Effect of fat replacement by fructooligosaccharide in hamburger: physicochemical, technological and sensorial analysis

Giovanna Luiza Hartmann
Department of Nutrition, Universidade Estadual do Centro-Oeste (UNICENTRO), Guarapuava, Paraná, Brazil.

Flávia Teixeira
Department of Nutrition, Universidade Estadual do Centro-Oeste (UNICENTRO), Guarapuava, Paraná, Brazil.

Jaqueline Machado Soares
Department of Nutrition, Universidade Estadual do Centro-Oeste (UNICENTRO), Guarapuava, Paraná, Brazil.

Kátia Aparecida da Silva
Department of Nutrition, Universidade Federal do Triângulo Mineiro (UFTM), Uberaba, Minas Gerais, Brazil.

Kélin Schwarz
Department of Nutrition, Universidade Federal do Triângulo Mineiro (UFTM), Uberaba, Minas Gerais, Brazil.

Dalton Luiz Schiessel
Department of Nutrition, Universidade Estadual do Centro-Oeste (UNICENTRO), Guarapuava, Paraná, Brazil.

Daiana Novello (Corresponding author)
Department of Nutrition, Postgraduate Program Interdisciplinary in Community Development, Universidade Estadual do Centro-Oeste (UNICENTRO).
Alameda Élio Antonio Dalla Vecchia, 838 - CEP 85040-167, Vila Carli, Guarapuava, Paraná, Brazil.
E-mail: nutridai@gmail.com

Abstract

The aim of this study was to evaluate the influence of fat substitution by fructooligosaccharide on physicochemical, technological and sensory characteristics of hamburgers. Five hamburgers formulations were prepared: F1 - standard (0% FOS) and the others added 1.25% (F2), 2.50% (F3), 3.75% (F4) and 5% (F5) of FOS. The Acceptability similar to standard sample was found for hamburgers with up to 3.75% prebiotic addition. However, all formulations had acceptability index above 70%. Cooking yield, moisture *retention, shrinkage and fat retention have been increased as FOS was added. Substitution of fat by FOS increased carbohydrate and fiber content and decreased lipid and calorie hamburgers content. FOS addition did not change red and yellow values, however it increased brightness of product. FOS is an ingredient with potential for addition in beef hamburger, improving physicochemical and technological parameters and with little influence on sensory characteristics.*

Keywords: Prebiotic; meat products; healthiness.

1. Introduction

Meat and meat products are essential diet components, providing high amounts of protein, fatty acids, vitamins and minerals [1]. Hamburgers are foods widely appreciated by different publics, due to their practicality to produce, cook and consumption. However, they are known to have low dietary fiber and high fat content, especially in saturated fatty acids [2]. Excessive consumption of this type of fat, coupled with low fiber intake, may increase the risk to developed noncommunicable diseases such as diabetes, cancer, obesity and cardiovascular disease [3,4]. In this regard, strategies are needed to add healthier ingredients in hamburgers to improve nutritional profile [5,6].

Currently, consumers are seeking a more practical and healthy diet. This fact has forced the food industries to rethink the way they produce their products, using ingredients that are more nutritious and have some health benefit. In this sense, the fat replacement in meat products by raw materials considered functional, such as dietary fibers, has gained prominence in the world scenario, beside adding economic food value to food [7,8]. The fat is an important ingredient in food as it has a positive influence on softness, juiciness and flavor, among other attributes [9]. Therefore, fat reduction may directly affect acceptability as it may interfere with technological aspects of meat product [10]. Studies have already shown the feasibility fat replacing fat in meat products with ingredients such as sugar cane and sesame oil [10], green banana flour [11], cellulose fiber [9], fructooligosaccharide (FOS), inulin [12] and pectin [8]. In these products, good sensorial acceptability and improvement in technological and nutritional characteristics were verified with incorporation of different compounds as fat substitutes.

FOS is a type of non-digestible carbohydrate knowing by body as prebiotic, as it selectively stimulates the growth and activity of particular species of bacteria in colon [13,14]. FOS is extracted from plants such as onion, artichoke, garlic, chicory root and yacon potato. It is low in calories, high in dietary fiber and not cariogenic. Furthermore, because its functional properties, it can help strengthen immune system, lower lipid, cholesterol and blood glucose levels [15]. Considering this context, the using FOS as a fat substitute in meat products becomes a viable alternative, aiming to improve nutritional profile of products and promote consumer health benefits [16]. However, research has already shown occurrences of impairments technological and sensory after prebiotics addition in different foods, such as meat products [12], pasta [17], chocolates [18] and breads [19]. Knowing this, the aim of this study was to evaluate the influence of fat substitution by fructooligosaccharide on physicochemical, technological and sensory characteristics of hamburgers.

2. Materials and methods

2.1. Beef patties processing and cooking

Five hamburgers formulations added with different FOS levels were prepared in triplicate: F1: standard (0%), F2 (1.25%), F3 (2.50%), F4 (3.75%) and F5 (5%). Percentages were defined by means of preliminary sensory tests carried out on the product. In addition to FOS percentages, following ingredients were used: beef (shoulder clod) (77.9%) ice flakes (15%), homogenized pork fat (F1: 5%; F2: 3.75%; F3: 2.50%; F4: 1.25% and F5: 0%), sodium chloride (1.5%), onion powder (0.2%), garlic powder (0.2%) and black pepper (0.2%).

To hamburgers elaboration, meat (approximately 14 kg) was ground in a meat grinder (C.A.F., Brazil) in 3 mm disk and temperature about 4 ºC. Subsequently, ground beef was homogenized in commercial blender (Super Cutter Sire, Brazil) for 1 minute. Onion and garlic powder, black pepper, sodium chloride, ice flake and pork fat were added to mixture and homogenized again for 3 minutes at temperature 7 ± 1 °C.

FOS was incorporated into mass and homogenized for additional 3 minutes at 7 ± 1 °C. Addition levels of ground beef and FOS varied in each formulation as described above. The resulting mass of each formulation was burger shaped (weight 100 g, 10 cm in diameter and 1 cm thick) using manual hamburger press (Picelli, HP 128, Brazil). Products were stored in plastic bags of low-density polyethylene and frozen in conventional freezer (-18 °C) until the analysis moment.

Frozen burgers were grilled on electric plate with grill on upper and lower sides (Britânia Grill, Mega 2N, Brazil) heated to 200 °C. Hamburger internal temperature was controlled by digital thermometer (Tp 101, Brazil) until reaching 71 °C at its geometric center [20]. The average cooking time was 7 to 8 minutes.

2.2. Consumer study

Participated in sensory analyses 80 untrained volunteer subjects, hamburger usual consumers. Consumers had aged between 18 and 29 years and were recruited among students and staffs of Universidade Estadual do Centro-Oeste (UNICENTRO), Guarapuava, Paraná, Brazil. For conducting the sensory test, hamburgers have been cooked as previously described. All samples were evaluated by means of acceptance test using 9-point hedonic scale, with extremes ranging from: dislike extremely (1) to like extremely (9) [21]. Were evaluated attributes related to appearance, aroma, flavor, color and texture, beyond overall acceptance. For purchase intent test 5-point attitude structured scale was used, varying from: definitely would not buy it (1) to definitely would buy it (5) [21]. Sensory acceptability index (AI) was calculated by multiplying average score reported by consumers to product by 100, dividing result by the maximum score given to product within the hedonic scale for 9.0 points. Each sample was served to consumers in white plates coded with randomly selected 3-digit numbers in monadic form and using balanced design [22]. Sensory evaluations were performed by consumers under fluorescence lighting. After consuming each sample, consumer was instructed to drink water for palate cleansing. Samples were evaluated in triplicate in separate session.

2.3. Physicochemical composition

All analyzes were performed on three replicates in triplicate for cooked hamburger, FOS and pork fat. Water activity (Aw) was determined using Aw analyzer (Novasina, Labswift model, Switzerland), at 20 °C. pH was measured using pH-meter (Tecnopon, MPA-210 model, Brazil). To stablish color, five hamburgers were used per treatment, evaluated in five different hamburgers points. Color was evaluated by system of Commission Internationale de L'Eclairage (CIE), lightness (L^*), redness (a^*), yellowness (b^*), colorimeter reading (Konica Minolta, Chroma Meter CR 4400 model, Japan) with illuminating calibration D65 and angle of observation 10º, previously calibrated.

Moisture, ash, protein, fat and dietary fiber content were determined by AOAC methods [23]. Moisture content was determined by drying in greenhouse (105 ± 2 ºC). Fat content was determined according to Soxhlet method, using petroleum ether. Protein was analyzed according to Kjeldahl method. Factor 6.25 was used for nitrogen conversion to crude respectively. Ash was performed by muffle furnace. Total, soluble and insoluble dietary fiber was determined by enzymatic method. Carbohydrate content was evaluated by means of theoretical calculation (by difference) in triplicates results, according to the formula:

$$\%\ \text{carbohydrate} = 100 - (\%\ \text{moisture} + \%\ \text{protein} + \%\ \text{lipid} + \%\ \text{ash} + \%\ \text{fiber dietary})$$

Total caloric value (kcal) was calculated theoretically using Atwater factors [24] for lipid (9 kcal g^{-1}), protein (4 kcal g^{-1}) and carbohydrate (4 kcal g^{-1}).

2.4. Technological characteristics

Five hamburgers from each formulation were cooked in same procedure as mentioned previously then cooled to room temperature at 23 ºC for 2 h. Following cooking characteristics were evaluated: cooking yield and fat retention [25], shrinkage [26] and moisture retention [27]. All experiments were done in triplicate. Hamburgers were measured according to following equations:

$$\%\ \text{cooking yield} = \frac{\text{weight of cooked sample}}{\text{weight of raw sample}} \times 100$$

$$\%\ \text{fat retention} = \frac{(\text{weight of cooked sample}) \times (\%\ \text{fat in cooked sample})}{(\text{weight of raw sample}) \times (\%\ \text{fat in raw sample})} \times 100$$

$$\%\ \text{shrinkage} = \frac{(\text{diameter of raw sample} - \text{diameter of cooked sample})}{\text{diameter of raw sample}} \times 100$$

$$\%\ \text{moisture retention} = \frac{\%\ \text{cooking yield} \times \%\ \text{moisture content of cooked sample}}{100}$$

2.5. Statistical Analysis

Results were analyzed in randomized blocks using analysis of variance (ANOVA). The means were compared by Tukey's test at 5% significance level ($p \leq 0.05$). The Software R was used to perform statistical calculations.

2.6. Ethical Issues

Study was approved by the Ethics in Research Committee of UNICENTRO, Brazil, under the number 2.451.570/2017.

3. Results and discussion

3.1. Consumer study

Sensory results test of cooked hamburgers added at different FOS levels are described in Table 1. Higher scores ($p<0.05$) for appearance, flavor, overall acceptance and purchase intention attributes were found for sample F1 compared to F5. There was no significant difference ($p>0.05$) between other samples. Formulations F1, F2 and F3 were better accepted than F5 for flavor. The rest samples had similar acceptance in this attribute. Hamburger texture and color were not influenced by FOS addition ($p>0.05$). Similar results were observed in sausage with FOS addition [28,29,30] and mortadella with inulin addition [31]. According Salazar et al. [29], FOS addition in meat products generally does not modify sensory characteristics. Thus, changes observed in hamburger can be attributed to the fat reduction, as it negatively influences some sensory aspects, reducing acceptability of the product. In the flavor case, low fat level may decrease concentration of fat-soluble compounds [32], such as aliphatic hydrocarbons, aldehydes, ketones, alcohols, carboxylic acids and esters [33], which are released during chewing [34], which reduces acceptance. Similarly, this have occurred with aroma parameter, as lipids act as solvents for aromatic compounds [35]. These results corroborate with Olivares et al. [36] who studied low-fat sausage.

Product appearance was hampered by fat reduction, although consumers did not notice significant differences in texture and color. Fat-reduced hamburgers looked drier, as also reported by Bolumar et al. [37] studying 35% fat reduced in sausages. Despite the lower grades attributed to formulation with addition of 5% FOS, all samples presented AI above 70%, classifying them with good sensory acceptance [38]. Thus, it is demonstrated the feasibility of adding FOS as a fat substitute in hamburger, which promotes healthier food intake.

Table 1 - Sensory scores (mean ± standard deviation) obtained for hamburger with different levels addition of fructooligosaccharide (FOS)

Parameter	0%	1.25%	2.50%	3.75%	5%
Appearance	7.70±0.95^{a}	7.23±1.18^{ab}	7.42±1.13^{ab}	7.19±1.27^{ab}	7.06±1.35^{b}
AI (%)	85.56	80.33	82.44	79.89	78.44
Aroma	7.76±1.19^{a}	7.68±1.10^{a}	7.72±1.14^{a}	7.36±1.28^{ab}	7.09±1.49^{b}
AI (%)	86.22	85.33	86.55	81.78	78.78
Flavor	7.85±1.16^{a}	7.49±1.42^{ab}	7.56±1.41^{ab}	7.23±1.65^{ab}	7.13±1.45^{b}
AI (%)	87.22	83.22	84.00	80.33	79.22
Texture	7.14±1.56^{a}	6.9±1.67^{a}	6.94±1.60^{a}	6.91±1.68^{a}	6.78±1.64^{a}
AI (%)	79.33	76.67	77.11	76.77	75.33
Color	7.53±1.24^{a}	7.14±1.44^{a}	7.20±1.37^{a}	7.08±1.60^{a}	7.11±1.39^{a}
AI (%)	83.67	79.33	80.00	78.67	79.00

Overall Acceptance	7.6±1.30^{a}	7.41±1.42^{ab}	7.23±1.49^{ab}	7.15±1.52^{ab}	6.96±1.51^{b}
AI (%)	84.44	82.33	80.33	79.44	77.33
Purchase Intention	4.19±0.71^{a}	3.94±0.97^{ab}	3.88±1.02^{ab}	3.84±1.01^{ab}	3.73±1.02^{b}

Different letters in the same row differ significantly by the Tukey's test ($p<0.05$); AI: Acceptability Index.

3.2. Physicochemical composition

The physicochemical composition results of cooked hamburgers added at different levels of FOS are presented in Table 2. Prebiotic addition to hamburger proportionally increased moisture, carbohydrate and fiber content in product, however reduced lipid and calorie content. This is because FOS is free of lipid and contains low calorie contribute (1.46 kcal g^{-1}) [39] compared to pork fat that has 0.8 kcal g^{-1} lipid and 7.86 kcal g^{-1} [40]. There was no significant difference ($p>0.05$) between ash and protein content of the formulations, since both FOS [39] and pork fat [40] do not contain these nutrients in their composition. Higher moisture content in F5 is due to hygroscopic capacity of soluble fibers present in FOS (98%), which retain water within the hamburger protein matrix [41]. Similar results have been found in other surveys with the prebiotics addition in meat products [31,30,42].

There was no statistical difference in Aw results between samples, as already reported in literature [28,30]. FOS addition levels up to 2.5% increased pH in hamburger, while higher levels reduced this parameter. Higher FOS contents are likely to increase the lactic acid formation by the bacteria present in meat, which reduces pH in product [43,44]. Similar results were observed in sausage with addition of 0 to 30% inulin and pectin [8].

Table 2 - Physicochemical composition (mean ± standard deviation) of cooked hamburger with addition of different levels fructooligosaccharide (FOS)

Parameter	**0%**	**1.25%**	**2.50%**	**3.75%**	**5%**
Moisture (g 100 g^{-1})	52.69±0.04^{e}	54.95±0.05^{d}	56.05±0.09^{c}	56.55±0.06^{b}	62.95±0.08^{a}
Ash (g 100 g^{-1})$^{\alpha}$	5.35±0.08^{a}	5.36±0.07^{a}	5.34±0.05^{a}	5.33±0.08^{a}	5.37±0.09^{a}
Protein (g 100 g^{-1})$^{\alpha}$	50.55±0.10^{a}	50.58±0.08^{a}	50.66±0.11^{a}	50.69±0.12^{a}	50.57±0.10^{a}
Lipid (g 100 g^{-1})$^{\alpha}$	28.79±0.08^{a}	27.81±0.09^{b}	25.90±0.10^{c}	24.12±0.06^{d}	20.38±0.08^{e}
Carbohydrate (g 100 g^{-1})$^{\alpha*}$	15.31±0.19^{e}	16.25±0.21^{d}	18.10±0.18^{c}	19.86±0.15^{b}	23.68±0.13^{a}
Energy value (kcal 100 g^{-1})$^{\alpha**}$	522.55±0.88^{a}	517.61±0.53^{b}	508.14±0.45^{c}	499.29±0.47^{d}	480.42±0.63^{e}
Soluble fiber (g 100 g^{-1})$^{\alpha***}$	ND	1.28±0.13^{d}	2.55±0.15^{c}	3.83±0.18^{b}	5.10±0.17^{a}
Insoluble fiber (g 100 g^{-1})$^{\alpha***}$	ND	ND	ND	ND	ND
Total fiber (g 100 g^{-1})$^{\alpha***}$	ND	1.28±0.13^{a}	2.55±0.15^{a}	3.83±0.18^{a}	5.10±0.17^{a}
pH	5.84±0.02^{b}	5.98±0.03^{a}	6.06±0.03^{a}	5.55±0.08^{c}	5.63±0.06^{c}
Water activity	0.95±0.02^{a}	0.95±0.03^{a}	0.95±0.04^{a}	0.95±0.07^{a}	0.95±0.05^{a}

Distinct letters in the same row differ significantly by the Tukey's test ($p<0.05$); $^{\alpha}$Values calculated in dry basis; *Include dietary fiber; **Theoretical calculus: lipid (9 kcal g^{-1}), protein (4 kcal g^{-1}) and carbohydrate (4 kcal g^{-1}); ***Dietary fiber; ND: not detected.

Results for objective color analysis for hamburgers are presented in Table 3. The FOS addition significantly increased the L^* values as FOS have shown higher brightness (98.02 ± 0.4) than pork fat (74.43 ± 0.43). However, there was no change in a^* and b^* values (p>0.05). In hamburger, formation of a translucent whitish gel from the prebiotic fiber prevents changes in values of a^* and b^* [28], which preserves characteristics of the standard product. Similar effects were reported by Menegas et al. [45] after addition of 7% inulin in fermented chicken sausage.

Table 3 - Color parameters L^*, a^* e b^* (mean ± standard deviation) of cooked hamburgers with addition of different levels fructooligosaccharide (FOS)

Formulation	Lightness (L^*)	Redness (a^*)	Yellowness (b^*)
0%	45.34 ± 1.75^c	4.36 ± 0.19^a	9.34 ± 0.07^a
1.25%	47.59 ± 1.78^b	4.26 ± 0.32^a	9.37 ± 0.75^a
2.50%	47.51 ± 0.55^b	4.28 ± 0.24^a	9.35 ± 0.31^a
3.75%	47.29 ± 1.34^b	4.20 ± 0.07^a	9.32 ± 0.03^a
5%	50.38 ± 1.25^a	4.21 ± 0.19^a	9.38 ± 0.16^a

Distinct letters in the same column differ significantly by the Tukey's test (p<0.05).

3.3. Technological characteristics

Hamburgers technological characteristics results with addition of different levels fructooligosaccharide (FOS) are show in Table 4. The FOS addition to hamburgers proportionally increased cooking yield, fat retention and moisture values. Only 5% increment of FOS increased (p<0.05) the product % shrinkage. The soluble short chain fibers present in FOS interact with meat proteins forming a network that prevents water migration from product to surface [46]. Thus, there was increase in moisture retention and, consequently, in yield of hamburger cooking. Nevertheless, the use of very low levels fat may negatively affect technological characteristics of this product [47,48,16]. In meat products, fat provides flavor and texture, further promotes emulsion of ingredients while maintaining structure of food. Thus, it is possible to explain the greater shrinkage found in F5, since it is fat free, which increases water loss [49]. There was greater fat retention in hamburgers added with FOS (F3, F4 and F5, p<0.05), corroborating Tornberg et al. [50], Berry [26] and Troy et al. [47]. Hamburgers with higher fat content have higher fat loss during cooking. This is due to the greater likelihood that fat droplets will meet and expand since these products naturally have a higher lipid content. In addition, protein matrix of low lipid hamburger prevents fat from escaping from the product [50].

Table 4 - Technological characteristics (mean ± standard deviation) of cooked hamburger with addition of different levels fructooligosaccharide (FOS)

Formulation	Cooking Yield (%)	Fat Retention (%)	Shrinkage (%)	Moisture Retention (%)
0%	30.57±1.48^{d}	57.25±0.83^{c}	15.34±1.30^{b}	15.97±0.68^{d}
1.25%	31.36±1.76^{cd}	57.07±0.85^{c}	16.70±2.80^{b}	17.23±0.97^{c}
2.50%	32.91±1.00^{bc}	65.43±0.88^{b}	16.77±3.02^{b}	18.45±0.56^{b}
3.75%	33.34±1.11^{b}	68.83±0.99^{a}	16.40±1.04^{b}	18.85±0.63^{b}
5%	36.71±1.09^{a}	68.76±0.78^{a}	20.56±0.37^{a}	23.11±0.69^{a}

Distinct letters in the same column differ significantly by the Tukey's test ($p<0.05$).

4. Conclusions

It is concluded that FOS can be used as fat substitute in beef hamburger, withal it improves its nutritional profile, increasing carbohydrate and dietary fiber content and, reducing lipid amount and calories in product. It also has favorable influence on technological parameters of hamburger, increasing the cooking yield and moisture retention. Replacing up to 3.75% fat with hamburger FOS maintains sensory acceptability similar to standard product, with good commercialization expectations.

5. Acknowledgement

Authors thanks Araucaria Foundation of Supports Scientific and Technological Development in the Parana State - Brazil for financial support.

6. References

[1] Cofrades, S., Benedí, J., Garcimartin, A., Sánchez-Muniz, F. J., Jimenez-Colmenero, F. A comprehensive approach to formulation of seaweed-enriched meat products: From technological development to assessment of healthy properties. Food Research International, 99 (3) 1084-1094, 2017.

[2] Jiang, J., Xiong, Y. L. Natural antioxidants as food and feed additives to promote health benefits and quality of meat products A review. Meat Science, 120 (1) 107-117, 2017.

[3] Klurfeld, D. M. Research gaps in evaluating the relationship of meat and health. Meat Science, 109 (1) 86-95, 2017.

[4] Boada, L. D., Henríquez-Hernández, L. A., Luzardo, O. P. The impact of red and processed meat consumption on cancer and other health outcomes: Epidemiological evidences. Food Chemical Toxicology, 92 (1) 236-244, 2016.

[5] Barbut, S., Wood, J., Marangoni, A. Potential use of organogels to replace animal fat in comminuted meat products. Meat Science, 122 (1) 155-162, 2016.

[6] Jimenez-Colmenero, F., Salcedo-Sandoval, L., Bou, R., Cofrades, S., Herrero, A. M., Ruiz-Capillasa, C. Novel applications of oil-structuring methods as a strategy to improve the fat content of meat products.

Trends Food Science and Technology, 44 (2) 177-188, 2015.

[7] Afoakwah, N. A., Dong, Y., Zhao, Y., Xiong, Z., Owusu, J., Wang, Y., Zhang, J. Characterization of Jerusalem artichoke (*Helianthus tuberosus L.*) powder and its application in emulsion-type sausage. Food Science and Technology, 64 (1) 74–81, 2015.

[8] Méndez-Zamora, G., García-Macías, J. A., Santellano-Estrada, E., Chávez-Martínez, A., Durán-Meléndez, L. A., Silva-Vázquez, R., Quintero-Ramos, A. Fat reduction in the formulation of frankfurter sausages using inulin and pectin. Food Science and Technology, 35 (1) 25-31, 2015.

[9] Schmiele, M., Mascarenhas M. C. C. N., Barretto, A. C. S., Pollonio, M. A. R. Dietary fiber as fat substitute in emulsified and cooked meat model system. Food Science and Technology, 61 (1) 105–111, 2015.

[10] Zhuang, X., Han, M., Kang, Z., Wang, K., Bai, Y., Xu, X., Zhou, G. Effects of the sugarcane dietary fiber and pre-emulsified sesame oil on low-fat meat batter physicochemical property, texture, and microstructure. Meat Science, 113 (1) 107–115, 2016.

[11] Alves, L. A. A. S., Lorenzo, J. M., Gonçalves, C. A. A., Santos, B. A., Heck, R. T., Cichoski, A. J., Campagnol, P. C. B. Production of healthier bologna type sausages using pork skin and green banana flour as a fat replacers. Meat Science, 121 (1) 73–78, 2016.

[12] Felisberto, M. H. F., Galvão, M. T. E. L., Picone, C. S. F., Cunha, R. L., Pollonio, M. A. R. Effect of prebiotic ingredients on the rheological properties and microstructure of reduced-sodium and low-fat meat emulsions. Food Science and Technology, 60 (1) 148–155, 2015.

[13] Praznik, W., Loeppert, R., Viernstein, H., Haslberger, A. G., Unger, F. M. Dietary fiber and prebiotics. Polysaccharides bioactivity and bioavailability. Berlin: Springer, 2015.

[14] Singla, V., Chakkaravarthi, S. Applications of prebiotics in food industry: A review. International Journal of Food Science and Technology, 23 (8) 649–667, 2017.

[15] Campos, D., Mescua, L., Aguilar-Galvez, A., Chirinos, R., Pedreschi, R. Effect of Yacon (Smallanthus sonchifolius) fructooligosaccharide purification technique using activated charcoal or ion exchange fixed bed column on recovery, purity and sugar content. International Journal of Food Science and Technoloy, 52 (12) 2637-2646, 2017.

[16] Angiolillo, L., Conte, A., Del Nobile, M. A. Technological strategies to produce functional meat burgers. Food Science and Technology, 62 (1) 697–703, 2015.

[17] Park, E. Y., Jang, S. B., Lim, S. T. Effect of fructo-oligosaccharide and isomaltooligosaccharide addition on baking quality of frozen dough. Food Chemical, 15 (213) 157-162, 2016.

[18] Aidoo, R. P., Afoakwa, E. O., Dewettinck, K. Rheological properties, melting behaviours and physical quality characteristics of sugar-free chocolates processed using inulin/polydextrose bulking mixtures sweetened with stevia and thaumatin extracts. Food Science and Technology, 62 (1) 592–597, 2015.

[19] Rubel, I. A., Pérez, E. E., Manrique, G. D., Genovese, D. B. Fibre enrichment of wheat bread with Jerusalem artichoke inulin: Effect on dough rheology and bread quality. Food Structure, 3 (1) 21–29, 2015.

[20] American Meat Science Association (AMSA). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of meat. Champaign: American Meat Science Association, 2015.

[21] Meilgaard, M., Civille, G. V., Carr, B. T. Sensory evaluation techniques. Boca Raton: CRC, 1999.

[22] Macfie, H. J., Bratchell, N., Greenhof, K., Vallis, L. V. Designs to balance the effect of order of presentation and first order carry over effects in hall tests. Journal of Sensory Studies, 4 (2) 129-148, 1989.

[23] Association of Official Agricultural Chemists (AOAC) International. Official Methods of Analysis of AOAC International. Gaithersburg: Association of Official Analytical Chemists, 2011.

[24] Atwater, W. O., Woods, C. D. The chemical composition of American food materials. US Official Experiment Stations. Experiment Station Bulletin, 28 (1) 461-462, 1896.

[25] Murphy, E. W., Criner, P. E., Gray, B. C. Comparisons of methods for calculating retentions of nutrients in cooked foods. Journal of Agricultural and Food Chemistry, 23 (6) 1153-1157, 1975.

[26] Berry, B. W. Low Fat Level Effects on Sensory, Shear, Cooking, and Chemical Properties of Ground Beef Patties. Journal of Food Science, 57 (3) 537–537, 1992.

[27] El-Magoli, S. B., Laroia, S., Hansen, P. T. M. Flavour and texture characteristics of low fat ground beef patties formulated with whey protein concentrate. Meat Science, 42 (2) 179-193, 1996.

[28] Cáceres, E., García, M. L., Toro, J., Selgas, M. D. The effect of fructooligosaccharides on the sensory characteristics of cooked sausages. Meat Science, 68 (1) 87–96, 2004.

[29] Salazar, P., García, M. L., Selgas, M. D. Short chain fructooligosaccharides as potential functional ingredient in dry fermented sausages with different fat levels. International Journal of Food Science and Technology, 44 (6) 1100–1107, 2009.

[30] Santos, B. A., Campagnol, P. C. B., Pacheco, M. T. B., Pollonio, M. A. R. Fructooligosaccharides as a fat replacer in fermented cooked sausages. International Journal of Food Science and Technology, 47 (6) 1183–1192, 2012.

[31] García, M. L., Cáceres, E., Selgas, M. D. Effect of inulin on the textural and sensory properties of mortadella, a Spanish cooked meat product. International Journal of Food Science and Technology, 41 (10) 1207–1215, 2006.

[32] Archer, B. J., Johnson, S. K., Devereux, H. M., Baxter, A. L. Effect of fat replacement by inulin or lupin-kernel fibre on sausage patty acceptability, post-meal perceptions of satiety and food intake in men. British Journal of Nutrition, 91 (4) 591-599, 2004.

[33] Mottram, D. S. Flavour formation in meat and meat products: a review. Food Chemical, 62 (4) 415–424, 1998.

[34] Devereux, H. M., Jones, G. P., McCormack, L., Hunter, W. C. Consumer Acceptability of Low-Fat Foods Containing Inulin and Oligofructose. Journal of Food Science, 68 (5) 1850-1854, 2003.

[35] Chevance, F. F. V., Farmer, L. J., Desmond, E. M., Novelli, E., Troy, D. J., Chizzolini, R. Effect of Some Fat Replacers on the Release of Volatile Aroma Compounds from Low-Fat Meat Products. Journal of Agricultural and Food Chemistry, 48 (8) 3476–3484, 2000.

[36] Olivares, A., Navarro, J. L., Flores, M. Effect of fat content on aroma generation during processing of dry fermented sausages. Meat Science, 87 (3) 264–273, 2011.

[37] Bolumar, T., Toepfl, S., Heinz, V. Fat Reduction and Replacement in Dry-Cured Fermented Sausage by Using High Pressure Processing Meat as Fat Replacer and Olive Oil. Polish Journal of Food and Nutrition Sciences, 65 (3) 175–182, 2015.

[38] Corradini, S. A. S., Madrona, G. S., Visentainer, J. V., Bonafe, E. G., Carvalho, C. B., Roche, P. M., Prado, I. N. Sensorial and fatty acid profile of ice cream manufactured with milk of crossbred cows fed palm oil and coconut fat. Journal of Dairy Science, 97 (1) 6745-6753, 2014.

[39] Mapric Greentech Company [internet]. Access in: 27 de jul 2019. Available in: https://mapric.com.br/

[40] United States Department of Agriculture [internet]. FoodData Central. Access in: 24 de jun 2019. Available in: https://ndb.nal.usda.gov/ndb/search/list.

[41] Figuerola, F., Hurtado, M. L., Estévez, A. M., Chiffelle, I., Fasenjo, F. Fibre concentrates from apple pomace and citrus peel as potential fibre sources for food enrichment. Food Chemical, 91 (1) 395-401, 2005.

[42] Keenan, D. F., Resconi, V. C., Kerry, J. P., Hamill, R. M. Modelling the influence of inulin as a fat substitute in comminuted meat products on their physico-chemical characteristics and eating quality using a mixture design approach. Meat Science, 96 (3) 1384–1394, 2014.

[43] Dykes, G. A., Cloete, T. E., Von Holy, A. Quantification of microbial populations associated with the manufacture of vacuum-packaged, smoked Vienna sausages. International Journal of Food and Microbiology, 13 (4) 239–248, 1991.

[44] Kaplan, H., Hutkins, R. W. Fermentation of Fructooligosaccharides by Lactic Acid Bacteria and Bifidobacteria. Applied and Environmental Microbiology, 66 (6) 2682-2684, 2000.

[45] Menegas, L. Z., Pimentel, T. C., Garcia, S., Prudencio, S. H. Dry-fermented chicken sausage produced with inulin and corn oil: Physicochemical, microbiological, and textural characteristics and acceptability during storage. Meat Science, 93 (3) 501–506, 2013.

[46] Anderson, E. T., Berry, B. W. Effects on inner pea fiber on fat retention and cooking yield in high fat ground beef. Food Research International, 34 (1) 689–694, 2001.

[47] Troy, D. J, Desmond, E. M., Buckley, D. J. Eating quality of low-fat beef burgers containing fat-replacing functional blends. Journal of the Science of Food and Agriculture, 79 (4) 507–516, 1999.

[48] Afshari, R., Hosseini, H., Khaksar, R., Mohammadifar, M. A., Amiri, Z., Komeili, R., Khaneghah, A. M. Investigation of the Effects of Inulin and β-Glucan on the Physical and Sensory Properties of Low-Fat Beef Burgers Containing Vegetable Oils: Optimisation of the Formulation Using D-Optimal Mixture Design. Food Technology and Biotechnology, 53 (4) 436-445, 2015.

[49] Beuschel, B. C., Partridge, J. A., Smith, D. M. Insolubilized whey protein concentrate and/or chicken salt-soluble protein gel properties. Journal of Food Science, 57 (4) 852-855, 1992.

[50] Tornberg, E., Olsson, A., Persson, K. A comparison in fat holding between hamburgers and emulsion sausages. Proceedings International Congress on Meat Science Technology, 35 (1) 753-757, 1989.