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Influence of infrared final cooking on color, texture and cooking characteristics of ohmically pre-cooked meatball

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ABSTRACT

The objective of the current study was to improve the quality characteristics of ohmically pre-cooked beef meatballs via infrared cooking as a final stage. Samples were pre-cooked in a specially designed-continuous type ohmic cooker at a voltage gradient of 15.26 V/cm for 92 s. Infrared cooking was then applied to the pre-cooked samples at different combinations of heat fluxes (3.706, 5.678, and 8.475 kW/m^2), application distances (10.5, 13.5, and 16.5 cm) and application durations (4, 8, and 12 min). Effects of these parameters on color, texture and cooking characteristics of ohmically pre-cooked beef meatballs were investigated. The appearance of ohmically pre-cooked meatball samples was improved via infrared heating. A dark brown layer desired in cooked meatballs formed on the surface of the meatballs with lowest application distance (10.5 cm) and longest application duration (12 min). The texture of the samples was also improved with these parameters. However the cooking yield of the samples decreased at the longest application duration of infrared heating.

1. Introduction

The micro-structure of meat products undergo substantial structural changes during cooking and therefore the quality of the meat product which mainly depends on the meat structure also changes drastically after cooking (Tornberg, 2013). The physical properties and quality of cooked meat are strongly affected by the degree of protein denaturation resulting from different heat treatment conditions, such as temperature and time (Ishiwatari, Fukuoka, & Sakai, 2013). Products such as meat patties are mainly comprised of comminuted meat fibers containing a high fraction of water and fat. Meat proteins contract as a result of thermal denaturation during thermal processing which leads to a substantial weight loss (Oroszvári, Bayod, Sjöholm & Tornberg, 2005; Palka & Daun, 1999; Pan & Singh, 2001). There are different methods for preparing meat patties for consumption such as deep fat frying, single-sided and double-sided contact frying, microwaving, infrared radiation and convection heating (Erdogdu, Zorrilla, & Singh, 2005; Zorrilla & Singh, 2000). Since the exterior region of the samples is heated faster than the interior region in conventional heating, the inadequate cooking could occur in the interior regions (Somavat, Mohamed, Chung, Yousef, & Sastry, 2012). A more homogenous heating can be achieved, by using processing technologies such as high pressure and/or electro-based heating (radio frequency cooking and ohmic heating) with and without additional heating due to the fact that volumetric heating is a type of heating process in which the whole volume is heated at the same time (Tornberg, 2013).

Ohmic heating has been developed during the past two decades and is used in commercial scale operations for processing a variety of food products (Sastry & Salengke, 1998; Yildiz-Turp, Sengun, Kendirci, & Icier, 2013). It is based on the passage of electrical current through a food product with electrical resistance (Icier & Ilicali, 2005; Reznick, 1996). Heat is generated instantly inside the food and the amount of heat is directly related to the voltage gradient and the electrical conductivity (Sastry & Li, 1996). The uniform heat generation results in uniform temperature distribution. Ohmic cooking has other advantages when compared with conventional heating such as shorter processing times and higher yield while still maintaining the color and nutritional value of the food (Castro, Teixeira, Salengke, Sastry, & Vicente, 2004; Icier & Ilicali, 2005; Leizerson & Shimoni, 2005a, 2005b; Vikram, Ramesh, & Prapulla, 2005; Wang & Sastry, 2002). Several studies have been conducted on the application of ohmic treatment to meat and meat products for the purpose of achieving fast and energy efficient cooking/semi-cooking (Bozkurt & Icier, 2010a, 2010b; Ozkan, Ho, & Farid, 2004; Sengun, Yildiz Turp, Icier, Kendirci, & Kor, 2014; Shirsat, Brunton, Lyng, McKenna, & Scannell, 2004; Vasanthi, Venkataramanujam, & Dushyanthan, 2007; Wills, Dewitt, Sigfusson, & Bellmer, 2006; Zell, Lyng, Denis, Cronin, & Morgan, 2009). On the other hand, it has also been reported as an inefficient cooking method for the complete inactivation of microorganisms and for the desirable changes in the surface color and texture of meat products (Bozkurt & Icier, 2010a, 2010b a;b; Icier & Bozkurt, 2011; Sengun et al., 2014). Although ohmic cooking provides homogeneous

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cooking, it does not form a sufficient crust on the outer surface of the meatballs which is necessary for visual acceptability (Kendirci, Icier, Kor, & Altug-Onogur, 2014; Yildiz-Turp et al., 2013).

Infrared is a form of electromagnetic energy that can cause heating on the surface of objects when absorbed (Huang & Sites, 2012). Infrared cooking is of particular interest to the food ingredients and the processed meat sector since conventional cooking ovens using high velocity hot air convection can cause overheating, oxidation, charring, impingement damage, low yield, difficult emissions as well as high energy costs. Infrared radiation has intrinsic advantages such as having no direct intention or necessity to heat the air, keeping oven temperatures and humidity at low values. A further advantage of this method is the ease with which heat can be applied evenly over a broad surface area (Sheridan & Shilton, 1999).

The combination of ohmic and infrared cooking could provide improvement in quality characteristics of meatball samples while achieving energy efficiency and reduced total cooking time compared to conventional cooking methods. There is no study on the evaluation of color, texture and cooking characteristics of meatball samples treated with a system consisting of a combination of ohmic and infrared cooking. Infrared cooking is mainly effective for surface heating and in this study it was applied as a final cooking method following the ohmic pre-cooking to improve especially the surface appearance of beef meatballs. Meatball samples were ohmically pre-cooked via the procedure put forth by Icier, Sengun, Yildiz Turp, and Arserim (2014). The objective of this current study was to determine the effects of infrared cooking on color, texture and cooking characteristics of ohmically pre-cooked beef meatballs.

2. Materials and methods

2.1. Samples

Lean beef as boneless rounds were supplied from a local processor (Burdur Güçbirligi Meat Facility A.Ş.) and stored at −18 °C which were used within one week. Thawed meat samples (at 4 °C for 12 h) were ground through a 3 mm plate grinder (Arçelik, Turkey) and mixed with the ingredients. Meatballs were produced according to the following recipe: meat (96%, *w*/*w*), onion powder (1%, *w*/*w*), salt (0.5%, *w*/*w*), sodium carbonate (0.5%, *w*/*w*) and distilled water (2%, *v*/*w*) (Icier et al., 2014). The mixture was kneaded for 15 min by hand, to obtain a homogeneous batter. The prepared batter was stored in a refrigerator (at 4 °C) for an hour after which it was shaped into cylindrical meatballs with a diameter of 0.025 m and length of 0.05 m length using a hollow cylinder block. Since the contact between the meatball and the electrode should be perfect for the uniform passage of the electrical current during ohmic cooking, the hollow cylindrical block was used as a standard mold to give the smooth cylindrical shape to the meatball batter. The production process stages of meatballs were carried out at room (20 ± 1 °C) temperature.

2.1.1. Ohmic cooking procedure

Ohmic cooking was applied as a pre-treatment before the final cooking of meatballs. Experiments were conducted in a specifically designed custom-made continuous belt type ohmic cooking system which consisted of a power supply, an isolating-variable transformer, a microprocessor board, temperature measurement units, ohmic cooking unit and a rotating belt system (Fig. 1a). The cooking unit was designed specially and includes rotating belt (Polyester Monofilament) with motor for controlling speed, two removable stainless steel electrodes (5 cm × 30 cm), electrically isolated Teflon mountings and electrical connections to the transformer unit. The electrodes were replaced in longitudinally parallel configuration (Fig. 1b). Temperature measurements were conducted by using Teflon coated T-type thermocouples (Cole Parmer, USA). The microprocessor board that was used to monitor the temperature, current (A) and voltage 141 applied (V) transmitted this information simultaneously to the microcomputer at constant time intervals (1 s) (Fig. 1b). The microprocessor was specifically custom designed for this system by Ege University Ege Vocational School of Higher Education Micro-Processing Program Laboratory. The detailed information about the ohmic cooking system was given in Icier et al. (2014). The sample was placed at the inlet of the continuous type cooking unit and sandwiched between the electrodes with compression. The belt was rotated at the speed of 0.25 cm/s following the sealing of the system and power was given to the system. The optimum ohmic treatment condition for the purpose of precooking the meatballs was determined as 15.26 V/cm voltage gradient (Icier et al., 2014). Ohmic cooking time required to reach the center temperature of 75 °C from the initial temperature of 20 °C was 92 s.

2.1.2. Infrared cooking procedure

Ohmically pre-cooked meatball samples were directly transferred to the infrared cooking device which was already combined to the ohmic cooking unit (Fig. 1b). The infrared cooking unit was designed to involve a specially rotating belt with motor for controlling speed, a power supply controlled with closed-circuit microprocessor unit and a heating cabinet (Fig. 1c). The detailed information about the infrared cooking procedure was put forth by Kendirci et al. (2014). The infrared heating cabinet consisted of specially polished reflective stainless steel inside walls, infrared heating source (4 μm wavelength, Philips) and temperature measurement units. (T-type thermocouples). The application heat fluxes could have been adjusted in the range of 3–10 kW/m^2. Cylindrical meatball was placed longitudinally into the continuous belt of the infrared system. The application distance between the infrared source and the meatball surface could have been adjusted in the range of 10–16.5 cm (Fig. 1c). The speed of the belt of the infrared unit was adjusted to obtain the prescribed residence times (4, 8 and 12 min) of the meatballs in the infrared unit. Since the infrared radiated directly the upper lateral surface of the meatball, samples were turned over to radiate the other surface for the half application time of the process. Infrared cooking parameters were selected as three different heat fluxes (3.706, 5.678 and 8.475 kW/m^2), three different application distances (distance between infrared unit and surface of meatball; 10.5, 13.5 and 16.5 cm) and three different application durations (4, 8 and 12 min).

2.2. Cooking yield

Percentage of cooking yield was determined by calculating the weight differences of the meatball samples before and after cooking (Murphy, Criner, & Grey, 1975). The cooked samples were cooled down to room temperature for 30 min and were reweighed to calculate the cooking yield.

2.3. Reduction in meatball diameter

Measurements of meatball samples were made by using a digital micrometer (Mitutoyo, Japan). The reductions in the diameters of meatballs were determined by calculating the diameter differences of the samples before and after cooking.

$$\text{Reduction in meatball diameter} = \frac{\text{uncooked meatball diameter} - \text{cooked meatball diameter}}{\text{uncooked meatball diameter}} \times 100. \qquad (1)$$

2.4. Reduction in volume

The reductions in the volume of meatballs were calculated by determining sample dimensions before and after the cooking process.

$$\text{Reduction in meatball volume} = \frac{\text{uncooked meatball volume} - \text{cooked meatball volume}}{\text{uncooked meatball volume}} \times 100 \qquad (2)$$