Evaluation of heat transfer coefficients associated with thermal processing systems employed for commercial sterilization

Hosahalli S. Ramaswamy

Professor, Department of Food Science and Agricultural Chemistry, Macdonald Campus of McGill University, Ste Anne-de-Bellevue, PQ, H9X3V9 Canada, 514-398-7919 (Tel); 514-398-7977 (Fax)
Hosahalli.ramaswamy@mcgill.ca

INTRODUCTION

Thermal processing has been one of the most effective methods of preserving foods to ensure the product remains safe from harmful bacteria. Heat treatment used to ensures a safe food supply however, it can also have deleterious effects on the sensory characteristics of the product, such as color, texture and nutritional value. For rapid heating products, such as juices and beverages, soups, sauces, vegetables in brine and sparsely distributed meat in light gravy, high temperature-short time processing (HTST) has employed to provide better quality retention while assuring product safety. This method is successful because, compared with microorganisms, the nutrients in foods have a higher resistance to thermal destruction and a lower sensitivity to temperature changes, making it possible to apply the HTST technique to sterilize the product while retaining high quality. This is true mostly for processes that promote rapid heating conditions like aseptic processing. In aseptic processing, the product is rapidly heated to a high temperature and held for a short time, cooled and then packed into a pre-sterilized containers inside a sterile chamber. Since these products are heated outside of the packaging materials, product sterilization is not limited by container configurations and it would thus be possible to optimize / enhance the heat transfer process within the product. However, the technology has been limited to liquids such as milk and juice and liquids that contain only small particles like that of soups, and yet to be fully realized for canned liquid foods that contain large particles.

HTST processes are not beneficial for conduction-heating food products that heat slowly by comparison, exhibiting large temperature differences between the surface and the center of the container, and so some alternatives have been used to enhance the heat transfer rates in solid and semi-solid products. Agitating the container to enhance mixing (in particulate fluids which normally heat by conduction) and the use of thin profile packages (retort pouches) are some other approaches used to promote better quality. In these products the overall rate of heat transfer to the packaged food is enhanced either by product mixing or by keeping the heat transfer distance short. Rotary retorts can increase the convection in containers containing liquid-particle mixtures such as high quality peas, corn, asparagus, mushrooms and a variety of semi-solid or viscous foods such as sauces or soups containing meat chunks or vegetables. Rotary processing leads to the rapid heating and uniform temperature distribution inside the product, therefore requiring less energy and shorter process times and providing higher quality retention. Rotary retort processing is more suitable to semi-solid products (liquid with particulates) because of the faster heat transfer to the liquid and particles by enhanced convection. Since particulate liquid canned foods are not ideal candidates for aseptic processing, rotary retort processing is a potential alternative to aseptic processing for such products and is not limited by the problems associated with thin profile processing such as
slow filling and sealing speed, high manual labor etc., although it needs a special retort in order to agitate the containers.

**Heat transfer studies**

Presently, designing a thermal process for canned foods in retort processing requires experimentally gathered heat penetration data. Since safety is the prime focus of regulatory agencies in approving a designated thermal process, worst case scenario data on temperature time history of the product undergoing thermal process are a necessity for their approval. While attempts have been largely focused on conservative estimates of cold-point time temperature data, process optimization has always been achieved using mathematical modeling approaches.

Mathematical models based on the heat transfer studies can predict the transient heat penetration of canned foods, hence reducing the number and the cost of the experiments required to achieve product safety and quality. Two key factors, the overall heat transfer coefficient from the retort heating medium to the canned liquid, \( U \), and the fluid to particle heat transfer coefficient, \( h_{fp} \), are needed to predict heat transfer rates to the particle at the coldest point inside the can. Because of the practical difficulty in monitoring the transient temperature history of the particle moving inside an agitated liquid, the associated \( h_{fp} \) is one of the important gaps in our knowledge of heat transfer.

Many studies have been conducted on the determination of \( U \) and \( h_{fp} \) in retort processing and aseptic processing systems. When experimentally determined temperature data are available, it is easy to fit them to a heat transfer model to evaluate the heat transfer coefficients. But when moving particles are involved, it is difficult to measure the true particles temperature due to the problems associated with attaching measuring devices or without restricting the particle movement. Since factors like centrifugal, gravitational, drag and buoyancy forces all can have an effect on the particle motion and therefore \( U \) and \( h_{fp} \), to not represent these in a simulation would cause deviations in the measured heat transfer coefficients. Measurements of \( h_{fp} \) in a free motion situation, therefore, have been divided into three categories: using data from only temperature and combining it with mathematical modeling, use indirect devices to measure particle temperatures or measuring particle temperatures by attaching very thin wire thermocouple providing for particle motion during processing. In the author’s lab, many different techniques have been used for evaluating \( U \) and \( h_{fp} \) under a range of thermal processing conditions. This presentation will highlight developed methodologies for the evaluation of associated heat transfer coefficients under the various thermal processing conditions including conduction heating in still retorts to agitation processing under end-over-end, fixed axial and free axial conditions as well as aseptic processing conditions.

**REFERENCES**

