Paper No.: 02

Paper Title: The Principles of the Food Processing & Preservation

Module No. : 23

Module: Processing & Preservation By Non-Thermal Methods

23.0 Introduction

Food processing procedures like cooking, blanchingor freezing are familiar to the consumers, because theyapply them in their own households. In the food industrythese and other operations are carried out by the aidof modern process-technology plants utilising technicalpossibilities that are normally not available for theconsumer. Modern food technology on the one handdeals with further development of traditional methods,e.g. high-temperature short time heating or vacuumcooking, and on the other hand with procedures, thathave been taken over from different industry-branchesand adapted to food processing, e.g. extrusion, microwave-technology or high pressure-treatment. Newlydeveloped food technologies usually focus on preservationwhile keeping food quality attributes. Although thermal preservation provides safer food, there exists loss of food properties like nutrientsand sensory attributes. The main objectives of new techniques are, to retain the nutrients, sensory properties and to increase the shelf life without any adverse effect on its quality. The other objectiveof preservation is to increase the shelf life by reducing the microbial load and also the water activity.Both can be achieved by either traditional method of preservation methods or by non thermaltreatments like microwave heating, Pulsed Electric Field (PEF) Technology, High Pressure Processing(HPP), Pulsed Light Technology, Ohmic Heating, Irradiation, Ultra sonics, Pulsed X-Rays,Oscillating Magnetic Fields (OMF). The selection of particular preservation method for the particular food product is based onthe criteria like cost of production, scale of production, type of product either milk,meat, poultry, fruits or vegetables, shelf life and end product usage either ready-to-eat or ready-to cook product. The non thermal techniques are recently used for all the food products for shelf lifee xtension.

Objectives of Non thermal food processing are:

- Render foods free of pathogenic & spoilage organisms
- Retain color, flavor
- Improve shelf life
- Improve texture

Non thermal food processing techniques are more suitable for liquid foods thansolid and semi-solid and also for processing of ready-to-cook packed foods. It is also reviewed that uniform distribution of heat is not achievedin processing of solid foods using new trends in food processing. Investment cost of new methods of food processing is quite high and it can be applied to large scale industries when compared to smallscale industries. The better quality is achieved in non thermal processing and its shelf life is alsoincreased by this method.

23.1Ohmic heating

Ohmic heating is a thermal method that minimizes equipped with several electrodes. The advantage ofohmic heating is its ability to heat materials rapidly anduniformly, including products containing particulates. The principal mechanisms of microbialinactivation in ohmic heating are thermal while someevidence exists for non-thermal effects of ohmic heating as well. A large numberof potential future applications exist for ohmic heating,including its use in blanching, evaporation, dehydration, fermentation and extraction. Ohmic heating isemployed in pasteurising and sterilising of liquid and particulate foods, especially of ready-to-serve meals,fruits, vegetables, meat, poultry or fish, and is an alternativeto sterilisation of foods by means of conventionalheat exchangers or autoclaves. The applicability is limitedto foods with sufficient conductivity.

23.2High electric field pulses

The first attempts to treat foods (milk) with electro-impulseswere reported at the end of the 1920s in theUSA. Further experiments followed inthe 1960s primarily within molecular-biological researchfor incorporation of foreign gene material into microorganisms.During the last few years research in thefood-area has been reinforced again.High intensity pulsed electric field (PEF or HELP)processing involves the application of pulses of highvoltage (typically 20ï 80 kV/cm) to foods placedbetween two electrodes. HELP may be applied in theform of exponentially decaying, square wave, bipolar,or oscillatory pulses and at ambient, sub-ambient, orslightly above-ambient temperature for less than 1second.Energy loss due to heating of foods is minimised, reducingthe detrimental changes of the sensory and physicalproperties of foods. Microbial inactivation by HELP hasbeen explained by several theories. The most studiedpossibilities are electrical breakdown and electroporation. Electric high-voltageimpulsesgenerate a trans-membrane potential acrossthe cell membrane of, for example, a bacterial cell whichoverlays the natural membrane potential. If the differencebetween outer and inner membrane potential risesabove a critical value of about 1 V, polarisation and inthe end breakdown of the membrane is induced. Atsufficient high field-strength (above 10 kV/cm) andduration of the pulses (usually between nano- andmicroseconds) vegetative micro-organisms in liquidmedia are inactivated due to irreversible membranedestruction. Bacterial spores, however, are not inactivated.

Factors that affect the microbial inactivationwith HELP are process factors (electric field intensity,pulse width, treatment time and temperature and pulsewave shapes), microbial entity factors (type, concentrationand growth stage of micro-organism) and mediafactors (pH, antimicrobials and ionic compounds, conductivityand medium ionic strength). Important aspectsin pulsed electric field technology are the generation ofhigh electric field intensities, the design of chambers thatimpart uniform treatment to foods with a minimumincrease in temperature and the design of electrodes thatminimise the effect of electrolysis. Different laboratoryandpilot-scale treatment chambers have been designedand used for HELP treatment of foods. Two industrialscaleHELP systems are available including treatmentchambers and power supply equipment. HELP has beenapplied mainly to improve the quality of foods. Applicationof HELP is restricted to food products that can
Withstand high electric fields, i.e. have low electricalconductivity, and do not contain or form bubbles. Theparticle size of the liquid food in both static and flowtreatment modes is also a limitation. Although HELPhas potential as a technology for food preservation,existing HELP systems and experimental conditions arediverse, and conclusions about the effects of criticalprocess factors on pathogens of concern and kinetics ofinactivation need to be further studied.Based on practical experience from pilot plantsemployment of HELP will mainly be in the sparingpasteurisation of liquid foods e.g. juices, milk or liquidwhole egg. Conclusive data on the absence of potentialhealth risks or on the impact of the process on foodcomponents are hardly available yet.

23.3Light pulses

Pulsed light is a method of food preservation thatinvolves the use of intense and short-duration pulses ofbroad spectrum ótówhite lightôö (ultraviolet to the nearinfrared region). For most applications, a few flashesapplied in a fraction of a second provide a high level ofmicrobial inactivation. This technology isapplicable mainly in sterilising or reducing the microbialpopulation on packaging or food surfaces. It could beshown that light-impulses are able to extend the durabilityof bread, cakes and pastries, sea food or meat.As light pulses penetrate certain packaging materials,wrapped items also can be treated. Still there is a needof independent research on the inactivation kineticsunder a full spectrum of representative variables of foodsystems and surfaces.

23.4Oscillating magnetic fields

Experiments have shown, that strong static (SMF) oroscillating (OMF) magnetic fields (5ï 50 Tesla) have theenergy input and thus reduces thermal damage to food.If an electric current is passing through a conductivemedium, in this case the food, the medium warms up asa result of the movement of ions. The conductive electricresistance heatingð ohmic heatingð utilises the effect
of the electrical resistance within a conductive liquid orsolid material. In this manner a direct conversion of electricenergy into heat takes place. In production plants theproduct is continuously pumped through a column potential to inactivate vegetative micro-organisms. Theimpulse duration is between 10 ms and several miiliseconds.

The frequencies are maximally 500 MHz,because above that value the items begin to warm upnoticeably. Preservation of foods with OMF involvessealing food in a plastic bag and subjecting it to 1ï 100pulses in an OMF at temperature of 0 to 50 _C for atotal exposure time ranging from 25 to 100 ms. Theeffects of magnetic fields on microbial populations haveproduced controversial results. Before consideringthis technology for food preservation purposes consistentresults concerning the efficacy of the method areneeded.

23.5Ultrasound

Ultrasonic waves (energy generated by sound wavesof 20,000 Hz or more) generate gas bubbles in liquidmedia, that produce a high temperature-and pressureincrease when they immediately burst. The bactericidal effectof ultrasound is attributed to intracellular cavitation,that is, micro-mechanical shocks that disrupt cellularstructural and functional components up to the point ofcell lysis. Critical processing factors are the nature of theultrasonic waves, the exposure time with the microorganisms,the type of micro-organism, the volume offood to be processed, the composition of the food, andthe temperature.

The effects, however, are not severe enough for a sufficientreduction of micro-organisms so most applicationsuse combinations with other preservation methods. Because of thecomplexity and sometimes protective nature of the foodthe singular use of ultrasound as a preservation methodis impracticable. Although ultrasound technology has awide range of current and future applications in thefood industry, including inactivation of micro-organismsand enzymes, presently, most developments forfood applications are non-microbial. There are notmany data on inactivation of food micro-organisms byultrasound. Research activities centred on the combinationof ultrasound with other preservation processes(e.g. heat and mild pressure) which appears to have thegreatest potential for industrial applications.

23.6High pressure processing

The technology of high pressure processing (HPP),also referred to as ultra high pressure UHP) or highhydrostatic pressure (HHP) has been known to be apotential preservation technique for more than a century; for instance, microbial spoilage ofmilk could be delayed by high pressure. Technical-scientificprogress has led to a renaissance of food pasteurization by hydrostatic high pressure recently. A rangeof pressure-treated products has already been introducedinto the markets of Japan, France, Spain andUSA. HPP subjects liquid and solid foods, with orwithout packaging, to pressures between 100 and 800MPa. Process temperature during pressure treatment
can be from below 0°C to above 100°C. Exposuretimes can range from a few seconds to over 20 min.Food treated in this way has been shown to keep itsoriginal freshness, colour, flavour and taste. HPP actsinstantaneously and uniformly throughout a mass offood independent of size, shape and food composition.Compression will increase the temperature of foodsapproximately 3°C per 100 MPa and may also shift thepH of the food as a function of imposed pressure. Pressurepasteurisation

is feasible also at room temperatureand energy saving as compared to heat treatment.Water activity and pH are critical process factors in theinactivation of microbes by HPP. An increase in foodtemperature above room temperature and to a lesserextent a decrease below room temperature in some casesincreases the inactivation rate of micro-organisms duringHPP treatment. Temperatures in the range of 45ï 50°C appear to increase the rate of inactivation of food pathogens and spoilage microbes. Temperatures rangingfrom 90 to 110°C in conjunction with pressures of500ï 700 MPa have been used to inactivate spore-formingbacteria such as Clostridium botulinum. Currentpressure processes include batch and semi-continuoussystems.

Besides destruction of micro-organisms there are further influences of pressure on foodmaterials to be expected: protein denaturation or modification,enzyme activation or inactivation, changes in enzymeï substrate interactions, changes in the propertiesof polymer carbohydrates and fats. Generally any process and any reaction in foodto which the principle of Le Chatelier applies are of interest. According to this principle, under equilibriumconditions, a process associated with a decrease involume is favoured by pressure, and vice versa. Anincrease of pressure has been found to change the reactionrate of chemical reactions in solution. But thiseffect is small as compared to the influence of temperature.The renewed interest in high-pressure pasteurization of food has raised questions e.g. on the pressure - temperature behaviour of macromolecular food components such as proteins, lipids and polysaccharides.For example, the mechanism of protein gelation and of the sol/gel behaviour of polysaccharides are not wellunderstood. Little is known so far about chemical reactionsof low-molecular weight compounds in the food matrix under pressure, usually in aqueous media. Highpressure, on the other hand, has for long been a meansof manipulating organic-chemical reactions. High pressure influences organic reactionsin general. So at pressures >500 MPa which areemployed for food sterilisation chemical reactions in thefood are to be expected which may be of desirablecharacter or not.

23.7 Conclusion

The main problem with the thermal processing of food is loss of volatile compounds, nutrients, andflavour. To overcome these problems non thermal methods came into food industries to increase production rate and profitability. The non thermal processing is used for all foods for its better quali ty, acceptance, and for its shelf life. The new processing techniques are mostly employed to the liquid packed foods when compared to solid foods. Since the non thermal methods are used for bulk quantities of foods, these methods of food preservation are mainly used in the large scale production.The costof equipments used in the non thermal processing is high when compared to equipmentsused in thermal processing. After minimising the investment costs of non thermal processing methods,it can also be employed in small scale industries

Table 1: Summary of Non Thermal Food Processing Methods

Process	Description	Critical factors	Mechanism of inactivation	Status
UV-light/pulsed light	UV radiant exposure, at least 400 J/m^2 Intense and short-duration pulses of broad spectrum (ultraviolet to the near infrared region).	Transmissivity of the product, the geometry, the power,wavelength and arrangementof light source(s), the productflow profile	DNA mutations induced by DNA absorption of the UV light	Used for disinfection of watersupplies and food contact surfaces
Ultrasound	Energy generated by sound waves of 20,000 Hz or more	The heterogeneous andprotective nature of food (e.g.inclusion of particulates) severelycurtails the singular use ofultrasound for preservation	Intracellular cavitation(micro-mechanical shocks thatdisrupt cellular structural andfunctional components up cell lysis)	Combination with e.g. heat,pressure has certain potential
Oscillating magnetic field (OMF)	Subjecting food sealed in plastic bags to1ï 100 OMF pulses (5ï 500 kHz, 0ï 50°C, 25ï 100 ms)	Consistent results concerning the efficacy of this method are needed	Controversial results on effects ofmagnetic fields on microbial populations	Application at the moment not considered
Pulsed electric field (PEF)	High voltage pulses to foods between twoelectrodes (<1 s; 20ï 80 kV/cm; exponentiallydecaying, square wave, bipolar, or oscillatorypulses at ambient, sub-ambient, or aboveambient temperature)	Electric field intensity, pulse width,treatment time, temperature, pulsewave shapes, type, concentrationand growth stage of microorganism,pH, antimicrobials, conductivityand medium ionic strength	Most theories studied are electricalbreakdownand electroporation	Different laboratory-and pilot-scale treatment chambersdesigned and used for foods,only two industrial-scale PEF systems available
High pressure processing (HPP)	Liquid/solid foods, with/without packaging (100ï 800 MPa, below 0°C to >100°C, from a few seconds to over 20 min Instantaneously and uniformly throughout a mass of food independent of size, shape and food composition	Pressure, time at pressure,temperature (including adiabatic heating), pH, composition	Denaturation of enzymes, proteins;breakdown of biological membranes;cellular mass transfer affected	In use since 1990 (Japan, USA,France, Spain) Current pressureprocesses include batch andsemi-continuoussystems