OVERVIEW PAPER

Novel Food Technologies for Enhancing Food Security and Safety

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ABSTRACT

Achieving global food security is an institutional responsibility worldwide. Achieving food security means providing adequate amounts of safe and nutritious food for the global population. On one hand it requires production and procurement of sufficient food and on the other hand to enhance technologies to preserve them. Existing or continuing government policies and priorities often focus on improving and adaptation of farm level technologies so that the well being of the farmer is enhanced. Education programs are set in place for making such concepts sustainable. This is an adorable job and helps to reduce food losses. When large quantities of food are produced, it becomes necessary to empower the food bio-processing industries with tools to preserve the surplus and transform them into safe and nutritious products. Many food processing technologies have been developed and practiced in order to achieve this goal. Many novel processes have evolved to meet this demand as well as to produce safe and nutritious products with extended shelf-life.

INTRODUCTION

By the turn of the century, consumers have been more demanding, sophisticated and discretionary. They will want much safer, high-quality, and convenience foods. The food processor will need to get the best from his existing processing technology in addition to looking for newer ones. New and alternative food processing methods &/or novel combinations of existing methods are continually being investigated by the industry in pursuit of producing better quality foods more economically. Examples of these include: novelties include novelties in conventional thermal processing such as thin profile, rotational and aseptic processing, use of nonconventional heating sources such as microwave, radio frequency, ohmic heating, or novel technologies such as ultrahigh pressure processing, pulsed electric fields, pulsed UV, irradiation, membrane processing, new forms of packaging, use of nanotechnology, among many other technological concepts.

Thermal processing is one of the most important food preservation techniques that was first introduced at the beginning of 1800 and has evolved itself in to one of the most scientific mature food processing techniques of recent times. Both science and technology have gone through tremendous transformation in the last two centuries and today it is the most reliable method to assure food safety and stability.

Principles of Thermal Processing

Thermal processing (commonly called canning) is one of the important preservation techniques for producing packaged shelf-stable food products. Processed foods constitute a significant portion of a typical diet. Traditionally, the primary objective of thermal processing has been the destruction of micro-organisms of public health concern and those causing spoilage of food packaged in hermetically sealed containers (tin plate cans, glass jars, flexible or semi-rigid laminated plastic containers). Associated with thermal processing is always some degradation of heat-sensitive quality factors that is undesirable. Since much demand is on safe and shelf-stable food products along with a high quality attributes, processing schedules are designed to keep the process time to the required minimum. Foods subjected to thermal processing are not sterile and the processes are not designed to make them sterile. The success of thermal processing does not depend on the complete destruction of all types of microorganisms which would result in low product quality due to the long heating required. Instead, all pathogenic and most spoilage causing microorganisms in a hermetically sealed container are destroyed, and an environment is created inside the package that does not support the growth of spoilage-type microorganisms and their spores. The principle of thermal processing is demonstrated in Figure 1 (Ramaswamy and Marcotte, 2005; Stumbo, 1973).

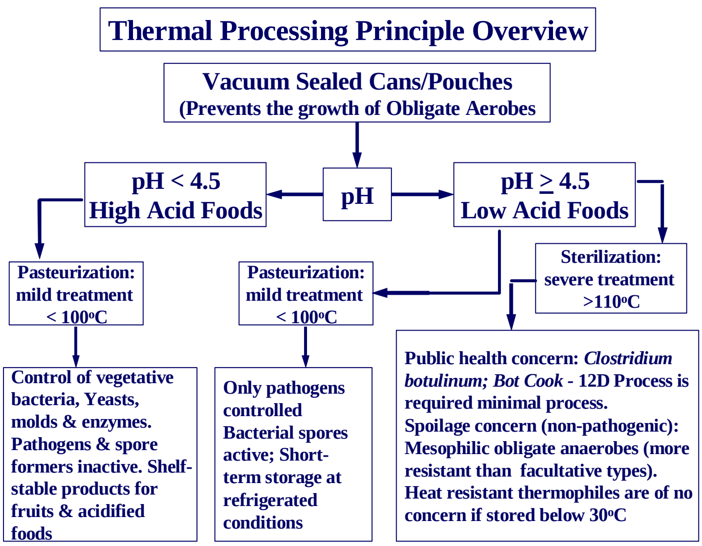

Figure 1. Schematic principles of thermal processing

To determine the extent of heat treatment several factors must be known: the type and the heat resistance of the target microorganism, spore, or enzyme present in the food; the pH of the food; the storage conditions following the process; the heating conditions as well as the thermo-physical properties of the food and container shape and size. The process is scientifically established taking in to account all the above factors using either a graphical or numerical integration procedure (general methods) or using analytical models (formula methods).

Optimizing the Quality in Thermally Processed Foods

Today, the consumer needs demand more than the production of safe, shelf-stable foods. An optimal thermal process may be defined as the minimum heat treatment required to achieve commercial sterility because heating cost and product quality losses increase if the process time is prolonged. The objective is primarily to maximize quality retention while assuring the minimal safety level required. One of the early methods used for quality optimization is the so called high temperature short time method which is based on the principle that nutrients and microbial spores have differential temperature sensitivity to thermal destruction, and as the process temperature increases, for a given heat treatment, there is greater destruction of microbial spores than nutrients. Hence when established to give a specific level of microbial destruction, the result in better retention of nutrients and other quality factors. Figure 2 illustrates the fact that different time-temperature treatments from t1-T1 to t4-T4 progressively results in lower level of nutrient destruction while achieving same level of destruction of *Clostridum botulinum*) (Ramaswamy and Marcotte, 2005).

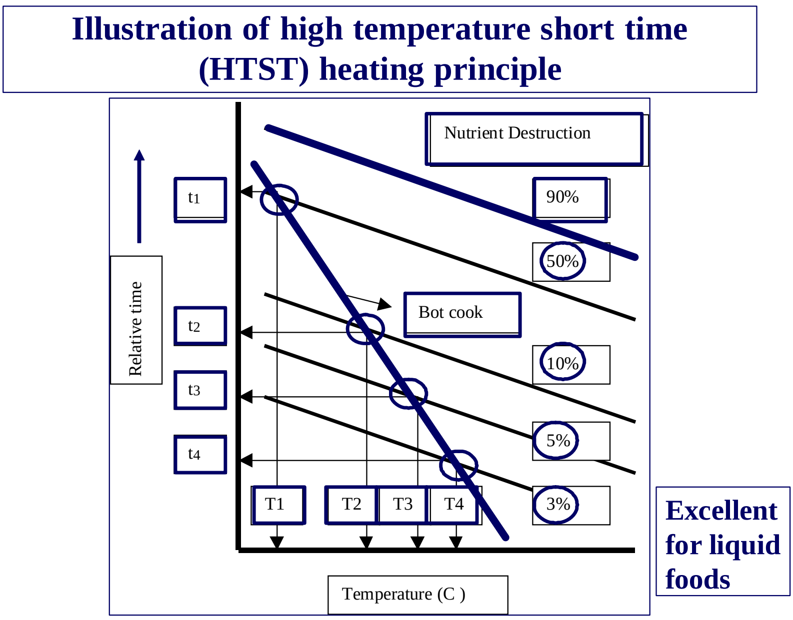

Figure 2. Demonstration of the HTST concept for improved nutrient retention

Other methods of achieving better nutrient/quality retention are by improving the rate of heat transfer in to the product. This can be done by agitating the containers during cooking (agitation processing, end over end and axial type), by keeping the product in thin profiles (retort pouch or thin profile processing) and through a process in which the product and package are sterilized separately and then the product is filled in to the sterile containers in an aseptic environment (aseptic processing). These are illustrated in Figure 3.

The rotary processes induce agitation and product mixing thereby promoting faster heat transfer. These products heat by conduction in conventional static retort systems and therefore are subjected to long heating times and result in poor product quality and poor energy efficiency. There are two types of agitation induced in the rotary autoclaves – end over end and axial. The end over end type of agitation is characteristic of batch systems in which the cans are locked in cars which are rotated at adjustable speeds during cooking. The axial type is characteristic of continuous flow systems (Ramaswamy and Dwivedi, 2011; Hassan and Ramaswamy, 2011).

In aseptic processing, typically, a feed pump continuously meters the liquid-particulate mixture through an SSHE which quickly raises the fluid temperature to the sterilizing levels, then through a holding tube where the sterilization process is completed through temperature equilibration, a back pressure regulator, and a cooling heat exchanger (usually another SSHE) to a sterile tank which serves as a feed tank for the aseptic filler. Pre-sterilized containers are filled with the cold product in a chamber that prevents recontamination, and the containers are sealed with pre-sterilized closures within the aseptic chamber(Ramaswamy and Dwivedi, 2011).

In thin profile processing, the heating rate is faster because the shorter distance the heat has to travel within the container. The retort pouch is a laminate of three materials: an inner layer of polypropylene to provide food contact surface and heat sealability, middle layer of aluminum foil for barrier properties, and an outer layer of Nylon for strength and printability (Ramaswamy and Tung, 1988; Ramaswamy, and Grabowski, 1996).

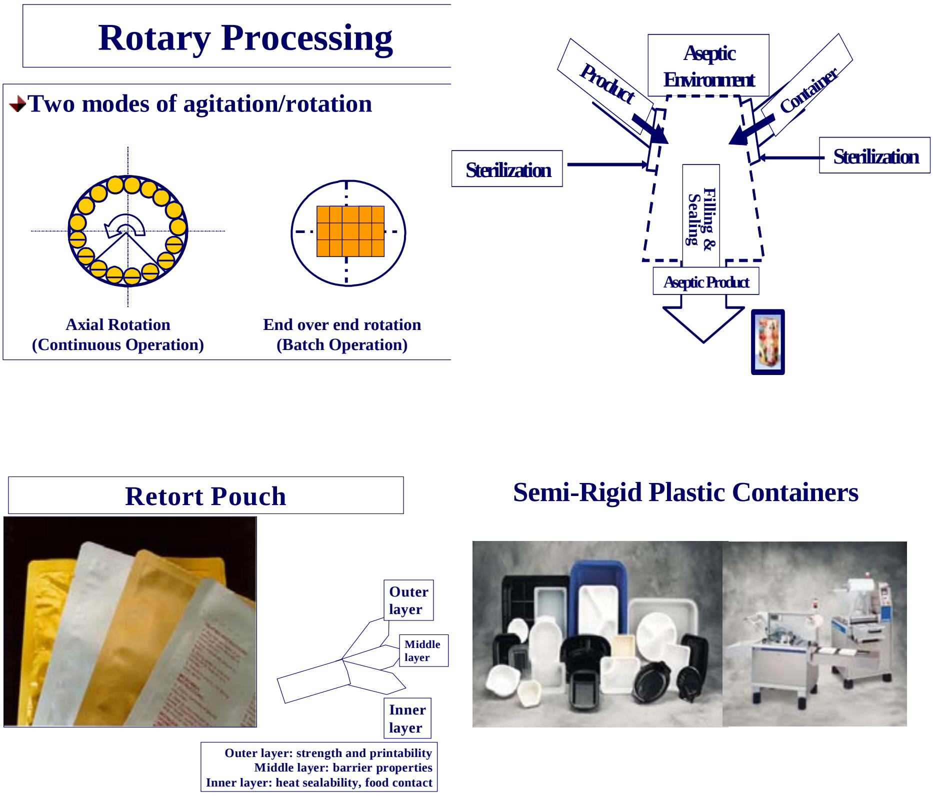

Figure 3. Novel thermal processes

Microwave, RF and Ohmic Heating

Microwave (300 MHz - 300,000 MHz) and radio frequency waves (0.003 MHz - 300 MHz) are a part of the electromagnetic spectrum. Microwave (MW) and radio frequency (RF) energy generates heat in dielectric materials such as foods through dipole rotation and/or ionic polarization. Microwave ovens are now common household appliances. Popular industrial applications of MW heating in food processing operations include tempering meat or fish blocks and precooking bacon or meat patties, while RF heating is commonly used in finishing drying of freshly baked products. Such applications shorten processing times, reduce floor space, and improve product qualities compared to conventional methods. Extensive research has been carried out over the past fifty years on MW and RF energy in pasteurization, sterilization, drying, rapid extraction, enhanced reaction kinetics, selective heating, disinfestations, etc., but with limited applications. Technological challenges remain and further research is needed for those applications. Microwave/RF sterilization applications demand more thorough and systematic studies as compared to other applications. These studies will have far reaching impacts to the food industry and research communities (Ramaswamy and van de Voort, 1990; Tajchakavit *et al.*, 1998; Lin and Ramaswamy, 2011).

Ohmic heating is based on the passage of alternating electrical current through a food product that serves as an electrical resistance. Due to the current passing through the food sample, relatively rapid heating occurs. Ohmic heating has good energy efficiency since almost all of the electrical power supplied is transformed into heat. In practice, heating can be done by applying alternating current at low frequencies (50 or 60 Hz), but low frequencies have an electrolytic effect similar to that of direct current. The major electrolytic effect is the dissolution of the metallic electrodes, which may contaminate the product. To avoid such problems generally electrodes made out of titanium are employed in food industry. Recently such problems have been over come by the use of high frequency alternating currents; under these processing conditions, regular stainless steel electrodes can be employed. Many factors affect the heating rate of foods undergoing ohmic heating: electrical conductivities of fluid and particles, the product formulation, specific heat, particle size, shape and concentration as well as particle orientation in the electric field and the electrical conductivity of the food product (Piette *at al.*, 2004)

High Pressure Processing

High pressure (HP) processing is an innovative technological concept that has a great potential for extending the shelf-life of foods with minimal or no heat treatment. It is a process aimed at controlling deteriorative changes such as microbial and enzymatic activity without subjecting the product to drastic heat (thermal processing) and mass (drying) transfer techniques such that the original quality is retained. The application of hydrostatic pressure to food results in the instantaneous and uniform transmission of the pressure throughout the product independent of the product volume. The treatment is unique in that the effects neither follow a concentration gradient nor change as a function of time. A significant advantage is the possibility of operation at low or ambient temperatures so that the food is essentially raw. Gelation, gelatinization and texture modification can be achieved without the application of heat. Presumably, hydrostatic pressure, a physical treatment, is not expected to cause extensive chemical changes in food system. Once the desired pressure is reached, the pressure can be maintained without the need for further energy input. Liquid foods can be pumped to treatment pressures, held, and then decompressed aseptically for filling as with other aseptic processes.

The main efforts to find uses for high hydrostatic pressure technology in the food industry have been made in Japan. The first high pressure processing line was introduced in Japan for jam manufacture in 1990 and has since been upgraded to fruit yogurts, jellies, salad dressings and fruit sauces. The early batch processes have been extended to semi-continuous operations for bulk treatment of citrus juices at 4000-6000 liters/h. Machines are now available with operating pressures up to 10,000 kg/cm^2.

High pressure processing is a novel technique for processing of foods and has attracted considerable attention in recent years. It has been commercialized for a variety of acid and acidified food products. For low acid foods, it has been used only as a temporary measure of extending the shelf-life under refrigerated storage conditions. It has also been used for several other purposes including control of some pathogens, viruses, for inducting functional changes as well as improving nutritional and sensory quality of foods.

HPP has been used mainly for refrigerated and high-acid foods. Pasteurization by HPP can be carried out at pressures in the range 400-600 MPa at relatively moderate temperatures (20-50°C). Under these conditions, HPP can be effective in inactivating most vegetative pathogens and spoilage microorganisms. High pressure processing is, as yet, an unscheduled process for the production of low acid foods with the FDA or any regulatory body.

At McGill University, extensive investigation has been carried out on HP processing of several foods for pasteurization purposes: milk, meat, pork, fish, orange juice and apple juice. These studies have aimed at generating the necessary kinetic data useful in establishing HP processes for different foods, and then verifying their validity through inoculated pack / challenge studies with pathogens. Figure 4 shows the HP pilot plant facilities at McGill University and types of products that can be successfully processed by the application of high pressure processing (Basak, and Ramaswamy, 1998; Shao and Ramaswamy, 2011).

Affordable Technologies for the Developing World

While it is important recognize the advances in food processing technologies, it is also important to recognize those simple one which can be used in the developing world. These include simple techniques for cooling like evaporative coolers, simple air drying techniques including solar drying, simple processing techniques suitable for home canning (jams, jellies, pickles etc), simple fortification techniques for enhancing value of processed foods, coating of fruits and vegetables for extending their shelf life, use of good storage containers and structures (FAO work) etc. (Azarpazhooh and Ramaswamy, 2010; Houjaij *et al.*, 2009; Maftoonazad and Ramaswamy, 2008; Germain et al., 2006; Prabhanjan *et al.*, 1995; Ramaswamy *et al.*, 1991; Ramaswamy *et al.*, 1982). A few are illustrated in Figure 5 and some references are listed for others. The beautiful fruits and vegetables of Ethiopia, as shown, will end up in garbage aggravating the food security problems if appropriate processing techniques are not adapted.

Concluding Remarks

There several established and mature technologies for food processing like canning, freezing, drying, concentration, fermentation, use of preservatives etc. Some of these have been traditionally used for a long time and science has provided the basis for their commercialization. Technology has always been evolving and newer techniques are added to replace the older ones. Food industry's challenge is to make use of every niche in the technological advance to remain competitive in the market place. This article presents only an overview of the concepts involved in some of the novel and emerging technologies for food processing. Additional details are available in many publications in the area of food science and engineering.

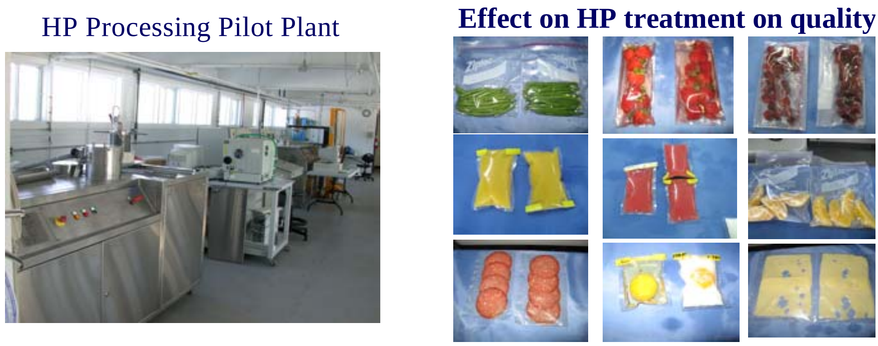

Figure 4. The high pressure pilot plant at McGill University, Canada and examples of successful products from high pressure processing

Figure 5. Affordable technologies for the developing world

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