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Ohmic Heating: An Industrial Approach for Food Processing

Sawant Sanket R.
Assistant Professor, Vignan University-Vadalmudi, Guntur (A.P.)

SUMMARY

Agricultural process engineering or food process engineering defined by composition of different unit operations. The objective of involved unit operations in food processing is to be enhance the shelf life of agricultural commodities. Among, that unit operations, thermal processing is one of the important and leading operation, frequently used by different agro producers. Conventionally evaporators, condenser plates, heating burner, open kettle were used to give the thermal/ heat treatment for pasteurization, sterilization, blanching, drying, extraction processing etc. The high demand of heat utilization, high in operating cost and reduction in qualitatively loss need conventional method to replace by modern thermal method. Taken into considerations of stated limitations of conventional thermal method need to explore the modern thermal methods. Ohmic heating is one of the modern thermal method, evolved and succefully work on agro produce commodities since last two decades. In this article we will look into basic definition, principle, mechanisms, and industrial applications of the ohmic heating..

INTRODUCTION

A recent interest in rapid, environmental friendly, simple and energy efficient methods of food processing has resulted in considerable attention towards ohmic heating as novel thermal technology. Ohmic heating is a novel thermal food processing technology now a day's getting popularize as "green technology". It is known by various names like Joule heating, electro conductive heating, electro heating and electrical resistance heating (Pereira and Vicente, 2010). The basic principle of this method is very simple and based on the Ohm's law of electricity. The passage of alternating electric current through electricity conductive food material such as a liquid, liquid particulates or pumpable foods obeys Ohm's law and heat is generated due to electrical resistance of the material (Patel and Singh, 2018). The food materials which contain sufficient amount of water and electrolytes (mineral salts) can act as electric charge carriers and allows electric current to pass through them resulting generation of internal heat due to electrical resistance of food. In conventional methods of heating, heat transfer occurs from a heated surface to the food material by mean of convection and conduction, while in case of ohmic heating it occurs volumetrically from inside the food (Joshi, 2018). The rate of heat generation mainly depends on two factors in ohmic heating one is electric field strength and other is electrical conductivity.

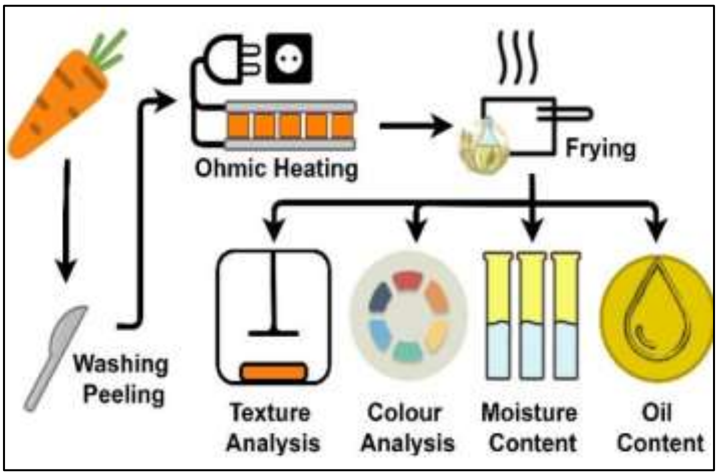

Figure.1: Industrial Set-up of Ohmic heating

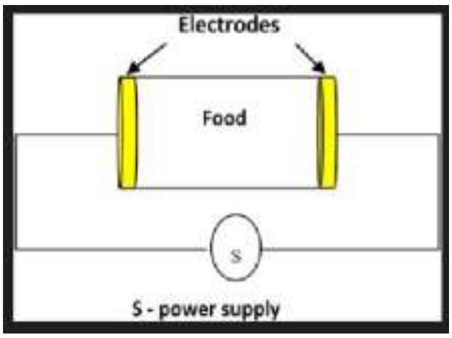

Fig.2: Schematic View of set-up

It avoids thermal damage to nutritional components of food material, such as vitamins and pigments, and prevents overheating. This modern food processing method has wide range of applications in food processing and various researchers had used it for sterilization, pasteurization, extraction, blanching, dehydration, evaporation, juice extraction, peeling, thawing, fermentation and rice bran stabilization. Its advantages over conventional heating include volumetric, faster and uniform heating, higher energy efficiency, technically simple, low capital cost and maintenance. Several advantages of this method have been reported by various researchers such as uniform and rapid heating; continuous process; higher sterilization and pasteurization at comparatively lower temperatures; good product quality and processing of foods with high solid fractions.

Industrial Applications of ohmic heating:

Ohmic heating is attractive commercial technique for processing of food material. It has several potential applications in food processing sector include blanching, thawing, sterilization, online detection of starch gelatinization, pasteurization, fermentation peeling, and dehydration. Zell *et al.* (2011) performed test to examine the effect of design of cell on the uniformity of batch type of ohmic heater in heating solid foods. In the preliminary trials, they tried to minimize heat loss from the surface of cell by insulating it or by giving supplementary heat with heating belt or heating panel but finally they discarded this options and done housing to the cell in a hot air chamber or cabinet maintained at 80 ºC and thus eliminates the cell body around. Before selection of platinised titanium electrodes with 1 mm thickness the trials conducted on various electrode materials. They finally developed design combined ohmic and convection heating with the food material kept in a plastic casing pressurised with two spring loaded electrodes. They found that maximum temperature variation of 12.1 ºC a optimised conditions inside the product and achieved after 150 s which was further reduced to 8.6 ºC after 180 s standing time. Ranmode and Kulshreshtha (2011) conducted the test to increase carrot juice recovery with two stages pressing in ohmic heating processing. They found that the total juice yield increased with increase in the time of first pressing and maximum increase in juice recovery in two stage expression by ohmic heating as compared to control was 13.76%. Total solid percentage in two stage pressing ranged from 7.55 to 11.12% and it was increased with increasing the time duration of first pressing. Total soluble solids in two stage pressing ranged from 3.6 to 6.6 ºBrix and it was found to be increasing at lower voltage gradient and high temperatures. It was observed that two stages pressing with ohmic heating did not cause much change in the colour. They concluded that 98.9% juice recovery can be obtained with first pressing for 2.72 min., heating at 65.6ºC under a voltage gradient of 15 V/cm followed by second pressing for10 min. Mercali *et al.* (2012) evaluated and compared degradation of vitamin C present in acerola pulp during ohmic heating and conventional heat treatment. Central composite rotatable design was used considering solids content of the pulp 2 to 8 g/100 g and voltage 120 to 200 V as variables to study the ohmic heating effect on acerola pulp. They found that ascorbic acid degradation was significantly affected by both variables. Voltage gradient affected linearly and in quadratic manner on degradation of vitamin C. They observed that when ohmic heating treatment applied with low voltage gradients, it promoted the degradation of both vitamin C and ascorbic acid in the way similar to conventional heat treatments. High voltage gradients cause more effect on ascorbic acid degradation due to electrochemical reactions in the pulp. Delfiya and Thangavel (2016) conducted a detailed experiment to study the effect of ohmic heating on the activity of polyphenol oxidase (PPO) with the possible effect on the rate of heating, electrical conductivity and physicochemical properties of water taken from tender coconut. Fresh water of tender coconut obtained and heated ohmically at 15 and 20 V/cm voltage gradients, at 80, 90 and 100 °C heating temperatures and 0, 90 and 180 s holding times. There was no significant difference in the value of pH, titrable acidity and color of the sample after treatment with ohmic heating. With increase in the range of voltage gradient from 15 to 20 V/cm and also increasing holding time from 0 to 180 s decrease the polyphenol oxidase activity significantly in the sample. They found that the sample heated ohmically at 80 °C and 20 V/cm for 180 s shows the minimum polyphenol oxidase activity (30.55 ± 0.92%) also the pink discoloration was controlled till a week when the samples stored at room temperature. Li *et al.* (2017) determined the structure and functional properties of heated soybean milk protein and compared it with ohmic heating (17, 23, 30, and 37 V/cm) and common resistance wire heating. The results of this study indicates that the structure of protein was not changed significantly with other functional attributes and foaming activity reduced by 10, 15, 35, and 40% for the different level of voltage, free amino groups increased by 14% while surface hydrophobicity and sulfhydryl content decreased, foam stability reduced by 28.3, 12.9, 18.3, and 8.3%, respectively with applied voltage, the EAI increased by 38%, whereas ESI decreased by 65%. Abhilasha and Pal (2018) heated and analysed the juice obtained from sugarcane by two different methods ohmic heating and conventional heating. The study revealed that the TPC (total plate count) decreased with ohmic heating method i. e. it was reduced from 6.3 to 3.47 log cfu/ml when sugarcane juice was heated ohmically at 90 ºC for 15 mint. They concluded that ohmic heating of sugarcane juice at 70 ºC for 3 min was optimum condition by observing the result of Polyphenol oxidase (PPO) inactivation, color change and microbial inactivation. Hence, more inactivation of microbes was observed during ohmic heating than conventional heating. Abedelmaksoud *et al.* (2018b) examined the effect of different parameters of ohmic heating (OH) on deactivation kinetics of polyphenoloxidase (PPO) and pectinmethylesterase (PME) enzymes juice prepared from mango. In order to optimize the processing parameters in this experiment, the multiple response surface methodology (RSM) was used. Mango juice treated ohmically at voltage gradient 40 V cm-1, temperature 80 ºC and holding time for 60 sec and conventionally at 90 ºC, holding time for 60 sec found to inactivate PPO completely and the inactivation of PME at same conditions was 96 and 90%, respectively. The ascorbic acid degradation in case of ohmic heating was 11.3% and it was found significantly less than in case of conventional heating i. e. 20%. Increase in the value of total phenolic content was 8 and 5% respectively for ohmic heating and conventional eating treatments while decrease in carotenoids level was significantly less in the ohmic heating (10.9%) than in conventional heating (19.4%). They concluded that ohmic heating for the production of mango juice is a potential mild thermal process which could improve functional properties than conventional heating.

Advantages of Ohmic Heating:

- Temperature required achieved very quickly
- Rapid uniform heating of liquid with faster heating rates
- Reduced problems of surface fouling
- No residual heat transfers after shut off of the current
- Low maintenance costs and high energy conversion efficiencies
- Instant shutdown of the system
- Reduced maintenance costs because the lack of moving parts
- A quiet environmentally friendly system
- Reducing the risk of fouling on heat transfer surface

Disadvantages of Ohmic Heating

- Lack of generalized information
- Requested adjustment according to the conductivity of the dairy liquid
- Narrow frequency band
- Difficult to monitor and control
- Complex coupling between temperature and electrical filed distribution

CONCLUSIONS

In last two decades the rate of applications of ohmic heating was drastically increased by food technologists and food engineers in different sectors including, value additions, preservations, storage, extraction, etc. Due to their positive scientifically proven on efficiently heat utilization, decreased the rate in valuable compounds and comparatively low cost in operation makes ohmic heating popularized. Ohmic heating is best option for conventional thermal processing in various agro based produce sectors.

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