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Dietary fiber as fat substitute in emulsified and cooked meat model system

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ABSTRACT

Fat intake has been associated with increased risk of cardiovascular disease, obesity, and diabetes. The aim of this study was to reformulate meat products using amorphous cellulose fiber (Z-trim®) as a fat substitute. Based on a Response Surface Methodology, an emulsified and cooked meat model system was carried out with a standard formulation with 20 g/100 g pork fat, and replacement levels of pork fat (from 0 to 20 g/100 g) by amorphous cellulose fiber (from 0 to 1.5 g/100 g). The independent variables within the levels studied influenced the dependent variables emulsion stability (from 73.64 to 91.76 g/100 g), firmness (from 27.32 to 48.02 N), hardness (from 50.86 to 83.00 N), b^* color coordinate (14 days) (from 13.08 to 14.45), and weight loss during storage (from 1.88 to 5.16 g/100 g). Comparing the fitted models to the results of the standard sample, it is possible to obtain products with 1.3 g/100 g amorphous cellulose fiber and 10 g/100 g pork fat (50% fat reduction), with technological characteristics similar to the standard sample.

1. Introduction

Processed meat products are important protein sources with high biological value, energy, vitamins (B6 and B12), and minerals (Fe and Zn). Such products, however, have been criticized due to their high sodium content, low fiber content, and high animal fat level in several formulations (20–30 g/100 g), being often considered harmful to health (Judge, Aberle, Forrest, Hedrick, & Merkel, 1989; Pearson & Tauber, 1984; Trindade, 1998; Webb & O'neill, 2008). Decrease fat in diet is needed because many researches correlate fat intake with chronic disease event like cardiovascular diseases (mainly saturated fat and cholesterol), cancer, type 2 diabetes, and others related to obesity (Decker & Park, 2010; Giese, 1996; Lima & Nassu, 1996; Monteiro, Mondini, & Costa, 2000; Santarelli, Pierre, & Corpet, 2008; Schönfeldt & Gibson, 2008; Vasconcelos, 2004; Vickery & Rogers, 2002).

Animal fat has high saturated fatty acids content (from 30 to 60 g/100 g), which show influences on final consistency of meat products. The pork back fat consisting of roughly 90 g/100 g fat and 10 g/100 g moisture and is mostly used to make processed meat products with high technological quality due to its significant properties, such as high melting point due to its fatty acid composition, and desirable sensory characteristics. However, there is on average 61 mg/100 g cholesterol and it can vary with breed, sex and diet (Feiner, 2006).

Increasing demand for products with low and/or reduced fat levels systems from the need to have healthier diets and has led to the development of new products to replace the fat in traditional formulation. Three different techniques can be applied in meat product segmentto decrease fat, such as modifying carcass chemical composition for meat with lower fat content, manipulating animal raw material by selecting leaner meat, and making meat products through use of fat substitutes, by adding water and functional ingredients. This latter tactic depicts a considerable opportunity to add value to processed meat products by the addition of new ingredients, additives and technological process research, aiming for healthier products (Bernardi, Oetterer, & Contreras-Castillo, 2008; Mendoza, Garcia, Casas, & Selgas, 2001; Trindade, 1998).

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Neverthelles, replacing animal fat in meat products is an enormous technological challenge. Although being a high caloric formulation ingredient, animal fat in meat products holds a great and positive way in terms of softness, succulence, taste, and important attributes of quality.

Chemical and physical properties of fat such as viscosity, heat stability, plasticity, dispersion, physical stability (emulsification, migration, and coalescence), chemical stability (rancidity and oxidation), and microbiological stability (water activity and food safety) affect fat intake and shelf-life of meat (Jones, 1996; Webb & O'neill, 2008).

Reducing and/or replacing fat in processed meat products, therefore, can cause a big hit on sensorially portrayed final products, mainly on traits such as appearance, aroma (taste intensity and sense), satiety, and texture sensation (succulence, creamy texture and palatability), as well as on physical stability of products, mainly on emulsified meat products (Jones, 1996; Lima & Nassu, 1996; Monteiro, Carpes, Kalluf, Dyminski, & Cândido, 2006; Nonaka, 1997; Rodrigues-Amaya, 2003).

By excessively decreasing fat in meat products, other ingredients which supply products sensorial quality traits can help in achieving this challenge, such as spices, flavorings, and suchlike, which works as fat substitutes (Jiménez-Colmenero, Reig, & Toldrá, 2006; Rogers, 2001) are needed in order to avoid products becoming dry, hard and tasteless (Nabeshima, 1998).

According to Giese (1996), fat substitutes are divided into three main groups as those derived from protein – milk, eggs, or vegetables (i.e. soy protein isolate); derived from modified lipids - synthetic lipid (Olestra® sucrose polyester); and derived from carbohydrates – modified starches, resistant starches and dietary fibers (Hahn, 1997; Monteiro et al., 2006).

Substitutes derived from carbohydrates are usually hydrophilic due to the large number of hydrogen bonds with water, creating a fat-based system depending on the food texture aimed (Nonaka, 1997). They are commonly obtained from cereals or leguminous plants used more frequently than others (Hahn, 1997).

The amorphous cellulose fiber (Z-trim®) is a carbohydrate based fat substitute that has been few studied in creating meat products. It is used in food products since its discovery in 1996, commonly in milk and bakery products (Z-TRIM, 2014). It is an insoluble fiber from the husk of oat, soya, rice grains, wheat or corn bran (Akoh, 1998). It is available in market as powder and turns into a gel when rehydrated. When it is ingested, it does not contain calories (Xu et al., 2010), holding a cellulose:hemicellulose ratio of roughly 80:20 (Z-TRIM, 2014). Campagnol, Santos, Wagner, Terra, and Pollonio (2012) studied the effect of the replacement of pork back fat by amorphous cellulose fiber on several quality parameters of fermented sausages and found that the substitute up to 50 g/100 g of pork back fat content not decreased the product quality, which allows the production of healthier fermented sausages due to a decrease in fat and cholesterol levels by approximately 45% and 15%, respectively.

When the amorphous cellulose fiber particles absorb water, they swell promoting viscosity and, sensorially, a sense of smoothness, softness and plasticity in the mouth (Z-TRIM, 2014). Furthermore, Z-TRIM is considered a GRAS (Generally Recognized as Safe) ingredient, and does not cause any problems when ingested (Hahn, 1997; Monteiro et al., 2006).

The aim of this study is to evaluate the performance of the use of amorphous cellulose fiber as fat substitute in an emulsified and cooked meat model system. Through the Response Surface Methodology, are investigated the physicochemical parameters such as emulsion stability, cooking loss, weight loss during storage and instrumental color and texture.

2. Materials and methods

2.1. Characterization of raw material

Quality assured beef (Margen, São Paulo/BRA), and pork meat and pork fat (Marchiori, São Paulo/BRA) were purchased in a local supermarket. The raw materials were characterized for moisture, crude protein, and ash content according to AOAC methods (Association of Official Analytical Chemists, 1997) and fat content was determined according to the Bligh & Dyer's method (Bligh & Dyer, 1959). Carbohydrates were calculated by difference. The amorphous cellulose fiber (Z-trim®) was donated by Kraki Kienast & Kratschmer Ltda (São Paulo/BRA).

2.2. Water holding capacity of the amorphous cellulose fiber

The water holding capacity of the amorphous cellulose fiber was determined in triplicate according to the methodology reported by Smith, Juhn, Carpenter, Mattil, and Cater (1973) with modifications. For that, 1.0 g amorphous cellulose fiber (dry basis) was placed into a 50 mL centrifuge tube and 20 mL saline solution (3.5% w/v NaCl, pH adjusted at 6.2 with 100 mmol/L HCl or 100 mmol/L NaOH) was added. The tubes were placed in a TE-052 thermostatic bath at 85.0 ± 0.2 °C (TECNAL® Dubnoff Fibralimentar, Piracicaba/BRA) and stirred for 15 min at 100 rpm. Then, the tubes were cooled in running water for 5 min. The suspension was centrifuged at $2200 \times g$ for 10 min using a 204NR centrifuge (FANEM, Piracicaba, BRA). The supernatant was discarded and the water holding capacity was determined by the ratio: [(weight of wet fiber – weight of sample on dry basis)/weight of sample on dry basis].

2.3. Standard formulation of the meat model system

The standard formulation of the meat model system contained 27.82 g/100 g beef, 27.82 g/100 g pork meat, 20 g/100 g pork fat, 19.80 g/100 g ice, 2.0 g/100 g sodium chloride, 2.0 g/100 g maltodextrin (GLOBE® 1905, with 5.0 maximum dextrose equivalent, Corn Products International – Mogi Guaçu/BRA), 0.015 g/100 g sodium nitrite, 0.045 g/100 g sodium erythorbate, and 0.50 g/100 g potassium tripolyphosphate. The pork fat used in the standard formulation was varied in the trials according to the experimental design.

2.4. Experimental design

The replacement of pork fat by amorphous cellulose fiber was assessed by a two-variables Central Composite Design (CCD), with four factorial trials, four axial trials and three repetitions at the center point, resulting in 11 trials, and the corresponded levels are shown in Table 1. The amount of fat replaced by the fiber was adjusted by addition of ice.

The dependent variables were emulsion stability (batter), weight cooking loss (product not sliced), and instrumental color and texture (sliced product) after 24 h of storage at 5 °C in a BOD

Table 1
Levels of independent variables in the central composite design to substitution of pork fat by amorphous cellulose fiber.

Encoding	Independent variables	Levels				
		$-\alpha$	-1	0	+1	$+\alpha$
X_1	Pork fat (g/100 g)	0	2.9	10	17.1	20
X_2	Amorphous cellulose fiber (g/100 g)	0	0.2	0.75	1.3	1.5

$\pm|\alpha| = 1.41$.