Food Structure 12 (2017) 73–81

Contents lists available at ScienceDirect

Food Structure

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

Filled myofibrillar protein gels: Improving cooking loss and texture with model filler particles

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ARTICLE INFO

Article history:
Received 7 June 2016
Received in revised form 3 November 2016
Accepted 8 December 2016
Available online 9 December 2016

Keywords:
Myofibrillar proteins
Gelation
Water stability
Microstructure
T_2 relaxation
Comminuted meat

ABSTRACT

The influence of incorporating filler particles of varying size and hydrophilic strength in a model myofibrillar protein gel was investigated. Two particle sizes (7–10 μm and 30–50 μm) having differing surface chemistry (uncoated, or amino-coated) were incorporated into a comminuted meat system at varying volume fractions (ϕ_f). Both particle sizes were able to reduce and arrest cooking loss during gelation, as well as improve large deformation mechanical attributes such as Hardness and Resilience. The smaller particles were found to increase these parameters at lower ϕ_f, reaching a plateau as the filler content increased (at $\phi_f \geq 0.03$). The use of amino-coated particles resulted in a greater increase in liquid retention and large deformation properties; however, not significantly so. The larger particles produced a continuous decrease in cooking loss during gelation, but there was an associated lag in the improvement in large deformation properties. At the highest ϕ_f tested ($\phi_f = 0.12$), the large deformation mechanical properties of the composites containing the 30–50 μm particles either reached a plateau (uncoated) or exhibited a slight decrease (amino-coated). This was attributed to the clustering of particles at higher ϕ_f, which would weaken the gel network, as the glass particles only weakly interacted with the protein network, as suggested by SEM images. Pulsed NMR relaxometry indicated the presence of the glass particles stabilized the aqueous phase prior to gelation, resulting in the improved water retention which was associated with the observed increase in mechanical properties. However, despite the stronger dipole moment associated with the amino functional groups bound to the surface of the coated glass beads, these particles did not provide an improvement in the stability or large deformation mechanical properties of the composite gels. This work corroborates with previous studies suggesting that micron-sized, insoluble, hydrophilic filler could be used to improve the mechanical attributes and water retention of comminuted meat products.

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1. Introduction

A variety of food systems can be described as particle-filled soft solids, in which a dispersed fat phase is embedded in a continuous matrix, such as a protein gel. Some examples include cheese and processed cheese products, fat-filled puddings or custards, and processed meats such as frankfurters, bologna, and pâté. In such systems, the size, quantity, and physical state of the particulate inclusions can influence the rheological, mechanical, and organoleptic properties of the product (Sala, van Vliet, Cohen Stuart, van de Velde, & van Aken, 2009). The rheological properties of particle- and emulsion-filled food gels have been described using various theoretical models, such as those originally proposed by van der Poel (1958), and Kerner (1956), with subsequent modifications by Smith (1975), and Lewis and Nielsen (1970), respectively. Such theories describe the modulus of the composite (the filled gel) as a function of the volume fraction filler (ϕ_f) incorporated. They have been shown to work reasonably well in several model and actual food systems such as heat-induced gelatine (Sala, Van Aken, Cohen Stuart, & Van de Velde, 2007) and soy (Kim, Renkema, & van Vliet, 2001) protein gels, acidified milk (van Vliet, 1988), comminuted meats (i.e. myofibrillar protein gels; Gravelle, Barbut, & Marangoni, 2015), and cheddar cheeses, (Yang, Rogers, Berry, & Foegeding, 2011) among others. Generally, these particle-reinforcement theories predict a gradual increase in reinforcement at lower ϕ_f, which becomes much more pronounced as the ϕ_f increases (i.e. $\phi_f > 0.10$).

Abbreviations: IPF, Interfacial protein film; TPA, Texture profile analysis.

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http://dx.doi.org/10.1016/j.foostr.2016.12.002
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In a recent study, we compared the effect of filler size and surface chemistry (hydrophobic vs. hydrophilic) on the large deformation properties of particle-filled myofibrillar protein gels (Gravelle et al., 2015). Through this investigation, it was shown that incorporating glass beads could improve gel stability and increased the Young's modulus of the composites, despite their apparent weak interaction with the continuous phase. This effect was found to be strongly dependent on the filler size, where smaller particles produced a greater reinforcement with increasing ϕ_f. This finding was in contrast to established particle-reinforcement theories, which account only for ϕ_f, and do not consider filler particle size. In a follow-up study, it was demonstrated that significantly smaller particles (on the order of 4 μm) have a much more pronounced effect on improving the large deformation properties and decreasing cooking loss during thermal gelation (Gravelle, Marangoni, & Barbut, 2016). It was shown that cooking loss was completely arrested, and there was a plateau in the observed reinforcement in the large deformation mechanical attributes at $\phi \geq 0.03$, which is far below the regime where particle-reinforcement is theoretically expected. It was thus hypothesized that the aqueous phase was stabilized at the surface of the hydrophilic glass particles during gelation. This was demonstrated by T_2 relaxometry, where shorter relaxation values were observed in the samples prior to gelation, indicating a reduction in water mobility during the gelation process. It was therefore hypothesized that water migration through the protein network was restricted, resulting in a decrease in the formation of water channels and micro-fractures within the gel, giving rise to the observed decrease in liquid expulsion and improvement in mechanical attributes.

The goal of the present study is to further investigate the influence of particle size and surface properties (extent of hydrophilicity) on the reinforcement of myofibrillar protein gels at low ϕ_f. Through this work, we hope to further elucidate the mechanism by which a solid, insoluble particle which weakly interacts with the gel matrix is able to improve the stability and large deformation properties of these composite materials.

2. Materials and methods

2.1. Materials

Approximately 25 kg of fresh boneless, skinless chicken breast meat was purchased from a national supermarket (Kirkland Signature, Costco Wholesale Canada Ltd., Ottawa, ON, Canada). Within 24 h of purchasing, all visible fat and connective tissue was removed and the meat was chopped in a bowl chopper (Schneidmeister SMK 40, Berlin, Germany) at the low speed setting for approximately 60 s and incorporated by hand to produce a homogeneous mixture. The meat was then portioned into ~800 g batches in bags, vacuum packed, and stored at −20 °C until use. Protein content was determined to be 21.2 wt% using the Dumas method and a nitrogen conversion factor of 5.53 (Mariotti, Torné, & Mirand, 2008).

Two sizes of spherical glass beads were obtained for the present study, having a mean diameter of 7–10 μm and 30–50 μm (Potters Industries, LLC, Malvern, PA, USA), according to manufacturer specifications. A second version of each filler size with a coating made up of amino-functional groups chemically attached to the surface was also obtained. All particles had a density of 2.5 g/mL and a minimum of 85% sphereicity, according to manufacturer specification sheets. All particles were used as received.

2.2. Preparation of filled myofibrillar protein gels

All composites were prepared in a household food processor (Braun Household, Germany) and formulated to have a final protein content of 11 wt% in the continuous phase. Glass beads were added on a volume fraction basis (volume fraction filler, ϕ_f), from $\phi_f = 0$ to 0.05 for the 7–10 μm particles and from $\phi_f = 0$ to 0.12 for the 30–50 μm particles. The 7–10 μm particles were first dispersed in a portion of the aqueous phase prior to being incorporated into the meat slurry, to avoid the formation of dry aggregates. The 30–50 μm particles were mixed in by hand immediately after the chopping procedure, as they incorporated into the meat more readily. Prior to preparation, each portion of meat was completely defrosted overnight under refrigerated conditions (~4 °C), and any remaining connective tissue was removed by hand. Meat batters were prepared using a previously described method (Gravelle et al., 2015) and were formulated to produce a total of ~200 g of sample. Briefly, two parts meat (74–104 g, depending on the formulation) were chopped for 60 s, followed by the addition of one part distilled water (10 s chopping) and an additional 2.5% NaCl (10 s chopping). The slurry was then put in an ice bath for 5 min to facilitate the extraction of salt-soluble myofibrillar proteins (ionic strength ~0.42 M). The remaining water was added and the mixture was further chopped for a total of 80 s. For batters prepared with the 7–10 μm particles, the particles were dispersed in this final portion of water prior to incorporation. To ensure the mixture was chopped homogeneously, the batter was scraped off the base and walls of the chopping unit at regular intervals throughout the preparation procedure. After chopping, the batter was refrigerated at ~4 °C for a minimum of one hour prior to thermal treatment. All formulations were independently prepared and each was repeated three times in a randomized block design.

After chilling, for each composite batter, 40 g samples were stuffed into four 50 ml polypropylene centrifuge tubes (Fisher Scientific, Ottawa, ON, Canada) and centrifuged (model 225, Fisher Scientific) at a low speed for 30 s to remove large air pockets. To induce gelation, the composite batters were gradually heated to an internal temperature of 72 °C in a water bath (Haake W-26, Haake, Berlin, Germany). The heating process took approximately 75 min and the internal temperature was monitored using thermocouple unit (Fluke Co. Inc., model #52 K/J, Everett, WA, USA) fed through a rubber stopper. Once the target temperature was reached, the composites were briefly transferred to an ice bath to arrest the gelation process and subsequently refrigerated overnight prior to analysis.

2.3. Cooking loss

After overnight storage, the composite gels were equilibrated to room temperature and the excess liquid which was expelled during thermal treatment was drained and weighed. Cooking loss was expressed as the mass of the total expelled liquid relative to the mass of the meat batter (i.e. excluding the filler) prior to thermal treatment. No fat loss was observed.

2.4. Large deformation/textural properties

Evaluation of mechanical and textural properties of the gels was carried out using a two cycle uniaxial compression test (Bourne, 1978). For each sample, a total of 12 cylindrical cores (height: 10 mm; diameter: 15 mm) were compressed twice between two parallel plates to 50% of their original height using a texture analyzer (model TA.XT2, Stable Micro Systems, Texture Technologies Corp., Scarsdale, NY, USA) outfitted with a 30 kg load cell. The crosshead speed was fixed at 1.5 mm/s and all composites were tested at room temperature. From this test, a variety of parameters were obtained, including Hardness, Resilience, Springiness, and Cohesiveness (Bourne, 1978).

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