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ELECTRO HEATING OF FOOD- A NEW NON-CHEMICAL METHOD OF PROCESSING

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INTRODUCTION

Use of heat treatment to preserve food is an age old practice and is widely acceptable and applied to all kind of food processing industry. Pasteurization to blanching, retorting, pasteurization are some of the methods of treating foods that helps to enhance its shelf-life. Most of these processes either involve conduction, convection or radiation to produce heat. However, each of these processes have some limitations that prevents their application in one kind of food or other.

Hence to overcome these problems, alternative technologies have been developed that utilizes directly the electrical current to produce heat energy. The technique is somewhat referred to as ‘electro-heating’, ‘ohmic-heating’ or resistance heating. However, electro-heating of food is not new. Some of the patents of 19th century revealed that electrical current was being used for heating or treating flowable materials (Ruan et al.,). Schade (1951) reported a patent for ‘electric’pasteurization of milk. During the pasteurization process, milk was made to pass through parallel plates with a voltage difference between them. The pasteurizers were widely acceptable in United States (Sastry & Palaniappan, 1992). Schade also described blanching of potatoes using electro-heating that prevented enzymatic discolouration.

In the design of McConnel & Olsson (1938) frankfurter sandwiches were cooked by passing through electrical current for a pre-determined time. At that time it was conceived that the lethal effects on microbial or enzymatic growth could be attributed to electricity. However, eventually due to the lack of sufficient resources, a suitable inert electrode material, cost etc. the technology could not gain popularity and was limited to the electroconductive thawing only.

Concept and Principle

The electro-heating of food considers food as liquid-particulate mixture which holds electrical conductivity and can act as a part of an electric circuit. Food that acts as a part of the circuit itself, the alternating current (AC) is made to flow through it, causing generation of heat with in the food due to the electrical resistance it holds. Therefore, if electrical conductivity of two phases are comparable, heat could be generated at the same or comparable rates in both phases where food is a liquid-particulate mixture i.e., it offers two different phases for electricity conduction. The passage of an electric current through a food heats by the Joule effect. Indeed, the food behaves as a resistor in an electrical circuit.

Basic principle of electro-heating of foods is based on the basic principle of ohmic heating of objects where the passage of alternating current through a body such as liquid-particulate food system which serves as an electrical resistance in which heat is generated (Ruan et al.,). The product is treated by placing it in between two electrodes through which the electrical current i.e., alternating current (AC) passes through both the ends of the product body. The rate of heating is directly proportional to the square of the electric field strength, i.e., electricity and electrical conductivity. An electrical current will pass through a food only if sufficient free ions are present to provide electrical conductivity.

The use of direct current is less effective because of the occurrence of electrolysis, due essentially to the exchange of electrons at the contact surface between the food and the electrodes. Alternating current is more suitable and in fact creates an oscillatory movement of ions, which generates the heat dissipation underlying the resistance-heating phenomenon.

The electrical conductivity of the product is the key factor in the electro-heating of food. If the product has more than one phase such as in case of a mixture of particulate and liquid, the electrical conductivity of all the phases has to be considered. Electrical resistance of the food causes the power to be translated directly in to heat. Also, the electrical conductivity increases with rising temperature suggesting that ohmic heating becomes more effective as temperature increases. Also, as electrical conductivity in the products is influenced by ionic content, it is possible to adjust the electrical conductivity of the product (both phase) with ion (eg., salts) levels to achieve effective ohmic heating.

Working

According to the principle of ohmic heating or electro heating of foods, the food to be treated should contain water and ionic salts so that electrical current is easily conducted, but also have a resistance which generates heat when electric current is passed through it. Electric resistance of food also determines how quickly the food will heat. Electrical conductivity measurements are made in the product formulation process control and quality control for all foods that are heated electrically. In composite foods, conductivity of the particles are measured by difference (i.e., product conductivity-carrier medium conductivity). Kim et al (1996) has reported electrical conductivity of various foods as given in Table1.

S. No.	Food	Electrical conductivity (S/m)
1	Potato	0.037
2	Carrot	0.041
3	Pea	0.17
4	Beef	0.42
5	Starch solution (5.5 %) With 0.2% salt	0.34
6	Starch solution (5.5 %) With 0.55% salt	1.3
7	Starch solution (5.5 %) With 2% salt	4.3

Most foods containing mineral salts and having sufficient water content (>70%) are electrical conductors and thus may be heated by resistance heating. The conductivity of such foods is typically between 0.1 and 10 S/m. Pure fats and oils, bone, and crystalline structures (ice) are poor conductors or non-conductors of electricity.

Over a temperature rise of 120^{O} C, the electrical resistance of food falls by a factor of 2 to 3. The electrical resistance is different in different directions, for parallel flow its different and is different for a cellular structure where the flow is across it. Any change in the cell structure changes the resistance also. Eg., the resistance of blanched food is different from the unblanched category of foods, as the air between the cells has been removed and hence the movement is faster. Similarly, for gelatinized foods it is different as compared to free flowing particulate mixture. If the heated medium, as it is in the case of meat emulsions, has a homogeneous conductivity between the electrodes, heating will be uniform. There will be no temperature gradients and therefore no heating by conduction, convection, or radiation from hot zones towards cool zones. This makes it possible to heat foods very rapidly (5 to 20°C/min) without altering food properties by over-heating. In the case of heterogeneous media (liquid-particle mixtures), the current passes preferentially through certain zones thereby creating temperature gradients (e.g. between fluid and solid particles).

Equipment design

Ohmic heaters or electro heaters for food must include electrical properties with respect to the food required to be heated. The concept behind is that the food or the product to be treated is an electrical conductor and thus the flow of current to generate heat should be properly calculated as per the requirement of end product. The electrical resistance of the product with a change in resistance during the application viz., with variation in temperature is the foremost factor to be considered. Besides, flow rate of current and time taken to raise the temperature to desired degree are essentials to be considered. The rate of heating required i.e., upto what temperature the product has to be heated and the heater has to be operated as well as the holding time required for complete electro-heating the food are to be considered while designing the equipment. Parrot (1992) gave the following flow sheet for a standard ohmic heating system (Fig.1).

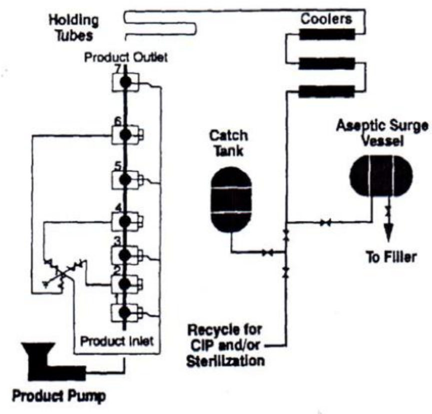

Fig 1: Schematic representation of Commercial Ohmic Design (Parrot 1992).

Design of ohmic heater must consider electrical properties of the foods to be treated and the purpose of treatment i.e., whether it is used for blanching purposes or for the purpose of sterilization or any other treatment has to be given. Heating is faster in solids or the low moisture foods. The food products with high resistance will heat up early as the current will be too low at maximum voltage. Similarly, if the resistance of food is too low the maximum limiting current will be reached at a low voltage and the heating power will be very low.

Resistance in an ohmic heater depends on specific resistance of products and geometry of the heater. Also, this resistance determines the current that is generated in the product. Therefore, it is important to note that one kind of heater with specific resistance can only be used for only one kind of food products and certain modifications shall be required for treating other kind of food product.

The temperature rise in a electro-heater is calculated

Where,

The rate of heat generation depends on:

1. Specific heat capacities of each component
2. The way that food flows through the equipment
3. The residence or the holding time of the product in the heater.

Application and Uses

Electro-heating can heat and sterilize particulate foods (food with solid particles) under UHT conditions without causing heat damage to the liquid carrier or over cooking of outside particles. If in a two component food, a liquid and particles, the particles have a lower electrical resistance and hence are heated at a higher rate.

While heating a food in electro-heaters, it is desirable to pre-heat the carrier liquid to equilibrate resistance of the equipment. Also, gelatinizing the liquid during pre-treatemnt will help to maintain the heat as well as to melt and expel the fats inside the tissue structure. The electro-heating phenomenon is especially useful for stabilizing the sauces by the way of homogenization or for blanching of fruits and vegetables will kill or denature the enzymes. These are helpful in treating enzymatic marinades that could soften the texture of particles or solids in it and also helps in enhancing flavour of the food.

LIMITATIONS

The electro-heating is critically dependent on the electrical conductivity of the food being processed for which only limited information is available. However, to ensure complete sterilization the heating behaviour of the food must be understood. Process reliability and safety could be demonstrated at priority. Presently, following are the major challenges that are hindering the commercialization of the process:

- Lack of complete model that takes in to account difference in electrical conductivity between liquid and solid phases and the responses of the two phases to temperature changes, which affect relative rates and distribution.
- Lack of data concerning critical factors affecting heating, including residence time, orientation, loading levels etc.
- Lack of applicable temperature validating technology for locating cold/hot spots in food to be treated.

CONCLUSION

Conventional heating processes essentially consist of heat transfer mechanisms of conduction, convection and radiation. The internal resistance by conduction results in very heterogeneous treatment and notable loss of product quality. To overcome these problems, alternative technologies must be checked out for both processing and preservation purposes. Ohmic heating is a food processing operation in which heat is generated with in foods by the passage of alternating current. It yields better products, clearly superior in quality than those compared to conventional heating including being more uniform and faster process. There is higher yield and high retention of nutrients in treated foods.

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