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Application of the Ohmic Heating Process to Make a Semolina Dessert with Milk

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ABSTRACT

Traditional milk desserts are one of the most essential dessert groups that Turkish society consumes. Due to foaming activity, it was aimed to investigate the feasibility of the ohmic heating system to produce a semolina dessert with milk. Hence, an ohmic heating treatment was used to heat the milk, semolina, and sugar mix from 20°C to 100°C using three different voltage gradients (15, 17.5, and 20 V/cm) and then boil for two minutes. It was found that the current value escalated from 20°C to approximately 86°C but decreased after 86°C due to foaming. Since the total consumed energy during the ohmic cooking treatment was inversely proportional to the treatment time, the total consumed energy values decreased based on the rising voltage gradient. As a result, the feasibility of the ohmic heating treatment for making a traditional semolina dessert with milk was determined in this study.

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Introduction

Dairy products, such as milk-based desserts, provide several crucial nutrients to sustain health and avoid chronic diseases (Jouki et al., 2021; Kuriya et al., 2020; Parmar et al., 2018; Silva et al., 2020). Hence, many dairy products can be found in the market, such as desserts, dairy beverages, yogurt, and cheeses (Silva et al., 2021; Viana et al., 2021). Milk-based desserts contribute several nutrients, such as potassium, phosphorus, riboflavin, magnesium, fatty acids, niacin, and proteins, to the diet (Silva et al., 2021). In addition, these products are more attractive to many consumers worldwide due to their functional value (Kuriya et al., 2020). However, conventional heating processes adversely affect the bioactive components, product quality, and functionality of these products (Cappato et al., 2017; Kuriya et al., 2020). Therefore, an alternative heating method such as ohmic heating is needed to diminish the deterioration of these components and retain the functional, sensory, and nutritional quality of milk-based desserts.

Ohmic heating (OH), also known as "joule heating" and "electrical resistance heating," is the process of passing an alternating current through food between two electrodes. Thus, heat generation occurs in the product, and electrical energy is transformed into heat energy (Ariç Sürme and Sabancı, 2021; Rocha et al., 2022). It has been pointed out that this heating process provides a fast, efficient, and homogeneous heating process, especially for liquid foods (Alkanan et al., 2021; Ariç Sürme and Sabancı, 2021; Gavahian et al., 2019). The OH treatment has been applied in many foods for heating (Cappato et al., 2017), evaporation (Icier et al., 2017), drying (Acar et al., 2022), thawing (Cevik and Icier, 2021), cooking (Goksu et al., 2022), and extraction (Çilingir et al., 2021).

There have been a few studies where the OH treatment was applied in milk and dairy products (Kuriya et al., 2020; Parmar et al., 2018; Rocha et al., 2022; Silva et al., 2021). In a study, this treatment was used for ice cream production, and its electrical properties were determined (Suebsiri et al., 2019). In addition, the milk was evaporated using the ohmic heating process at various voltage gradients (Ariç Sürme and Sabancı, 2021). Recently, sweets were produced from whey using an ohmic heating process, and their quality properties and electrical conductivity values were examined (Coimbra et al., 2020). However, throughout the OH treatment at high voltage gradients increasing energy efficiency, foaming activity was observed in the milk near the boiling temperature (Ariç Sürme and Sabancı, 2021; Rocha et al., 2022). Similar trends were published for various fruit juices and similar products (Icier and Ilicali, 2004; Sabancı and Icier, 2019; Yildiz et al., 2009). Hence, this treatment should be proved whether it is suitable for producing milk-based desserts.

Therefore, the objective of the present study was to explore whether the OH treatment at high voltage gradients was suitable for making a semolina dessert with milk due to the foaming activity, affecting the electrical conductivity. During the heating process, the current and electrical conductivity values were examined, and then the total energy and average power values of the semolina dessert with milk were determined.

Materials and Method

Raw Materials

The semolina (Filiz, Bolu, Turkey), milk (Pinar, Izmir, Turkey), and sugar (Torku, Konya, Turkey) required for the cooking of the milk semolina dessert using ohmic heating were obtained from a local market in Tunceli, Turkey. Until the cooking time, the milk was kept at 4°C and the semolina and sugar in a cool and dark environment.

The Ohmic Heating System

The system image of the ohmic cooking process is demonstrated in Figure 1. The cooking process was achieved by heating the mixture of milk, sugar, and semolina from 20°C to 100°C using 3 different voltage gradients (15, 17.5, and 20 V/cm) and then cooking at 100°C for 2 minutes. The machine was not switched off for 2 minutes during the cooking process.

During the warm-up period, a custom-made microprocessor was run to store electrical properties, voltage, temperature, and current values were recorded every second. The test cell of the system was constituted of polyoxymethylene, and the electrodes are constituted of titanium. A T-type (Cole Palmer, UK) was used to measure the temperature value. Equations 1 and 2 were used to calculate the total energy and average power, respectively, consumed in the system.

$$Q\ (J) = I \times V \times t \quad (1)$$

Q, I, V, and t are the total consumed energy, current, voltage, and time, respectively.

$$P\ (W) = \frac{Q}{\Sigma t} \quad (2)$$

P is the average power.

Statistical Analysis

All experiments were done three times. SPSS software for Windows (version 20.0; IBM, Chicago, IL, USA) was used for analysis of variance (ANOVA) and the difference ($P<0.05$) between each voltage gradient were evaluated using Duncan`s multiple range test.

Results and Discussion

The time-dependent temperature change in the heating period, which is the first part of the cooking process of the semolina dessert with milk, is given in Figure 2. It was determined that the temperature value of the dessert raised as the processing time raised for all voltage gradients used in the present study (Table 1). It was also found that the high-voltage gradient has a higher temperature value at the same time among three voltage gradients. In addition, the voltage gradient has an impact on the heating rates from 20°C to the target cooking temperature. Furthermore, the first stage of this cooking process was that the mixing of semolina, sugar, and milk was heated up to 100°C, and the second stage was that it was cooked at 100 ˚C for 2 minutes. The total heating time of this mix differed for each voltage gradient. Accordingly, as the voltage gradient raised, the time needed to reach the boiling temperature value was reduced, so the processing time decreased by approximately 35% during the warm-up period. It has been revealed that the processing time was reduced due to the increased voltage gradient in several applications of OH, such as heating, cooking, reaching the required temperature for extraction, and dissolving different samples (Ariç Sürme and Sabancı, 2021; Çilingir et al., 2021; Goksu et al., 2022; Sabancı and Icier, 2019).

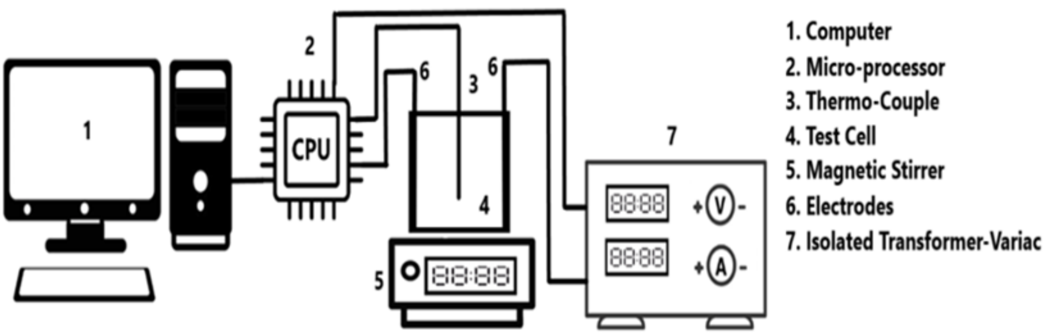

Figure 1. Schematic description of ohmic heating system

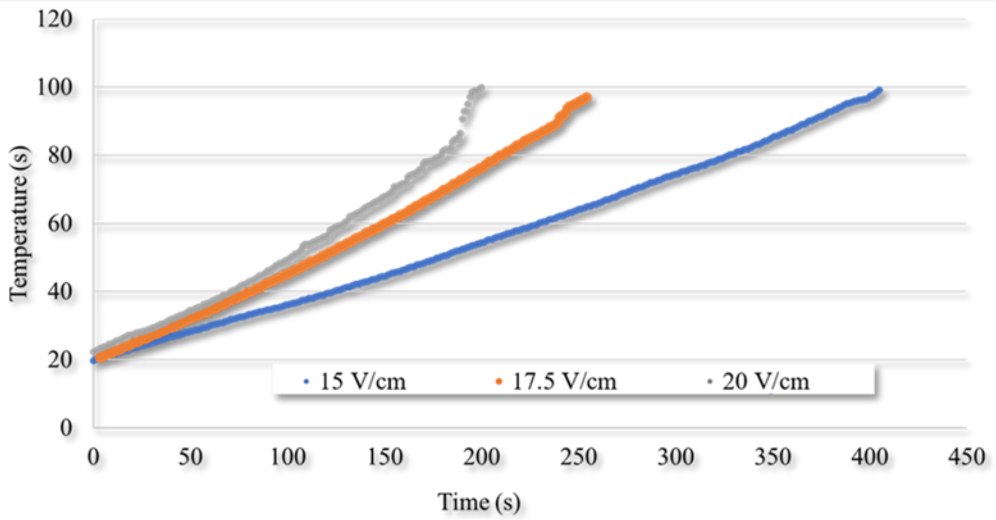

Figure 2. The changes in temperature with time during the heating period

Table 1. The total consumed energy (TCE) and average power (AP) for each voltage gradient

Treatment Period	Voltage Gradient (V/cm)	Process Time (s)	TCE (kJ)	AP (W)
Heating	15	391±13*[a]	27.4±0.8[a]	70±2.1[a]
	17.5	264±7[b]	24.8±0.3[b]	94.0±1.1[b]
	20	203±8[c]	25.4±0.7[b]	125.0±3.5[c]
Cooking	15	120±10[d]	7.0±2.4[c]	45.2±3.7[d]
	17.5		12.9±0.2[d]	107.3±1.7[e]
	20		15.5±0.2[e]	129.6±1.5[c]

[a, b, c, d, e] The values in a column with the same lowercase letter are not significantly different (P>0.05).; * Standard deviation.

In addition, the heating rates for each voltage gradient, 15 V/cm, 17.5 V/cm, and 20 V/cm, were 0.20, 0.30, and 0.39°C/s, respectively. It was reported that during the heating of pomegranate juice from 20°C to 85°C, the heating rate raised with increment in the voltage gradient, and the highest heating rate was reported as 55 V/cm (Sabancı and Icier, 2019).In another study, the voltage gradient influenced the warming rate of sea water during the warming period, and the highest heating rate was acquired at 11.04 V/cm (Assiry et al., 2010). Likewise, the heating rate affected by the voltage gradient was reported for various food process applications in which the ohmic heating process was used for heating (Icier and Ilicali, 2004; Sabancı and Icier, 2019; Yildiz et al., 2009).

The electrical conductivity (EC) value varies depending on the test cell (distance between two electrodes, product contact area) and electrical (current and voltage) properties (Icier et al., 2017; Icier and Ilicali, 2004). Especially during the warm-up period, the properties of the test cell and the voltage value are constant, while the EC value changes with the current value. Therefore, the change in current influences the EC value throughout the process. The variation of the temperature of the semolina desert with milk during the warming period is given in Figure 3. Accordingly, the change in the current for the temperature varied from 20°C and 100°C was altered from 0.41 to 1.15 A, from 0.48 to 1.32 A, and from 0.54 to 1.55 A for 15 V/cm, 17.5 V/cm, and 20 V/cm, respectively. As expected, the current value raised as the temperature raised in the present study.

The formation of foam in milk can hinder or even limit the application of ohmic heating because it reduces electrical conductivity (Gally et al., 2016). The foaming activity was observed at temperature values over 90 ˚C since milk is rich in proteins that behave as foaming agents. The volume of foam formed during the ohmic heating process increased with an increase in temperature, as reported in the previous study (Huppertz, 2010). In addition, as seen in Figure 3, when the foaming process started, there was a decrease in the current value. The decrease in the current value was first observed at 20 V/ cm (Fig. 3). This result may be due to the fact that the soluble salt fraction and water content were reduced at this voltage gradient. A study reported that the electrical conductivity of milk and whey is primarily because of their soluble salt fraction and water content (Mucchetti et al., 1994). Similarly, several studies reported that foaming occurred at the pre-boiling stage during the evaporation of milk or dairy products. Even though the temperature was low, foaming activity due to the high voltage gradients was reported in some studies (Ariç Sürme and Sabancı, 2021; Icier and Ilicali, 2004; Yildiz et al., 2009).

The alterations in the total consumed energy (TCE) and the average power (AP) values in the OH system during the production of the semolina dessert with milk are given in Table 1. At the end of the production of the dessert, the TCE and AP values were examined in two sections, the heating and cooking sections. In the heating part, the total energy spent in the OH treatment was 27.4±0.8 kJ, 24.8±0.3 kJ and 25.4±0.7 for 15 V/cm, 17.5 V/cm, and 20 V/cm, respectively. The results in this study displayed that TCE value decreased as the voltage gradient raised. This result can be pointed out by the shorter processing time and less heat loss due to the increasing voltage gradient.

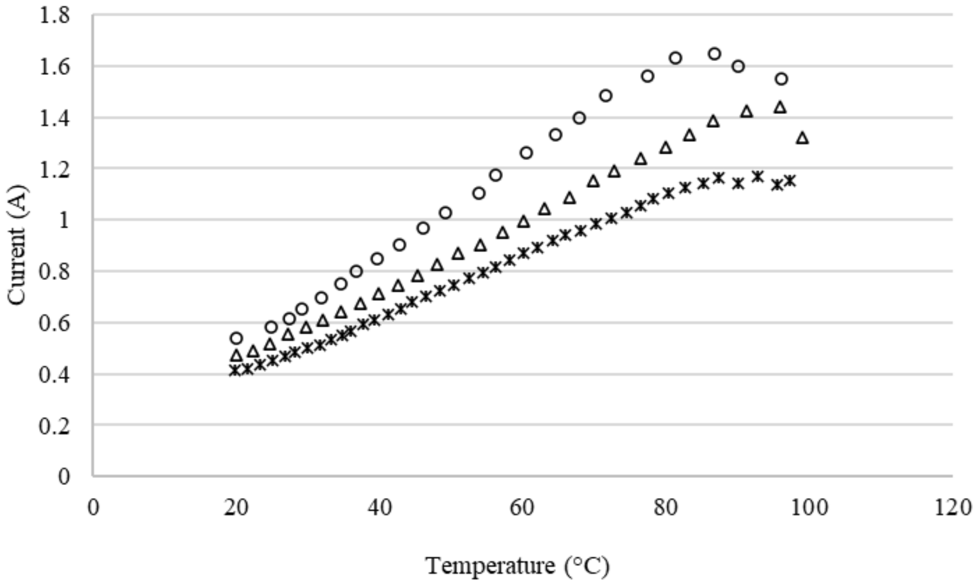

Figure 3. The changes in current with temperature during the heating period

Similarly, it has been reported in different usage of OH in food treatments that the processing time is shortened, and less energy is consumed with an increasing voltage gradient during ohmic heating applications (Çilingir et al., 2021; Goksu et al., 2022; Icier et al., 2017; Sabancı and Icier, 2019).

In addition, the TCE was determined to be 7.0±2.4 kJ, 12.9±0.2 kJ and 15.5±0.2 kJ for 15 V/cm, 17.5 V/cm and 20 V/cm, respectively, in the cooking part. It was discovered that as the voltage gradient raised in the ohmic cooking process, the TCE increased. The main reason for the difference between the two parts can be explained by the high current value at high voltage in the cooking process and, accordingly, more energy consumption at the same time (Goksu et al., 2022; Sabancı and Icier, 2019).

It was verified that the AP value raised when the voltage gradient raised in both, first and second parts. The AP value is a function of TCE, and the process time as seen Eq. 2. Therefore, it varies depending on whether the process time is short or high-energy. In the OH treatment, many studies reported that the average power value increased when the voltage gradient raised in various food process applications including heating, cooking, extraction, and evaporation processes (Çilingir et al., 2021; Goksu et al., 2022; Kuriya et al., 2020; Sabancı and Icier, 2019).

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Conclusions

It was accomplished that the semolina dessert with milk was produced by using the ohmic heating (OH) treatment instead of the conventional heating process. Although the foaming activity was observed, the cooking process was done with the ohmic heating process. It was demonstrated that the treatment time was reduced because of the increased voltage gradient, and the heating rate reached 0.44°C/s from 0.18°C/s due to the increment in the voltage gradient from 15 V/cm to 20 V/cm, respectively. In addition, the TCE in the heating period reduced as the voltage gradient raised, while the TCE in the cooking section increased due to the raising voltage gradient. Furthermore, the AP value escalated with the raise in voltage gradient for both the heating and cooking parts. As a result, this study proved that high voltage gradients can be used for making milk-based desserts, but further studies are needed for the assessment of the quality properties of milk-based desserts treated with ohmic heating at high voltage gradients due to the short processing time.

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