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Effects of ohmic heating for pre-cooking of meatballs on some quality and safety attributes

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ABSTRACT

Effectiveness of ohmic treatment on some quality attributes of semi-cooked meatballs was studied. Meatball samples were semi-cooked by 15.26 V/cm voltage gradient and 0 s holding time at 75 °C. Although ohmic cooking significantly reduced the numbers of total mesophilic aerobic bacteria, mould-yeast, *Staphylococcus aureus* and completely eliminated *Salmonella* spp. from meatball samples ($p < 0.05$), it was not found efficient to inactivate all *Listeria monocytogenes* cells. Ohmic semi-cooking process was resulted at higher cooking yields, which were supported by high fat and moisture retention values in meatball samples. Metal levels (iron, chromium, nickel and manganese) of ohmically semi-cooked meatball samples were found below the upper level of dietary exposure levels. Ohmic cooking procedure was found to be safe in terms of PAH formation and mutagenic activity. Sensory evaluation showed that the overall acceptance of the semi-cooked meatball samples were good. These results demonstrate considerable potential for the application of ohmic process for semi-cooking of meatballs.

1. Introduction

Ohmic heating, a well-known electro-heating technique, has been developed during the past two decades and is used in commercial scale operations for processing a number of food products (Sastry & Salengke, 1998). The system is based on the passage of electrical current through a food product that has electrical resistance (Icier & Ilicali, 2005). The electrical energy is converted to heat, while the amount of heat generated through the food product is directly related to the voltage gradient and the electrical conductivity (Sastry & Li, 1996). Ohmic treatment is used in a wide range of applications such as preheating, cooking, blanching, pasteurization, sterilization and extraction of food products (Mizrahi, 1996; Lima & Sastry, 1999; Leizerson & Shimoni, 2005a; 2005b; Icier, Yildiz, & Baysal, 2005). Shorter processing times, higher yields, maintenance of the colour and nutritional value of foods are some of the advantages of ohmic cooking when compared to conventional heating (Wang & Sastry, 2002; Castro, Teixeira, Salengke, Sastry, & Vicente, 2004; Icier & Ilicali, 2005; Leizerson & Shimoni, 2005a; 2005b; Vikram, Ramesh, & Prapulla, 2005).

Since the uniform heat generation gives uniform temperature distribution, especially for liquid foods, USDA (United States Department of Agriculture) and FDA (Food and Drug Administration) suggested the usage of ohmic technologies for pumpable foods. Although the technique appears both simple and advantageous and has proved to be a successful technology to process liquids, the ohmic treatment of solid foods such as meat and meat products has not yet been applied industrially due to several difficulties encountered (de Halleux, Piette, Buteau, & Dostie, 2005).

Meat samples commonly have heterogeneous structure, which affects the uniform distribution of heat (Shirsat, Lyng, Brunton, & McKenna, 2004). Geometric properties such as the size of the piece of meat are important factors that limit the use of ohmic cooking technology in meat and meat products (Aymerich, Picouet, & Monfort, 2008). On the other hand, ohmic cooking offers the potential for safer meat products by effectively inhibiting microbial growth through uniform temperature distribution in the product and cooking faster and instantly inside the food (Sastry & Li, 1996; Ozkan, Ho, & Farid, 2004). Several studies have been conducted about the application of ohmic treatment to meat and meat products for cooking purposes (Ozkan et al., 2004; Shirsat et al., 2004; Wills, Dewitt, Sigfusson, & Bellmer, 2006; Vasanthi, Venkataramanujam, & Dushyanthan, 2007; Zell, Lyng, Denis, Cronin, & Morgan, 2009; Bozkurt & Icier, 2010a,2010b). Although ohmic cooking serves the fast and homogeneous cooking chance for the meat products, microbiological and toxicological safety of the ohmically cooked meat products must also be evaluated. Moreover, there has been no study done regarding the effect of

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ohmic cooking on formation of PAHs and mutagenicity in foods, according to the best of the authors' knowledge. Almost all cooking procedures cause PAH formation on meat and meat products in low or high amounts according to the cooking conditions. For example smoking, grilling and roasting cause PAH formation in high levels, while mild cooking conditions such as steaming can reduce the level of PAH formation (Yildiz-Turp, Sengun, Kendirci, & Icier, 2013). Although the temperatures for ohmic cooking procedure is quite mild (<100 °C), this procedure still can cause high levels of PAH formation in meat and meat products because of direct contact of the electrodes and the samples (Yildiz-Turp et al., 2013).

In a recent study, meatball samples prepared by same procedure given in this paper were semi-cooked ohmically by using 3 different voltage gradients (15, 20 and 25 V/cm) and three different holding times (0, 15 and 30 s). Desirability function in response surface methodology was used to determine the optimum ohmic cooking condition as a pretreatment by considering the criteria of minimizing hardness ratio, maximizing chewiness, resilience, log reduction in microbial load, outside chroma ratio, inside chroma ratio and in range of springiness, gumminess and inside L-ratio. By this method, optimum ohmic pre-cooking condition in the same cooking system has been determined as cooking up to 75 °C centre temperature by applying 15.26 V/cm voltage gradient and no holding time requirement (Icier et al., 2013). The aim of the present study was to determine the effects of ohmic cooking conducted in the same system by applying optimum ohmic pre-cooking condition for evaluation of microbiological, toxicological, physical, chemical and sensory attributes of semi-cooked meatball.

2. Materials and methods

2.1. Sample preparation

Lean beef as boneless rounds were supplied from a local processor (Burdur Güçbirliği Meat Facility A.Ş.) and were transported to Ege University, Food Engineering Department's Electrical Operation Laboratory in vacuumed packages with maintaining cold chain (−18 °C). Meat was removed from the vacuum packages and re-packaged in low density polyethylene (LDPE) bags, 0.2 kg each, and stored at −18 °C until used within one month. Thawed meat samples (at 4 °C for one night) 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). Mixture was kneaded for 15 min by hand, to obtain homogeneous dough. The prepared dough was stored in a refrigerator (at 4 °C) for an hour and then shaped into cylinder meatballs having 0.025 m diameter and 0.05 m length by using a cylinder block. All the production process of meatballs was carried out at room (20 ± 1 °C) temperature.

2.2. Ohmic cooking procedure

Ohmic cooking was applied as pre-treatment before final cooking of meatballs. Experiments were conducted in specifically designed custom-made continuous belt type ohmic cooking system, which consisted of a power supply, an isolating-variable transformer, a microprocessor board and a data recording system, temperature measurement units, ohmic cooking unit and a rotating belt system (Fig. 1). The cooking unit was designed specially, which includes rotating (Polyester Monofilament) belt with motor for controlling speed, two removable stainless steel electrodes (5 cm × 30 cm), electrically isolated Teflon mountings and electrical connections to transformer unit. Temperature measurements were conducted by using Teflon coated electronic temperature sensors (Omega Eng. Inc., Stanford, CT). Teflon coated electronic temperature sensors had special design and isolation to electric current. They could have been immersed into meatball. The occurrence of the signal interference in the system was avoided by the usage of Teflon as a coating material, and other possible signals were taken into account by the control program of the microprocessor. The time constants of temperature sensors were determined by calibrating them in standard calibration solutions (Omega Eng. Inc., Stanford, CT). The microprocessor board that was used to monitor the temperatures, current (A) and voltage applied (V), and it transmitted this information simultaneously to the microcomputer at constant time intervals (1 s) (Fig. 1).

The sample was placed at the inlet of the continuous type cooking unit and sandwiched between the electrodes with the compression. After the system was sealed, belt was rotated at the speed of 0.25 cm/s, and the power was given to the system. The optimum ohmic condition for precooking purpose for meatball has been determined as 15.26 V/cm voltage gradient and 0 s holding time. After ohmic cooking, samples were cooled down to 20 °C in refrigerated ambient and then immediately transferred to analyses.

Cooking time, which was parameterized that the time required reaching 75 °C of the centre temperature of meatball samples from the initial temperature of 20 °C, was 92 s. Temperature

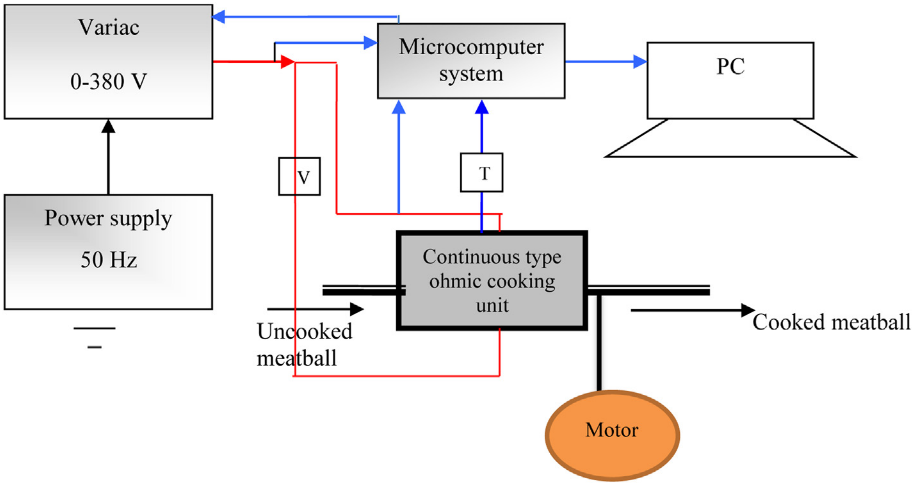

Fig. 1. Ohmic cooking system.