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Study of heating pattern during heat treatment of milk by ohmic heating

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Abstract
Ohmic heating is one of the novel thermal techniques that involve the passage of an electrical current through a food product resulting in heat generation. Efforts are being made to apply ohmic heating in heat treatment of milk commercially. In the present study, heating pattern of milk was studied during heat treatment of milk by ohmic heating. Provision was made in the ohmic heating set up to place multiple temperature sensors to determine uniformity of heating in the bulk liquid. Cow milk was heated from 20 to 90 ^oC using ohmic heating technology. The parameters for study were heating rate, thermal efficiency, temperature distribution and temperature profile. Rapid heating was observed with heating rate of 3.5 ^oC/min and the thermal efficiency of the ohmic heating unit obtained was 88.8%. Low temperature gradient in the range of 0-1 ^oC was observed indicating uniform heating of milk by this novel technique.

Keywords: heating pattern, temperature gradient, milk, ohmic heating

1. Introduction
Conventional methods of heat treatment of food products have been successful till date when consumers became aware of the nutritive value of the food. These methods work on principles of conduction and convection. Non-uniform heating is a major problem in conventional heat treatment processes. Internal resistance to heat conduction in different sections of the food results in heterogenous heating, thus resulting in the loss of texture and aesthetic quality of the product (Icier, 2012). Homogeneous heat treatment is an essential factor for preventing food borne diseases (ICMSF, 1998). Fouling is another major problem in conventional heating which leads to a reduction in the overall heat transfer coefficient. Thus for the above mentioned reasons, industries are looking for novel thermal techniques for heat treatment of food products.

OH (also referred to as Joule heating, electroheating, and electroconductive heating) is the process of passing electric current (usually alternating) through food materials with the primary purpose of heating them. Ohmic heating utilizes the electrical resistance of food to generate heat when an alternating current is passed through the food. Excess water and dissolved ionic salts in food are the reason which make the food electrically conductive and enable ohmic heating to work. Almost all foods are resistant to passage of electric current and thus have ability to generate heat by converting electrical energy into thermal energy. Heat generation takes place volumetrically within the food because of its inherent electrical resistance (Marcotte, 1999) [7]. The temperature increases without the need of heat transfer through solid – liquid interfaces (Sarkis *et al*., 2013) [8]. It is possible to obtain a temperature rise in food of 100 ^oC with a residence time between 10-100s in commercial applications (Kim *et al*. 1996) [6]. Electrical conductivity and the current induced by the voltage applied determines the quantity of heat generated in the food. Many factors affect the heating rate of foods undergoing ohmic heating: electrical conductivities of fluid and particles, specific heat, particle size, shape and concentration as well as particle orientation in the electric field (Skudder and Biss, 1987) [10]. Ohmic heating is distinguished from other electrical heating methods either by the presence of electrodes in direct contact with the food (as opposed to microwave and inductive heating, where electrodes are absent) or by the frequencies and waveforms used (FDA, 2000) [2].

This technology is currently being utilized in a range of applications including thermal processing of liquid foods, solid-liquid food mixtures, meats, fruits and vegetables (Bansal and Chen, 2006) [1]. James Prescott Joule was the first to elucidate the phenomenon of dissipation of electrical energy into heat in this manner; therefore, this technology can also be referred to as Joule heating, electro-conductive heating, electro-heating, electrical resistance heating, and direct electrical resistance heating (Sastry, 2008) [9].

Ohmic heating provides numerous benefits. Ohmic heating offers the potential of thermal processing of materials without relying on an inefficient mechanism like conduction of heat from a surface into the fluid (Fryer, 2003) [3]. The major advantage of ohmic heating is that it allows rapid and uniform heating. Thus we can expect minimum changes in structural, nutritional and sensory attributes of the food. Particularly for products with high viscosities and those containing particulate matter, ohmic heating is of great value as it enables the solid and liquid phases to have equal heating rates thus preventing overheating of the solid surfaces and also for shear sensitive products, the process is ideal. The instant startup and stopping ability of this process makes it even more simple and easy to use. Another major advantage of ohmic heating is that it takes very short time to reach the required temperature. It is comparable to microwave heating without an intermediary step of converting electricity into microwaves before heating and, unlike microwave heating, the depth of heat penetration is virtually unlimited (Marcotte, 1999) [7].

Ohmic heating is mainly applied till now for solid-liquid products. Moreover it has been widely applied to meat and fruits and vegetables. Work on milk and milk products are very limited. Very few studies are done on milk and even in them very small quantity of milk has been taken under consideration. So there is scope to study application of ohmic heating for milk processing and in the present study heating pattern of milk during ohmic heating was studied.

2. Materials and Methods

A semi-continuous ohmic heating setup was designed and developed for processing 5 litre milk. The setup was provided with the provision of taking the milk out through a valve fitted at the base of the setup. To check the feasibility of the developed setup, preliminary trials were conducted. Priliminary trials were taken by heating 1 litre milk by ohmic heating. The feasibility of the setup was judged based on the time taken for heating of the milk and the extent of fouling. To check the feasibility of the setup, cow milk with 3.5% fat & 8.5% SNF was taken and was heated in the ohmic heating setup. Same milk was simultaneously heated using induction heating.

As the results were promising, 5 litre milk was heated using ohmic heating from 20 to 90ºC. The conceptual diagram of the setup is shown in Fig. 1. The setup consisted of ohmic reactor vessel, heating plates, control unit for varying voltage, thermocouples and temperature data logger. All the trials were conducted in triplicates.

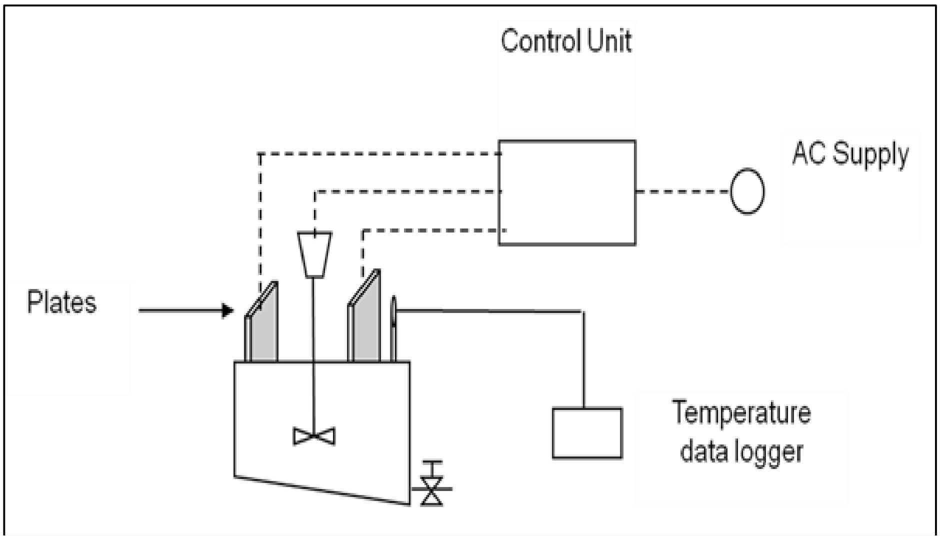

Fig 1: Ohmic heating setup

Temperature profile: Temperature profile indicates the pattern of temperature rise in milk heating during ohmic heating. To get the temperature profile of milk, average temperature was plotted against time.

Heating time: Total time required to increase temperature of cow milk from 20 to 90 ºC was calculated as total heating time.

Heating rate: Average heating rate was calculated as follows:

$$H_R = \Delta T/t = \text{Temperature gradient/ Total time taken}$$

Where, ΔT = temperature difference (90 – 20 ºC), t = time.

Average temperature gradient: To study of uniformity of ohmic heating of milk, average temperature gradient was calculated. Four temperature sensors were used to determine the average temperature gradient. Temperature of pt 100 sensors was recorded as T_1, T_2, T_3 and T_4 respectively. The sensors were positioned at the four corners of the ohmic heating vessel to get the average temperature as a representative of the whole lot of milk.

$$\text{Average Temperature Gradient} = \frac{|T_1 - T_3| + |T_2 - T_4|}{2}$$

3. Results and Discussion

Milk heated using induction heater showed a very high level of fouling at the bottom of the container for 5 litre quantity. As a result of fouling, there was extremely slow rate of heating after a temperature of 60 ºC and it took very long time to reach 90 ºC. On the other hand, ohmic heating showed no signs of fouling at the bottom of the container and there was uniform heating for the whole lot of milk. Also heating on the induction heater took longer time to heat the milk from 20-90 ºC as compared to when heated for the same temperature range using ohmic heating. These observations confirmed the feasibility of the ohmic heating setup to conduct further trials.

Heating rate obtained on heating milk in the ohmic reactor vessel was 3.5 ºC /min. Figure Fig. 2 shows the temperature profile of milk during ohmic heating. Upto around 600 sec, temperature increase followed a linear trend. After 600 sec, as currents increased to the set value and voltage was reduced to bring current in the required range. Therefore, decrease in heating rate was observed after 10 min which was supposed to be due to the decrease in the voltage applied to bring the current within the permissible range.

The thermal efficiency of the system obtained was 88.8%. According to the literature, thermal efficiency of the ohmic reactor is reported to be more than 90%. Thermal efficiency was less than 90% maybe because initially no thermal insulation was used in the system. Insulation between the reactor vessel and cabinet would have resulted in higher thermal efficiency of more than 90%.

Time required for heating five litre milk from 20 ºC to 90 ºC was 21 min in the ohmic heating system. This time was calculated as an average of time taken during all the trials. Time taken in ohmic heating was much less as compared to other conventional heating systems like induction and electrical heating. Hence the results matched with the literature, that ohmic heating is a rapid method of non-thermal heating.

Temperature gradient was monitored to check the uniformity of heating as is claimed in the literature for ohmic heating. Low temperature gradient (0-1 ºC) was observed indicating uniform heating, which has been also reported in literature studies. Also initially the temperature gradient was more but it decreased slowly as heating progressed. Such trend may be due to circulation of bulk fluid due to natural convective heating towards the later part of trials. From the results discussed above, the feasibility of the developed prototype for the five litre ohmic heating system was established. Operational parameters like maximum applied voltage (120 V) and current (10 A) were maintained during the trials.

There were no signs of fouling observed at the bottom of the reaction vessel as in the case of induction heating. There was not much difference in the aesthetic quality of milk treated with ohmic heating compared to the conventionally heated milk. These observations of the study confirmed the feasibility of ohmic heating for milk treatment.

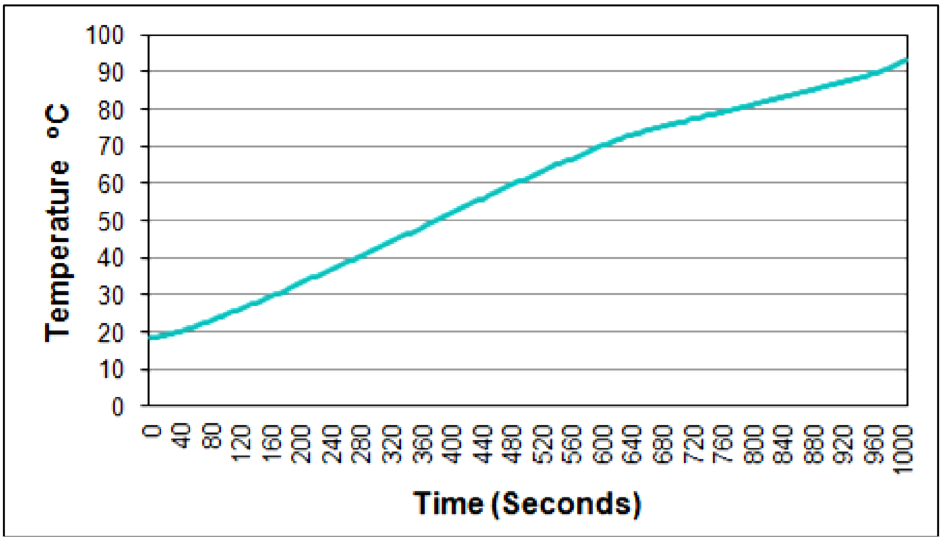

Fig 2: Temperature profile of milk heated in ohmic heating system

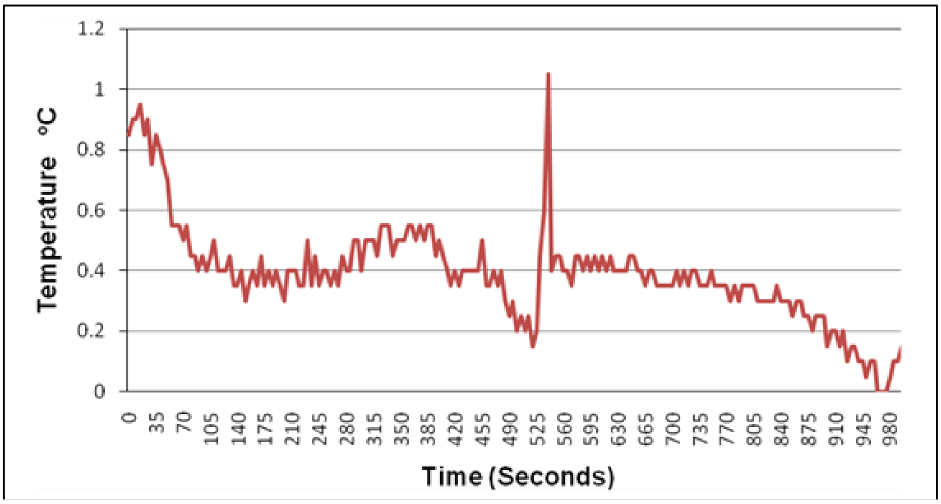

Fig 3: Temperature gradient of milk heated in ohmic heating system

4. Conclusion

Results obtained from the study confirmed the feasibility of heating of milk by ohmic heating technology. Heating rate was observed to be satisfactory with a rate of 3.5 ºC /min proving the rapid heating rate concept by ohmic heating. Heating time for heating 5 litre milk from 20-90 ºC was 21 min. Thermal efficiency of the system was higher (88.8%) than other conventional electric heating systems, without the use of any insulation material. There was no fouling on the bottom of the container and the aesthetic quality of the milk was maintained. The study presented the feasibility of scaling up of the system for higher capacities and for treatments like pasteurization.

5. References

1. Bansal B, Chen XD. Effect of temperature and power frequency on milk fouling in an ohmic heater. Food and Bioproducts Processing. 2006; 84(4):286-291.
2. FDA. United States of America, Food and Drug Administration, Center for Food Safety and Applied Nutrition. Kinetics of microbial inactivation for alternative food processing technologies: ohmic and inductive heating, 2000.
3. Fryer PJ. Electrical Process Heating. Encyclopaedia of Food Sciences and Nutrition, Elsevier Science Ltd, Oxford, UK. 2003, 3044-3049.
4. Icier F. Ohmic heating of fluid foods.In: Novel thermal and non-thermal technologies for fluid foods, (Eds. P.J. Cullen, B.K. Tiwari, & V.P. Valdramidis), USA: Academic press, Elsevier Inc, 2012, 305-368.
5. ICMSF (International Commission on Microbiological Specifications for Foods). Meat and meat products. In T. A. Roberts, J. I. Pitt, J. Farkas, & F. H. Grau (Eds.), Microorganisms in Foods, London, UK: Blackie Academic and Professional. 1998, 6.
6. Kim HJ, Choi YM, Yang APP, Yang TCS, Taub IA, Giles J, *et al*. Microbiological and chemical investigation of ohmic heating of particulate foods using a 5 kw ohmic system. Journal of Food Processing and Preservation, 1996; 20(1):41-58.
7. Marcotte M. Ohmic heating of viscous liquid foods. Doctoral dissertation, McGill University, 1999.
8. Sarkis JR, Mercali GD, Tessaro IC, Marczak LDF. Evaluation of key parameters during construction and operation of an ohmic heating apparatus. Innovative Food Science and Emerging Technologies. 2013; 18:145-154.
9. Sastry SK. Ohmic heating and moderate electric fields processing. Food Science and Technology International. 2008; 14:419.
10. Skudder P, Biss C. Aseptic processing of food products using ohmic heating, The Chemical Engineer. 1987, 26-28.