pacheco, E. and N. Techeira, 2009. Propiedades químicas y funcionales del almidón nativo y modificado de ñame (*Dioscorea alata*). Interciencia, 34(4): 280-285.

Pacheco Perez, W.A., D.A.R. Molina and J.U.S. Valencia, 2011. Revisión: Uso de ingredientes no cárnicos como reemplazantes de grasa en derivados cárnicos. Rev. Fac. Nac. Agron., 64(2): 6257-6264.

Paternina, C.A., M.J. Salcedo and B.P. Romero, 2016. Efecto de la harina de ñame (*Dioscórea rotundata* P.) sobre las propiedades texturales de salchichas. Agron. Colomb., 1(Supl. 1): S379-S381.

Pérez, E. and E. Pacheco de Delahaye, 2005. Características químicas, físicas y reológicas de la harina y el almidón nativo aislado de *Ipomoea batatas* Lam. Acta Cien. Venez., 56(1): 9-15.

Peuckert, Y.P., V.B. Viera, L.H.R. Hecktheuer, C.T. Marques and C.S. Rosa, 2010. Caracterizacao e aceitabilidade de barras de cereais adicionadas de proteina texturizada de soja e camu-camu (*Myrciaria dúbia*). Alim. Nutr. Araraquara, 21(1): 149-155.

Pietrasik, Z. and J.A.M. Janz, 2010. Utilization of pea flour, starch-rich and fiber-rich fractions in low fat bologna. Food Res. Int., 43(2): 602-608.

Rincón, A.M., L.B. Rached, L.E. Aragoza and F. Padilla, 2007. Efecto de la acetilación y oxidación sobre algunas propiedades del almidón de semillas de fruto de pan (*Artocarpus altilis*). Arch. Latinoam. Nutr., 57(3): 287-294.

Rivera Ruiz, I.N., 2012. Reducción de grasa y alternativas para su sustitución en productos cárnicos emulsionados, una revisión. Nacameh, 6(1): 1-14.

Salcedo-Sandoval, L., S. Cofrades, C.R.C. Pérez, M.T. Solas and F. Jiménez-Colmenero, 2013. Healthier oils stabilized in konjac matrix as fat replacers in n − 3 PUFA enriched frankfurters. Meat Sci., 93(3): 757-766.

Salcedo, J., D. Chávez, E. Lozano and A. Fernández, 2014. Rediseño y evaluación de un equipo para la obtención de almidón de ñame y subproductos. Rev. Fac. Nac. Agron., 67(2): 353-356.

Salcedo Mendoza, J., J. Hernández Ruy Diaz and A. Fernández Quintero, 2016a. Effect of the acetylation process on native starches of yam (*Dioscorea* spp.). Rev. Fac. Nac. Agron., 69(2): 7997-8006.

Salcedo Mendoza, J.G., M.C. Rodríguez-Lora and J.A. Figueroa-Florez, 2016b. Efecto de la acetilación en las propiedades estructurales y funcionales de almidones de yuca (*Manihot esculenta* Crantz) y ñame (*Dioscorea alata* cv. *Diamante 22*). Rev. Mex. Ing. Quím., 15(3): 787-796.

Sukhija, S., S. Singh and C.S. Riar, 2016. Effect of oxidation, cross-linking and dual modification on physicochemical, crystallinity, morphological, pasting and thermal characteristics of elephant foot yam (Amorphophallus paeoniifolius) starch. Food Hydrocolloid., 55: 56-64.

Techeira, N., 2008. Formulación y evaluación de productos alimenticios dirigidos al adulto mayor a base de almidones modificados y harina de ñame (*Dioscorea alata*). Ph.D. Tesis, University Central de Venezuela, Caracas DC.

Techeira, N., L. Sívoli, B. Perdomo, A. Ramírez and F. Sosa, 2014. Caracterización físicoquímica, funcional y nutricional de harinas crudas obtenidas a partir de diferentes variedades de yuca (*Manihot esculenta* Crantz), batata (*Ipomoea batatas* Lam) y ñame (*Dioscórea alata*), cultivadas en Venezuela. Interciencia, 39(3): 191-197.

Tokusoglu, Ö. and M.K. Ünal, 2003. Fat replacers in meat products. Pak. J. Nutr., 2(3): 196-203.

Tomaschunas, M., R. Zörb, J. Fischer, E. Köhn, J. Hinrichs and M. Busch-Stockfisch, 2013. Changes in sensory properties and consumer acceptance of reduced fat pork Lyon-style and liver sausages containing inulin and citrus fiber as fat replacers. Meat Sci., 95(3): 629-640.

Torres, A., 2012. Evaluación del efecto almidón obtenido a partir de malanga (*Colocasia esculenta*) en las propiedades de un producto cárnico. M.S. Tesis, University del Zulia, Maracaibo.

Torres Rapelo, A., P.M. Castillo and M.D. Lengua, 2013. Propiedades fisicoquímicas, morfológicas y funcionales del almidón de malanga (*Colocasia esculenta*). Rev. Lasallista Investig., 10(2): 52-61.

Totosaus, A. and M.L. Pérez-Chabela, 2009. Textural properties and microstructure of low-fat and sodium-reduced meat batters formulated with gellan gum and dicationic salts. LWT-Food Sci. Technol., 42(2): 563-569.

Weiss, J., M. Gibis, V. Schuh and H. Salminen, 2010. Advances in ingredient and processing systems for meat and meat products. Meat Sci., 86(1): 196-213.

Xu, Y.X., Y. Dzenis and M.A. Hanna, 2005. Water solubility, thermal characteristics and biodegradability of extruded starch acetate foams. Ind. Crop. Prod., 21(3): 361-368.

Yoo, S.S., S.H. Kook, S.Y. Park, J.H. Shim and K.B. Chin, 2007. Physicochemical characteristics, textural properties and volatile compounds in comminuted sausages as affected by various fat levels and fat replacers. Int. J. Food Sci. Tech., 42(9): 1114-1122.

Zhang, W., S. Xiao, H. Samaraweera, E.J. Lee and D.U. Ahn, 2010. Improving functional value of meat products. Meat Sci., 86(1): 15-31.