

Effect of Chicory Fiber and Smoking on Quality Characteristics of Restructured Sausages

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Abstract

This study was conducted to investigate the effects of chicory fiber for the replacement of fat and smoking on quality characteristics of restructured sausages. Treatments were as follows; Control: Pork backfat 20%, T1: Pork backfat 10% + Chicory fiber 10%, T2: Control + Smoking, T3: T1 + Smoking. The addition of chicory fiber significantly reduced the moisture, fat, hardness and pH values, whereas the smoking treatment increased the fat, redness and pH values of restructured sausages ($p < 0.01$). Additionally, interaction of them significantly affected the ash, chewiness and hardness values of restructured sausages. As a result, although the addition of chicory fiber decreased the quality characteristics of sausage, smoking treatment improved the reduced quality. Therefore, the chicory fiber and smoking treatment is helpful to develop restructured sausage products with reduced fat and compensated quality.

Keywords: chicory fiber, smoking, quality characteristics, restructured sausage

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Introduction

Meat and meat products are primary protein sources (Oostindjer *et al.*, 2014). In Korea, meat product production increased by 211,109 tons in 2014 compared to 2010 (180,640 tons). The westernized food consumption pattern has had a significant impact on increase of meat production. Excessive intake of meat products can cause diseases, such as obesity, diabetes, cardiovascular diseases, and cancer (Kouvari *et al.*, 2016; Pounis *et al.*, 2010). Also, consumers demand meat products with reduced fat content for healthier diets, which has led to the development of new meat products to replace the fat in traditional formulations (Schmiele *et al.*, 2015). Thus, consumers' demand for functional foods has increased and raised concerns regarding the high level of fat in processed meat products.

Consequently, food and regulatory bodies have targeted

issues such as fat reduction in processed products. Organizations such as the World Health Organization (WHO) is driving measures to reduce fat content in foods (Fellendorf *et al.*, 2015). Previous studies have investigated fat-reduced versions of meat products such as frankfurters, bologna sausages, and beef and pork sausages (Berasategi *et al.*, 2014; García-García and Totosaus, 2008; Kähkönen and Tuorila, 1998). Significant differences in physico-chemical properties and sensory qualities were found in previous reports. These differences are caused by the functional roles of fat in processed meat.

Recently, dietary fiber has received attention in the meat product industry. In general, dietary fiber is defined as non-digestible oligosaccharides and fructooligosaccharides (Gibson and Roberfroid, 1995). Dietary fiber is widely known to prevent constipation. Furthermore, dietary fiber intake beneficially affects the host by selectively stimulating the growth of endogenous bifidobacteria (Gibson and Roberfroid, 1995). Depend on the type of dietary fibers, the addition of dietary fibers to foods enhances nutritional value and technological properties, as well as prevents and treats some diseases (Thebaudin *et*

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al., 1997). Furthermore, dietary fiber facilitates improvement of properties such as solubility, viscosity and gelation-forming ability, water-binding or holding capacity, oil-binding capacity, and mineral and organic molecule-binding capacity in food (Tungland and Meyer, 2002).

Chicory contains inulin, which accounts for 65-70% of the chicory dry weight (Lee and Shin, 1997). Inulin, a carbohydrate derived from plant sources, can be classified as a soluble fiber. Additionally, inulin has a bland flavor and a fat-like texture, and it can be incorporated into various food preparations to replace sugar and fat (Davidson *et al.*, 1998). Increased inulin intake can be used to increase fecal frequency (Den Hond *et al.*, 2000). The addition of 10 g inulin to the daily diets of subjects with moderately high blood lipids significantly reduced insulin levels and triacylglycerol concentrations (Jackson *et al.*, 1999). Inulin has been reported to enhance colonic functions and systemic functions and reduce disease risk (Roberfroid, 2007). According to the report of Keenan *et al.* (2014), the addition of inulin for fat reduction not only decreased the cooking loss, but also improved the emulsion stability, texture properties and eating quality in the pork sausage.

Smoking is one of the oldest technologies for meat products (Pöhlmann *et al.*, 2012; Toth, 1982). Smoke is produced by the process of incomplete combustion of wood (Goulas and Kontominas, 2005). Smoking has been used for the development of smoke color, taste, appearance, flavor, shelf life and bite in meat products (Lingbeck *et al.*, 2014). In addition, smoking increases the shelf-life of meat as a result of the combined effects of antimicrobial and antioxidant activities of formaldehyde, carboxylic acids, and phenols (Goulas and Kontominas, 2005; Kim *et al.*, 2014). Therefore, this study was conducted to evaluate the effect of animal fat replacement by chicory fiber addition and smoking on quality properties of restructured sausages for the development of healthy and superior quality sausage products.

Materials and Methods

Materials

Certified organic grade-vacuum packed, refrigerated pork loin and frozen pork backfat were obtained from meat processing plant (Hansalimfood Inc., Korea). The dried chicory fiber powder was purchased from market (Lyntz Inc., Korea), and used for sausage manufacturing.

Manufacture of restructured sausages

Restructured sausages were processed using 4 treat-

ments and prepared three replications: Control: pork backfat 20%, T1: pork backfat 10% + chicory fiber 10%, T2: Control + smoking, T3: T1 + smoking. Restructured sausages contained 80% ground pork loin and 20% ground pork backfat. For the main ingredients, we added 12.5% of ice, 1% of sodium triphosphate (STPP), 1.5% of NaCl, 0.2% of ascorbic acid, and 0.6% of spice. For each treatment, pork loin (4.5 mm and 8.0 mm = 1:1) and backfat (4.5 mm) were ground using a meat grinder (M-12S, Fujee, Korea), and were mixed well, then NaCl and STPP added to the meat and mixed for 3 min. Chicory fiber was added and mixed for 3 min. The temperature of the blended pork meat was maintained below 10°C during mixture preparation. The mixtures were stuffed into collagen casing (20-22 mm of diameter, Nippi Collagen Industry, Japan). The non-smoking samples were heated at 78°C for 30 min to an internal temperature of 75°C in water-bath (SW-90MW, Jeio Tech, Korea). The smoking samples were dried at 50°C for 25 min, and smoked 60°C for 30 min by sawdust, and then heated at 78°C for 30 min to an internal temperature of 75°C in smokehouse (Bastramat 1500; Byan & Strackbein GmbH, Germany). The cooked sausages were cooled at below 15°C for 30 min until sausage surface temperature was less than 10°C. The restructured sausages were used for analysis of experiments.

pH

pH was measured using a digital pH meter (Delta 340, Mettler-Toledo, Ltd., UK). Approximately 10 g of the sample was cut into small pieces and 90 mL of distilled water added. Slurry was then made using a homogenizer (Nihonseiki, Japan) and the pH was recorded using a pH meter. The pH meter was calibrated daily with standard buffers of pH 4.0 and 7.0 at 25°C.

Color

The L*, a*, and b* values were determined on the surface of cut restructured sausage after 20 min bloom time using a Spectro-Colormeter (Model JX-777, Color Techno. System Co., Japan) calibrated to a white plate (L*, 98.39; a*, 0.13; b*, -0.51). L*, a*, and b* values were described using the Hunter lab color system (L* = lightness, a* = redness, b* = yellowness) using a white fluorescent light (D65) as a light source. Each measurement was performed in 5 replicates, taking the mean value as the result of the assay.

Proximate analysis

Moisture, lipid and ash were assayed according to

AOAC methods (1995).

Texture profile analysis (TPA)

Samples were cut into 10×10×10 mm (width × length × height) pieces. Texture profile testing was conducted using a rheometer (Compac-100, Sun Scientific Co., Japan) under the following operational conditions: table speed of 60 mm/min, load cell (max) of 4 kg and probe diameter of 5 mm using the Rheology Data System version 2.01.

Statistical analysis

The entire experiment was replicated three times at different times in the same place, and a completely randomized design was used. The data of restructured sausages were analyzed by General Linear Model procedure of SAS program, the statistical model included fat substitute with chicory, smoking, and interactions of them. Effects of the fat substitute with chicory, smoking, and their interactions with $p < 0.01$ were judged as ‘significance’ respectively. All data analysis was performed using SAS for Windows, version 9.1.3 (SAS, 2008).

Results and Discussion

Proximate analysis of restructured sausages

The proximate analysis of restructured sausages formulated with chicory fiber and smoking treatment is shown in Table 1. The addition of chicory fiber significantly decreased the moisture and fat contents of restructured sausages ($p < 0.01$). However, the restructured sausages with smoking treatment had higher fat and lower ash contents than un-treated restructured sausages ($p < 0.01$). As well as the fat and ash contents was influenced by interaction of chicory addition and smoking ($p < 0.01$). Generally, dietary fiber have a function to retain moisture content in meat products. In the studies related to water retention of dietary fiber (Choi *et al.*, 2008, 2014), the moisture contents in meat products replaced fat with dietary fiber were higher than those of control because the supplement water was added to the meat batter as much as the amount of animal fat substitute. According to the Hwang and Rhee (2003), pork backfat was composed of 15.2% water, 6.7% protein, and 77.6% fat. Thus, it was considered that the fat and moisture contents of restructured sausages containing chicory fiber was to be lowered than those of control with added backfat 20%. Similar results for moisture and fat contents have been reported in other meat products when different types of dietary fiber were added (López-Vargas *et al.*, 2014; Yilmaz and Dağlıoğlu, 2003).

Table 1. Proximate analysis (%) of smoked (or not) restructured sausages following addition of chicory dietary fiber

Treatments ¹⁾	Moisture	Fat	Ash
Control	65.44	11.72	2.53
T1	62.31	8.56	2.33
T2	64.54	14.25	1.76
T3	61.91	9.55	1.86
SEM	0.52	0.65	0.09
F ¹⁾	<0.01	<0.01	-
S ²⁾	-	<0.01	<0.01
F×S ³⁾	-	<0.01	<0.01

¹⁾Control: Pork backfat 20%, T1: Pork backfat 10% + Chicory fiber 10%, T2: Pork backfat 20% + Smoking, T3: Pork backfat 10% + Chicory fiber 10% + Smoking

²⁾F: Fat substitute with chicory

³⁾S: Smoking

⁴⁾F×S: Interaction between fat substitute and smoking

Also, Choi *et al.* (2008) reported the addition of 3% wheat fiber was decreased of moisture and fat content and increased ash content. However, Choe *et al.* (2013) and Sánchez-Zapata *et al.* (2013) reported that an increase in different types of fiber content resulted in increased moisture content of frankfurter-type sausages and chorizo. In addition, when meat products are smoked in the smoking house, it makes surface film because of fat flowing outwards (Ledesma *et al.*, 2015, 2016). Thus, the separation of fat was reduced by the smoking treatment. Furthermore, it was determined that the ash contents were kept in a low ratio in the sausages by the reduced fat separation.

Texture profile analysis of restructured sausages

The texture profile analysis of restructured sausages formulated with chicory fiber and smoking treatment is shown in Table 2. The fat substitution with chicory fiber significantly decreased the hardness of restructured sausages, and the interaction between fat substitution and smoking influenced on the chewiness and hardness values ($p < 0.01$). On the other hand, the springiness and cohesiveness values were not affected by any factors. Opposite results were observed in the preceded studies which used inulin as a fat substitute in comminuted meat product (Garcia *et al.*, 2006; Keenan *et al.* 2014; Menegas *et al.*, 2013). Additionally, fat is physically softer than inulin crystals (Keenan *et al.* 2014). Some studies showed that the addition of dietary fiber increased the hardness and chewiness of meat products (Choi *et al.*, 2011; Huang *et al.*, 2005; Zhuang *et al.*, 2015). According to the Choi *et al.* (2011), the heat-induced gel containing with 1% rice bran fiber had greater sarcoplasmic protein and myofibril-

Table 2. Texture profile analysis of smoked (or not) restructured sausages following addition of chicory dietary fiber

Treatments ¹⁾	Springiness (%)	Cohesiveness (%)	Chewiness (kg)	Hardness (kg)
Control	78.88	56.33	0.77	0.56
T1	78.78	56.50	0.51	0.40
T2	77.99	58.92	0.61	0.51
T3	81.43	59.89	0.80	0.65
SEM	0.86	1.47	0.03	2.63
F ²⁾	-	-	-	<0.01
p-value S ³⁾	-	-	-	-
F×S ⁴⁾	-	-	<0.01	<0.01

¹⁾Control: Pork backfat 20%, T1: Pork backfat 10% + Chicory fiber 10%, T2: Pork backfat 20% + Smoking, T3: Pork backfat 10% + Chicory fiber 10% + Smoking

²⁾F: Fat substitute with chicory

³⁾S: Smoking

⁴⁾F×S: Interaction between fat substitute and smoking

lar protein solubilities than those of control. On the other hand, Álvarez and Barbut (2013) reported how the addition of inulin increases the creamy characteristics and softness of sausage. According to the Garcia *et al.* (2006) texture properties of meat products exhibited a difference, depending on the type of inulin. When added as powder, the hardness of meat products is increased, whereas when added as a gel, it shows soft products. Nowak *et al.* (2007) reported that the addition of more than 6% inulin lead to bad texture characteristics of meat products. In addition, Ledesma *et al.* (2016) reported the hardness of meat products increased as smoking time increases. According to the result of Choi *et al.* (2014), the hardness value of smoked pork sausage was significantly higher than non-smoked sausage, and they claimed that this result was caused by dehydration during the smoking process.

Color and pH of restructured sausages

The color and pH of restructured sausages formulated with chicory fiber and smoking treatment is shown in Table 3. The yellowness value of the restructured sausages was significantly decreased by the fat substitution with chicory fiber, and the redness value of the restructured sausages was increased by the smoking treatment ($p < 0.01$). But, the lightness value was not influenced by any factors. Both fat substitution with chicory fiber and smoking treatment significantly affected the pH value of restructured sausages. Similar results were observed for L* and a* values in dry fermented chicken sausages with added 7% inulin (Menegas *et al.*, 2013). According to

Table 3. Color and pH of smoked (or not) restructured sausages following addition of chicory dietary fiber

Treatments ¹⁾	Hunter color ²⁾			pH
	L	a	b	
Control	62.10	12.30	11.01	6.03
T1	60.22	12.41	10.48	5.92
T2	63.55	13.99	11.61	6.09
T3	62.94	12.96	10.46	5.98
SEM	0.49	0.22	0.12	0.01
F ³⁾	-	-	<0.01	<0.01
p-value S ⁴⁾	-	<0.01	-	<0.01
F×S ⁵⁾	-	-	-	-

¹⁾Control: Pork backfat 20%, T1: Pork backfat 10% + Chicory fiber 10%, T2: Pork backfat 20% + Smoking, T3: Pork backfat 10% + Chicory fiber 10% + Smoking

²⁾L: lightness, a: redness, b: yellowness

³⁾F: Fat substitute with chicory

⁴⁾S: Smoking

⁵⁾F×S: Interaction between fat substitute and smoking

Cáceres *et al.* (2004) and Nowak *et al.* (2007), meat products with reduced fat content typically are darker due to the reduction in the shine that is provided by fat. Also, the yellowness seems to be decreased because of fat reduction. Cáceres *et al.* (2004) reported that inulin forms a whitish translucent gel, and Mendoza *et al.* (2001) claimed that the addition of inulin results shinier color in meat products. In fact, the chicory fiber used in this study was a brilliant white powder. Therefore, the addition of chicory fiber significantly did not affect the color parameters of restructured sausages. The smoking treatment led to increase the a* values, Kim *et al.* (2014) reported that smoking treatment increased a* values. It is similar results to our study, smoking treatment could contribute the improvement of the a* values of cooked sausages. Keenan *et al.* (2014) reported that pH values were not significantly different following the addition of inulin, and Menegas *et al.* (2013) reported that the addition of inulin did not affect the pH of the sausages. These results also are observed in several studies (Mendoza *et al.*, 2001; Salazar *et al.*, 2009). The low fat sausages showed a lower pH than high fat sausages (Lorenzo and Franco, 2012; Olivares *et al.*, 2010) because the pH value of fat is higher than lean meat. As a result, the pH value of restructured sausages treated smoking was higher than those of untreated restructured sausages because the smoking treatment had reduced the loss of fat in restructured sausages.

Conclusion

The results suggest that the fat substitute with 10% chic-

ory fiber and smoking treatment significantly affected the quality characteristics of restructured sausages. Further, the addition of chicory fiber significantly decreased the moisture, fat, hardness, and pH values. Whereas the fat content, a^* , hardness, and pH values of restructured sausages were increased by the smoking treatment ($p < 0.01$). Additionally, the color parameters (L^* and a^*) and sensory evaluation attributes (data not shown) in the sausages with 10% chicory fiber were similar with those of control. As well as the smoking treatment improved a falling-off in quality characteristics (pH, fat content and hardness) of restructured sausages due to the fat replacement. It was concluded that the addition of chicory fiber and smoking treatment is helpful to develop the restructured sausage products with health and compensated quality.

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References

- Álvarez, D. and Barbut, S. (2013) Effect of inulin, β -glucan and their mixtures on emulsion stability, color and textural parameters of cooked meat batters. *Meat Sci.* **94**, 320-327.
- Berasategi, I., Navarro-Blasco, Í., Calvo, M. I., Cavero, R. Y., Astiasarán, I., and Ansorena, D. (2014) Healthy reduced-fat Bologna sausages enriched in ALA and DHA and stabilized with *Melissa officinalis* extract. *Meat Sci.* **96**, 1185-1190.
- Cáceres, E., García, M. L., Toro, J., and Selgas, M. D. (2004) The effect of fructooligosaccharides on the sensory characteristics of cooked sausages. *Meat Sci.* **68**, 87-96.
- Choe, J. H., Kim, H. Y., Lee, J. M., Kim, Y. J., and Kim, C. J. (2013) Quality of frankfurter-type sausages with added pig skin and wheat fiber mixture as fat replacers. *Meat Sci.* **93**, 849-854.
- Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Kim, H. W., Jeong, J. Y., and Kim, C. J. (2011) Effects of rice bran fiber on heat-induced gel prepared with pork salt-soluble meat proteins in model system. *Meat Sci.* **88**, 59-66.
- Choi, Y. S., Jeong, J. Y., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Kim, H. W., Paik, H. D., and Kim, C. J. (2008) Effects of dietary fiber from rice bran on the quality characteristics of emulsion-type sausages. *Korean J. Food Sci. An.* **28**, 14-20.
- Choi, Y. S., Kim, H. W., Hwang, K. E., Song, D. H., Choi, J. H., Lee, M. A., Chung, H. J., and Kim, C. J. (2014) Physico-chemical properties and sensory characteristics of reduced-fat frankfurters with pork back fat replaced by dietary fiber extracted from makgeolli lees. *Meat Sci.* **96**, 892-900.
- Davidson, M. H., Maki, K. C., Synecki, C., Torri, S. A., and Drennan, K. B. (1998) Effects of dietary inulin on serum lipids in men and women with hypercholesterolemia. *Nutr. Res.* **18**, 503-517.
- Den Hond, E., Geypens, B., and Ghoois, Y. (2000) Effect of high performance chicory inulin on constipation. *Nutr. Res.* **20**, 731-736.
- Fellendorf, S., O'Sullivan, M. G., and Kerry, J. P. (2015) Impact of varying salt and fat levels on the physicochemical properties and sensory quality of white pudding. *Meat Sci.* **103**, 75-82.
- García, M. L., Cáceres, E., and Selgas, M. D. (2006) Effect of inulin on the textural and sensory properties of mortadella, a Spanish cooked meat product. *Int. J. Food Sci. Technol.* **41**, 1207-1215.
- García-García, E. and Totosaus, A. (2008) Low-fat sodium-reduced sausages: Effect of the interaction between locust bean gum, potato starch and κ -carrageenan by a mixture design approach. *Meat Sci.* **78**, 406-413.
- Gibson, G. R. and Roberfroid, M. B. (1995) Dietary modulation of the human colonie microbiota: Introducing the concept of prebiotics. *J. Nutr.* **125**, 1401-1412.
- Goulas, A. E. and Kontominas, M. G. (2005) Effect of salting and smoking-method on the keeping quality of chub mackerel (*Scomber japonicus*): Biochemical and sensory attributes. *Food Chem.* **93**, 511-520.
- Hwang, H. Y. and Rhee, S. K. (2003) Effects of emulsifying stability and product quality of sausages by adding different amount of fat and water. *Hankyong National University* **35**, 167-176.
- Huang, S. C., Shiau, C. Y., Liu, T. E., Chu, C. L., and Hwang, D. F. (2005) Effects of rice bran on sensory and physicochemical properties of emulsified pork meatballs. *Meat Sci.* **70**, 613-619.
- Jackson, K. G., Taylor, G. R. J., Clohessy, A. M., and Williams, C. M. (1999) The effect of the daily intake of inulin on fasting lipid, insulin and glucose concentrations in middle-aged men and women. *Br. J. Nutr.* **82**, 23-30.
- Kähkönen, P. and Tuorila, H. (1998) Effect of reduced-fat information on expected and actual hedonic and sensory ratings of sausage. *Appetite* **30**, 13-23.
- Keenan, D. F., Resconi, V. C., Kerry, J. P., and Hamill, R. M. (2014) 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 Sci.* **96**, 1384-1394.
- Kim, H. W., Choi, J. H., Choi, Y. S., Han, D. J., Kim, H. Y., Lee, M. A., Shim, S. Y., and Kim, C. J. (2009) Effects of wheat fiber and isolated soy protein on the quality characteristics of frankfurter-type sausages. *Korean J. Food Sci. An.* **29**, 475-481.
- Kim, H. W., Choi, J. H., Choi, Y. S., Kim, H. Y., Lee, M. A., Hwang, K. E., Song, D. H., Lee, J. W., and Kim, C. J. (2014) Effects of kimchi and smoking on quality characteristics and

- shelf life of cooked sausages prepared with irradiated pork. *Meat Sci.* **96**, 548-553.
22. Kouvari, M., Tyrovolas, S., and Panagiotakos, D. B. (2016) Red meat consumption and healthy ageing: A review. *Maturitas* **84**, 17-24.
 23. Ledesma, E., Laca, A., Rendueles, M., and Díaz, M. (2016) Texture, colour and optical characteristics of a meat product depending on smoking time and casing type. *LWT-Food Sci. Technol.* **65**, 164-172.
 24. Ledesma, E., Rendueles, M., and Díaz, M. (2015) Characterization of natural and synthetic casings and mechanism of BaP penetration in smoked meat products. *Food Control* **51**, 195-205.
 25. Lee, J. S. and Shin, H. K. (1997) Effects of addition of chicory extract on starch hydrolysis *in vitro* and glucose response in healthy subjects. *Korean J. Food Sci. Technol.* **29**, 1295-1303.
 26. Lingbeck, J. M., Cordero, P., O'Bryan, C. A., Johnson, M. G., Ricke S. C., and Crandall P. G. (2014) Functionality of liquid smoke as an all-natural antimicrobial in food preservation. *Meat Sci.* **97**, 197-206.
 27. Lorenzo, J. M. and Franco, D. (2012) Fat effect on physicochemical, microbial and textural changes through the manufactured of dry-cured foal sausage lipolysis, proteolysis and sensory properties. *Meat Sci.* **92**, 704-714.
 28. López-Vargas, J. H., Fernández-López, J., Pérez-Álvarez, J. Á., and Viuda-Martos, M. (2014) Quality characteristics of pork burger added with albedo-fiber powder obtained from yellow passion fruit (*Passiflora edulis* var. *flavicarpa*) co-products. *Meat Sci.* **97**, 270-276.
 29. Mendoza, E., Garcia, M. L., Casas, C., and Selgas, M. D. (2001) Inulin as fat substitute in low fat, dry fermented sausages. *Meat Sci.* **57**, 387-393.
 30. Menegas, L. Z., Pimentel, T. C., Garcia, S., and Prudencio, S. H. (2013) Dry-fermented chicken sausage produced with inulin and corn oil: Physicochemical, microbiological, and textural characteristics and acceptability during storage. *Meat Sci.* **93**, 501-506.
 31. Nowak, B., Von Mueffling, T., Grotheer, J., Klein, G., and Watkinson, B. M. (2007) Energy content, sensory properties, and microbiological shelf life of German bologna-type sausages produced with citrate or phosphate and with inulin as fat replacer. *J. Food Sci.* **72**, S629-S638.
 32. Olivares, A., Navarro, J. L., Salvador, A., and Flores, M. (2010) Sensory acceptability of slow fermented sausages based on fat content and ripening time. *Meat Sci.* **86**, 251-257.
 33. Oostindjer, M., Alexander, J., Amdam, G. V., Andersen, G., Bryan, N. S., Chen, D., Corpet, D. E., De Smet, S., Dragsted, L. O., Haug, A., Karlsson, A. H., Kleter, G., de Kok, T. M., Kulseng, B., Milkowski, A. L., Martin, R. J., Pajari, A.-M., Paulsen, J. E., Pickova, J., Rudi, K., Sødring, M., Weed, D. L., and Egeland, B. (2014) The role of red and processed meat in colorectal cancer development: a perspective. *Meat Sci.* **97**, 583-596.
 34. Pöhlmann, M., Hitzel, A., Schwägele, F., Speer, K., and Jira, W. (2012) Contents of polycyclic aromatic hydrocarbons (PAH) and phenolic substances in Frankfurter-type sausages depending on smoking conditions using glow smoke. *Meat Sci.* **90**, 176-184.
 35. Pounis, G. D., Tyrovolas, S., Antonopoulou, M., Zeimbekis, A., Anastasiou, F., Bountziouka, Metallinos, G., Gotsis, E., Lioliou, E., Polychronopoulos, E., Lionis, C., and Panagiotakos, D. B. (2010). Long-term animal-protein consumption is associated with an increased prevalence of diabetes among the elderly: the Mediterranean Islands (MEDIS) study. *Diabetes Metab. J.* **36**, 484-490.
 36. Roberfroid, M. B. (2007) Inulin-type fructans: Functional food ingredients. *J. Nutr.* **137**, 2493S-2502S.
 37. Sánchez-Zapata, E., Zunino, V., Pérez-Alvarez, J. A., and Fernández-López, J. (2013) Effect of tiger nut fibre addition on the quality and safety of a dry-cured pork sausage ("Chorizo") during the dry-curing process. *Meat Sci.* **95**, 562-568.
 38. SAS (2008) SAS/STAT Software for PC. Release 9.2, SAS Institute, Cary, NC.
 39. Schmiele, M., Mascarenhas, N., Chiarinelli, M. C., Barretto, d. S., Carla, A., Pollonio, R., and Aparecida, M. (2015) Dietary fiber as fat substitute in emulsified and cooked meat model system. *LWT-Food Sci. Technol.* **61**, 105-111.
 40. Salazar, P., Garcia, M. L., and Selgas, M. D. (2009) Short-chain fructooligosaccharides as potential functional ingredient in dry fermented sausages with different fat levels. *Int. J. Food Sci. Technol.* **44**, 1100-1107.
 41. Thebaudin, J. Y., Lefebvre, A. C., Harrington, M., and Bourgeois, C. M. (1997) Dietary fibres: Nutritional and technological interest. *Trends Food Sci. Tech.* **8**, 41-48.
 42. Toth, L. (1982) *Chemie der Räucherung*. Weinheim, Berlin: Verlag Chemie.
 43. Tungland, B. C. and Meyer, D. (2002) Nondigestible oligo- and polysaccharides (dietary fiber): Their physiology and role in human health and food. *Compr. Rev. Food Sci. F.* **1**, 90-109.
 44. Yilmaz, I. and Dağlioğlu, O. (2003) The effect of replacing fat with oat bran on fatty acid composition and physicochemical properties of meatballs. *Meat Sci.* **65**, 819-823.
 45. Zhuang, X., Han, M., Kang, Z. L., Wang, K., Bai, Y., Xu, X. L., and Zhou, G. H. (2016) Effects of the sugarcane dietary fiber and pre-emulsified sesame oil on low-fat meat batter physicochemical property, texture, and microstructure. *Meat Sci.* **113**, 107-115.