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Biscuit dough structural changes during heating: Influence of shortening and cellulose ether emulsions

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ABSTRACT

The effect of using a variety of cellulose ether emulsions as a fat source, instead of a conventional shortening, on the structural changes occurring in a dough biscuit recipe during heating were studied. Linear viscoelastic properties and texture properties during heating were compared. In comparison to conventional shortenings, the cellulose ether emulsions are a healthier option characterized by lower fat content, lower saturated fatty acids content and the absence of trans fatty acids.

In the dough with shortening, temperature had the biggest influence on the viscoelastic properties, characterized by a decrease in viscoelasticiy within the temperature range from 25 °C to 45 °C. In the cellulose ether emulsions dough the increase in temperature produced a slow linear decrease in the elastic and viscous moduli. At 80 °C all dough showed similar viscoelastic behavior. The texture development during baking differed among the recipes. In the shortening dough the texture changes appeared since the first minute of heating, while in the emulsion dough, the effects were noticeable after 5 min of baking and varied according to the cellulose ether thermal gelation properties. A final crispy texture was obtained in all the recipes, although the cellulose emulsion biscuits required longer baking times.

1. Introduction

The reduction of fat in the everyday diet has become a public health issue and is an important concern for most consumers who wish to follow healthier habits (Zoulias, Oreopoulou & Tzia, 2002). In the topic of fat reduction, the most important concern is the reduction of saturated fat and the elimination of trans fatty acids from the diet. Although some controversy exists regarding the health effects of saturated fatty acids, the negative health effects of trans fatty acids have been accepted. While the debate regarding the exact health effects of these fatty acids (particularly saturated fatty acids) is unsolved what is clear is that food manufacturers have initiated a trend of moving away from ingredients containing saturated fatty acids and trans-fatty acids on the basis of consumer demand (Co & Marangoni, 2012). The World Health Organization recommends that fat consumption should be shifted towards unsaturated fats, as opposed to saturated-fats and trans-fats (W.H.O., 2004).

Fat sources higher in unsaturated fatty acids lack structure at room temperature. As a consequence, they can produce adverse effects in food products which often results in a reduction of product quality when used as a direct substitute for solid fats (Hughes, Marangoni, Wright, Rogers, & Rush, 2009; Youssef & Barbut, 2009).

Nowadays, transesterification is the highly employ method to increase fatty acids saturation, as contrary to the partial hydrogenation process no trans fatty acids are formed. However, the ideal option should be the possibility to employ fat sources higher in unsaturated fatty acids such as edible oils, as such, without the need to increase its saturation.

In short-dough biscuits fat is an essential ingredient and it is the largest component after flour (Manohar & Rao, 1999). The major functions of fats in baked systems are imparting shortening, richness, and tenderness all which contribute to improve flavor and mouthfeel (Pareyt & Delcour, 2008). In general, higher percentages of fat produce more tender biscuit (Lai & Lin, 2006). While the water or sugar solution in the absence of shortening would interact with the flour proteins to create cohesive and extensive gluten. When shortening is present, the fat surrounds the proteins and the starch granules, isolates them, therefore breaking the continuity of

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the protein and starch structure (Ghotra, Dyal, & Narine, 2002). This phenomenon results in eating properties after baking that are described as less hard, shorter, and more inclined to melt in the mouth.

Due to the important functionality of fat in biscuits, fat reduction without affecting quality properties and consumer acceptability is a challenging task.

Different approaches have been carried out to reduce fat in biscuits with various levels of success. Fat replacement in biscuits has been studied by many different authors (Inglett, Warner, & Newman, 1994; Laguna, Primo-Martín, Varela, Salvador, & Sanz, 2014; Laguna, Varela, Salvador, Sanz, & Fiszman, 2012; Rößle, Ktenioudaki, & Gallagher, 2011; Sudha, Srivastava, Vetrimani, & Leelavathi, 2007; Zbikowska & Rutkowska, 2008; Zoulias, Oreopoulou & Kounalaki, 2002; Zoulias, Oreopoulou & Tzia, 2002).

Hydroxypropyl methylcellulose (HPMC) has been used as fat replacer in baked goods, frozen desserts, dry mix sauces, dressings (Akoh, 1998) and gluten free breads (Mariotti, Pagani & Lucisano, 2013; Sabanis & Tzia, 2011). Methylcellulos (MC) and HPMC thermal gelation properties were also employed to reduce fat absorption in flour based batters; MC and HPMC confers the flour semisolid consistency at lower temperatures than frying temperatures and the formation of a barrier again moisture loss and oil absorption (Sanz, Fernández, Salvador, Muñoz, & Fiszman, 2005; Sanz, Salvador, & Fiszman, 2004; Sanz, Vélez, Salvador, Muñoz, & Fiszman, 2005). HPMC was used as fat replacer in short-dough biscuits by Laguna et al. (2014). In this first work, authors used a pre-hydrated HPMC solution, which was added to the dough as a fat replacer in the biscuit, however, they did not achieve shortening replacement higher than 15%, due to negative consumers' score in acceptance.

Tarancón, Fiszman, Salvador, and Tárrega (2013) investigate the use of a vegetable oil cellulose ether emulsion as shortening replacer. The consistency provided by the cellulose emulsion makes it possible to incorporate liquid oil in the biscuit recipe and provides a good consistency to manipulate the biscuits (laminate, cut and baked) in the same way that a full fat recipe would.

In this way not only a reduction of the total amount of fat is accomplished but also a reduction of saturated fatty acids and the elimination of trans fatty acids. Biscuits prepared with the cellulose emulsions had good consumer acceptability (Tarancón et al., 2013; Tarancón, Sanz, Fiszman & Tárrega, 2014; Tarancón, Sanz, Salvador & Tárrega, 2014).

The cellulose ethers methylcellulose (MC) and HPMC are employed to prepare the emulsions to have thermo-gelling ability. In solution these polymers are completely hydrated and with little polymer–polymer interaction other than simple entanglement. As the temperature is increased, an initial drop in viscosity is observed due to the decrease in the water hydration. When critical temperature is reached, sufficient dehydration occurs to promote polymer–polymer interactions instead of polymer–solvent interactions. As a consequence, these cellulose ether solutions start to gel. Upon cooling, the gelation process is completely reversed and the gel formed will revert to a sol state, recovering its original consistency. The temperature at which the gelation process starts and the strength of the gel formed depends on; the type and degree of substitution of the cellulose, molecular weight, concentration and presence of electrolytes (Nishinari, Hofmann, Moritaka, Kohyama, & Nishinari, 1997; Sarkar, 1979).

The thermal gelation properties of cellulose ethers appear to have an important role in the success of the cellulose emulsions as fat replacers, as emulsions without these property (xanthan gum emulsion) did not provide successful sensory properties. However, the role of the thermal properties of the cellulose ethers in texture development during biscuit baking has not been studied.

In a previous study the interaction of the cellulose ether with the other ingredients of a biscuit recipe was investigated at room temperature by the study of the rheological properties at small deformation (creep and viscoelastic properties). The cellulose emulsion conferred higher deformability to the dough and lower percentage of recovery in comparison to a control dough prepared with shortening, which was associated to higher spread and greater diameter in the final biscuits. The obtained biscuit texture properties could not be associated to the dough's rheological properties at room temperature (Tarancón, Hernández, Salvador & Sanz, 2015).

The aim of this study is to investigate the structural changes occurring during baking in a conventional biscuit dough (prepared with shortening) and in doughs' prepared with different cellulose emulsions as shortening replacers. First, the thermo-rheological properties of the different cellulose ether emulsions employed as shortening replacers and of the different biscuit dough (with shortening and with cellulose ethers) were studied. Second, the dough biscuit texture changes at different stages during baking was also investigated and related to rheological properties.

2. Materials and methods

2.1. Emulsion preparation

Oil-water-cellulose ether emulsions were prepared with three different cellulose ethers each with different thermo-gelling ability, supplied by The Dow Chemical Co. (E4M, K4M and A4M). They differ in their methoxyl and hydroxypropoxyl percentages. E4M and K4M are hydroxypropyl methylcellulose with 29.0% methoxyl and 9.3% hydroxypropoxyl (E4M) and 22.8% methoxyl and 8.1% hydroxypropoxyl (K4M), and A4M is a methylcellulose with 29.9% methoxyl. All have a viscosity around 4000 mPa s at 2% aqueous solution at 20 °C, A4M (3938 cps), E4M (5063 cps) and K4M (3183 cps) measured by The Dow Chemical Company following reference methods ASTM D1347 and ASTM D2363. The ingredients of the emulsion were sunflower oil with high level of oleic acid (Carrefour, Madrid, Spain), water and the different cellulose ethers. The proportions employed were sunflower oil 51%, water 47% and cellulose ether 2%. The cellulose ether was first dispersed in the oil using a Heidolph stirrer at the lowest speed for 5 min. The mixture was then hydrated by gradually adding the water at 10 °C while continuing to stir. The water temperature of 10 °C was selected according to the specific hydration requirement of cellulose ethers. Stirring continued using a homogenizer (Ultraturrax T18, IKA, Germany) until the emulsion was obtained.

2.2. Biscuit dough preparation

The dough ingredients (flour weight basis) were shown in Table 1. The composition data of the soft wheat flour provided by

Table 1
Biscuit formulations prepared with shortening or emulsion as a shortening replacer.

Ingredient (%)	Control	Emulsion
Flour	100	100
Shortening	32.15	–
Emulsion as shortening replacer	–	32.15
Sugar	29.45	29.45
Milk powder	1.75	1.75
Salt	1.05	1.05
Sodium bicarbonate	0.35	0.35
Ammonium bicarbonate	0.2	0.2
Water	9.00	9.00
Glycerol	–	3.2