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Effect of regenerated cellulose fiber on the properties and microstructure of emulsion model system from meat batters

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A B S T R A C T

For better application of regenerated cellulose (RC) in fat-reduced emulsified meat products, the research evaluated the effect of regenerated cellulose fiber on the stability, surface protein concentration, rheological behaviors and microstructure of emulsion model system from meat batters. The range of the RC fiber concentrations in the emulsion system was 0%, 0.4%, 0.8% and 1.2% (w/w). The oil droplets size decreased and the creaming stability was improved with increasing RC fiber levels, in particular that the emulsion system with 0.8% RC fiber showing smallest droplet size and inhibited creaming obviously. The rheological results showed that RC fiber enhanced the viscosity and exhibited gel-like property. Surface protein concentration measurement and confocal laser scanning microscopy (CLSM) image exhibited that the RC fiber improved the surface protein concentration of lipid particles. The cryo-scanning electron microscopy (cryo-SEM) provided evidence for cross-linked network structure formation with increasing RC fiber concentrations of emulsion model system. These results indicate that RC fiber is of great importance for improving the emulsifying and stability of emulsion model system from meat batters.

1. Introduction

The emulsion-type meat products are generally referred to as comminuted compositions of muscle proteins, lipid particles, water and a variety of non-meat ingredients (Gordon & Barbut, 1992; Santhi, Kalaikannan, & Sureshkumar, 2017). Two theories for the emulsifying mechanism of the emulsified meat system have been reported (Youssef & Barbut, 2010). The first is oil-in-water emulsion theory, emphasizing the formation of myofibril protein interfacial protein film on the fat particles to prevent fat globules aggregation. The second theory is the physical embedding theory, which describes that fat particles are entrapped in the protein matrix and fat particles are stabilized by myofibrillar protein (MP) gel network. The salt-soluble MP extracted from lean meat as an emulsifier by the chopping process, and the animal fat is chopped into fine fat particles (Gordon & Barbut, 1992; Kumar, Kairam, Ahmad, & Yadav, 2016). Chopping operation is an emulsification process of protein from lean meat, fat and water. A successful and stable emulsion system is the balance between protein–fat and protein–water interactions. In meat batters, MP not only act as an emulsifier to maintain the combination of lipid and moisture, but also form a gel network structure during the heating process (Kim, Setyabrata, Lee, & Kim, 2018; Sarma, Reddy, & Srikar, 2000). The fat droplets are wrapped and fixed in the protein matrix and play an important role in meat products (Kumar et al., 2016). Fat interact with other ingredients which contribute to improve the stability of the meat emulsion system as well as providing appropriate texture, flavor and juiciness (Choi et al., 2009). However, many researches have reported that consuming excessive intake fat could lead to hypertension, cardiovascular disease, diabetes and obesity. (Luruena-Martinez, Vivar-Quintana, & Revilla, 2004; Oezvural & Vural, 2008).

In the meat products, one promising method to reduce fat content is generally with the addition of various dietary fiber as substitute for animal fat such as rice bran fiber, carrageenan, pectin and cellulose hydrocolloid (Henning, Tshalibe, & Hoffman, 2016; Mehta, Ahlawat, Sharma, & Dabur, 2015; Zhang, Xiao, Himali, Lee, & Ahn, 2010). Flores, Giner, Fisman, Salvador, and Flores (2007) reported that the emulsion capacity of meat emulsion systems was improved by using new carrageenan emulsifier. The regenerated cellulose (RC) fiber is derivative from microcrystalline cellulose (MCC) and could be produced by a modified method of acid dissolution and water regeneration (X. Jia et al., 2013). Compared to MCC, RC possesses gel properties and high water-binding capacity. Moreover, RC has strong surface activities due

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to the presence of hydrophobic and hydrophilic groups (Hu, Xing, et al., 2016). And the gel-like RC fiber possesses also has a similar appearance and mouth feel to the animal fat (Jia et al., 2014; X.; Jia et al., 2013). Our previous research has investigated the influence of RC fiber on the characters of fat-reduced emulsified sausages. Preliminary findings have indicated that RC fiber could enhance the emulsion stability and improve the texture of products. The emulsion system stability of meat batters and the gel strength formed by heating play an important part in quality of final products. Moreover, the report has been indicated that RC fiber could obviously stabilize o/w vegetable oil emulsion at lower concentrations (Hu, Xing, et al., 2016; Jia et al., 2013). However, the mechanism for studying the effect of RC fiber as an emulsifier on the emulsion model system from meat batters is still limited. Thereby, the present work focused on the influence of RC fiber on the stability, rheological properties, surface protein concentration and microstructure of MP-lard emulsion model system from fat-reduced meat batters.

2. Materials and methods

2.1. Materials

The commercial microcrystalline cellulose (MCC) and 85% food grade phosphoric acid was purchased from Linghu Xinwang Chemical Co., Ltd. (Huzhou, China) and Chengxing Phosph-chemicals Co., Ltd. (Jiangsu, Chian), respectively. The fresh lean pork meat (72.18% moisture, 20.96% protein, 4.32% fat) and pork back fat (fat 85.91%, moisture 13.88%) were purchased from Yurun Food Co., Ltd. (Jiangsu, China). The pork meat and pork fat were frozen and stored at − 20 °C until used to extract the myofibrillar protein and prepare liquid lard. All other chemical reagents were commercially available and belong to analytical grad.

2.2. Regenerated cellulose fiber preparation

RC fiber was prepared as previously described with dissolution and regeneration method (Hu, Pereira, et al., 2016). The 4 g MCC and 16 mL deionized water were mixed together in beaker flask. Next 160 mL of phosphoric acid was added to the beaker flask. Then the homogeneous cellulose suspension was incubated for 24 h in a shaker at speed of 150 rpm at 4 °C to form a clear and viscous solution. The clear solution (pH 0.3–0.5) was added with 800 mL deionized water and then rested 2 h. And then the suspension solution was centrifuged at 16,500 g for 20 min. The washing regeneration and the centrifugation were repeated until a constant pH was achieved at 6 to 6.5. The final concentration of the white and gel-like cellulose was 4.43% (w/w) as measured by gravimetric analysis. The photograph of RC fiber appearance and image of microstructure of RC fiber are shown in Fig. 1.

2.3. Extraction of myofibrillar protein and liquid lard preparation

MP was extracted according to the method by Han, Zhang, Fei, Xu, and Zhou (2009) and the concentration of final protein was evaluated with bovine serum albumin as a standard by the Biuret method. The MP was diluted by buffer (0.6 M NaCl, 50 mM Na_2HPO_4/NaH_2PO_4, pH 7.0) and the final concentration was 20 mg/mL. The liquid lard was prepared by Wang et al. (2017) with slight modification. The pork back fat was chopped and heated at 100–120 °C with stirring. The impurities were removed by filtration in order to obtain liquid lard.

2.4. Emulsion system preparation

The MP-lard emulsions were prepared by mixing MP solution with the liquid lard and were subsequently homogenized with a homogenizer (Ultra TurraxT25 BASIS, Germany) at 15,000 rpm for 2 min. After 2 min, the RC fiber and remaining water were added to the pre-emulsions and were homogenized at 12,000 rpm for 2 min. The final emulsions contained 1% (w/w) MP, 20% (w/w) lard and 0%, 0.4%, 0.8%, and 1.2% (w/w) RC fiber, and all emulsion samples were added sodium azide (0.02%) to avoid microbial growth. The lard and emulsion were kept in a 30 °C water bath to prevent solidification after emulsification and analyzed within 24 h.

2.5. Visual assessment of creaming stability

After emulsions were formed, 15 g freshly emulsions were moved into glass test tubes and were kept at room temperature for 7 d. The cream layer and serum layer were formed at top and bottom of emulsion samples, during storage and photographs were taken on day 1 and day 7 for recording. The creaming index (CI%) was the ratio of the serum layer height (H_S) to the total height (H_E) during storage, and the equation as follows: $CI\% = \frac{H_S}{H_E} \times 100$.

2.6. Particle size determination

The determination of particle size and distribution of the oil droplets were analyzed by a mastersizer (Malvern Mastersizer 3000, England). The emulsion was added into distilled water until the obscuration rate reached 10%–15%. The refractive and absorption indices of lard particles were 1.520 and 0.001, and the refractive index of water was set as 1.330. The particle size was reported as $D_{3,2}$ and $D_{4,3}$, where the $D_{3,2}$ and $D_{4,3}$ represent surface-weighted average particle size and the volume-weighted average particle size, respectively. The determination was carried out immediately after preparation of the emulsion.

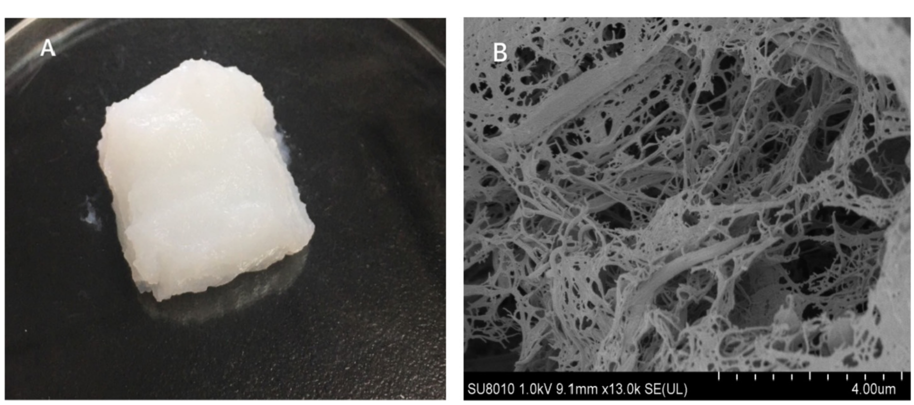

Fig. 1. Photo and microscopic images of RC fiber (A) The photograph of the 4.43% (w/w) gel-like state RC fiber; (B) The scanning electron microscope (SEM) microstructure of RC fiber.