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Effect of radio-frequency on heating characteristics of beef homogenate blends

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ABSTRACT

The heating characteristics of different lean-to-fat ratios in ground beef (90/10, 85/15, 80/20, 73/27) was investigated using radio-frequency (RF) heating of ground beef homogenates. A homogenate model system was prepared with ground beef in phosphate buffer (pH 6.0). Homogenate blends were packaged in vacuum bags, immersed in pre-heated water at 10, 25 and 50 °C, and heated in the RF equipment to a target temperature of 60 °C. Beef homogenate blends with more lean and less fat (90/10 and 85/15) heated more rapidly, reaching the target temperature faster than the higher fat composition blends. The RF heating rates of the beef homogenate blends varied with water temperature; higher temperature resulted in rapid RF heating. The RF heating rate at 50 °C was the most rapid in heating all homogenate blends. The instrumental color characteristics for RF heated homogenate blends exhibited lower L^* and a^* values than uncooked homogenate blends. RF heating resulted in reduced redness and more oxidation of myoglobin (metmyoglobin formation) and lesser oxy- and deoxy-myoglobin redox forms in all beef homogenate blends independent of the initial water temperature. The results present scope to explore short time heating processes which will minimize quality deterioration in RF heated meat products.

1. Introduction

Radio-frequency (RF) involves generating heat energy inside a food product using an electromagnetic field. RF is a form of dielectric heating with direct interaction between food and electromagnetic waves. A food product is positioned between two electrode plates emitting radiofrequency waves and it provides deep penetration and uniform heating across the food sample, which makes RF a promising technology (Laycock, Piyasena, & Mittal, 2003; Wang, Wig, Tang, & Hallberg, 2003; Zhao, Flugstad, Kolbe, Park, & Wells, 2000). During RF heating, heat is generated within the product that may create a temperature gradient between the surface and interior of the product (Bengtsson, Green, & Valle, 1970; Brunton et al., 2005; Laycock et al., 2003; Lyng, Cronin, Brunton, Li, & Gu, 2007). Several authors (Bengtsson et al., 1970; Brunton et al., 2005; Kirmaci & Singh, 2012; Laycock et al., 2003; Luechapattanaporn et al., 2005; Lyng et al., 2007) have documented the benefits of RF heating in commercial products.

RF heating has the potential for industrial application for pasteurization and sterilization of solid and semi-solid foods (Luechapattanaporn et al., 2005, 2004). Houben, Shoenmakers, Van Putten, Van Roon, & Krol (1991) evaluated potential for RF heating for pasteurizing sausage emulsions. Several studies (Brunton et al., 2005; Buffler, 1993; Datta & Davidson, 2000; Kirmaci & Singh, 2012) have compared the efficiency of RF heating to conventional cooking methods, such as water bath, steam, and microwave cooking. However, RF heating has often been linked to arcing, which may result in dielectric breakdown and thermal runaway (Brunton et al., 2005; Kirmaci & Singh, 2012; Parker, Reath, Krauss, & Campbell, 2004; Zhao et al., 2000). Immersing food products in water during RF heating prevents both dielectric breakdown and arcing and limits heat dissipation (Kirmaci & Singh, 2012; Lyng et al., 2007). The RF cooking of meat products is faster, reduces cooking loss, and improves juiciness and water holding capacity (Laycock et al., 2003). In a similar study, McKenna, Lyng, Brunton, & Shirsat (2006) reported that RF cooked meat were firmer than steam cooked samples. These authors also reported that the RF cooked leg hams exhibited higher Hunter a^* values and lower hue angles than steam cooked leg hams.

Dielectric properties of foods and food components determine how they interact with RF energy, and the lipid content in meat products acts as a non-conductive barrier in different meat-fat blends (Bozkurt & Icier, 2010). Varying lean/fat percentages in ground beef products affects their electrical conductivity (Bozkurt & Icier, 2010) and may differ in heating pattern and final product quality under RF treatments. Meat products containing more than

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one component such as lean and fat has been suggested to exhibit dielectric properties of each component separately (Farang, Lyng, Morgan, & Cronin, 2011). Higher composition of lean in fat-to-lean blend have a greater tendency for lean to heat at a faster rate as compared to fat (Bengtsson, Melin, Remi, & Söderlind, 1963). The low dielectric properties of fat compared to lean would suggest a greater temperature gradients with higher fat contents when subjected to RF heating (Farag, Marra, Lyng, Morgan, & Cronin, 2009). However, McKenna et al. (2006) noted that dielectric properties may not always relate to the gross composition of the product due to complexity of chemical and physical binding of the food components.

To validate that RF heating of ground beef products varies with lean/fat ratio, a beef homogenate was selected as model system. Since, addition of water to a solid system will significantly change the physical properties, we used phosphate (100 mMol/L) instead of water at the same pH as ground beef. Preliminary experiments performed did not show a significant change in the physical and heating properties except the heating rate effects. Moreover, beef homogenates are physically homogeneous with a fairly uniform water and fat distribution, and are convenient to package into sealed packets which can be immersed in water trays for RF processing. The objectives of this study were to determine the effects of initial temperatures (10, 25, and 50 °C) of immersion water and fat levels of ground beef (10, 15, 20, and 27 percent) on the RF heating rates of homogenates and also evaluate the effects of RF heating on beef homogenate instrumental color properties and myoglobin redox forms.

2. Materials and methods

A flow diagram of the RF heating procedure is provided in Fig. 1. Preliminary studies were conducted to select type of heating tray, packaging material, heating medium (water) temperature, and distance between electrodes. A customized polyetherimide grid was built and placed on top of the homogenate bags to hold them firmly immersed in water during RF heating (Kirmaci & Singh, 2012).

2.1. Beef homogenates preparation

Fresh ground beef (lean/fat ratios: 90/10, 85/15, 80/20, 73/27) were obtained from a local retail store. We obtained certificate of

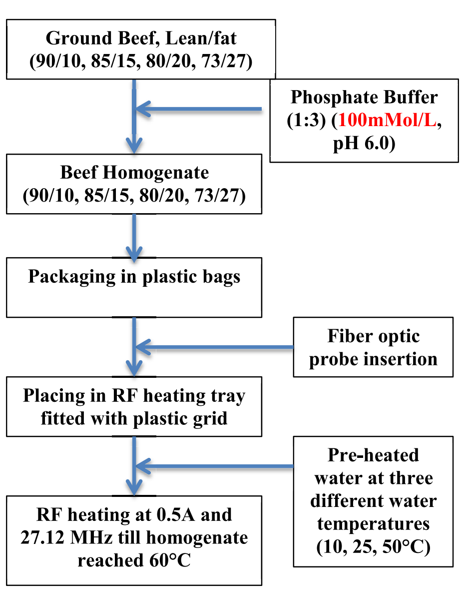

Fig. 1. Flow diagram showing radio-frequency heating protocol for beef homogenate.

analysis from the beef purveyor to verify the fat to lean ratio of the purchased meat. The ground beef (devoid of connective tissue) was homogenized with phosphate buffer (100 mMol/L, pH 5.8–6.0; 1:3 ratio). Samples were homogenized at 5000 rpm with a variable speed homogenizer (Model: Tissue Master 125, VWR International, LLC, Arlington Heights, IL, USA) for 25 s. Homogenates (230 mL) were poured into transparent 4 Mil vacuum pouches (Bunzl Processor Division, St. Louis, MO, USA) and sealed with a bar sealer (Omcan Impulse bag sealer, Hotel Supply Warehouse, Inc., Deerfield Beach, FL, USA). The homogenate bags (3 cm height × 12 cm width × 16 cm length) were stored overnight in the dark at 10 °C before subjecting to RF heating. The ground beef homogenate was stored in the dark to protect myoglobin from light induced oxidation before RF heating. pH of the beef homogenate was measured using a metal probe pH meter (I.Q. Scientific Instruments, Loveland, CO, USA).

2.2. RF equipment

The electric current and heating for the RF were adjusted based previously reported experiments conducted in our laboratory (Deshpande, 2008; Kirmaci & Singh, 2012). The RF equipment (Model S061B Stray-field Ltd, Reading, UK) set up consisted of a RF generator, two electrodes, and a conveyor belt. The RF equipment was operated at a constant frequency of 27.12 MHz and at 6 kW. The homogenate samples were placed between the two electrodes on a stationary conveyor belt, and the RF equipment was operated at a constant active current of 0.5 A by adjusting the gap between electrodes.

2.3. RF heating procedure

The homogenate bags were each fitted with a fiber optic temperature probe (Fiso Tech. Inc., Quebec, Canada) inserted through a sealed stuffing box (C-5.2D, Eucklund-Harrison Tech., Fort Myers, FL) and placed in the RF heating tray (48.26 × 27.94 × 6.35 cm^3). 6750 mL of water was used in the trays to keep the homogenate bags completely submerged in the tray throughout RF heating in a static aqueous medium. A polyetherimide grid (27.94 × 19.05 × 3.81 cm^3) was placed on top of the bags to hold the bags under the water. Water was either heated or cooled to 10, 25, and 50 °C, filled in the trays and the beef homogenate bags were immersed in it. The RF heating was started, and the temperature rise was recorded every 5 s by a computer connected to the signal conditioner. Heating stopped once the homogenate bags reached the target temperature (60 °C). The temperatures of the homogenates were measured during RF heating using a fiber optic temperature probe (Fiso Tech., Inc., Quebec, Canada) that was held in place using a stuffing box (C-5.2D, Eucklund-Harrison Tech., Fort Myers, FL, USA) with the fiber optic probe inserted and screwed down in the center. Since the temperature of the homogenate bag was measured at the center only, a temperature gradient between the surface and the interior of the product was not observed. After RF heating, homogenate bags were immediately removed from the hot water and allowed to cool down at 20 °C temperature before further measurements were made.

2.4. Color measurements

Color measurements of the raw and RF heated samples were performed using the Hunterlab® MiniScan EZ Spectrophotometer (D/8-S, 45/0 LAV, 14.3 mm diameter aperture, 10° standard observer, Illuminant A; Hunter Associates Laboratory, Inc., Reston, VA, USA). CIE parameters for L^* (Lightness), a^* (redness), b^* (yellowness) were determined for raw and RF treated homogenates to highlight the effect of RF heating on meat color and myoglobin