



Ohmic Heating for Efficient Thermal Processing of Foods

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DESCRIPTION

Ohmic Heating (OH) is an electrical heating technology in which electric current passes directly through a food material and generates heat within the product. Unlike conventional heat transfer, where energy moves from an external heating surface toward the center of the food, OH produces volumetric heating. This characteristic can provide rapid temperature increases and is particularly interesting for liquid, semi-liquid and particulate food products.

The operating principle of OH depends on the electrical conductivity of the food. When an alternating electrical field is applied, current passes through the product and electrical energy is converted into heat because of electrical resistance. Heating performance depends on conductivity, electric-field strength, temperature, product composition and electrode configuration.

Food composition strongly influences OH. Water-soluble salts, acids, minerals and other electrically conductive components determine how easily current can pass through the product. A food with high electrical conductivity may heat more rapidly than a low-conductivity material under the same electrical conditions. Conductivity can also change during processing as temperature increases, making the heating rate dynamic rather than constant.

OH is particularly attractive for foods containing suspended particles. In conventional heat exchangers, particles can require considerable time to reach the desired internal temperature because heat must travel from the surrounding liquid toward the particle center. Direct electrical heating can reduce some of these heat-transfer limitations when the electrical properties of the product are suitable.

Applications of OH include pasteurization, sterilization, blanching, cooking, evaporation and extraction. Continuous-flow processing systems can move food through a treatment chamber while electrical energy is supplied. This arrangement may support rapid processing and high throughput.

Microbial safety is an important application. Rapid heating can allow food to reach target temperatures within relatively short periods. If the system is correctly designed and validated, OH may provide effective thermal treatment while reducing the time during which food is exposed to elevated temperatures. However, temperature uniformity must be demonstrated rather than assumed.

Several factors can affect uniformity. Particle size, concentration, electrical conductivity, flow pattern and electrode arrangement may create differences in heating behavior. If different parts of a product reach different temperatures, microbial safety and product quality may be compromised. Process modeling and experimental validation are therefore necessary.

Electrode design is a critical engineering consideration. Electrodes must transfer electrical energy efficiently while maintaining food compatibility and resisting corrosion. Electrode material, geometry, surface condition and electrical insulation can influence system performance.

It may also offer energy advantages because electrical energy is generated directly within the product rather than transferred through multiple heat-transfer barriers. The actual energy efficiency depends on the system and electricity source. Energy requirements associated with pumps, controls, cooling and other auxiliary equipment must also be considered in a complete process assessment.

One limitation is that low-conductivity foods may be difficult to heat effectively using OH. In some cases, formulation changes may be required to achieve suitable electrical properties. Such changes can influence taste, nutritional composition and regulatory status, so they should not be introduced solely for engineering convenience without evaluating their effects on the finished product.

Fouling and electrode degradation can also affect long-term operation. Food residues accumulating on equipment surfaces may alter electrical resistance and heat transfer. Hygienic design and appropriate cleaning procedures are therefore necessary for industrial applications.

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Received: 21-Nov-25, Manuscript No. JFPT-25-32880; **Editor assigned:** 24-Nov-2025, Pre QC No. JFPT-25-32880 (PQ); **Reviewed:** 08-Dec-2025, QC No. JFPT-25-32880; **Revised:** 15-Dec-2025, Manuscript No. JFPT-25-32880 (R); **Published:** 22-Dec-2025, DOI: 10.35248/2157-7110.25.16.1194

Citation: Suzuki R (2025). Ohmic Heating for Efficient Thermal Processing of Foods. J Food Process Technol.16:1194.

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Combining OH with conventional heating or other preservation methods may expand its usefulness. Hybrid systems can exploit rapid electrical heating while using additional technologies for final treatment or cooling. Digital monitoring of conductivity and temperature may further improve process control. Future research will focus on improved electrode materials, computational simulation, automated control and real-time monitoring. Better understanding of multiphase foods may also enable more accurate prediction of heating behavior.

In conclusion, ohmic heating demonstrates how electrical engineering principles can be applied directly to food processing. Its ability to generate heat throughout a food material provides opportunities for rapid and potentially efficient thermal treatment. With appropriate product selection, equipment design and validation, OH can contribute to innovative processing systems capable of improving throughput and controlling thermal exposure.