# Effect of different types of inulin as fat replacers in meat burgers

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# Abstract

Research in meat products has proven that dietary fibers could be used as fat replacers as they improve cooking yield, water loss, and textural properties. Inulin, a dietary fiber with many applications, was partially or completely replaced fat in meat burgers, made with lean beef and pork fat. Three types of inulin were incorporated (long-chain inulin, native inulin, and oligofructose) in four different concentrations (5%, 10%, 15%, 20% w/w) and the samples were compared with a control burger made with 20% of fat. The comparison between the different formulations was made based on sensorial and textural parameters. The results showed that the addition of inulin improved the cooking yield in all samples compared with the control sample, especially in long chain inulin. Texture Profile Analysis revealed that samples that were replaced with 5% and 10% of inulin didn't show a significant difference ($p>0,05$) with the control burger in terms of hardness, chewiness, and gumminess but no effect could be seen regarding the inulin type. The sensory analysis revealed that most of the samples were accepted by panelists even in higher concentrations. Lastly, burgers that were preferred more than the control burger in terms of juiciness and texture were samples with oligofructose and native inulin. In conclusion, all three types of inulin could successfully replace fat, thought the optimal concentration should be further investigated.

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# 1. Introduction

## 1.1 Background Information

Over the last years, consumers have become more health-conscious and strive to improve their eating habits (Paglarini et al., 2018). There is an increasing demand among consumers for reduced fat products (Jalal et al., 2015). Meat, one of the main diet components in Europe and USA has been associated lately with cardiovascular diseases and obesity due to the high fat content (Tokusoglu & Ünal, 2003; Furlán et al., 2014). Thus, a fat reducing strategy in the meat industry could improve this image (Tokusoglu & Ünal, 2003; Barbut et al., 2016).

The fats in meat have a functional role in the meat system. They contribute to the texture, mouthfeel, juiciness and sensory acceptability of meat products (Barbut et al., 2016; Savell & Cross, 1988). Hence, assuring palatability while developing a lean product is of major importance. Removing only the fat is not always accepted by the consumers. Fat replacers should be incorporated instead of fat. They are proven to influence the functional and nutritional properties of the new product and it could reach an acceptable quality. (Tokusoglu & Ünal, 2003).

Fat replacers can be introduced in meat products to meliorate water and fat binding properties, improve the cooking yield and the flavor (Sampaio et al., 2004). The ingredients that can be used as fat substitutes could be sorted as protein- based substitutes, synthetic compounds, fat-based and carbohydrate-based substitutes. Ingredients like soy, whey protein, starch, gums, and vegetable oils were successfully replaced fat completely or partially in different meat products (Jalal et al., 2015). Among them, several studies showed that carbohydrate-based substitutes demonstrated better functional properties as fat replacers as they improve water holding capacity, cooking yield and textural properties (Agyei-Amponsah et al., 2019; Zoulias et al., 2002; Mendoza et al.,2001). As carbohydrate-based fat mimetics, fibers could also be used which can give structure and stability in the food system (Tokusoglu & Ünal, 2003).

One of the most prevalent fibers is inulin, mostly extracted from chicory root or Jerusalem artichoke. The production of inulin includes extraction with hot water, purification and crystallization (Shoaib et al., 2016). Native inulin or chicory root extract consists of oligomers and longer polymer chains of fructose molecules with a degree of polymerization (DP) from 2 to 60. With partial enzymatic hydrolysis of the native inulin, oligofructose can be acquired which has an average DP value of 4. Alternatively, by physically removing oligomers with a DP below 10 from native inulin, long-chain inulin can be obtained (average DP 23) (Shoaib et al., 2016; Villegas & Costell, 2007).

Inulin has many applications in food due to its technological attributes. It is a fiber enriched, prebiotic, low fat and low sugar product. Inulin has a gelling capacity with water and can improve the stability, color and textural parameters of a system. Furthermore, it gives a creamier and softer product (Mendez- Zamora et al., 2015; Furlán et al., 2014). Besides, as a bio functional ingredient, it promotes the expansion of healthy bacteria that contribute to calcium and magnesium absorption and decreases the levels of cholesterol (Guven et al.,2008). Oligofructose, the short chain fraction is mostly used as a sweetener due to the high solubility and similar profile to sucrose. On the other hand, long-chain inulin which is more thermo-stable and more viscous as the native inulin is mostly used as a fat substitute (Villegas & Costell, 2007).

As a fat replacer inulin is mostly used in spreads, fillings, dairy products, dressings and meat products (Zahn et al., 2010). Mendoza et al. (2001) indicated that the incorporation of inulin powder in low-fat sausages could successfully replace the fat and give an improved texture to the product. A similar study by Garcia et al. (2006) showed that adding inulin in a gel form in mortadella showed better sensory attributes than inulin powder. However, most of the studies are focused on one type of inulin in low-fat products, with a high length chain. It was proven, that the physiochemical properties (gelling ability, solubility, rheological behavior) of inulin depend on the chain length and DP (Alvarez-Sabatel et al., 2015). Villegas & Costell (2007), reported that viscosity in milk beverages with different types of inulin was different, with long chain inulin to produce the most viscous beverage. In addition, Schaller-Povolny et al. (2000) have shown that the glass transition temperature ($T_g$) of the inulin types depends on the different degrees of polymerization. The $T_g$ indicates the formation of crystals and is an important parameter since inulin molecules form microcrystals that interact with each other, create aggregates with entrapped water and mimic the structure of fat (Villegas & Costell, 2007; Schaller- Povolny et al., 2000). Little information exists, though about the differences among inulin types and the interaction of each type with the ingredients in a meat system (Villegas & Costell, 2007).

Additionally, inulin was incorporated in the mixture of the meat product in one or two different concentrations (Garcia et al., 2006; O'brien et al., 2003). Garcia et al., (2006), proven that incorporation of inulin in three different concentrations increased the hardness of increased fat sausages significantly ($p<0,05$). Mendoza et al. (2001) reported similar results when they tested sausages formulated with inulin. It could be assumed that the concentration of the replacer is another important parameter that could affect the textural and sensorial parameters of low-fat meat products.

## 1.2 Aim of the study

Thus, the objective of the study is to examine the effect of different types (oligofructose, native and long-chain) and different concentrations of inulin as a fat replacer in a meat burger. The addition of inulin will be examined based on textural and sensorial properties of reduced-fat meat burgers and will be compared with products prepared with average fat levels.

## 1.3 Research questions and hypotheses

**1. Which of the different inulin fractions will demonstrate the best techno-functional properties?**

It is expected that at least one inulin fraction will have better water holding capacity. Long- chain inulin which is more viscous and insoluble is expected to behave better in a specific concentration.

2. What will the effect be of the addition of different types of inulin for the textural and sensorial properties of the meat burgers?

It is expected that at least one type of inulin, long chain inulin, will be a successful replacer as it has already been proven that inulin is a possible fat replacer that gives the product better texture and improved cooking yield.

3. What will be the effect of the inulin concentration on the textural and sensorial properties of the meat burgers?

It is expected that the concentration will affect the textural parameters of the meat burgers, especially the hardness of the burger.

# 2. Materials and Methods

An overview of the experimental design is depicted in figure 1.

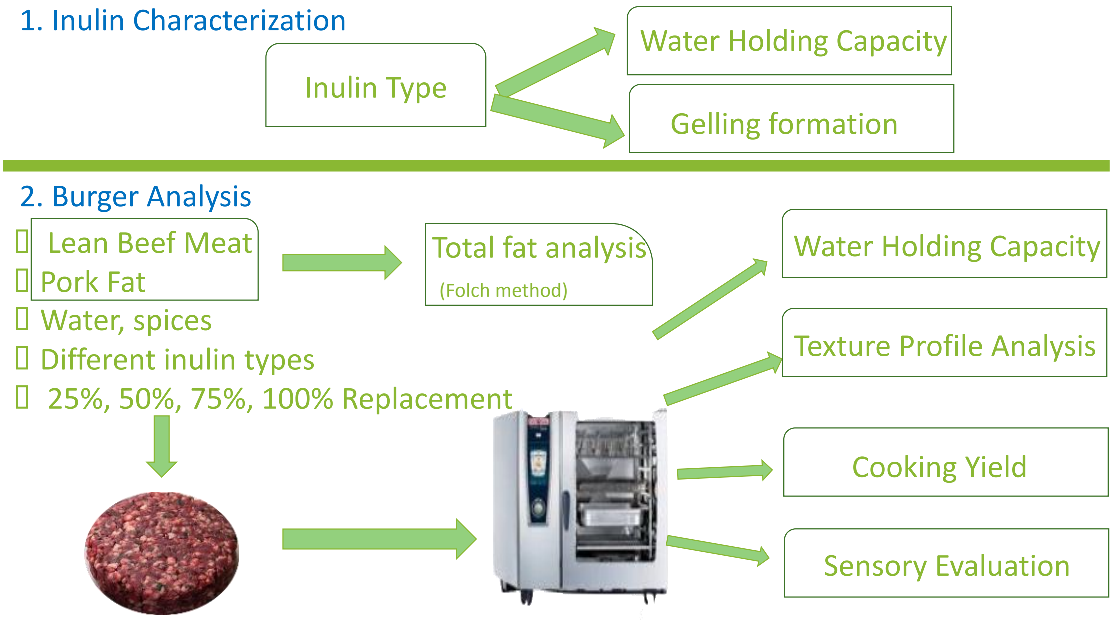


Figure 1. Overview of the experimental design.

## 2.1 Materials

Long chain length inulin (Frutafit TEX!), native inulin (Frutafit HD) and oligofructose (Frutafit CLR) were supplied from Sensus (Roosendaal, Netherlands). Lean beef and pork fat were obtained at the local butcher (Elings, Wageningen, Netherlands). The lean beef and pork fat were milled with a mixer (Blixer 2, Robot coupe, Netherlands). The fat and the lean beef were stored in the fridge at 4 °C.

Spices (Mix voor Gehakt Traditioneel, Verstegen), salt (Fijn zezout, La Balleine) and sugar (Kristalsuiker, Van Gilse) were obtained from the local supermarket (Jumbo, Wageningen, Netherlands). The burger press was purchased from the local market (Blokker, Wageningen, the Netherlands). All other chemicals and materials used were purchased from regular suppliers and were of analytical grade.

## 2.2 Inulin characterization

### 2.2.1 Water holding capacity

The water holding capacity (WHC) of different inulin types was determined with the method from Food Ingredients & Specialties. Firstly, 0,5 gram of each sample (Frutafit TEX!, Frutafit HD, Frutafit CLR) was added to a pre-weighed 15 mL Greiner tube. Afterward, 10 grams of demi-water was added to the tubes. The tubes were then shaken at 1400 rpm for 10 minutes in a tube shaker (Multi Reax, Heidolph, Germany) and centrifuged at 1500 g for 30 minutes in a centrifuge (Heraeus Multifuge X3 Centrifuge, ThermoFisher, USA). After centrifuging the supernatant was discarded and weighed. The tube with the sediment was weighted as well. The WHC was calculated using equation 1. The measurements were done in triplicate.

$$WHC\ (g/g) = \frac{Added\ water\ (g) - supernatant(g)}{Added\ powder\ (g)}\ (1)$$

### 2.2.2 Gelling formation of inulin types

#### 2.2.2.1 Preparation of gels

The inulin gels were prepared according to Chiavaro *et* al. (2007). Inulin powders were mixed with water in order to obtain concentrations of 20, 30, 40, 50% w/w for HD and CLR and 20, 30, 40% w/w for TEX respectively. The appropriate amount of inulin powder was slowly added to water in a 250 mL beaker. Water was held at a temperature of either 25 $^{\circ}$C or 50 $^{\circ}$C to avoid thermal degradation of inulin chains into shorter units because of the hydrolysis of inulin above 80 $^{\circ}$C (Kim et al., 2001). The suspensions were mixed with a magnetic stirrer for 15 min to obtain a slurry. Ten grams of each slurry was poured into polyethylene containers (diameter 25 mm, height 35 mm), and cooled down at room temperature. Finally, a gel-like structure was obtained. Samples were then stored at 4 $^{\circ}$C in the plastic containers sealed to prevent water loss.

#### 2.2.2.2 Texture analysis of inulin gels

Samples were analysed within twenty-four hours from production with a texture profile analyser (TA-XT2, Stable Micro Systems, UK). The test was carried out to a 5% compression level with a load cell of 500 g and a circular probe with a diameter of 2 cm. Pre- test speed was 3 mm/s, the test speed was the 1 mm/s and post-test speed was 1 mm/sec. The textural parameters considered were hardness (peak force of the first compression cycle in N) and adhesiveness (negative area under the baseline after the compression in N). Three replicates were run for each sample.

## 2.3 Burger analysis

### 2.3.1 Fat content of lean beef and pork fat

Both lean meat and pork fat were analyzed for their fat composition to assess the amount of fat in each sample. The meat was analyzed according to Folch method (Folch et al., 1957). 2,5 grams of sample were added in a centrifuge tube with 50 mL of dichloromethane DCM/methanol mixture (2:1 v/v) and were homogenized with a rotor stator homogenizer (T25 digital ULTRA-TURRAX, IKA, Germany). The sample was centrifuged for ten minutes at 1200 g. The centrifuged sample was filtered through folded filters of grade 595 ½ and diameter 185 mm (Whatman plc, United Kingdom), into 100 ml centrifuge tubes. Then, 2,5 mL of 0.9 % NaCl solution was added to the tube and each tube was mixed with a glass rod. The biphasic mixture was separated through centrifugation at 1200g for ten minutes. The upper aqueous layer was removed with the help of a Pasteur pipette. The lower layer of DCM was filtered through a folded filter of grade 595 ½ into a 100 mL beaker loaded with 2 g of anhydrous sodium sulphate. The solution was left 5 minutes to settle. Subsequently, the DCM layer was brought into a pre-weighted 100ml flat bottomed flask and the DCM was evaporated using a vacuum film evaporator (Rotavapor R-200, Büchi, Germany) in order to obtain the total fat of the sample. The total fat was calculated using equation 2.

$$Total\ fat\left(\%\frac{w}{w}\right) = \frac{Weight\ of\ flat\ bottom\ flask\ and\ fat\ after\ evaporation\ (g)}{Initial\ weight\ of\ sample\ (g) - Weight\ of\ flat\ bottom\ flask(g)} * 100\ (2)$$

### 2.3.2 Preparation of meat burgers

The lean beef, pork fat, inulin, water, sugar and spices were used to formulate the beef burgers according to Owon et al. (2007) with some modifications. Burgers with varying amounts of fat were made according to Table 1. The control beef burger was formulated to contain 65% lean beef, 20% pork fat, 10% of water and 5% salts and spices mixture. The minced meat was mixed with the other ingredients with hand stirring. Afterward, the burgers were shaped with a burger mold of a diameter of 6,5 cm. The average weight of the burgers was 49 *±2,4* g. The burgers were baked in a rational oven (SelfCookingCenter @5 Senses,Rational, Germany). The oven was set on program 'hot air', the humidity in the oven was set to 100% that led to less water loss during the baking. The burgers were heated at 200 $^{o}$ C until a core temperature of 72 $^{o}$ C was reached which was in the range of 6,5 to 7 minutes. The core temperature was measured with a core thermometer probe inside the oven. After baking they were removed from the oven, cooled down and stored in the fridge until further analysis.

Table 1. Formulations for different types of burgers with inulin.

| Samples | Pork fat (g) | TEX(g) | HD (g) | CLR (g) | Lean meat (g) | Water (g) | Spices (g)* |
|---|---|---|---|---|---|---|---|
| Control | 10 | 0 | 0 | 0 | 32,5 | 5 | 2,5 |
| 5% TEX | 7,5 | 2,5 | 0 | 0 | 32,5 | 5 | 2,5 |
| 5% HD | 7,5 | 0 | 2,5 | 0 | 32,5 | 5 | 2,5 |
| 5% CLR | 7,5 | 0 | 0 | 2,5 | 32,5 | 5 | 2,5 |
| 10% TEX | 5 | 5 | 0 | 0 | 32,5 | 5 | 2,5 |
| 10% HD | 5 | 0 | 5 | 0 | 32,5 | 5 | 2,5 |
| 10% CLR | 5 | 0 | 0 | 5 | 32,5 | 5 | 2,5 |
| 15% TEX | 2,5 | 7,5 | 0 | 0 | 32,5 | 5 | 2,5 |
| 15% HD | 2,5 | 0 | 7,5 | 0 | 32,5 | 5 | 2,5 |
| 15% CLR | 2,5 | 0 | 0 | 7,5 | 32,5 | 5 | 2,5 |
| 20% TEX | 0 | 10 | 0 | 0 | 32,5 | 5 | 2,5 |
| 20% HD | 0 | 0 | 10 | 0 | 32,5 | 5 | 2,5 |
| 20% CLR | 0 | 0 | 0 | 10 | 32,5 | 5 | 2,5 |

*Spices: 1 g salt, 1 g spices and 0.5 g sugar.

### 2.3.3 Cooking yield

The meat burgers were weighted before they were baked and after the oven when they were cooled down to room temperature. The cooking yield was calculated using equation 3.

$$Cooking\ Yield\left(\%\frac{w}{w}\right) = \frac{cooked\ weight\ (g)}{raw\ weight\ (g)} * 100 \quad (3)$$

### 2.3.4 Water holding capacity

Water holding capacity of the cooked burgers was determined with the same method as the powder provided by Fi&S (as described in 2.2.1.).

### 2.3.5 Texture analysis

The burgers were analysed using a Texture Profile Analyzer (TA-XT2, Stable Micro Systems, UK) at room temperature. The burgers were cut in 3 equal pieces of 2x2 cm and placed on the platform of the Texture Analyzer. In total 9 replicates were run for each different formulation. Samples were compressed twice to 50% of their original height with a load cell of 50 kg and a circular probe with a diameter of 2 cm. Pre- test speed was 1 mm/s, the test speed was the 2 mm/s and post-test speed was 2 mm/sec. The following textural parameters according to Pons and Fiszman (1996) were identified. Firstly, hardness (N) that is the maximum force required to compress the sample. The second parameter was springiness, which is the ability of a sample to recover its original form after the deforming force was detached. Cohesiveness, which is the degree to which a product resists the second deformation. The next parameter identified was gumminess (N), which is the force needed to break a semisolid meat sample for swallowing. Lastly chewiness (N), that equals to the work needed to masticate the sample for swallowing.

### 2.3.5 Sensory evaluation

A hedonic test was performed in which a total of 32 untrained panelists (10 women, 22 men) that evaluated the 13 meat samples. The recruited participants were mainly students and staff of Wageningen University and Research. All of them were consuming pork and beef burgers and didn’t have swallowing and eating problems. The evaluation was conducted in two different days, to avoid taste bud fatigue and minimize the loss of interest of the panelists. During the first day panelists evaluated 6 samples and during the second day 7 samples. The study was run from 12 pm to 2 pm in 4 different sessions of half an hour. Each session had been constituted by six or seven panelists that were requested not to eat one hour before the session.

The panelists were asked to visually examine the samples, smell and taste a piece of meat burger with dimensions approximately 3x3 cm in room temperature and record their perceptions by making marks on a vertical nine-point hedonic scale, that was presented with the help of a survey tool (Qualtrics, Provo, UT). The option 'Like it extremely' was presented as a first choice and 'Dislike it extremely' as the last one. The samples were coded with a 3- digit code and the order of the samples was randomized for each participant. The response parameters were appearance, color, flavor, texture and overall liking. The sample of the questionnaire is listed in Appendix 1.

## 2.4 Statistical analysis

For the burger analysis, a significance test was performed using a statistical software (IBM SPSS Statistics 24.0) with $p<0.05$. First, a one-way ANOVA (Analysis of Variance) was performed to determine whether the samples in each parameter were significantly different. This was followed by a Tukey test to determine which of the samples were significantly different. Since the subgroups created by the Tukey test were a lot, in order to reduce the variance, the samples were clustered based on differences in concentration and inulin type. Then one-way ANOVA has performed again, and the factor represented the fat replacement and the inulin type.

# 3. Results and Discussion

## 3.1 Inulin Characterization

### 3.1.1 Water Holding Capacity

The results obtained from the WHC test for the 3 different types of inulin are depicted in Table 2. The highest value was obtained from TEX (1,34 g/g) whereas HD had a value of 0,99 g/g. The value for the CLR is negative because the powder was dissolved in water after centrifugation, thus the measure is not taken into account.

Table 2. Water holding capacity of the different inulin types.

| Sample | WHC (g water/g powder) |
|---|---|
| TEX | 1,34 ± *0,07* |
| HD | 0,99 ± *0,14* |
| CLR | -0,82 ± *0,35* |

TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

The result of TEX was similar to the result of Furlan et al. (2013) and Collar et al. (2007) where long chain inulin products were used close to the structure of TEX. The difference between the three powders is in the different distribution of oligo- and polysaccharide fractions of inulin. TEX has an average length chain higher than 22 monomers and can entrap a higher amount of water during centrifugation, as the longer the molecule the longer space it occupies in solutions (Villegas & Costell, 2007). Furthermore, the amount of oligosaccharides chains is less than 0,5 % w/w, so a small amount is dissolved in water. On the contrary, HD and CLR have a much higher amount of oligofructose units (<10% w/w, <15% w/w respectively) and shorter chain length (8-13 for HD, and 7-9 for CLR). Water Holding Capacity is an important functional property of an ingredient and could be used later for comparison of the WHC of the powders and the WHC of burgers with different inulin fractions.

### 3.1.2 Gelling formation of the inulin types

The different types of inulin showed dissimilar gelling behavior. TEX formed a brittle white gel, in the range of 20%- 40% w/w. TEX couldn't form a gel in higher concentrations as no more powder could be dissolved in water and agglomerates were formed, thus it was not possible to obtain a gel. In the case of HD, the powder couldn't shape a gel at concentrations lower than 30% while CLR didn't form a gel below 40% w/w. The latter were softer compared to the gels obtained from TEX. This is a possible result of the low solubility of TEX compared to the other two samples. The results of the Texture Profile Analysis for the different samples are depicted in Table 3. The parameters identified were hardness and adhesiveness.

Table 3. Hardness, Adhesiveness of CLR, TEX, HD gels of different concentrations and temperatures.

| Sample | Hardness (%N/m$^2$) | Adhesiveness (N*s) |
|---|---|---|
| CLR40% (T=25° C) | 504,26 ± *3,14* | 0,074 ± *0,08* |
| CLR40% (T=50° C) | 251,48 ± *45,00* | 0,037 ± *0,03* |
| CLR50% (T=25° C) | 724,47 ± *9,04* | 0,089 ± *0,05* |

| | | | | | | |
|---|---|---|---|---|---|---|
| CLR50% (T=50° C) | 657,67 | ± | *19,02* | 0,079 | ± | *0,03* |
| HD30% (T= 25° C) | 714,10 | ± | *4,28* | 0,082 | ± | *0,01* |
| HD30% (T=50° C) | 305,45 | ± | *7,45* | 0,049 | ± | *0,03* |
| HD40% (T=25° C) | 743,58 | ± | *5,43* | 0,093 | ± | *0,03* |
| HD40% (T=50° C) | 604,14 | ± | *10,54* | 0,067 | ± | *0,08* |
| HD50% (T=25° C) | 542,52 | ± | *42,49* | 0,074 | ± | *0,04* |
| HD50% (T=50° C) | 749,50 | ± | *17,71* | 0,089 | ± | *0,03* |
| TEX20% (T=25° C) | 967,40 | ± | *10,49* | 0,129 | ± | *0,01* |
| TEX20% (T=50° C) | 978,93 | ± | *12,33* | 0,123 | ± | *0,09* |
| TEX30% (T=25° C) | 1113,19 | ± | *72,79* | 0,149 | ± | *0,39* |
| TEX30% (T=50° C) | 1911,92 | ± | *17,39* | 0,167 | ± | *0,00* |
| TEX40% (T=25° C) | 1407,55 | ± | *76,35* | 0,169 | ± | *0,03* |
| TEX40% (T=50° C) | 2339,49 | ± | *49,16* | 0,239 | ± | *0,39* |

TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

Hardness was measured as the slope of the linear part of the curve of stress as a function of strain. Hardness was found to be dependent from the different temperatures used and the difference in the distribution of the polysaccharides chain. Hardness increased with the increase of concentration in all three types of inulin. Furthermore, it was noticed that the gels that were processed in T= 25 °C were less strong compared to the ones prepared in T=50 °C. It may be assumed that at higher temperatures, the formation of junction zones may have been facilitated between the polymer chains because the heat has ruptured the ordered structure and exposed the inulin molecules and this concluded to a stiffer network (Osada& Khokhlov, 2001; Chiavaro et al., 2006). All three types of inulin could be compared in the same concentration of 40% w/w of inulin because it is the only one concentration that all three of them formed a gel. Gels made with TEX in this concentration were harder than the other two types in both temperatures (T=50 °C, T=25 °C). TEX contains higher amount of larger polymer chains and it is easier to form a three- dimensional network whereas the other two consists of smaller chains. Kim et al. (2001) also reported that a lower degree of polymerization of the inulin chain resulted in lower gelling formation.

Adhesiveness was calculated as the negative force area for the first bite. All the samples were found to be adhesive. The most adhesive samples were gels made with TEX compared with the ones processed with HD or CLR in the concentration of 40% w/w. In addition, the samples increased adhesiveness as the concentration increased. It is also observed that harder gels are more adhesive. This could be explained by the definition stated by Fiszman (1996) that adhesiveness is the work necessary to pull the probe away from the food sample. Thus, the harder the samples, the more work is needed to remove the attractive forces.

## 3.2 Burger Analysis

Pictures of the different burger formulations are depicted in Appendix 2.

### 3.2.1 Fat content of lean beef and pork fat

The average fat content of lean beef and pork fat is 10,23 ±*4,44* % w/w and 69,79 ±*3,37 %* w/w respectively. The results for the lean beef are similar with the fat content obtained from Turhan et al. (2005) where they mention a value of 9,18 % w/w for lean ground beef. The results obtained were used in order to estimate the fat content in each formulation of different types of burgers. For the control burger, the amount was found to be 20,5% w/w which is similar to a conventional meat burger (Owon et al., 2014; Turhan et al., 2005). For the 5%, 10%, 15%, and 20% Replacement the amount of fat was estimated to be 16,85% w/w, 13,4% w/w, 6,7% w/w and 6,5% w/w respectively. The latter values resemble the formulation of a low fat meat burger (Troy et al., 1999).

### 3.2.2 Cooking Yield

The results of the cooking yield of the different samples are presented in figure 2. The addition of inulin showed a significant difference ($p<0,05$) on the cooking yield of the sausages. 20% TEX had the highest value, while the Control burger had the lowest one. Thus, the addition of the fat replacer increased the cooking yield in all the samples compared with the Control burger. The results based on the different concentration showed significant difference ($p<0,05$) between the 5% Replacement, 10% Replacement and the 15% Replacement, 20% Replacement and the Control burger whereas no significant difference ($p>0,05$) was observed between the 3 different types of inulin.

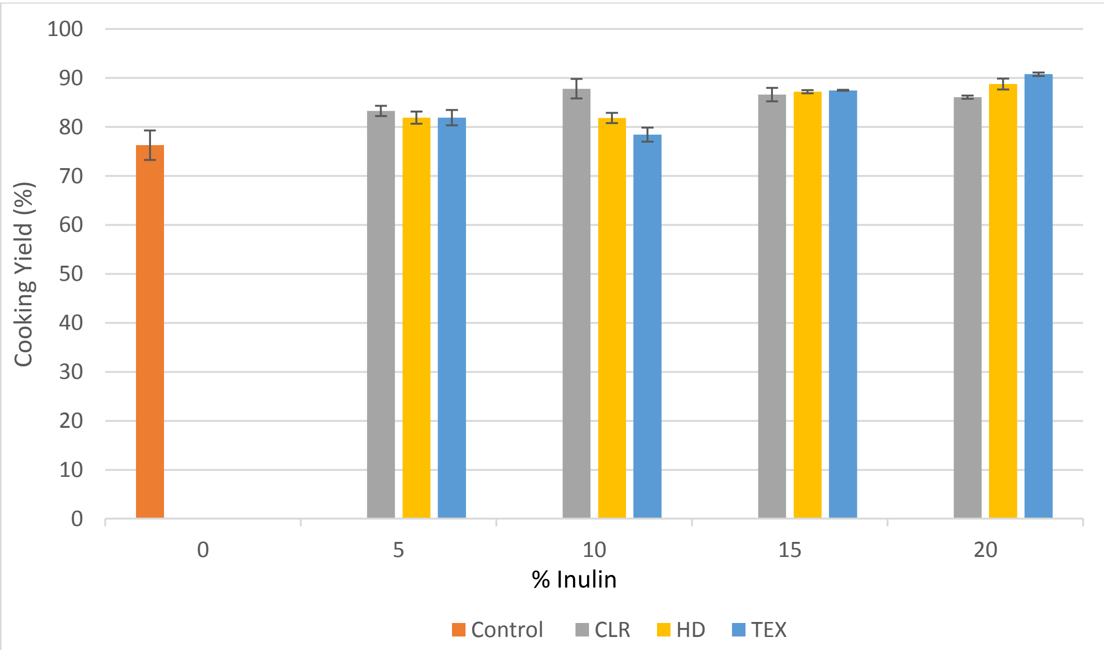


Figure 2. Cooking Yield of burgers with different inulin formulations.
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

Gök et al. (2011) et al. and Owon et al. (2014) also observed similar behavior, where the cooking yield increased with the addition of fat replacers in meat burgers. The low cooking yield of Control burger could be explained by moisture and fat loss due to fat separation and water release during cooking (Serdaroğlu, M., & Değırmencioğlu, 2004). The control burger has higher fat content compared to the other samples, thus the loss maybe is higher. A growth of cooking yield with the increase of inulin concentration was observed also by Méndez-Zamora (2015), which comes in alignment with the results of this study. It could be assumed that by increasing the concentration of inulin, the poly- and oligosaccharides could easier form the junction zones that lead to the creation of a tridimensional network of crystalline particles with the entrapped water and fat molecules. This leads to less water and fat loss which is an important attribute for the sensorial and textural parameters of the meat burgers.

### 3.2.3 Water Holding Capacity

In figure 3 the water holding capacities of the different burger formulations are depicted. As can be seen the water holding capacity of the 20% TEX has the highest value (0,54 g water/g product) and the lowest value is observed in 10% CLR. Although the differences between the different samples are not significant (p>0,05) a rise can be observed with an increased concentration of inulin. Furthermore, TEX seems to have to highest values followed by HD and CLR. This is in accordance with the results obtained from the WHC of inulin powders and could be due to the difference in the average length chain of the different types.

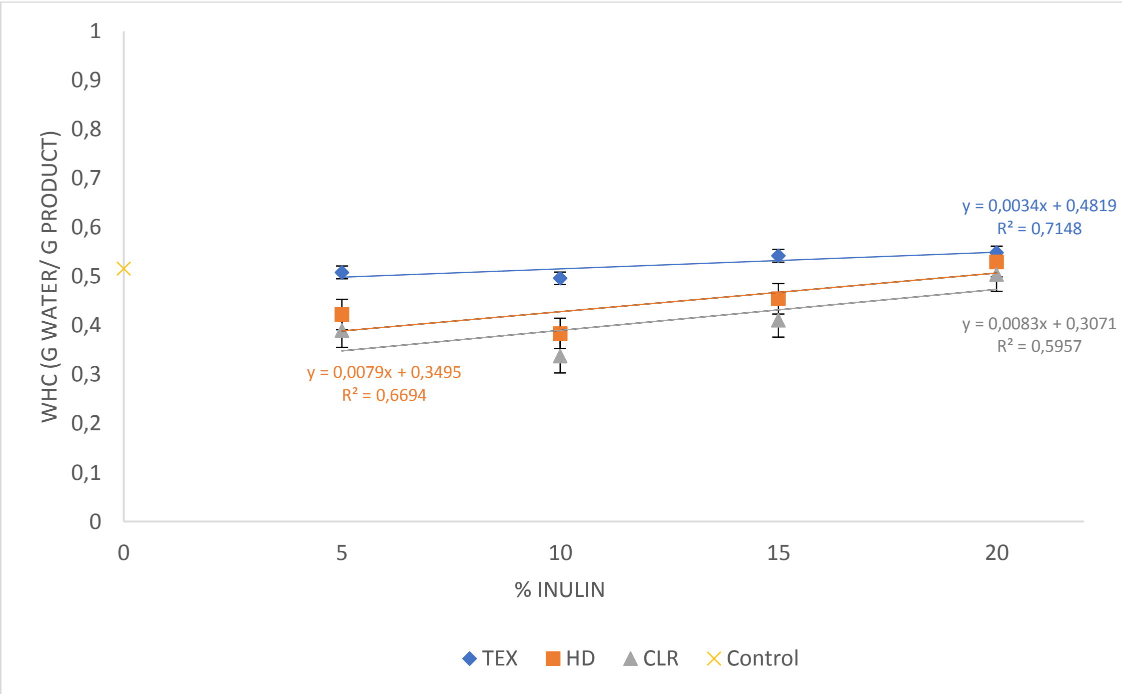


Figure 3. Water Holding Capacity of different burger samples.
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

Although the results are not significant, the values show similarities with the study of Méndez-Zamora (2015), who found that WHC increased significantly with the addition of inulin and pectin. Owon et al. (2014) also observed significant effects of the WHC with the addition of fat replacers. Moreover, the values obtained are not in alignment with the results of the Cooking Yield (as described in 3.2.3) which showed that the control burger has the lowest cooking yield, thus it was expected that the Control sample should have analogous values in WHC. A possible explanation could be the method followed in order to identify the WHC, which was the same procedure as the powders. Both Méndez-Zamora (2015) and Owon et al. (2014) followed an alternative method according to Tsai& Ockerman (1981) to estimate the WHC of frankfurter sausages and meat burgers. On the other hand, another possible explanation could be associated with the reduction of fat. Cengiz and Gokoglu (2007) reported that WHC was significantly lower (p<0,01) in low fat meat burgers, possibly because the strong intermolecular network of fat tissues could retain more water.

### 3.2.4 Texture Analysis

The texture profile analysis resulted in hardness, springiness, cohesiveness, gumminess and chewiness. The results are shown in figure 4 to figure 8.

Hardness was estimated as the peak force during the first compression cycle that represents the first bite. The results are shown in figure 4. It can be seen that among the different burger formulations, significant effects ($p< 0,05$) were detected regarding hardness. Clustering of the samples based on their different concentration showed that the burgers with 5% Replacement and 10% Replacement didn't have significant difference ($p>0,05$) with the Control burger whereas 15% and 20% Replacement made the burgers significantly ($p<0,05$) harder. In addition, when the samples were grouped based on their inulin type significant effects were found between the Control burger and the burgers processed with TEX inulin. Thus, it can be assumed that reduced fat content led to higher hardness. Mendoza et al. (2000) and García et al. (2008) found similar results, where the incorporation of inulin increased hardness significantly. The burgers had similar behavior with the inulin gels, where stronger gels were produced in higher concentrations (section 3.1.2). As the amount of inulin increases the network becomes stiffer. Since TEX has the highest average length chain it could explain why the burgers where significantly harder in this type of inulin.

The results of springiness are depicted in figure 5. Springiness was estimated as the distance of the detected height to the second peak (second compression) divided by the distance to the first peak (first compression). The results showed a significant difference ($p<0,05$) among the burgers with 10% Replacement and the Control sample. The values are not in alignment with other studies (García et al., 2008; Aleson-Carbonell et al., 2005) that noted that springiness was significantly different in the highest concentrations of fiber incorporation. A significant difference was observed ($p<0,05$) between the Control burger and burgers made with TEX inulin which maybe be due to the different structure of TEX.

Cohesiveness was measured as the ratio of the area under the second peak and the area under the first peak. The measurements of the samples in different concentrations are shown in figure 6. The incorporation of the inulin didn't show a significant effect ($p>0,05$) on the cohesiveness of the samples as a function of concentration and inulin type. The results were similar to Mendoza et al. (2000) where no significant effects were observed, and they reported a value of 0,47 for average fat meat formulations. Aleson- Carbonell (2005) also stated that all the textural parameters identified significant except for the cohesiveness when they replaced fat with fibers.

In terms of gumminess and chewiness, the values are similar to the results of hardness as they are secondary parameters calculated as hardness* cohesiveness. Burgers with higher amount of inulin (higher than 10%) found to be chewier and gummier (figure 7 and 8) which means that more energy is required to masticate these products. 5% and 10% Replacement burgers were similar to the control burger. No significant differences were observed between the different inulin types; Thus, the different microstructure of inulin is not affecting the cohesiveness, gumminess, and chewiness of the burgers.

It could be concluded that the addition of inulin affected the hardness, gumminess, chewiness, and springiness of the burgers while samples were not significantly different in terms of cohesiveness. 15% and 20% Replacement affected most of the parameters significantly (p>0,05) therefore it could be assumed that up to 10% Inulin Replacement could affect the textural parameters of the meat burgers and lead to harder and gummier products compared with the control burger. In terms of inulin type, no conclusion can be made since in most parameters every type of inulin attributed the same. These differences could be attributed to the fat content and the dietary fiber incorporated that can easily entrap water (Choi et al., 2014). Cierach et al. (2009) reported that the hardness in sausages is associated with their fat content, thus reducing the fat may lead to harder products.

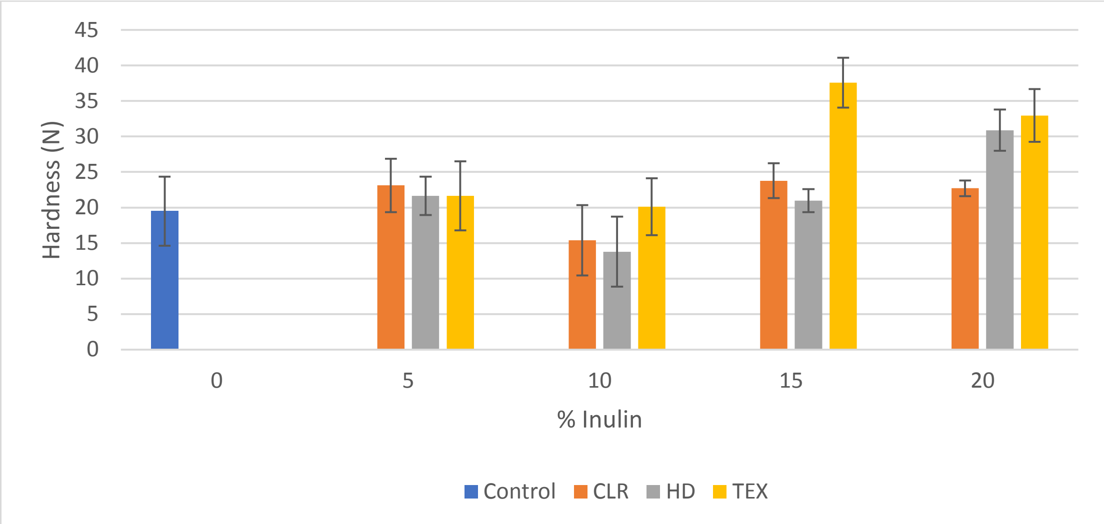


Figure 4. Hardness of the different burger formulations.
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

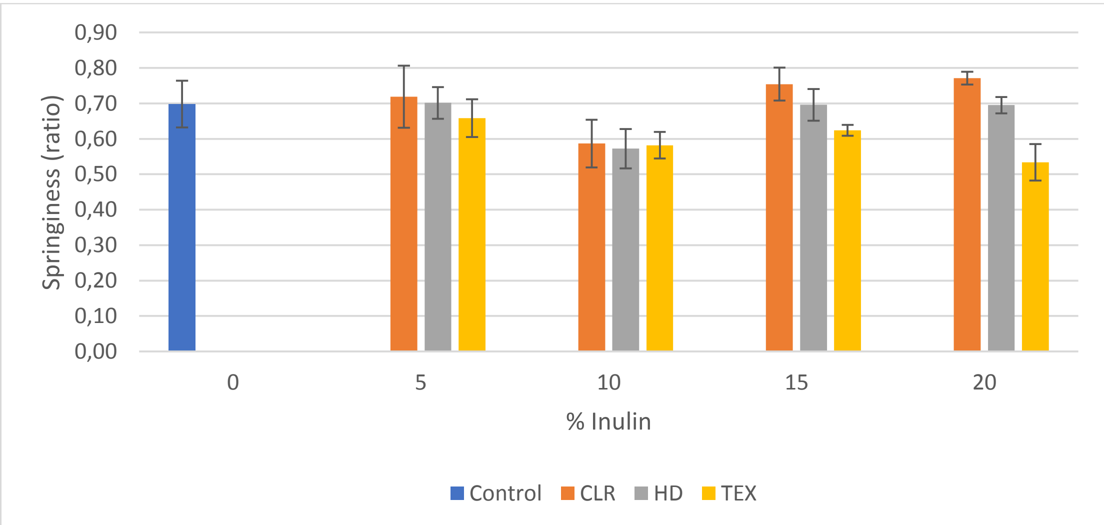


Figure 5. Springiness of the different burger formulations.
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

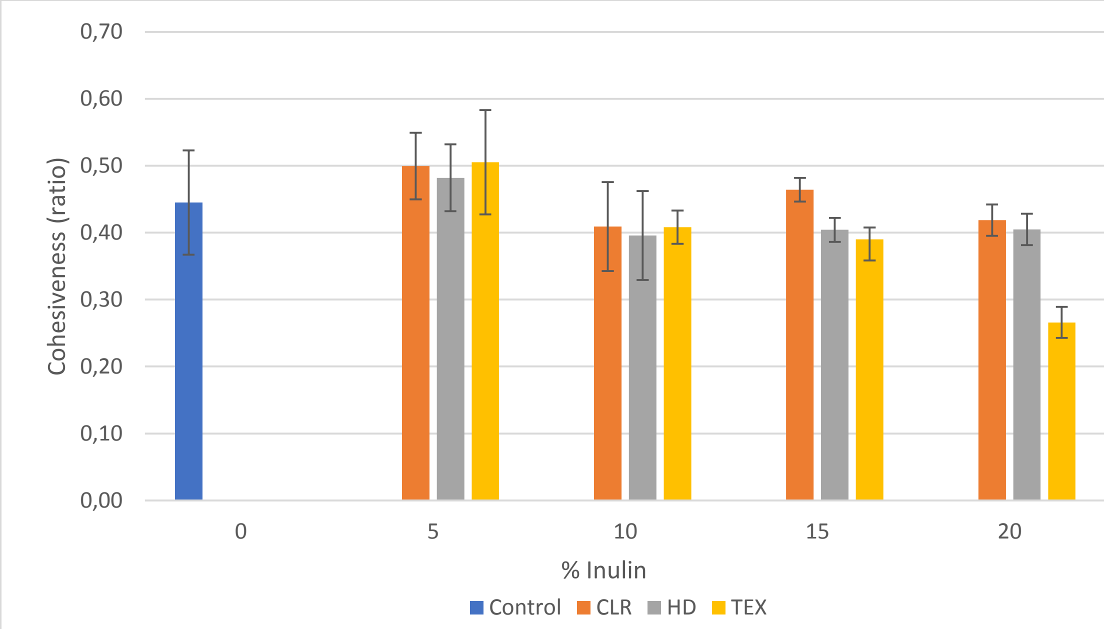

Figure 6. Cohesiveness of the different burger formulations.
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

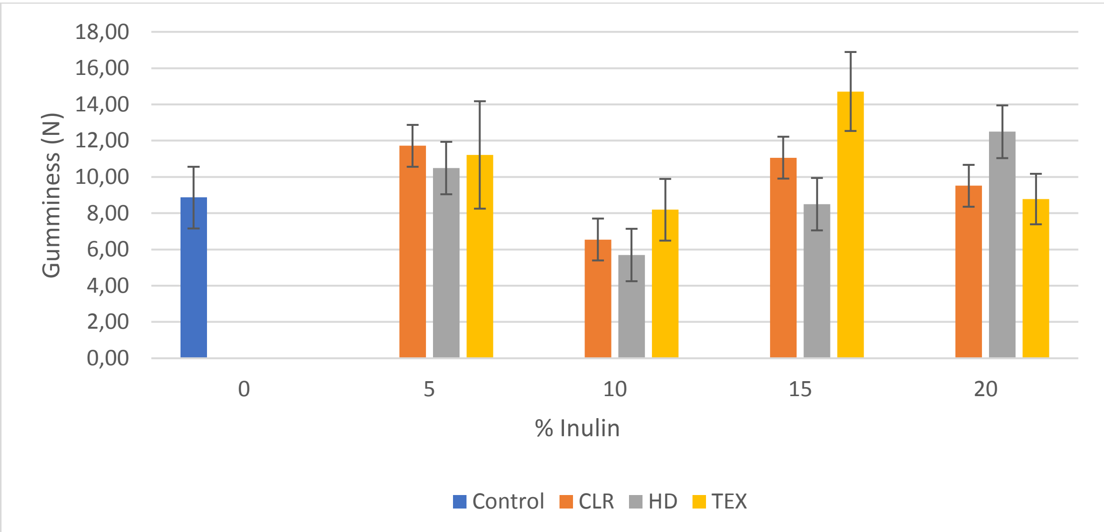

Figure 7. Gumminess of the different burger formulations.
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

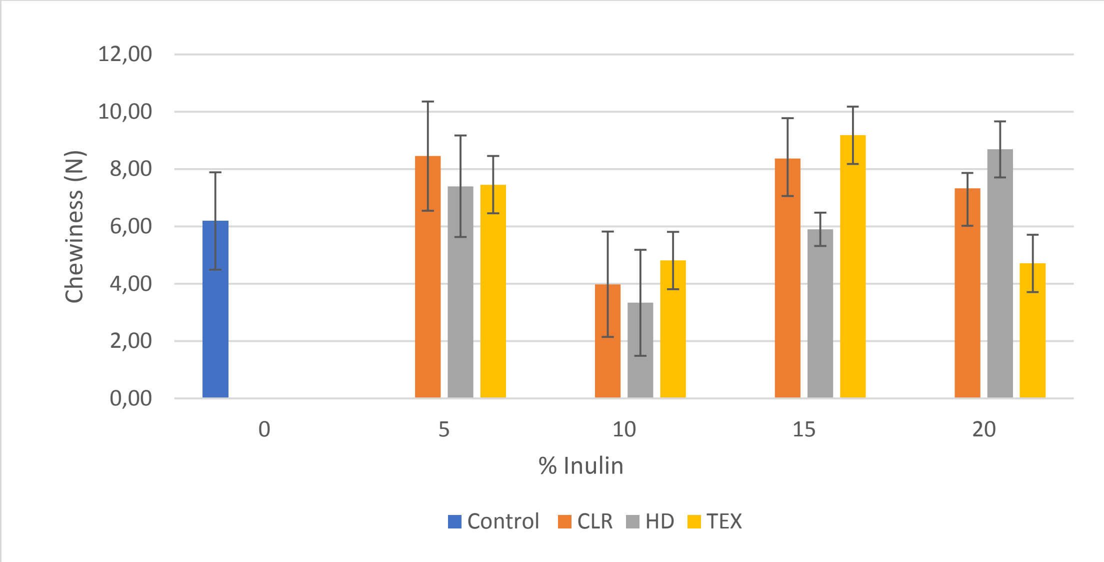


Figure 8. Chewiness of the different burger formulations.
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

### 3.2.5 Sensory evaluation

Pictures of the sensory evaluation are shown in Appendix 2. The sensory scores for the different samples are reported in Table 4. A 9-hedonic scale test was used which ranged from 1 to 9, where 1, 2, 3, 4, 5, 6, 7, 8 and 9 means: like it extremely, like it very much, like it moderately, like it slightly, neither like it nor dislike it, dislike it slightly, dislike it moderately, dislike it very much and dislike extremely respectively. The addition of inulin influenced most of the sensory attributes significant ($p<0,05$) except for odour.

In terms of appearance, the lowest score is for the sample 15%CLR which panelists liked it moderately, whereas the highest score is for the 20% TEX which was disliked slightly. The latter is the only sample that was significantly different ($p<0,05$) from the Control burger. This was possibly linked to the fact that the burger had a whitish color because of the high amount of long chain inulin which is most insoluble compared to the other two inulin types. The same sample was also disliked by panelists (5,83) concerning colour whereas 15% and 20% CLR Replacement scored the best (3,33 and 3,43 respectively). This could be due to the shiny appearance that CLR gave to the burger in higher concentrations in contrast with the control formula. This effect was also noted by Mendoza et al. (2000) where they observed shiny colour on sausages formulated with a product similar to CLR.

Table 4. Sensory evaluation of the different attributes of burgers with different formulations.

| Sample | Appearence | Colour | Odour | Flavor | Texture | Juiciness | Overal liking |
|---|---|---|---|---|---|---|---|
| Control | 4,53 (a,b) ± *2,13* | 5,03 (b,c) ± *2,03* | 4,10 ± *1,63* | 3,70 (a) ± *1,80* | 4,17 (a,b) ± *1,72* | 4,60 (a,b,c) ± *1,63* | 4,23 (a,b,c) ± *1,72* |
| 5%CLR | 4,23 (a,b) ± *1,74* | 4,10 (a,b) ± *1,92* | 4,37 ± *1,43* | 4,07 (a) ± *1,41* | 3,87 (a) ± *1,81* | 4,33 (b,c) ± *2,01* | 4,17 (a,b) ± *1,60* |
| 5%HD | 4,50 (a,b) ± *1,61* | 4,97 (b,c) ± *1,65* | 4,53 ± *1,28* | 4,00 (a) ± *1,60* | 4,03 (a,b) ± *1,90* | 4,00 (a,b) ± *1,66* | 4,23 (a,b,c) ± *1,87* |
| 5%TEX | 4,50 (a,b) ± *1,70* | 4,67 (a,b,c) ± *1,77* | 4,07 ± *1,75* | 4,27 (a) ± *1,93* | 4,43 (a,b) ± *1,70* | 5,10 (b,c) ± *1,49* | 4,23 (a,b,c) ± *1,87* |
| 10%CLR | 4,37 (a,b) ± *1,67* | 4,53 (a,b,c) ± *1,61* | 4,13 ± *1,38* | 3,73 (a) ± *1,41* | 4,53 (a,b) ± *1,43* | 4,33 (b,c) ± *1,41* | 4,07 (a,b) ± *1,48* |
| 10%HD | 4,37 (a,b) ± *1,40* | 4,47 (a,b,c) ± *1,98* | 4,43 ± *1,28* | 3,73 (a) ± *1,41* | 3,67 (a) ± *1,81* | 3,70 (a) ± *1,66* | 3,73 (a) ± *1,64* |
| 10%TEX | 4,77 (a,b) ± *1,65* | 5,00 (b,c) ± *1,70* | 4,60 ± *1,40* | 4,30 (a) ± *1,53* | 4,37 (a,b) ± *1,77* | 4,77 (a,b,c) ± *1,65* | 4,47 (a,b,c) ± *1,46* |
| 15%CLR | 3,87 (a) ± *1,49* | 3,33 (a) ± *1,49* | 4,17 ± *1,46* | 4,57 (a) ± *2,24* | 3,80 (a) ± *1,82* | 3,87 (a,b) ± *1,41* | 4,47 (a,b,c) ± *2,21* |
| 15%HD | 4,40 (a,b) ± *1,31* | 4,33 (a,b,c) ± *1,69* | 4,60 ± *1,40* | 4,27 (a) ± *1,55* | 4,03 (a,b) ± *1,90* | 5,10 (b,c) ± *1,49* | 4,67 (a,b,c) ± *1,40* |
| 15%TEX | 5,47 (a) ± *1,72* | 5,17 (c,d) ± *1,72* | 5,17 ± *1,80* | 4,87 (a,b) ± *1,93* | 5,07 (a,b) ± *2,05* | 4,33 (c ) ± *2,01* | 5,70 (c ) ± *1,80* |
| 20%CLR | 3,97 (a) ± *1,79* | 3,43 (a) ± *1,61* | 4,57 ± *1,96* | 4,13 (a) ± *1,63* | 4,37 (a,b) ± *1,77* | 5,70 (a,b) ± *1,71* | 4,70 (a,b,c) ± *1,90* |
| 20%HD | 4,60 (a,b) ± *1,90* | 4,67 (b,c) ± *1,77* | 4,53 ± *1,43* | 5,10 (a,b) ± *1,86* | 5,43 (b) ± *1,83* | 5,63 (c ) ± *1,69* | 5,43 (b,c) ± *1,83* |
| 20%TEX | 6,37 (c ) ± *2,17* | 5,83 (d) ± *2,09* | 5,23 ± *1,89* | 6,37 (b) ± *1,75* | 7,17 (c ) ± *1,68* | 7,40 (d) ± *1,35* | 7,40 (d) ± *1,38* |

a-d Means (±standard error) in the same column with different letters are different (p<0,05).
TEX: long- chain inulin; HD: native inulin; CLR: oligofructose

The odour of the burgers was analogous in all samples with different formulations. However, in terms of flavor, 20% TEX was disliked the most and the value obtained showed a significant difference with the Control burger. TEX has a neutral taste and panelists noticed that saltiness and sweetness in this sample were normal. The high score could be possibly linked with the high amount of TEX inulin which increased the hardness, altered the color of the burger and created an adverse effect regarding the other sensorial attributes. As flavor is a multisensory perception, crossmodal interaction might have occurred and the negative information concerning the color may have affected the perception of taste. The addition of inulin in meat formulations did not alter the taste in previous reports as stated by García et al. (2008), Mendoza et al. (2000) and Méndez-Zamora (2015).

Samples that scored lower than the control burger in terms of texture and juiciness are samples that either CLR or HD was incorporated, which reveals that also these types of inulin could give a softer texture to the product. Huang et al. (2011) suggested that the solubility of inulin improved the textural properties of sausages. The samples were significantly different regarding the parameter overall liking (p>0,05). However, most of them have no significant difference with the control burger and some of them even scored better than the Control sample. These results indicate that inulin could replace the fat in a conventional formula of meat burgers even to the extent of 15% incorporation of long chain inulin, and 20% incorporation of the other 2 types of inulin without negative effects on the sensorial attributes. On the contrary, panelists perceived better sensorial attributes in some burger samples. Dereveux et al. noticed similar results when replacing long chain inulin and oligofructose instead of fat in beef sausages. Both types of inulin were acceptable by the panelists although Drewnowski et al. (1989) stated that the acceptability of products is reversely related to their fat content. Mendoza et al. (2000) reported that the addition of 11,5 % w/w of native inulin scored the best in product acceptability of dry fermented sausages.

# 4. Conclusion

Regarding the inulin characterization, different inulin types show differences in the water holding capacity and gelling formation. TEX attributed best in terms of water holding capacity and formed a stronger and more adhesive gel. This could be associated with the high amount of long polymer chains that differentiates this powder among the other 2. The effect of temperature was also noticed as the powders formed stronger gels in higher temperatures.

In terms of burger analysis contrasting results were obtained concerning the different types of inulin and the concentration. All the samples processed with inulin showed improved cooking yield compared to the control burger which is possibly associated with the highest fat and water content that the pork fat gave to the control burger. In contrast, the control burger had the highest WHC, which is in contrast with other studies and the results of the cooking yield, and this could be due to the method followed. However, this behavior could be associated with the high percentage of fat in the control burger that have the ability to entrap more water.

The addition of different concentrations of inulin affected the hardness, gumminess, chewiness and springiness, where samples with 5% Replacement and 10% Replacement were more similar than the control burger. However, most of the samples (except from TEX) in higher concentrations were accepted from the panelists in the sensory evaluation. From the texture analysis no results could be made regarding the effect of the different inulin types in the burgers. Although if we compare the results with the sensory evaluation samples, CLR and HD were most preferred by panelists and attributed even better than the control burger in terms of texture, juiciness and overall liking. Thus, it could be assumed that native inulin and oligofructose could also be used as a fat replacer in meat products.

# 5. Recommendations

The study has shown that apart from inulin with a higher degree of polymerization, native inulin and oligofructose could replace fat successfully and even improve the mouth feel of conventional meat products. The addition of powdered inulin could be an excellent replacement for fat in meat formulations as it gives a softer texture, and tenderness and springiness very similar to the conventional formula. Although the optimal concentration couldn't be identified in this research, incorporation of up to 10% w/w of long- chain inulin is recommended. Higher concentrations increase the hardness of the burgers and are not accepted by consumers.

For further research, it would be advised to define an optimal concentration for the different inulin types that would give the product the best sensorial and textural attributes. In this research the effect of concentration was not clear enough. The Texture Profile Analysis gave values with high standard deviations since the meat burger was not a homogenous product and it was made by hand. Thus, maybe more replications should be conducted to identify the optimal concentration. The results could be supported with a sensory analysis by a trained panel where after training panelists should be able to distinguish differences among the different samples in a more proper way than consumer panel. In addition, the environment should be controlled with specific lights, temperatures and booths.

Finally, it would be interesting to explore the interaction of inulin with water at higher temperatures to be able to compare the behavior of inulin with the burgers. Studies have shown (Kim et al., 2001; Chiavaro et al., 2006) that temperatures up to 70 °C, hydration of inulin is performed that affects its gelling behavior.

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# Appendix

## 1. Sample of the questionnaire

Sample code #

Before you taste each product, take a sip of water and bite of cracker so that you remove any lingering tastes in your mouth. You will be given a piece of hamburger to eat. Please make sure to eat at least one-half of the product so that you can form an opinion. Once you are done with the entire questionnaire, there will be a 5-min break and then you will go on to the next product. The same procedures will be followed for the second product.

**BEFORE TASTING PLEASE HAVE A GOOD LOOK AT THE PRODUCT!!**

1. How much do you **LIKE** or **DISLIKE** the **OVERALL APPEARANCE** of the burger? ("X" ONE BOX BELOW)
    1. Like it extremely........... ☐
    2. Like it very much.......... ☐
    3. Like it moderately......... ☐
    4. Like it slightly............... ☐
    5. Neither like nor dislike it. ☐
    6. Dislike it slightly.......... ☐
    7. Dislike it moderately...... ☐
    8. Dislike it very much........ ☐
    9. Dislike it extremely......... ☐

2. How much do you **LIKE** or **DISLIKE** the **COLOR** of the burger? ("X" ONE BOX BELOW)
    1. Like it extremely........... ☐
    2. Like it very much.......... ☐
    3. Like it moderately......... ☐
    4. Like it slightly............... ☐
    5. Neither like nor dislike it. ☐
    6. Dislike it slightly.......... ☐
    7. Dislike it moderately...... ☐
    8. Dislike it very much........ ☐
    9. Dislike it extremely......... ☐

3. How much do you **LIKE** or **DISLIKE** the **SMELL** of the burger? ("X" ONE BOX BELOW)

    1. Like it extremely........... ☐
    2. Like it very much.......... ☐
    3. Like it moderately......... ☐
    4. Like it slightly............... ☐
    5. Neither like nor dislike it. ☐
    6. Dislike it slightly.......... ☐
    7. Dislike it moderately....... ☐
    8. Dislike it very much........ ☐
    9. Dislike it extremely......... ☐

NOW YOU MAY TASTE THE BURGER
Thinking specifically about the way the burger tastes

4. How much do you **LIKE** or **DISLIKE** the **OVERALL FLAVOR/TASTE** of the burger? ("X" ONE BOX BELOW)

    1. Like it extremely........... ☐
    2. Like it very much.......... ☐
    3. Like it moderately......... ☐
    4. Like it slightly............... ☐
    5. Neither like nor dislike it. ☐
    6. Dislike it slightly.......... ☐
    7. Dislike it moderately....... ☐
    8. Dislike it very much........ ☐
    9. Dislike it extremely......... ☐

5. And how would you **DESCRIBE** the **OVERALL SALTINESS** of this burger? ("X" ONE BOX BELOW)

    Not at all salty.............. ☐
    Not quite salty enough.... ☐
    Just about right............. ☐
    Somewhat too salty........ ☐
    Much too salty.............. ☐

6. And how would you **DESCRIBE** the **OVERALL SWEETNESS** of this burger? ("X" ONE BOX BELOW)

    Not at all sweet.............. ☐
    Not quite sweet enough.... ☐

Just about right............. ☐
Somewhat too sweet........ ☐
Much too sweet.............. ☐

Thinking specifically about the texture of the burger

7. How much do you **LIKE** or **DISLIKE THE OVERALL TEXTURE** of this burger? ("X" ONE BOX BELOW)
    1. Like it extremely........... ☐
    2. Like it very much.......... ☐
    3. Like it moderately......... ☐
    4. Like it slightly............... ☐
    5. Neither like nor dislike it. ☐
    6. Dislike it slightly.......... ☐
    7. Dislike it moderately....... ☐
    8. Dislike it very much........ ☐
    9. Dislike it extremely......... ☐

8. Would you describe the **SOFTNESS/FIRMNESS** of this burger as ... ("X" ONE BOX BELOW)

Much too soft................ ☐
Somewhat too soft......... ☐
Just about right............. ☐
Somewhat too firm........ ☐
Much too firm.............. ☐

Thinking specifically about the juiciness of the burger

9. How much do you **LIKE** or **DISLIKE** the **JUICINESS** of the burger? ("X" ONE BOX BELOW)
    1. Like it extremely........... ☐
    2. Like it very much.......... ☐
    3. Like it moderately......... ☐
    4. Like it slightly............... ☐
    5. Neither like nor dislike it. ☐
    6. Dislike it slightly.......... ☐
    7. Dislike it moderately....... ☐
    8. Dislike it very much........ ☐
    9. Dislike it extremely......... ☐

10. Would you describe the **MOISTNESS/DRYNESS** of this burger as ... ("X" ONE BOX BELOW)

Much too moist............. ☐
Somewhat too moist....... ☐
Just about right............. ☐
Somewhat too dry.......... ☐
Much too dry................ ☐

11. Everything considered, how much do you **LIKE** or **DISLIKE** this product **OVERALL?** ("X" ONE BOX BELOW)

1. Like it extremely........... ☐
2. Like it very much.......... ☐
3. Like it moderately......... ☐
4. Like it slightly............... ☐
5. Neither like nor dislike it. ☐
6. Dislike it slightly.......... ☐
7. Dislike it moderately....... ☐
8. Dislike it very much........ ☐
9. Dislike it extremely......... ☐

## 2. Pictures of samples and sensory evaluation

Figure 9. Pictures of the sensory evaluation

Figure 10. Pictures of 15%TEX sample (left) and TEX20% sample (right)


Figure 11. Pictures of the Control burger (left) and 20%CLR (right).