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Short Communication

Migration of ohmic heating electrode components into a food

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Abstract

Ohmic heating has an advantage over conventional indirect heating methods because heater (electrode) surfaces temperatures are comparatively lower as heat is generated within bulk fluid. This process could develop the electrodes decay or corrosion.Food preparation and safety are major issues in this modern world.in this study we focus on migration of ohmic heating electrode components into a liquid-solid food and comparison migration in this method with conventional heating method. Concentrations of Fe, Cr, Ni, Mn, and Mo from the stainless steel electrode migrated into ohmically and conventionally treated soup were measured. Migration of the major key metal ions from stainless steel measured by Atomic Absorbtion shows that overall ohmic treatment yielded reduced migration residues of all metal ions, compared to the conventional retorting with similar electrodes. Concentrations of all metal ions migrated into food samples after ohmic treatment were far lower than dietary exposure levels so that this technique can ensure the safety and quality of food supplies.

Keywords: Corrosion, Metal ions, Ohmic heating, Stainless steel.

Introduction

Food preparation and safety are major issues in this modern world (Ozkan *et al*., 2004). There are a number of potential opportunities for exploiting the benefits of Electromagnetic technologies like ohmic in food processing. These technology can be applied in a variety of ways depending on the process requirements and the consumer demand. Processing of food products is a necessary requirement for extending the shelf life (Vikram *et al*., 2005). Direct ohmic heating is a technology to warm up the food using an electric energy (Icier, 2009). Ohmic heating has potential as an alternative to conventional heating techniques, due to its potential for better temperature uniformity, speed, and energy efficiency (Jun and Sastry, 2007). During ohmic heating, electrical energy is converted to thermal energy within a conductor by applying an alternating current across the material. The energy is almost entirely dissipated within the heated material; therefore, there is no need to heat intervening heat exchange walls, thus the process has close to 100% energy transfer efficiency (Shim et al., 2010) Conventional ohmic heating under typical low frequency alternating current (50 or 60 Hz) could cause hydrogen and oxygen evolution due to electrolysis of water (Amatore *et al*., 1998). However any decay or corrosion of electrodes in this technology should be studied since it could shorten the life time and contaminate the food (Perchonok and Bourland, 2002).

In ohmic heating, the electrical energy provided to the heating cell is ideally used only for heat generation and electrochemical reactions at electrode/solution interfaces are considered undesirable. Electrodes in ohmic heating can be regarded as a junction between a solid-state conductor (i.e. current feeder) and a liquid-state conductor (i.e. heating medium) (Samaranayake and Sastry, 2005). At low-frequency (50–60 Hz) alternating currents, corrosion of electrodes and apparent (partial) electrolysis of the heating medium were noticed with most of those electrodes. Tzedakis et al. described some effects of these reactions on ohmic heating of foods (Tzedakis *et al*., 1999). Jun et al. focused on migration of electrode components during ohmic heating of

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foods in retort pouches (Jun *et al*., 2007). Electrode and pH effects on electrochemical reactions during ohmic heating were studied by Samaranayake *et al*. (Samaranayake and Sastry, 2005).

We focus in this study on migration of ohmic heating electrode components into a liquid-solid food and comparison migration in this method with conventional heating method. For this purpose, migration of Fe, Cr, Ni, Mn, and Mo as the key elements of stainless steel migrated into the heating medium were investigated.

Materials and Methods

All the ohmic heating studies were performed using a batch ohmic heater (represented schematically in Fig. 1). The ohmic heating unit consisted of anamperometer, voltameter, interface, computer, voltage control unit and on/off switch. Cylindricalheating cell was chosen because of its symmetrical nature. The static cell used for the experiments was made of Teflon. The Teflon cylinder had internal radius of 45 mm. The distance between electrodes was 200 mm, resulting in a total sample volume of 1100 ml. Two stainless steel (316) circular plate was used as electrodes. Diameter of the electrode was 90mm. This electrodes were connected to the power unit. Powerconnection was a variable transformer (0-300 V), single-phase AC line. Four holes were incorporated to allow insertion of thermocouples at the top of the cell. Two thermocouples were placed close to each electrode. Two other thermocouples were placed mid-way between the centerof the cylinder and the thermocouples were placed close to each electrode on each side.

In all cases, the thermocouple floated free in the food system, and were never set inside particles. Time-temperature profiles of samples were recorded for all five thermocouples at 1s intervals. The microprocessor board monitored the temperatures, current and voltage applied and transmitted this information to the computer at constant time intervals (1 s). The sample was subjected to 15 V/cm electric field with a minimum of 2A to a maximum of 10A during heating. The ohmic heater was attached to the experimental setup as shown in Fig. 2

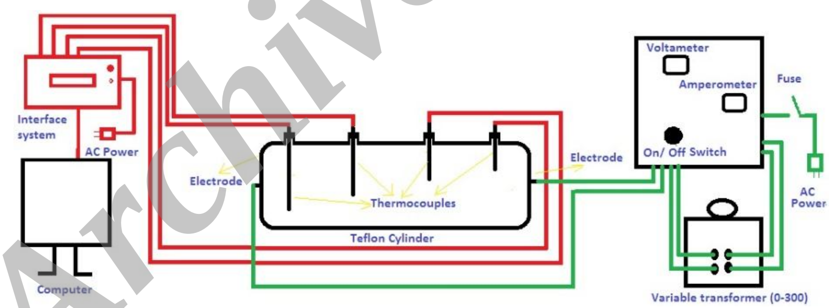

Fig. 1. A schematic of designed ohmic heater unit

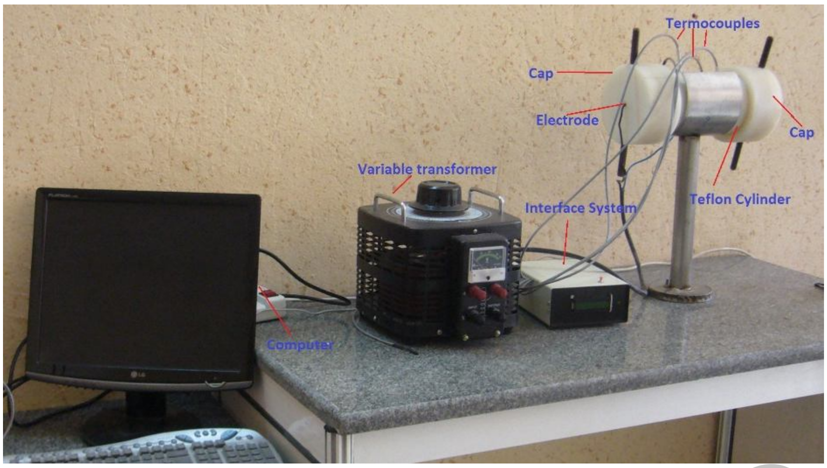

Fig. 2. Set up and design of ohmic heating unit

Sample preparation: Samples made from 0.5% salt (NaCl), 5% wheat starch, 1% sunflower oil, 5% carrot cube and pea, 5% tomato paste (brix= 28-30) and distillated water(pH=6). The sample was mixed then placed into the all-glass erlenmeyer flask, After the system was sealed, the sample was heated up to temperature of 95 C. The cooking treatment was performed by water bath (100 ºC) for 20 min. The soup sample was cooled and kept in the refrigerator at 4 C for 120 min.

Heating process: Teflon cylinder were equally filled with 1100 ml of the resulting soup. Experimentswere conducted with ohmic heater and retort. For the ohmic heating, the stainless steel electrodes were connected to the power supply, then Sample was heated using a constant voltage of 230 V for 30 min (in the constant temperature 100 ºC). A second set of experiments was also carried out using a retort. In this method Teflon cylinder (with stainless steel electrodes) was heated at 100 C for 30 min. A third set of samples were untreated blank samples.

Atomic absorptionmeasurement:

Concentrations of Fe, Cr, Ni, Mn, and Mo as the key elements of stainless steel migrated into the heating medium were determined by a GBC-Australian atomic absorption(Model:932-AA). Atomic Absorption spectroscopy involves the study of the absorption of radiant energy by neutral atoms in the gaseous state (in a 1600-1800 C). These methods require a digestion stage to decompose the sample and measurement by atomic absorption spectrometry. 5 g of Samples were digested with nitric acid, then each samples were heated and bring to 50 ml with distillated water at room temperature. In this method 1) the elements must be reduced to the elemental, neutral ground state by the flame, 2) the elements must be in vaporized state. 3) The elements must be imposed in the beam of radiation from the energy source.

Statistical Analyses:

The data were statistically analyzed by analysis of variance (ANOVA) and compared means by Duncan's multiple range post hoc test using the SPSS statistical software package (SPSS 15.0 for Windows statistical software package).

Results and Discussion

Fig. 3 and Fig.4 shows the column plots of concentrations of Fe and Cr metal ions, migrated from the stainless steel electrodes to the treated and blank soup. Result show no significant difference in the amount of migrated Fe ions between ohmic heating and retorting samples, and migrated Cr ions between retorted sample with electrodes and blank sample. The migration of Fe and Cr ions increased for ohmically treated samples compared to the blank soup. Statisticallyanalysis show that Fe ions increased in a retorting samples compared to the blank soup. It can be seen that the estimated intakes of Fe and Cr ions are far below the upper level of daily dietary exposure. This results are supported by existing literature; Jun *et al*., 2007. As can be seen in a fig. 5 there was no significant difference in the amount of migrated Mo ions between treated samples and control soups.

Fig. 6 and Fig.7 shows the concentrations of Ni and Mn ions, migrated from the electrodes to the samples. In this column plots theconcentration of Mn ions increased under ohmic heating and retorting (with electrodes) compared to the blank soup. Similarto the Mo ions, there was no significant difference between Ni concentration, in a treated and untreated samples. Similar result was obtained from other research (Wang and Farid (2011) and wang *et al*. (2015)).Wang and Farid (2011) indicated that high frequency plate/ohmic cooking can bring Ni and Cr close to a safe level.

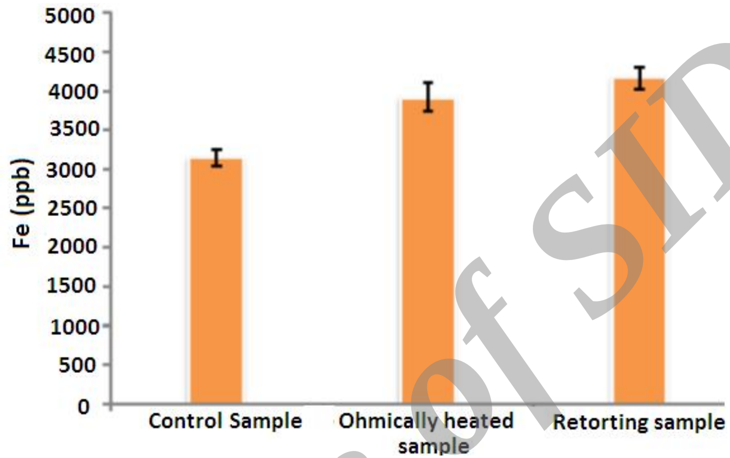

Fig. 3. Concentrations of Fe ions migrated into treated and control soups.

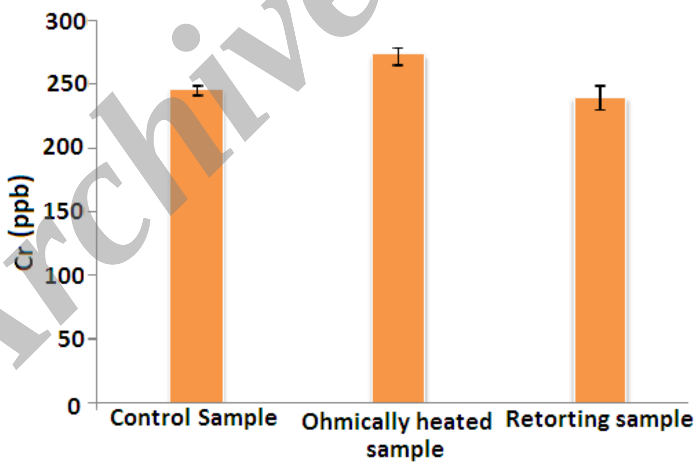

Fig. 4. Concentrations of Cr ions migrated into treated and control soups.

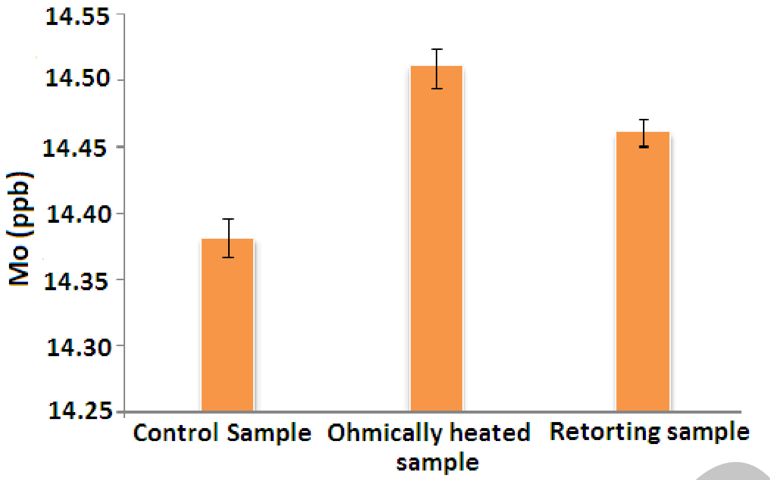

Fig. 5. Concentrations of Moions migrated into treated and control soups.

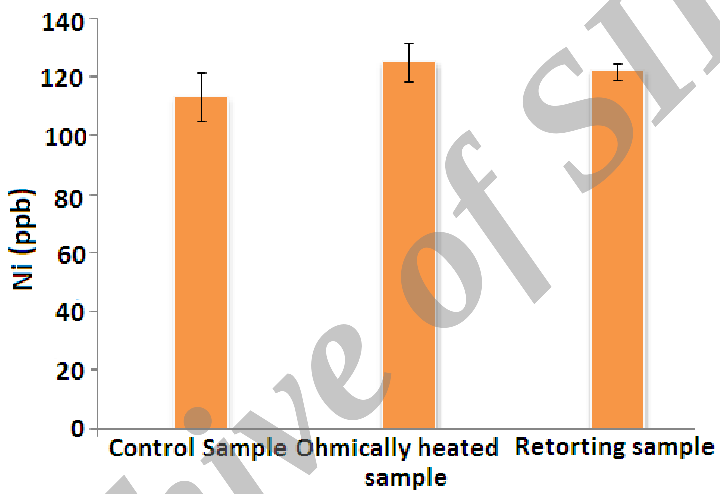

Fig. 6. Concentrations of Ni ions migrated into treated and control soups.

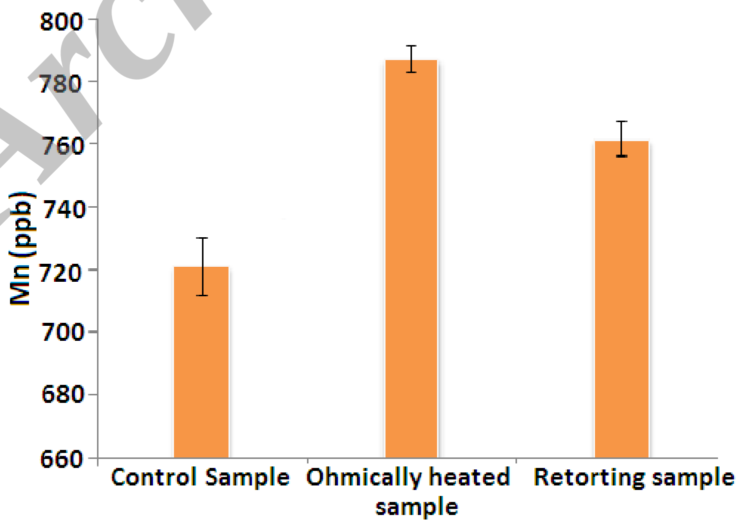

Fig. 7. Concentrations of Mn ions migrated into treated and control soups.

Conclusions: An important consideration in ohmic heating is the amount and the chemical nature of the corrosion products migrating into the food during the application of electrical power. Stainless steel is an iron-chromium alloy containing chromium (17%), nickel (10%), and molybdenum (2%) as major alloying elements. Using result, we estimated intakes of metal ions with respect to a typical meal of 8 oz (227 g) assuming the same conditions in food processing. The estimated values were then compared with recently published upper-level daily dietary exposure limits for adult consumers. This result indicates that migration of metal ions from the proposed ohmic treatment is far below the amounts that people are receiving in general. Therefore, food processing by ohmic heating may be performed without significant electrode migration.

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مقاله کوتاه پژوهشی

مهاجرت اجزاء الکترودهای حرارتی مقاومتی به درون غذا

محسن زندی*[1]- نازیلا دردمه[2]- سجاد پریسا[3] – هادی الماسی[4]

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چکیده

نبود سطح حرارت دهی از مزایای فرآیند اهمیک نسبت به سایر فرآیندهای متداول در حرارت دهی مواد غذایی است که در آن اعمال حرارت در حجم ماده غذایی صورت می پذیرد. این فرآیند حرارت‌دهی می‌تواند منجر به الکترولیز آب و به دنبال آن خوردگی الکترودها شود. هدف از این پژوهش بررسی میزان خوردگی الکترودها در طی فرآیند اهمیک بوده که به همین منظور میزان مهاجرت یونهای آهن، کروم، منگنز، مولیبدن و نیکل از الکترودهای به سیستم غذایی به عنوان معیاری از خوردگی اندازه گیری شد و علاوه بر آن میزان مهاجرت یون‌ها در فرآیند اهمیک با فرآیند اتوکلاو مقایسه گردید. در این تحقیق میزان مهاجرت یونهای فلزی با استفاده از روش جذب اتمی اندازه گیری و تمامی نمونه ها با نمونه کنترل (شاهد) مقایسه شدند. نتایج این مطالعه نشان داد که فرآیند حرارتی اهمیک در مقایسه با فرآیند حرارتی متداولی مثل اتوکلاو تاثیر معناداری بر میزان مهاجرت یون‌های فلزی به مواد غذایی نداشته و علاوه بر آن غلظت تمامی یون‌های فلزی که به ماده غذایی وارد شده از میزان مجاز بسیار کمتر است

واژه‌های کلیدی: سیستم حرارت دهی اهمیک، خوردگی، یون‌های فلزی، فولاد زنگ‌نزن

۱، ۳ ، ۴ و ۲- به ترتیب استادیاران و دانشجوی کارشناسی ارشد، گروه علوم و صنایع غذایی، دانشکده کشاورزی، دانشگاه ارومیه، ارومیه.
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