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Ohmic thawing of frozen ground meat

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In this study, the applicability of ohmic heating on tempering of the frozen ground meat was investigated. Ground beef meat has been shaped as a block of 1 cm ✕ 7 cm ✕ 10 cm in a specially designed container, and then frozen at air blast freezer (-30 °C). It was aimed to reach the center temperature of the frozen block meat to +20 °C from –18 °C. The ohmic tempering was performed by the application of different voltage gradients (10, 15 and 20 V cm^{-1}) whereas conventional tempering was performed at controlled conditions in the refrigerator (4 °C). The effects of the thawing method and the voltage gradient on tempering time, temperature distribution, color and pH were investigated. As the voltage gradient increased, the tempering time decreased in the range of 92-95 % comparing to conventional tempering. Average initial thawing temperature was measured as -1.1 °C for the samples. At the end of the tempering , the cold point of the ground meat was 0 °C while the minimum temperature value of surface were -4.7 °C, -3.3 °C and -3.4 °C for 10, 15 and 20 V cm^{-1} voltage gradients, respectively. Similarly, the thawing method and the voltage gradient affected the color properties (L*, a*, b*, Hue angle, chroma and total colour differences), significantly ($p<0.05$). The value of a*, which is important for meat samples, was similar for conventional thawing and ohmic thawing applied at 10 V cm^{-1}. It is thought that the results of this study will provide data for the scaling up of the industrial ohmic tempering or thawing systems and give useful insights to further studies on these subjects.

Keywords: Ohmic heating, Tempering, Ground meat

INTRODUCTION

Thawing of frozen foods by using conventional methods require long time, provide non-homogeneous thawing. They are generally applied at uncontrolled conditions under high temperatures (except for refrigerators) affecting the microbiological and nutrient quality of foods adversely. In recent years, the applicability of alternative thawing methods such as microwave, radio frequency and ohmic thawing has been studied [1-4]. Ohmic thawing could provide homogeneous and fast heating with minimum loss on the food quality and the nutrient value while obtaining microbiologically safe food. Optimum thawing procedures should be of concern to the food industry, and it is commonly accepted that it should be the rapid thawing at low temperatures and avoid a notable rise in temperature, and prevent the excessive dehydration of. However, it is difficult to accomplish them by using conventional thawing processes because the use of low temperatures reduces the temperature difference between the frozen sample and the environment, which is the principal driving force for the thawing process [5].

Ohmic treatment is one of the electroheating methods, and is based on the passage of electrical current through a food product having electrical resistance [6-8]. Heat is generated instantly inside the food [9,10]. The ohmic treatment is an alternative method for thawing of meat products. The application of ohmic thawing required less treatment times than conventional methods at the same temperature range [11]. Ohmic thawing technology showed high potential to supply thawed foodstuff on high quality [12]. However, very little research about the application of ohmic thawing has been carried out in the literature, and the primary food studied for the application of ohmic thawing on meat processing has been shrimp blocks [13-20].

This study focused on the applicability of ohmic thawing procedures for semi-solid type food at different voltage gradients. The main objectives of this work were to investigate the effect of voltage gradients on thawing time, temperature distribution, color properties, total dry matter content and pH of ground meat during ohmic thawing; and to compare the effects of ohmic and conventional thawing on these selected attributes. The result of this study would be beneficial for the setting up of the industrial or pilot-scale ohmic thawing units for meat products.

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EXPERIMENTAL

Meat was ground twice by meat grinder (Arçelik, Turkey) and ground meat was frozen in air blast freezer (Electrolux, Sweden) quickly by replacing it into an ohmic cell with dimensions of 1 cm x 7 cm x 10 cm. Frozen samples were tempered ohmically (10, 15 and 20 V cm^{-1}) and conventionally (+4 °C). Ohmic thawing experiments were performed using a custom-designed laboratory scale ohmic thawing system which consisted of a power supplying system (an isolating transformer and a variable transformer), a microprocessor board, the computer connection and the thawing cell (Fig. 1). The thawing cell used was made up of Teflon®. To compare the effect of ohmic thawing process, the conventional thawing method was performed in a refrigerator (Arçelik, Turkey) having controlled temperature (+4 °C).

During freezing and thawing, temperature values and time were recorded to find out temperature distribution, tempering time and initial freezing point. Temperature measurement was performed with insulated thermocouples and microprocessor (Omega, UK). Thermocouples located to the cold point of ground meat before freezing. Colour measurements of the samples were carried out by using a HunterLab Colorflex (CFLX 45–2 Model Colorimeter, HunterLab, Reston, VA). pH was determined by using a membrane pH meter (Hanna Instrument, USA). The instrument was standardized each time with a black glass and a white tile (*X*: 79.09, *Y*: 83.98, *Z*: 88.69 and *L*: 93.44, *a*: -1.12, and *b*: 1.02). Color values were expressed as *L*, a, and *b* at any time. Lightness value, *L*, indicated how dark/light the sample was (varying from 0-black to 100-white), *a* was a measure of greenness/ redness (varying from -60 to +60) and *b* was the grade of blueness/yellowness (also varying from -60 to +60). Four readings were performed for each replicate. The combination parameters (Hue angle) were calculated by using tristimulus values measured (Eqs. 1-6).

$$Chroma = \sqrt{a^{*2} + b^{*2}} \quad \text{Eq.1}$$

$$Hue\ angle = tan^{-1}\frac{b^*}{a^*} \quad \text{Eq.2}$$

$$\Delta E = \sqrt{(L^* - L_0{}^*)^2 + (a^* - a_0{}^*)^2 + (b^* - b_0{}^*)^2} \quad \text{Eq.3}$$

$$\Delta C = \sqrt{(a^* - a_0{}^*)^2 + (b^* - b_0{}^*)^2} \quad \text{Eq.4}$$

$$\text{Chroma ratio} = \frac{\text{Chroma value of thawing sample}}{\text{Chroma value of raw material}} \quad \text{Eq.5}$$

$$\text{Hue angle ratio} = \frac{\text{Hue angle ratio thawed sample}}{\text{Hue angle ratio raw material}} \quad \text{Eq.6}$$

The total dry content and pH of each sample were measured using AOAC procedures[24]. Statistical evaluations were performed by using SPSS Version 13.0.1 statistical package (SPSS, 2004). The comparison was made to analyze the effects of voltage gradient and thawing methods on thawing time, color, pH, total dry matter content properties by using Post Hoc (Duncan) test. The confidence level used to determine statistical significance was 95%.

RESULTS AND DISCUSSIONS

All samples were thawed successfully from -14 to 0 °C by the application of ohmic thawing at different voltage gradients (10, 15 and 20 V cm^{-1}). Thawing times were 2040 s, 1455 s, 1185 s for 10, 15 and 20 V cm^{-1} voltage gradients, respectively. On the other hand, conventional thawing time was 27520 s. Generally, thawing times were similar up to the initial thawing temperature for different voltage gradients during ohmic thawing, however after this point; it decreased as the voltage gradient increased ($p<0.05$) (Figure 2). Ohmic application decreased the thawing time in the range of 92-95 % comparing to conventional thawing (Figures 2 and 3). Average initial thawing temperature was measured as -1.8 °C for the sample having the moisture content of 77%. The amount of heat generation during ohmic treatment was directly related to the current induced by the voltage gradient in the field [21,22]. Similarly, Icier *et al.*[3,19] have already concluded that the increase in the voltage gradient provided the decrease in the ohmic thawing time. The change in color values has been reported as the most important criteria to predict the behavior of ground meat during thawing, and it could provide reliable information about organoleptic characteristics. It is known that the myoglobin protein is the primary heme pigment responsible for meat color, but there are other species contributing to color changes during thawing of meat samples (deoxymyoglabin, oxymyoglabin, sulfmyoglabin, metmyoglabin). The spectral features in the visible region allow us to explain these changes. Color changes were evaluated in terms of *L*, *a*, *b*, Hue angle, ΔE, ΔC, chroma and hue angle ratio values (Table 1). Color values of thawed samples were significantly different from raw material for both thawing methods ($p < 0.05$). The value of a*, b*, total color differences and chroma differences was highest at the high voltage gradient.

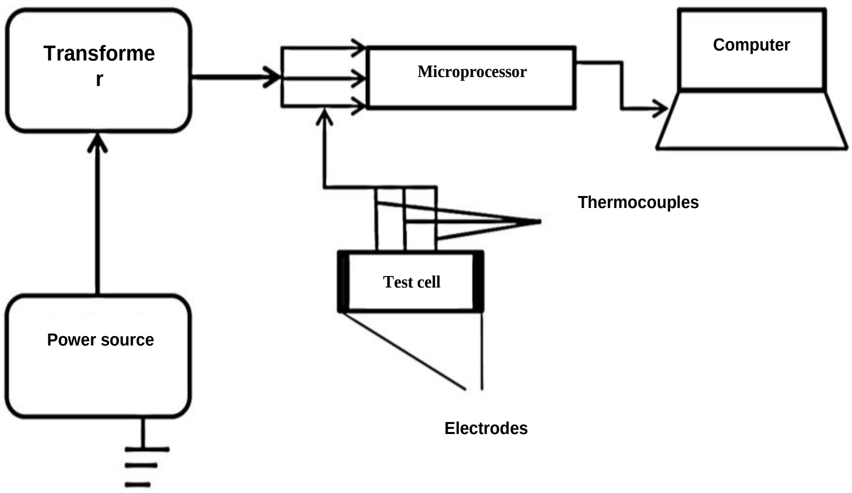

Fig. 1. Schematic diagram of laboratory scale ohmic thawing unit [8]

Table 1. Changes on color attributes of ground meat thawed by different methods

	L*	a*	b*	ΔE	ΔC	HUE	HUE ANGLE RATIO	CHROMA RATIO
Raw material	46.90+0.01	15.88±0.06	16.64±0.08	-	-	46.33±0.03	-	-
20 V cm^{-1}	47.78±0.42	19.82±1.04	17.87±1.08	4.35±1.15	4.25±1.11	42.01±1.48	0.91±0,03	1.16±0.06
15 V cm^{-1}	44.38±0.89	16.73±0.68	17.14±0.35	6.70±0.67	6.55±0.76	40.63±0.52	0.70±0.06	0.60±0.08
10 V cm^{-1}	47.38±0.66	19.54±1.67	19.26+0.4	3.58±1.75	3.34±1.69	44.68±1.94	1.06±0.05	0.90±0.05
Conventional	48.59+0.17	21.71±1.06	19.91±0.44	2.85±0.44	1.13±1.10	42.55±0.8	1.00+0,01	0.97+0.03

Table 2. Changes on total dry matter contents and pH of ground meat thawed by different methods

	THAWING METHODS				
Analysis	Raw material	10 V cm^{-1}	15 V cm^{-1}	20 V cm^{-1}	Conventional
Total dry matter	76.97 ± 0.04	77.18 ± 0.03	77.41 ± 0.01	76.53± 0.05	76.79± 0.08
pH	5.78 ± 0.04	5.81 ± 0.04	5.86 ± 0.05	5.88± 0.01	5.81 ± 0.01

There was a decrease in Hue angle values of thawed samples comparing to raw materials. When 10 V cm^{-1} voltage gradient was used, the color of ground meat was maintained successfully with comparably fast thawing then conventional thawing. Hence, 10 V cm^{-1} was recommended as the best voltage gradient for ohmic thawing of the ground meat. The effects of thawing method and voltage gradient on pH and total dry content values were not statistically significant (Table 2) (p>0.05).

The pH of meat that has been frozen and thawed tends to be lower than prior to freezing[23]. As pH is a measure of the amount of free hydrogen ions (H^+) in a solution, it is possible that freezing with subsequent exudate production could cause denaturation of buffer proteins, the release of hydrogen ions and a subsequent decrease in pH. Alternatively, the loss of fluid from the meat tissue may cause an increase in the concentration of the solutes, which results in a decrease in the pH. In

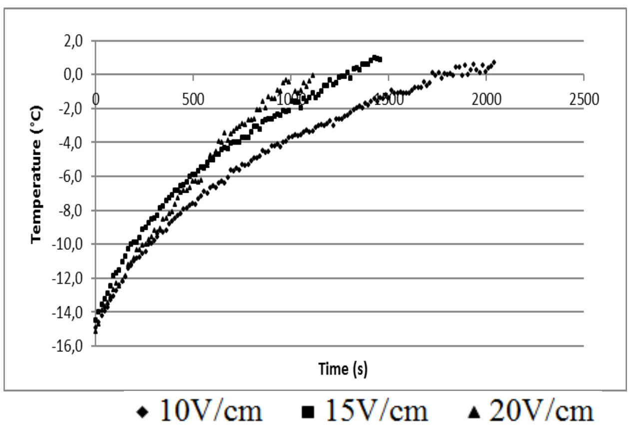

Fig. 2. Changes in the temperature of ground meat during ohmic thawing processes

this study, the effect of thawing method and the voltage gradient was not statistically effective on pH value of ground meat (p>0.05). However, there is an increasing trend in pH value as the voltage gradient increased to 20 V cm^{-1}. It could be concluded that ohmic thawing at low voltage gradients could not result to the denaturation of buffer proteins, the release of hydrogen ions, etc. However, further studies should be conducted on the determination of the effects of ohmic thawing conditions on protein content and the release of hydrogen ions.

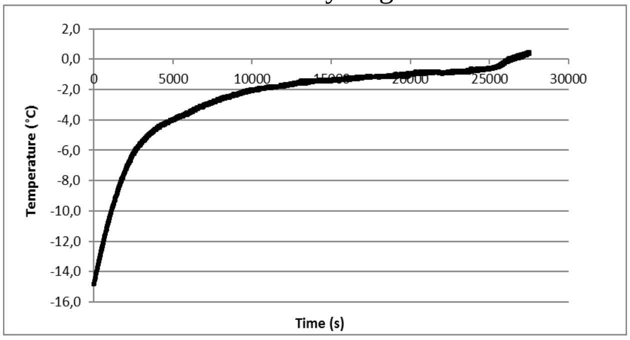

Fig. 3. The increase in the temperature of ground meat during conventional thawing processes

CONCLUSION

In the present study, the application of ohmic treatment as a thawing process was investigated by making the comparison with the conventional thawing method in terms of selected quality attributes. The applied voltage gradient did not have any significant effect on the pH, total dry matter content whereas it had significant effect on the thawing time, and color attributes of ground meat. In this study, it was aimed to obtain basic information on the effects of ohmic thawing on selected attributes of ground meat before the scaling up of industrial and pilot-scale thawing systems. In addition, further studies should be performed to determine whether the undesirable components in ohmic thawing have been occurred.

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ОМОВО РАЗМРАЗЯВАНЕ НА ЗАМРАЗЕНА КАЙМА

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(Резюме)

В настоящата работа е изследвана възможността за приложение на омовото отопление за темпериране на замразена кайма. Кайма от говеждо месо беше формувана в специално проектиран контейнер като блокче с размери 1 cm ✕ 7 cm ✕ 10 cm и след това замразена във въздуходувен фризер (-30 °C). Целта беше в центъра на замразеното блокче да се достигне температура от +20 °C, като се стартира от температура –18 °C. Омичното темпериране се извърши чрез прилагане на различни градиенти на напрежението (10, 15 and 20 V cm^{-1}), докато конвенционалното темпериране се извърши при контролирани условия в хладилник (4 °C). Беше изследван ефекта на метода на размразяване и на градиента на напрежението върху времето за темпериране, разпределението на температурата, цвета и pH. При увеличаване на градиента на напрежението, времето за темпериране намалява 92-95% в сравнение с конвенционалното темпериране. За образците беше измерена средна начална температура на размразяване -1.1 °C. В края на темперирането студената точка в каймата беше 0 °C, докато минималните стойности на температурата на повърхността бях -4.7 °C, -3.3 °C и -3.4 °C за градиенти на напрежението съответно 10, 15 and 20 V cm^{-1}. По подобен начин вида на размразяването и градиента на напрежението оказват съществено влияние ($p<0.05$) върху цветните характеристики (L*, a*, b*, ъгъл на Hue, хрома и цялостна цветна разлика). Стойността на a*, която е съществена за месни продукти, беше подобна за конвенционално размразяване и омово отопление, приложено при градиент на напрежението10 V cm^{-1}. Смята се, че резултатите от това проучване ще осигурят данни за постепенно повишаване на промишленото приложение на омовото темпериращи или размразяващи системи и дават полезна информация за по-нататъшни изследвания по тези въпроси.