Nutritional quality of beef patties with added flaxseed and tomato paste

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ABSTRACT
The aim of this work was to evaluate the physicochemical, sensory and nutritional properties of beef patties with added combinations of flaxseed (FS) and tomato paste (TP). Treatments were as follows: control = 0%FS + 0%TP; T1 = 0%FS + 20%TP; T2 = 5%FS + 15%TP; T3 = 10%FS + 10%TP; T4 = 15%FS + 5%TP; and T5 = 20%FS + 0%TP. Sensory properties in treatments T1 and T2 were similar to the control, while T3 showed acceptable sensory scores (>5.0). The α-linolenic acid content of beef patties increased as FS addition increased. The polyunsaturated fatty acid (PUFA)/saturated fatty acid ratio increased from 0.24 in the control treatment to 4.49 in T5. The PUFA ratio n6/n3 decreased from 7.18 in the control treatment to 0.29 in T5. A combination of FS and TP can be used as novel ingredients to develop beef patties with better nutritional profile without demerit of their sensory and physicochemical properties.

Calidad nutricional de hamburguesas de res adicionadas con linaza y pasta de tomate

RESUMEN
El objetivo de este trabajo fue evaluar las propiedades fisicoquímicas, sensoriales y nutricionales de hamburguesas de res adicionadas con combinaciones de linaza (FS) y pasta de tomate (TP). Los tratamientos fueron: control = 0%FS + 0%TP; T1 = 0%FS + 20%TP; T2 = 5%FS + 15%TP; T3 = 10%FS + 10%TP; T4 = 15%FS + 5%TP; y T5 = 20%FS + 0%TP. Las propiedades sensoriales para los tratamientos T1 y T2 fueron similares al control, mientras que T3 mostró puntuaciones sensoriales aceptables (>5.0). El contenido de ácido α-linolénico de las hamburguesas de res se incrementó al aumentar la adición de FS. La relación PUFA/SFA aumentó de 0.24 en el tratamiento testigo a 4.49 en T5. La relación n6/n3 de ácidos grasos poliinsaturados disminuyó de 7.18 en el tratamiento testigo a 0.29 en T5. La combinación de linaza y pasta de tomate puede utilizarse como nuevos ingredientes para elaborar hamburguesas de res con mejor perfil nutricional sin demérito de sus propiedades sensoriales y fisicoquímicas.

1. Introduction
The prevalence of obesity, overweight and noncommunicable diseases represents a serious health problem for any region or country. In Mexico, the combined prevalence of obesity and overweight is 71.28% (Ensanut, 2012), and it has been considered by the government as a health emergency that significantly affects the productivity of companies, children’s academic development and the economy of a country. Obesity and overweight have been associated with consumption of foods with high content of saturated fats or foods with high caloric content (Hoogerbrugge et al., 2001).

An important sector of the world population has some restrictions to meat and meat products consumption due to saturated fats, cholesterol, salt contents and its relationship with certain types of cancer (Cross et al., 2007), despite being a good source of protein, vitamins and minerals important for maintenance and development of the organism. Households in Mexico spend 34.1% of their total income in the purchase of food and beverages, and of this total, 23.3% is spent for purchasing meat (Enigh, 2014).

Changes in eating habits arising from the development of society in recent decades have led people to search for affordable and healthier foods with satisfactory taste and acceptable appearance. Thus, the food industry continually seeks to adapt and develop new formulations designed to improve quality, food safety and shelf life (Selani et al., 2011). A good strategy is to change the nutritional profile of traditional products by combining them with foods such as fruits, vegetables and cereals and in this way offer alternatives to those consumers that seek food with a health condition. With the incorporation of these new ingredients in the formulation of meat products, bioactive compounds could be added. Even more, this addition may help in reducing saturated fats, cholesterol and certain additives like salt. However, a challenge for the food technologist is to maintain the physicochemical and sensory properties of the product. Among the options of using nontraditional ingredients for the development of new meat products are flaxseed (FS) and tomato. FS is rich in α-linolenic acid (55% of total fatty acids), proteins (21%), dietary fiber (28%) and phytoestrogens such as lignans (Bloedon & Szapary, 2004). Tomato, on
the other hand, is a source of vitamins, minerals and phytochemical compounds which include carotenoids and polyphenols (Navarro-González, García-Valverde, García-Alonso, & Periago, 2011). Consumption of both foods has been associated with a decrease in cardiovascular disease and certain types of cancer (Barceló-Coblijn & Murphy, 2009; Canene-Adams, Campbell, Zaripheh, Jeffery, & Erdman, 2005; Dodin et al., 2008).

The scientific literature reports that the incorporation of FS in meat products improves the fatty acid profile, but color and sensory properties are affected when the addition is greater than 5% (Bilek & Turhan, 2009; Pelsel, Linssen, Legger, & Houben, 2007; Singh, Chattli, Biswas, & Sahoo, 2011). In the same way, color and sensory properties of meat products improve if tomato paste (TP) is added up to a maximum of 20% in the formulation (Canedo, 2002; Garcia, Calvo, & Selgas, 2009; Østerlie & Lefall, 2005). It is expected that with a combination of FS and TP, a more acceptable meat product with better fatty acid profile and sensory properties could be obtained. Thus, the aim of this work was to evaluate the physicochemical, sensory and nutritional properties of beef patties added with combinations of FS and TP.

2. Material and methods

2.1. Beef patties manufacture

Beef inside round (Semimembranosus, FS (Linum usitatissimum L.) and TP (Lycopersicum esculentum L.) were used to formulate the beef patties. All ingredients were obtained from the local market. As regards to the meat, all cuts were obtained from five animals per replicate within 5 days of slaughter. All meat was used the same day of purchase, cut into pieces no larger than 5 cm³ and ground into a batch using a Hobart grinder (model 4152, Troy, OH, USA) through a 3/16” plate. Ground meat was stored in refrigeration (2°C) until further use.

Our objective was to start with a low-fat beef patty as one of the nutritional goals for this product. At the same time, it would permit the inclusion of FS as a source of polyunsaturated fatty acids (PUFAs). One kilogram of ground meat per treatment was used for beef patties preparation. Meat (73% moisture, 6% lipids [saturated 43%, monounsaturated 49% and polyunsaturated 8%], 20% protein and 1% ash), FS (7% moisture, 31% lipids [saturated 9%, monounsaturated 18% and polyunsaturated 73%], 19% protein, 3% ash and 40% carbohydrate), TP (80% moisture, 0.4% lipids, 2.3% protein, 3.1% ash and 14.2% carbohydrate) and 2% of beef patty spice unit (Excalibur Seasoning Company LTD, Pekin, IL, USA) were mixed according to the following treatments: T0 = 100% FS; T1 = 80% FS + 20% TP; T2 = 50% FS + 15% TP; T3 = 10% FS + 10% TP; T4 = 15% FS + 5% TP; and T5 = 20% FS + 0% TP.

Ingredients in each batch were homogenized for 10 min and then beef patties were manually formed into 9 cm × 1 cm (diameter × thickness) to obtain approximately 70 g per unit. Each formulation was cooked according to the methodology of the American Meat Science Association (AMSA, 1995) at 170°C in an electric skillet (Cook Master Oster, Model 3222-3, Mississauga, Ontario, Canada) until reaching an internal temperature of 72°C, taken in the geometrical center of each patties through a hypodermic-type thermometer (Model HYP2-21-1/2-T-G-48-OST-M Omega, Stanford, CT, USA). Two replicates of the experiment were carried out in different times. In each replication, three patties per analysis were sampled (proximate analysis, physicochemical properties, lipid profile and cholesterol content and sensory evaluation) for a total of 12 patties per treatment.

2.2. Proximate analysis

Moisture, ash, protein (N × 6.25) and fat content were determined on raw beef patties using the appropriate Association of Official Analytical Chemists (AOAC, 2000) methodology. Moisture was determined according to AOAC Method 950.46. Protein content was determined by estimating the nitrogen content using the Kjeldahl method (AOAC Method 920.152). Ash content was determined by incineration at 525°C (AOAC Method 940.26), while fat was determined by the Soxhlet method (AOAC Method 963.15).

2.3. Physicochemical properties

2.3.1. pH

The pH was measured directly in cooked beef patties with a portable pH meter (Hanna, Model HI 98140, Woonsocket, RI, USA) equipped with a puncture-type combination pH electrode.

2.3.2. Color determinations

Color was evaluated by keeping all raw treatment samples at room temperature (18 ± 2°C) for 5 min prior to measurement using a spectrophotometer (Chroma meter CR-400, Konica Minolta Sensing, Inc., Osaka, Japan) with illuminant D65, 10° observer and 11 mm aperture of the instrument for illumination and 8 mm for measurement. Spectrally pure glass (CR-A51; Minolta Co.) was put between the sample and the equipment. The CIELab color space was studied following the procedure of Cassens et al. (1995). The following color coordinates were determined: lightness (L*, where 0 = black and 100 = white), redness (a*, where −60 = green and +60 = red) and yellowness (b*, where −60 = blue and +60 = yellow). Nine repeated measurements were taken for each sample, following the guidelines for meat color evaluation (Hunt et al., 1991).

2.3.3. Texture analysis

Texture profile analysis was performed in cooked beef patties samples at 4 ± 1°C with a Texture Analyzer TA-XT2 (Stable Micro Systems, Surrey, UK) following the methods for the objective measurement of meat product texture (Claus, 1995). Cubic samples (1 × 1 × 1 cm) were cut from cooked beef patties and subjected to a two-cycle compression test. Samples were compressed to 50% of their original height with a 7.5-cm diameter cylindrical probe attached to a 50-kg compression cell with a cross-head speed of 1 mm/s. Texture profile parameters were determined according to Bourne (1978) and interpreted as follows: hardness (kg), maximum force required to compress the sample; cohesiveness is the extent to which sample could be deformed prior to rupture (A2/A1), with A1 the total energy required for the first compression and A2 the total energy required for the second compression; springiness (cm) is the ability of the sample to recover its original shape after the deforming force is removed, and chewiness (kg × cm) is the work...
needed to masticate the sample for swallowing (hardness × cohesiveness × springiness).

2.4. Lipid profile and cholesterol content

Lipid extraction of raw beef patties was carried out by the procedure of Bligh and Dyer (1959) using chloroform:methanol (2:1 v/v). Before fatty acid methylation, the solvent was removed from lipid extracts in a water bath at 35°C under a nitrogen atmosphere. Lipid extracts were transmethylated in presence of boron trifluoride according to the method of Park and Goins (1994).

Composition of the fatty acid methyl esters (FAMEs) was performed in an Agilent gas chromatograph (Model 7890 B, Santa Clara, CA, USA) equipped with an autosampler (Model 7693) and a flame ionization detector (FID). Fatty acids were separated on a 100 m × 0.25 mm (internal diameter) fused silica capillary column (SP-2560, Supelco, Bellefonte, PA, USA). The oven temperature was programmed from an initial temperature of 150°C (20 min) to a final temperature of 220°C at the rate of 5°C/min. The injector temperature was set at 250°C and the FID temperature at 300°C. The samples were run using hydrogen at 17 psi pressure as the carrier and nitrogen as the make-up gas. Chromatograms were recorded with a computing integrator (ChemStation chromatography manager, Agilent Santa Clara, CA, USA). Fatty acids were identified by comparing retention times with those of FAME standards (Supelco 37 Component FAME Mix, Bellefonte, PA, USA). Fatty acids were expressed as a percentage of total fatty acids. Total percentages of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), PUFA, PUFA: SFA and n6/n3 ratios were calculated from these data. The cholesterol content was estimated by gas chromatography (GC) following the method modified by Thompson and Merola (1992). Cholestan was used as the internal standard. Samples were saponified with potassium methylate in methanol, then extracted with hexane and finally derivatized into trimethylchlorosilane ether. Cholesterol derivatives were analyzed by GC (Agilent, Model 7890 B, Santa Clara, CA, USA) equipped with an FID and an HP 1901 dimethylpolysiloxane capillary column (0.25 mm × 30 cm). Sample injection was performed in a pulse split port at 330°C. Oven temperature was set at 260°C and FID was held at 330°C. Nitrogen was used as carrier gas and helium as the make-up gas. Cholesterol was identified by the retention time of the standard mixture and quantified by the ChemStation computer program according to the internal standard quantity.

2.5. Sensory evaluation

Sensory evaluation was conducted by a nine trained member panel (ISO-8586-1, 1993) in an environmentally controlled (21 ± 1°C, 55 ± 5% relative humidity) room partitioned into booths. Three patties from each formulation were cooked as previously described, covered and maintained warm at 60°C in an oven until testing within 4–7 min. Square pieces approximately 1.5 × 1.5 cm were cut from the center of patties and were served immediately. Each sample was coded with randomly selected three-digit numbers. Panelists were instructed to clean their palates between samples using water. Each panelist evaluated all formulas in a randomized order and asked to mark on a 10-cm line scale for the following attributes: color, flavor, firmness and juiciness of bologna-type product, where 0 represented dislike extremely and 10 like extremely. Each attribute was discussed, and tests were initiated after the panelists were familiarized with scales. At the end of the test, panelists were asked to give a score for product overall acceptability from 0 to 10.

2.6. Statistical analysis

Data obtained for proximate composition, physicochemical analysis, sensory analysis, fatty acid profile and cholesterol content were analyzed by means of a one-way analysis of variance test. All statistics assays were performed using the Number Cruncher Statistical Systems 2007 (NCSS, Kaysville, UT, USA) software (Hintze, 2007). Significant differences were estimated at a probability level of 0.05. When significant differences between treatments were found, Tukey-Kramer test was performed.

3. Results and discussion

3.1. Proximate composition

The results for the proximate composition of the beef patties with different concentrations of FS or TP are presented in Table 1. The presence of FS or TP modified (p < 0.05) the moisture content. Therefore, the treatment with added 20% of TP and 0% of FS showed the highest values (p < 0.05) followed by the treatment with 15% of TP and 5% of FS with no differences (p > 0.05) between them. On the other hand, the addition of FS, at high concentration (15 and 20%) decreased the moisture content of beef patties (p < 0.05) with respect to control sample due to the increment in dry matter and lipid content. The results obtained were similar.

| Table 1. Chemical composition (g/100 g product) of beef patties formulated with flaxseed flour and tomato paste. | Table 1. Composición química (g/100 g de producto) de hamburguesas de res formuladas con pasta de tomate y harina de linaza. |
|---------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Control | T1 | T2 | T3 | T4 | T5 |
| Moisture | 69.51 ± 0.70<sup>ab</sup> | 74.89 ± 0.33<sup>ab</sup> | 71.80 ± 0.36<sup>ab</sup> | 65.5 ± 0.26<sup>ab</sup> | 64.95 ± 5.36<sup>d</sup> | 57.31 ± 0.08<sup>b</sup> |
| Lipid | 5.72 ± 0.13<sup>ab</sup> | 4.17 ± 0.03<sup>ab</sup> | 6.34 ± 0.04<sup>ab</sup> | 8.82 ± 0.06<sup>ab</sup> | 8.54 ± 0.44<sup>ab</sup> | 10.13 ± 0.14<sup>d</sup> |
| Protein | 23.3 ± 1.03<sup>ab</sup> | 19.40 ± 0.46<sup>ab</sup> | 20.7 ± 1.04<sup>ab</sup> | 23.65 ± 3.34<sup>ab</sup> | 25.5 ± 0.6<sup>ab</sup> | 27.37 ± 6.62<sup>ab</sup> |
| Ash | 1.55 ± 0.13<sup>ab</sup> | 1.60 ± 0.15<sup>ab</sup> | 1.57 ± 0.12<sup>ab</sup> | 1.74 ± 0.02<sup>ab</sup> | 1.86 ± 0.11<sup>ab</sup> | 2.20 ± 0.06<sup>ab</sup> |

Control = 0%FS + 0%TP; T1 = 0%FS + 20%TP; T2 = 5%FS + 15%TP; T3 = 10%FS + 10%TP; T4 = 15%FS + 5%TP; and T5 = 20%FS + 0%TP. FS: flaxseed flour; TP: tomato paste.

Different letters within the same row indicate significant differences (p < 0.05).

Promedio de seis determinaciones ± SE.
to those reported by Bilek and Turhan (2009) for beef patties formulated with FS flour from 0 to 15%. As regards to protein content (Table 1), the addition of TP at high concentrations (15% and 20%) produced a reduction in this parameter ($p < 0.05$) with respect to control samples. However, the addition of FS, at high concentrations (15% and 20%), increased the protein content of beef patties ($p < 0.05$) when compared to the other treatments. Likewise, lipid content (Table 1) of beef patties increased with FS addition. Thus, the samples with 20% of FS showed the highest ($p < 0.05$) lipid content followed by the samples with 15% and 10% of FS with no statistical differences ($p > 0.05$) between these two treatments. FS flour had a protein and lipid contents of 19% and 31%, respectively, and a high proportion of α-linolenic acid (Bloedon & Szapary, 2004), attributes that may be attractive to the beef patties consumer at the time of acquiring the product. According to a study carried out by Profeco (2010), on the nutritional quality of 24 brands of beef patties, protein and lipid contents ranged from 10% to 14.9% and from 11% to 15.5%, respectively. In general, the beef patties developed in this research, including the control, had an improved nutritional balance with regard to beef patties sold in Mexico. Finally, the addition of TP or FS did not modify ($p > 0.05$) ash content (Table 1), except the samples with 20% of FS which showed the highest ($p < 0.05$) values.

### 3.2. Physicochemical properties

The pH values, color coordinates ($L^*$, $a^*$ and $b^*$) and textural properties of beef patties with TP and FS are presented in Table 2. The addition of FS or TP to beef patties affected the pH values of the samples analyzed in different ways. FS flour slightly increased beef patties pH ($p < 0.05$) compared to control samples. This increase in pH could be attributed to FS basic nature. Yogesh, Langoo, Sharma, and Yaday (2015) reported a similar effect on pH values of meat batter with FS flour. In reference to the samples with TP, the addition of this product decreased ($p < 0.05$) pH values, fundamentally, due to its acidic nature ($pH = 4.2$). The lowest pH values were obtained for beef patties with 20% and 15% of TP. The values obtained for samples with TP in concordance with those reported by Candogan (2002) who mentioned that the pH values of beef burgers with 10% and 15% of TP decreased when compared with control sample. A similar effect of TP, on reduction of pH values, had been reported by other authors (Deda, Bloukas, & Fista, 2007; Garcia et al., 2009) when it was added on different meat products.

As regards, the color coordinates ($L^*$, $a^*$ and $b^*$) all were affected ($p < 0.05$) by TP or FS addition. Lightness ($L^*$) increased ($p < 0.05$) in all treatments where TP or FS was added to beef patties. This increase was higher in samples added, mainly, with TP than in samples added, mainly, with FS. This increase is probably due to the fact that TP or FS, structurally, is composed of macromolecules that are rehydrated and remain outside the meat matrix, affecting this coordinate. In the same way, red-green coordinate ($a^*$) values also were affected ($p < 0.05$). The samples with 15% and 20% of TP increased ($p < 0.05$) $a^*$ values with respect to control samples. This increase in $a^*$ coordinate might be due to the TP which has a typical red color because of lycopene, the main pigment present in the fruit (Arias, Lee, Logendra, & Janes, 2000) maintaining its color during the development of products. However, the beef patties with 15% and 20% of FS decreased ($p < 0.05$) $a^*$ values with respect to control. For the yellow-blue coordinate ($b^*$) (Table 2), the results showed that the addition of TP or FS, at different concentrations to the products, increases the value of this coordinate over the control with significant difference ($p < 0.05$). Nevertheless, no differences were found ($p > 0.05$) between the samples added with TP or FS. This increase in $b^*$ coordinate might be due to the extract used could contained yellow pigments which could increase the values of this coordinate. Candogan (2002) studied the effect of TP addition, at concentrations comprised between 5% and 15%, on quality characteristics of beef patties. This author reported an increase of $a^*$ values, a decrease in $L^*$ and without changes in the $b^*$ values. Yogesh et al. (2015) analyzed the incorporation of FS powder in a meat batter at levels of 1–5% and they reported that lightness ($L^*$) and red-green coordinate ($a^*$) values decreased when FS powder increased in the formulation.

Table 2 shows the effects of adding TP and FS, at different concentrations, on the textural properties of beef patties. FS flour and TP addition on beef patties reduced all texture parameters ($p < 0.05$). As regards to hardness, more than 48% hardness reduction occurred at all treatments compared to the control. However, no statistical differences were found ($p > 0.05$) between treatments. Depending on the amount and type of ingredient added to the meat matrix, controversial results have been reported on

| Table 2: Physicochemical properties of beef patties formulated with flaxseed flour and tomato paste. |
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| **Control** | **T1** | **T2** | **T3** | **T4** | **T5** |
| **L^*** | 40.26 ± 0.6a | 44.89 ± 0.45b | 46.69 ± 1.09b | 44.33 ± 1.02b | 42.43 ± 0.65ab | 41.83 ± 0.26ab |
| **a^*** | 15.42 ± 0.6ac | 19.06 ± 0.24d | 16.85 ± 0.76cd | 14.42 ± 0.4ab | 13.33 ± 0.54b | 12.26 ± 0.39a |
| **b^*** | 10.62 ± 0.17c | 14.21 ± 0.35b | 15.74 ± 0.58b | 16.05 ± 0.25 | 14.81 ± 0.28 | 16.01 ± 0.72b |
| **pH** | 5.55 ± 0.00bc | 5.42 ± 0.01a | 5.44 ± 0.01ab | 5.55 ± 0.01ab | 5.61 ± 0.00b | 5.65 ± 0.01b |
| **Hardness (kg)** | 20.52 ± 2.4 | 7.97 ± 1.25a | 7.93 ± 0.58b | 8.77 ± 0.52 | 10.56 ± 0.55 | 9.02 ± 0.57 |
| **Springiness (cm)** | 0.83 ± 0.02d | 0.77 ± 0.01c | 0.64 ± 0.0ab | 0.62 ± 0.02b | 0.59 ± 0.01b | 0.47 ± 0.01a |
| **Cohesiveness** | 0.65 ± 0.02a | 0.62 ± 0.02a | 0.54 ± 0.02ab | 0.47 ± 0.01b | 0.42 ± 0.02ab | 0.38 ± 0.02a |
| **Chewiness (kg x cm)** | 10.92 ± 0.95a | 3.87 ± 0.7b | 2.70 ± 0.03b | 2.59 ± 0.27ab | 2.65 ± 0.21ab | 1.59 ± 0.04a |

Control = 0%FS + 0%TP; T1 = 0%FS + 20%TP; T2 = 5%FS + 15%TP; T3 = 10%FS + 10%TP; T4 = 15%FS + 5%TP; and T5 = 20%FS + 0%TP.

FS: flaxseed flour; TP: tomato paste.

Different letters within the same row indicate significant differences ($p < 0.05$).

Average of six determinations ± SE.
hardness. Thus, both hardening and softening have been observed when different ingredients were added to various meat products (Ganhão, Morcuende, & Estévez, 2010; Sánchez-Zapata et al., 2010). For springiness, the samples with FS added at high concentration (20%) showed the lowest values (p < 0.05). Similar behavior was observed for cohesiveness and chewiness which showed the lowest values (p < 0.05) of all samples analyzed. The results obtained in this work were similar to those presented by Yogesh et al. (2015) in a study with meat batter incorporated with different levels of FS flour or the results obtained by Domènech-Asensi et al. (2013) in a cooked meat mortadella-type product added with TP at 10 g/100 g.

3.3. Lipid profile and cholesterol content

Lipid profile of beef patties is shown in Table 3. There were significant differences (p < 0.05) in the type and relative quantities of lipids between the control treatment and those with addition of FS. The largest percentage of SFAs occurred in control treatment and in those which only contained TP (T1); they had 50% of SFA, and it was reduced to 14.3% when FS was incorporated at a level of 20% (T5). In beef patties formulated with different levels of FS, the predominant SFA were palmitic (C16:0) and stearic (C18:0), while the most abundant MUFA was oleic acid (C18:1 n9), and the predominant PUFAs were linoleic acid (C18:2 n6) and α-linolenic acid (C18:3 n3). Similar results were obtained by Bilek and Turhan (2009) in beef patties formulated with different levels of FS and by Novello and Pollonio (2013) in beef patties added with 5% of FS flour. The PUFAs were higher in treatments with FS, mainly due to the high content of α-linolenic acid present in the FS flour (Rubilar, Gutiérrez, Verdugo, Shene, & Sineiro 2010). The PUFA/SFA ratio ranged from 0.24 in the control treatment to 4.49 in T5 treatment with 20% of FS. As expected, this ratio increased as FS increased in the beef patties formulation. The n6/n3 ratio was around 8.0 in the control and T1 treatment with 0% FS + 20% TP, different (p < 0.05) from treatments with FS added, where n6/n3 ratio was around 0.3. Similar trends were observed by Singh et al. (2011) in low-fat chicken meat patties incorporating 3% of linseed oil and in the study carried out by Pels et al. (2007) in a Dutch style fermented sausage manufactured with a substitution of pork backfat by different percentages of FS oil.

Regarding to cholesterol content, it was significantly higher (p < 0.05) in control beef patties than in treatments with added FS and TP at different proportions (Table 3). The values ranged from 73.03 mg/100 g in control beef patties to 268.89 mg/100 g in T5 with 20% FS representing a reduction of 63% in cholesterol content. An important reduction on cholesterol content was also observed in the other treatments with FS and TP addition. For example, in T3 with 10% FS and 10% TP, there was a reduction of 55% on cholesterol content. In a different study, Gök, Akkaya, Obuz, and Bulut (2011) also found a considerable decrease of cholesterol content in meat burgers with ground poppy seeds (GPS). They reported that the control sample had approximately ninefold higher cholesterol concentration than meat burgers with 20% GPS. Likewise, a similar trend was observed by Choi et al. (2010) who found lower cholesterol contents in reduced-fat frankfurters formulated with different pre-emulsified vegetable oils. They were able to decrease the cholesterol content of reduced-fat frankfurters by 45–50% when compared to the control.

3.4. Sensory evaluation

Sensory evaluation results are presented in Table 4. It was observed that all sensory attributes evaluated increased as TP level increased and FS flour levels decreased in beef patties formulation. For example, treatment T1 with 0% FS + 20% TP had the highest sensory score for juiciness, color and overall acceptance, which were different (p < 0.05) from T5 with 20% FS + 0% TP. There was no difference (p > 0.05) between T1 and control treatment in all sensory attributes. Similar results were presented by Candogan (2002) who reported that TP addition into beef patties up to 15% level increased juiciness and did not result in any adverse effect on flavor characteristics. Some research has shown that TP addition to meat products prevent lipid oxidation, the main cause for low scores on sensory evaluation (Candogan, 2002; Domènech-Asensi et al., 2013). On the other hand, incorporation of FS flour into meat products had an adverse effect on sensory attributes (Pelser et al., 2007). For example, T5 with 20% FS + 0% TP had the lowest sensory scores for flavor, juiciness, firmness, color and overall acceptance which were different (p < 0.05) to T1 and control treatments. This negative effect of FS flour on sensory attributes of beef patties has been reported by other works (Bilek & Turhan, 2009; Yogesh et al., 2015). FS oil may confer to the product a strong flavor, unpleasant odor and flavor because of either poor seed quality or unfavorable process or storage conditions (Wiesenborn, Kangas, Tostenson, Hall, & Chang, 2005). On the other hand, it is known that addition of FS to meat products increases the proportion of PUFAs and lipid oxidation (Pelser et al., 2007) affecting the sensory attributes of meat products (Singh et al., 2011). Nevertheless, despite the negative effects on sensory attributes that FS incorporation has in meat products, it also has multiple health benefits (Bloedon & Szapary, 2004; Kawakami et al., 2015). Conversely, as TP addition increased sensory attributes and objective color of beef patties, a balance between TP and FS addition can be accomplished, which could be attractive to consumers from the sensory and nutritional viewpoint. For example, T2 treatment with 5% FS + 15% TP had similar sensory score (p > 0.05) to T1 and control treatment in all evaluated attributes. The 5% FS incorporation in a meat formulation was the optimum addition reported in other studies (Bilek & Turhan, 2009; Yogesh et al., 2015); however, incorporation of 10% FS in combination with 10% TP as in T3 could be an alternative formulation to achieve acceptable sensory scores (Table 4) but with higher quantity of PUFAs and low cholesterol (Table 3).

4. Conclusion

The results of the present study showed that the combination of added FS flour and TP affected beef patties in different ways for nutritional, sensory and physicochemical attributes. A high proportion of TP (15% and 20%) resulted in a product with similar sensory attributes to the control treatment. When the proportion of FS increased, cholesterol content, SFAs and n6/n3 ratio decreased, while PUFAs and PUFA/SFA ratio increased, and in the same manner, sensory scores and physicochemical

Table 4
Table 3. Effect of flaxseed flour and tomato paste on fatty acid profile (percentage of total fatty acids) and cholesterol content (mg/100 g product) of beef patties.

|                | Control | T1     | T2     | T3     | T4     | T5     |
|----------------|---------|--------|--------|--------|--------|--------|
| **C10:0**      | 0.05 ± 0.00<sup>b</sup> | 0.04 ± 0.00<sup>b</sup> | 0.01 ± 0.00<sup>b</sup> | 0.01 ± 0.00<sup>b</sup> | 0.01 ± 0.00<sup>a</sup> | 0.01 ± 0.00<sup>a</sup> |
| **C12:0**      | 0.06 ± 0.01<sup>b</sup> | 0.05 ± 0.00<sup>b</sup> | 0.02 ± 0.00<sup>b</sup> | 0.02 ± 0.00<sup>b</sup> | 0.02 ± 0.00<sup>b</sup> | 0.02 ± 0.00<sup>b</sup> |
| **C14:0**      | 1.86 ± 0.14<sup>c</sup> | 1.62 ± 0.03<sup>c</sup> | 0.61 ± 0.02<sup>c</sup> | 0.48 ± 0.03<sup>b</sup> | 0.33 ± 0.03<sup>b</sup> | 0.24 ± 0.01<sup>a</sup> |
| **C16:0**      | 23.23 ± 0.22<sup>d</sup> | 22.13 ± 0.29<sup>d</sup> | 11.42 ± 0.14<sup>d</sup> | 9.21 ± 0.15<sup>d</sup> | 8.36 ± 0.26<sup>d</sup> | 7.60 ± 0.05<sup>d</sup> |
| **C17:0**      | 1.20 ± 0.07<sup>d</sup> | 1.08 ± 0.01<sup>d</sup> | 0.47 ± 0.01<sup>d</sup> | 0.36 ± 0.02<sup>d</sup> | 0.30 ± 0.02<sup>d</sup> | 0.22 ± 0.00<sup>d</sup> |
| **C18:0**      | 22.54 ± 4.05<sup>d</sup> | 26.14 ± 0.66<sup>d</sup> | 12.50 ± 0.18<sup>d</sup> | 9.48 ± 0.04<sup>d</sup> | 7.78 ± 0.28<sup>d</sup> | 6.47 ± 0.19<sup>d</sup> |
| Σ saturated    | 48.94 ± 3.61<sup>c</sup> | 51.06 ± 0.32<sup>c</sup> | 25.04 ± 0.36<sup>c</sup> | 19.51 ± 0.24<sup>c</sup> | 16.79 ± 0.03<sup>c</sup> | 14.35 ± 0.12<sup>c</sup> |
| **C14:1**      | 0.32 ± 0.03<sup>b</sup> | 0.30 ± 0.01<sup>b</sup> | 0.11 ± 0.00<sup>b</sup> | 0.07 ± 0.00<sup>b</sup> | 0.05 ± 0.00<sup>b</sup> | 0.04 ± 0.00<sup>b</sup> |
| **C16:1**      | 2.52 ± 0.22<sup>d</sup> | 2.33 ± 0.05<sup>d</sup> | 0.07 ± 0.00<sup>d</sup> | 0.56 ± 0.01<sup>d</sup> | 0.48 ± 0.05<sup>d</sup> | 0.34 ± 0.01<sup>d</sup> |
| **C18:1 n9c**  | 36.32 ± 4.25<sup>c</sup> | 32.87 ± 0.49<sup>c</sup> | 24.49 ± 0.10<sup>c</sup> | 22.24 ± 0.10<sup>c</sup> | 21.55 ± 0.60<sup>c</sup> | 20.83 ± 0.19<sup>c</sup> |
| **Σ mono unsaturated** | 39.17 ± 4.50<sup>b</sup> | 35.53 ± 0.56<sup>b</sup> | 24.69 ± 0.09<sup>b</sup> | 22.88 ± 0.12<sup>b</sup> | 22.11 ± 0.66<sup>b</sup> | 21.22 ± 0.20<sup>b</sup> |
| **C18:2 n6c**  | 7.88 ± 0.39<sup>b</sup> | 9.17 ± 0.19<sup>b</sup> | 12.43 ± 0.02<sup>b</sup> | 13.13 ± 0.12<sup>b</sup> | 13.56 ± 0.09<sup>b</sup> | 14.04 ± 0.04<sup>b</sup> |
| **C18:3 n6**   | 0.10 ± 0.00<sup>c</sup> | 0.10 ± 0.00<sup>c</sup> | 0.17 ± 0.00<sup>c</sup> | 0.18 ± 0.00<sup>c</sup> | 0.20 ± 0.00<sup>c</sup> | 0.22 ± 0.01<sup>c</sup> |
| **C20:3 n6**   | 0.52 ± 0.34<sup>c</sup> | 0.84 ± 0.02<sup>c</sup> | 36.47 ± 0.51<sup>c</sup> | 43.52 ± 0.21<sup>c</sup> | 46.69 ± 0.65<sup>c</sup> | 49.65 ± 0.01<sup>c</sup> |
| **Σ Polyun saturated** | 11.89 ± 0.89<sup>c</sup> | 13.41 ± 0.23<sup>c</sup> | 50.27 ± 0.45<sup>c</sup> | 57.61 ± 0.36<sup>c</sup> | 61.11 ± 0.69<sup>c</sup> | 64.63 ± 0.08<sup>c</sup> |
| **PUFA/SFA**   | 0.24 ± 0.00<sup>b</sup> | 0.26 ± 0.00<sup>b</sup> | 2.01 ± 0.04<sup>b</sup> | 2.95 ± 0.05<sup>b</sup> | 3.64 ± 0.05<sup>b</sup> | 4.49 ± 0.03<sup>b</sup> |
| **n6/n3**      | 7.18 ± 1.36<sup>c</sup> | 8.75 ± 0.27<sup>c</sup> | 0.57 ± 0.01<sup>c</sup> | 0.32 ± 0.00<sup>c</sup> | 0.30 ± 0.00<sup>c</sup> | 0.29 ± 0.00<sup>c</sup> |
| **Cholesterol** | 73.03 ± 1.97<sup>c</sup> | 63.59 ± 0.55<sup>c</sup> | 39.95 ± 0.80<sup>c</sup> | 39.92 ± 1.50<sup>c</sup> | 28.59 ± 0.49<sup>c</sup> | 26.89 ± 1.50<sup>c</sup> |

Control = 0% FS + 0% TP; T1 = 0% FS + 20% TP; T2 = 5% FS + 15% TP; T3 = 10% FS + 10% TP; T4 = 15% FS + 5% TP; and T5 = 20% FS + 0% TP. FS: flaxseed flour; TP: tomato paste.

Different letters within the same row indicate significant differences (p < 0.05). Average of six determinations ± SE.

Control = 0%FS + 0%TP; T1 = 0%FS + 20%TP; T2 = 5%FS + 15%TP; T3 = 10%FS + 10%TP; T4 = 15%FS + 5%TP; and T5 = 20%FS + 0%TP. FS: harina de linaza; TP: pasta de tomate. Diferentes letras dentro de la misma fila, indican diferencias significativas (p < 0.05). Promedio de seis determinaciones ± SE.
properties also decreased. Sensory attributes were acceptable (>5 score) when 10% FS and 10% TP were added in the beef patties formulation. This combination of ingredients improved product nutritional value and could provide an alternative for health-conscious consumers.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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