Meat Science 133 (2017) 159–165

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Designing healthier comminuted meat products: Effect of dietary fibers on water distribution and texture of a fat-reduced meat model system

Minyi Han[a,b,c], Hanne Christine Bertram[a,*]

[a] Department of Food Science, Kirstinebjergvej 10, 5792 Årslev, Aarhus University, Denmark
[b] Key Laboratory of Meat Processing and Quality Control, Ministry of Education, Nanjing 210095, PR China
[c] College of Food Science and Technology, Nanjing Agricultural University, Nanjing 210095, PR China

ARTICLE INFO

Keywords:
Fiber enrichment
Fat replacement
Water-binding capacity
Low-field NMR T_2 relaxation
Chitosan
Carboxymethyl cellulose (CMC)

ABSTRACT

Development of healthier meat products is needed to meet consumers' request. The effects of dietary fiber addition on the water distribution, water binding capacity (WBC), and textural properties of a fat-reduced model meat system enriched with inulin, cellulose, carboxymethyl cellulose (CMC), chitosan, pectin, respectively, were investigated in this study. The fibers were incorporated in powder form to constitute 2% (w/w) of the meat batter. In general, fiber enrichment resulted in significant lower cooking loss and improved WBC, while the impact on texture was dependent on the specific dietary fiber. Low-field NMR relaxometry revealed that chitosan impacted the heating-induced changes in water distribution differently from other fibers and that CMC had a higher capability to counteract the impact of heat-induced protein denaturation on water expulsion than the other fiber types. It is anticipated that this knowledge is useful in the development of novel strategies where dietary fiber enrichment is optimized to promote specific and desired technological attributes of healthy meat products.

1. Introduction

Finely comminuted emulsified meat products, such as frankfurters and luncheon meats, typically contain 20–30% fat and a high amount of water as well. Although fat is an important source of energy and essential fatty acids as well as carrier of fat-soluble vitamins in meat products (Choi et al., 2009; Henning, Tshalibe, & Hoffman, 2016), the possible association between saturated fat intake and a variety of chronic disease such as diabetes, cardiovascular disease, obesity, infectious and respiratory diseases has led to consumers' demand for healthier meat products (WHO, 2003). Consequently, the development of healthier meat products with added values relating to diet and low caloric content has become one of the key targets for the food industry. However, fat is also one of the main components in foods and contribute to their texture and flavor and increases the feeling of satiety during meals (Almeida, Wagner, Mascarin, Zepka, & Campagnol, 2014; Campagnol, dos Santos, Wagner, Terra, & Pollonio, 2012). For these reasons, fat reduction in product formulas usually implies undesirable effects on the technological and textural properties (such as increased cooking losses, deteriorated texture and lower heating stability). Consequently in the manufacture of fat-reduced meat products, it is necessary to minimize the sensory and textural modifications occurring as a result of fat reduction (Colmenero, 2000). One of the strategies that has been applied to reduce fat content in meat products is based on substituting the fat with non-meat ingredients such as animal or plant protein, hydrocolloid or dietary fibers to achieve the desired textural characteristics and to achieve certain functional characteristics or to influence the composition of the final product (Claus & Hunt, 1991; Colmenero, 1996; Gibis, Schuh, & Weiss, 2015).

Various dietary fibers alone or in combination have been evaluated to substitute fat in meat products to change the health attributes and maintain the desirable textural properties as a result of their different functional properties such as water retention, emulsion stability, lubrication, texture modification and neutral flavor (Desmond, Troy, & Buckley, 1998; do Amaral et al., 2015; García, Cáceres, & Selgas, 2006; García, Rodríguez, Hidalgo, & Bertram, 2016; Gibis et al., 2015; Henning et al., 2016; Kehlet, Pagter, Aaslyng, & Raben, 2017; Oz, Kızıl, Zaman, & Turhan, 2016). Using dietary fiber as a fat replacer not only reduces the fat content but also enhances the nutritional attributes of the product. It is established that consuming more dietary fiber decreases the risk of obesity, cardiovascular disease and colon cancer. For adults, the recommended intake of dietary fiber is 28–36 g/day, of which 70–80% should be insoluble fiber (Mehta, Ahlawat, Sharma, & Dabur, 2015). A high proportion of the

---

[*] Corresponding author.
E-mail address: hannec.bertram@food.au.dk (H.C. Bertram).

http://dx.doi.org/10.1016/j.meatsci.2017.07.001
Received 4 February 2017; Received in revised form 21 June 2017; Accepted 2 July 2017

population has insufficient intake of this health-beneficial nutrient (Debusca, Tahergorabi, Beamer, Matak, & Jaczynski, 2014). Another important reason to use dietary fibers is that their sources are commonly agricultural by-products that are relatively cheap, and incorporation in meat products may reduce overall production costs (Mehta et al., 2015). Henning et al. (2016) used 1% pineapple dietary fibers and water to replace pork back fat in a beef sausage and found that addition of fiber and water resulted in increases in purge loss, lightness, hue and chroma while reducing pH and textural properties. Schmiele, Mascarenhas, Barretto, and Pollonio (2015) reformulated meat products using amorphous cellulose fiber as a fat substitute. Fermented sausages were formulated with 20% pork back fat (control), and three fat-reduced formulas were prepared by replacing 25%, 50%, and 75% of the fat with a mixture of collagen, dietary fiber and ice (Ham et al., 2016). Lin and Chao (2001) revealed that the addition of chitosan to reduced-fat Chinese-style sausage resulted in no detrimental effects on textural properties.

Dietary fibers render technological functions such as water binding and water retention, thereby reducing shrinkage, cooking loss, drip loss during storage, and minimizing production costs, offsetting the undesired textural changes of formula alterations without affecting sensory properties of the final product (Almeida et al., 2014; Besbes, Attia, Deroanne, Makni, & Blecker, 2008; Biswas, Kumar, Bhosle, Sahoo, & Chatli, 2011; Henning et al., 2016). In addition, the nutritional attributes were improved when dietary fibers were included in the formulation as the lipolysis process was shown to be altered by the addition of dietary fibers (Lairon, Play, & Jourdheuil-Rahmani, 2007), and the amount of free fatty acids was lower in beef patties containing chitosan and pectin than other beef patties after in vitro digestion. A previous study also showed that beef patties containing various fibers had lower thiobarbituric acid-reactive substances (TBARS) values than patties with no fibers added (Hur, Lim, Park, & Joo, 2009).

Nuclear magnetic resonance (NMR) relaxation has gained wide use in meat research, as it provides unique qualitative and quantitative information regarding the physical state of water and fat in meat and meat products. As a result of the development of relatively inexpensive low-field NMR equipment, ^{1}H NMR relaxation, in particular, has become increasingly attractive within food science (Bertram, 2016). Although NMR relaxometry has been widely used in studies on muscle tissue, fresh meat and meat processing (Bertram, Engelsen, Busk, Karlsson, & Andersen, 2004; García et al., 2016; Han, Wang, Xu, & Zhou, 2014; Montero, Hurtado, & Pérez-Mateos, 2000; Rubio-Celorio, Fulladosa, Garcia-Gil, & Bertram, 2016; Yang et al., 2015), currently the effects of dietary fibers addition on the water distribution and mobility in meat products have not been investigated by low-field NMR. The objective of this study was to examine the influence of selected dietary fibers on the intrinsic water distribution and mobility, WBC and textural characteristics of a fat-reduced model a comminuted meat product to obtain a better mechanistic understanding of how different dietary fibers impact the technological attributes of a meat-based food matrix.

2. Material and methods

2.1. Raw materials

Minced pork (8–10% fat content) and minced pork back fat were purchased from a local meat distributor, and split into portions of 150 g and 30 g, respectively, then stored at − 20 °C until use. Inulin, medium size cellulose, carboxymethyl cellulose sodium salt (CMC), low molecular weight chitosan, pectin were purchased from Sigma Aldrich (St. Louis, MO, USA). The chemical abstracts service (CAS) and molecular weight of the dietary fibers used in the present are displayed in Table 1. All chemicals used were of analytical grade.

Table 1
The chemical abstracts service (CAS) and molecular weight of the dietary fibers used.

Fiber type	CAS	Molecular weight
Inulin	9005-80-5	~5,000
CMC	9004-32-4	~100,000–250,000
Cellulose	9004-34-6	Not available
Chitosan	9012-76-4	50,000–190,000 (based on viscosity)
Pectin	9000-69-5	~23,000–71,000

Table 2
Formulation of the model meat for the five different treatments (control and the five batches: inulin, chitosan, CMC, pectin, cellulose, containing 2% of the specific fiber).

Ingredient	Control	Treatments
Minced pork	75% (w/w)	75% (w/w)
Minced back fat	15% (w/w)	15% (w/w)
Ice water	8.5% (w/w)	6.5% (w/w)
NaCl	1.5% (w/w)	1.5% (w/w)
Dietary fiber	0% (w/w)	2% (w/w)

2.2. Manufacture of the model meat product

The formulations for the model meat product used in the manufacture of the control and samples with various dietary fibers are shown in Table 2. Five formulations (control, inulin, CMC, cellulose and chitosan) were manufactured in three replicate batches on different occasions, and pectin was added in two replicates batches. Addition of 2% fiber was chosen based on previous experience showing that within this range both acceptable sensory and technological attributes of the final product are be obtained (Cegielka & Tambor, 2012; do Amaral et al., 2015; Gibis et al., 2015; Schuh et al., 2013).

The meat and fat were thawed overnight at 4 °C. Then the minced pork, fat, ice, NaCl and dietary fibers were added to a LB20E Waring variable speed laboratory blender (Waring Commercial Blender, New Hartford, CT, USA), and blended 2 min with a speed of 10,000 rpm, and during the blending, there was 10 s rest in every 30 s interval. The meat emulsion was transferred to a 50 mL caped plastic test tube, centrifuged at 5000 rpm for 6 min at 4 °C using a Sorvall RC 5B Plus Centrifuge (Sorvall Products, LP Newton, CT, USA) to remove the air bubbles in the sample. Thereafter the samples were heated from 20 to 70 °C in a water bath (Lauda Ecoline RE 306; Lauda-Königshofen, Germany), and maintained 20 min at 70 °C. The samples were subsequently cooled at room temperature, and water binding capacity and texture were determined.

2.3. Water binding capacity (WBC)

Two approaches were applied for the determination of WBC: cooking loss and expressible water, as described in the following sections.

2.3.1. Cooking loss (CL)

After the samples were cooled to RT, they were removed from the centrifuge tube, liquid release on the surface of the cooked meat batters was removed using tissues before weighing. CL was measured in triplicate by subtracting the post-cooking weight of meat batters (W1) from the pre-cooking weight of the batters (W2), expressed as a percentage of pre-cooked meat batters using the following equation:

$$\text{Cooking loss (CL,\%)} = \frac{\text{W2} - \text{W1}}{\text{W2}} \times 100$$

2.3.2. Expressible water (EW)

The expressible water (EW) of the sausages was determined using the compression method adapted from Mendez-Zamora et al. (2015)