LWT - Food Science and Technology 60 (2015) 148–155

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Effect of prebiotic ingredients on the rheological properties and microstructure of reduced-sodium and low-fat meat emulsions

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A R T I C L E I N F O

Article history:
Received 23 April 2014
Received in revised form
3 August 2014
Accepted 6 August 2014
Available online 14 August 2014

Keywords:
Fat reduction
Gelling
Meat emulsion
Prebiotic fibers
Sodium reduction

A B S T R A C T

The technological and rheological properties were evaluated for low-fat and reduced-sodium meat emulsions containing various levels of prebiotic fibers (inulin, FOS, polydextrose, and resistant starch) as fat and starch substitutes. Low emulsion stability was observed, mainly in the treatments containing inulin and polydextrose (3 and 6 g/100 g). Higher tenderness was observed in the low-fat bologna sausages containing prebiotic fibers. The prebiotic fibers influenced the color of the meat batters but not that of the bologna sausage, probably due to the curing reactions and fat melting and subsequent solidification reaction. The meat batters presented elastic behavior, demonstrated by a G' value that was higher than the G'' value during oscillatory tests. An increase in the gelation temperature may result from the addition of the fibers, which delayed the gelation reaction of the myosin. The microstructures showed a porous matrix in the treatments containing prebiotic fibers, and a compact and dense network was observed only in the control formulations and that one containing inulin, due to its chain length. Further studies are required to evaluate the suitable levels in low-fat and reduced-sodium meat emulsions of prebiotic fibers, including cassava starch, which it is not possible to remove completely from the formulations.

1. Introduction

Meat and meat products are important components of the current diet and an excellent source of proteins, iron, zinc, niacin and vitamins (Brewer, 2012). However, these products are also recognized for their high sodium and fat contents and a fatty acid profile rich in saturated fatty acids and cholesterol, which can increase the incidence of coronary heart disease (CVD), obesity, high blood cholesterol and certain types of cancer (Colmenero, 1996; Desmond, 2006; Hooper et al., 2001; Keeton, 1994; Zhang, Xiao, Samaraweera, Lee, & Ahn, 2010). Excessive sodium intake is considered a critical public health issue, and it has been correlated to an increase in hypertension (WHO, 2006).

Over recent decades, several public health organizations (American Heart Association, American Cancer Society) have proposed to limit the daily total fat intake to no more than 30 g/100 g of total calories, saturated fatty acids to less than 7 g/100 g of calories and a maximum of 300 mg cholesterol/day to further reduce the risk of CVD (Skulas-Ray, Flock, & Kris-Etherton, 2013). Regarding sodium intake, the World Health Organization (WHO) recommends a maximum of 5 g NaCl daily. These recommendations, consequently, have contributed to promoting extensive research on low-fat and low-sodium meat products, which is a big challenge to the meat industry due to the technological importance of these components (Ansorena & Astiasarán, 2004; Carrapiso, 2007; Jiménez-Colmenero, Reig, & Toldrá, 2006).

Sodium chloride plays an important role in the extraction of the myofibrillar proteins that are responsible for development of functional properties of emulsified meat products (bologna sausage and frankfurters), such as the water-holding capacity, gel formation

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http://dx.doi.org/10.1016/j.lwt.2014.08.004
0023-6438/

and emulsification (Desmond, 2006). Sensorial acceptance and microbiological stability are also attributed to NaCl in emulsified meat products. Fat contributes to the flavor, texture, mouthfeel, overall sensation of lubricity and appearance of meat products (Brewer, 2012). Thus, the major problems in reducing fat and sodium chloride in finely comminuted meat products include the low sensorial acceptance and reduced global stability (Campagnol et al., 2013; dos Santos, Campagnol, Pacheco, & Pollonio, 2012; Vural, Javidipour, & Ozbas, 2004).

Many studies have reported the addition of functional ingredients as fat substitutes in emulsified meat products that significantly improve the nutritional value (Caceres, Garcia, Toro, & Selgas, 2004; Nowak, von Mueffling, Grotheer, Klein, & Watkinson, 2007; dos Santos et al., 2012; Santos et al., 2013). Among these compounds, prebiotic fibers enhance the growth of beneficial bacteria in the lower intestine, contributing to gastrointestinal health (Li, 2010). An immune function has been indicated by relevant scientific studies, in particular due to their resistance to hydrolysis by digestive enzymes (Homayouni et al., 2014; Jiménez-Colmenero, Carballo, & Cofrades, 2001).

FOS, inulin, resistant starch, and polydextrose are examples of potential prebiotic components which can be applied in meat emulsions to substitute for fat, based on their technological properties. FOS shows a neutral taste, stability over a wide pH and temperature range and has successfully been used in certain meat products (Caceres et al., 2004). Inulin has been added to many products, including sausages, meatballs and restructured products, and has shown good performance as a fat substitute due to its ability to form a gel when mixed with water (Álvarez & Barbut, 2013; García, Cáceres, & Selgas, 2006; Huang, Tsai, & Chen, 2011; Santos et al., 2013). Polydextrose is also odorless, showing high solubility in water (80 g/100 g at 20 °C), which allows the formation of high-viscosity solutions and the improvement of texture by replacing fat. Resistant starch can also be easily incorporated into food products due to its microparticulate structure that does not affect the appearance of the final product (Burdock & Flamm, 1999; Murphy, 2001; Niness, 1999; Sajilata, Singhal, & Kulkarni, 2006). However, there are few studies reporting the use of polydextrose and resistant starch in meat products, and the potential application of all of these fibers has not been sufficiently studied in emulsified meat products with simultaneous fat and sodium chloride reduction.

Therefore, the present study aimed to evaluate the effect of the addition of various prebiotic fibers on the rheological and technological properties and the microstructure of an emulsified meat product (bologna), with a simultaneous reduction of sodium chloride (NaCl) and pork-back-fat content.

2. Material and methods

2.1. Meat-batter formulation

Bovine raw material (knuckle – *M. quadriceps femoris*) and pork fat were obtained from a local market in Campinas (SP, Brazil) with guaranteed quality. The meat pieces were previously cleaned to remove the visible fat, cut into strips and then frozen. The pork fat was portioned, ground into 3-mm disks and stocked at −18 °C until use.

Bologna sausage formulations (FC1, FC2, FC3, F1–F10) were prepared based on a traditional emulsified meat product containing 60 g/100 g beef, 0.25 g/100 g sodium polyphosphate, 0.05 g/100 g sodium erythorbate, and 150 ppm sodium nitrite. Fructo-oligosaccharide (FOS) (NutraFlora® P95), resistant starch (Hi-Maize 260), inulin (Orafti® GR) and polydextrose (Sta-Lite® III) were added in two levels (3 and 6 g/100 g). Ice was added to attain 100 g/100 g for the formulation (Table 1).

All bologna sausage formulations were processed in a pilot plant on the same day according to industrial procedures. Condiments were not used because sensory evaluation was not the focus of the study. The portioned and frozen beef (−1 °C) was ground into 5-mm disks at the time of use and placed into a cutter (Mado, model MTK – 661, Germany) with NaCl and was comminuted for 3–4 min at low speed to extract myofibrillar proteins. The other additives were slowly added when the temperature reached 5–6 °C, and the temperature of the meat batters never exceeded 12 °C. A portion of the meat batter was packaged in plastic packages (30 × 50 cm) under vacuum and kept under refrigeration (4 °C) for further analysis. The other portion was embedded into impermeable cellulose wrappers (Clariant, ø 9 cm) with approximately 0.5 kg of product per package. The bologna sausage pieces were placed in a water bath for cooking, with a gradual increase in temperature until the pieces reached the final core temperature of 72–74 °C. After cooking (~2 h) the products were cooled in an ice bath, vacuum-packaged and stored at 4 °C before analysis.

2.2. Physical analysis of batters and bologna sausage

2.2.1. Emulsion stability

The emulsion stability was performed according to Parks and Carpenter (1987), with some modifications to the cooking process: 40 °C/30 min followed by 70 °C/30 min. The total amount of liquid released was expressed as a percentage of the sample weight.

2.2.2. Color measurements

The color was measured using a spectrophotometer CM-5 (Konica Minolta) with a 20-mm port size, illuminant D65, SCI and a 10° standard observer. CIELAB L^*, a^* and b^* values were determined as indicators of lightness, redness and yellowness, respectively. The refrigerated meat batters were placed in the sampler with at least 0.5 cm in height, and the bologna sausage samples were sliced (0.5-cm thick). Measurements were performed in triplicate for each treatment.

2.2.3. Instrumental texture

The instrumental texture was measured using a TA XT2i texture analyzer (Texture Technologies Corp., Scarsdale, NY) equipped with a 25-kg load cell, using Texture Expert V1.19 software (Stable Micro Systems). The meat batters were stored at 4 °C/24 h in a container (5 cm × 7 cm) for stabilization, and the force required to penetrate 2.5 cm material was measured at 2 mm/s using a 60° conical probe. The bologna sausage samples were cut into cylinders (20 mm × 20 mm), and the compression strength (50% of their original height) was measured with a cylindrical probe of 35 mm in diameter at 1 mm/s.

2.2.4. Rheological properties

The rheological behavior of the samples was evaluated by oscillatory shear measurements in a controlled-stress rheometer (AR 1500ex rheometer, TA Instruments, England) equipped with a circular parallel-plate (2-cm diameter, 1.5 mm gap). The samples of batters were gently placed onto the plate and allowed to equilibrate for 5 min at 4 °C. Frequency sweeps from 0.01 to 10 Hz were performed on the meat batters at 7 °C and a fixed strain of 1%. Temperature sweeps (1 °C/min) were performed in two steps to simulate the batter cooking: a heating step from 25 to 75 °C followed by a cooling step from 75 to 25 °C, both at 1 Hz and 60 Pa. The changes in the slope of the complex viscosity (η^*) *versus* temperature curve were maximized from the derivation of the data using the Savitzky and Golay filter (1964), and the gel point was determined when the slope of the log (η^*) was greater than 0.01 (Picone & Cunha, 2011).