
U. S. Food and Drug Administration
Center for Food Safety and Applied Nutrition
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Kinetics of Microbial Inactivation for Alternative Food Processing Technologies

Glossary

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Activation energy constant, E. Temperature coefficient determined from the slope of a $\ln(k)$ versus $1/T_A$ plot.

Activation volume constant, V. Pressure coefficient obtained from the slope of the $\ln(k)$ versus a pressure difference ($P-P_R$) plot.

Adiabatic compression. Compression or decompression processes occurring without heat transfer.

Bacteriophage. A bacterial virus; a virus capable of infecting bacteria.

Batch treatment. Treatment of a static mass of food in bulk or packaged.

Biological indicator system. A system (bacteria or enzyme) used to determine whether a process cycle has met the specified requirements.

Bremsstrahlung. One of the three possible ways to generate X-rays, and the one commonly used to create X-rays for food irradiation. Literally translated from the German it means "braking" (brems) "radiation" (strahlung). Bremsstrahlung X-rays are generated when electrons accelerate on coulomb collision with other particles or when a beam of particles decelerates on encountering an obstacle. Synchrotron radiation or Compton scattering can also generate X-rays.

Broad spectrum light. For pulse light technology, it refers to ultraviolet, visible, and infrared spectrum of light.

Capacitor bank. Network of two or more capacitors used to store the energy supply from a DC power source.

Cavity. The metallic enclosure in the microwave system where the microwaves coming from the waveguide do the heating.

Cell lysis. The rupturing of a bacterial cell.

Chemical indicator system. A system using calibrated chemical agents (one type of which changes color as a function of time and temperature of exposure to heat) to determine whether a process cycle has met the specified requirements.

Co field flow. One possible configuration for a PEF continuous chamber

Compression time. Recorded time to bring a mass of food from 0.1 MPa to process pressure (s).

Conductivity (Electrical), σ . Physical property of a food material that determines its ability to conduct electricity and is expressed in Siemens per cm (S/cm). In ohmic heating, it enables heating to occur.

Conductivity (Thermal). Physical property of a food material which determines its ability to conduct heat. Expressed in Watts/meter °C.

Continuous chamber. Opposite to static chamber, it processes liquid foods that are pumped between pulsing electrodes.

Continuous HPP process treatment. Treatment of liquiform products using a hold chamber designed to insure every food element receives a specified residence time at process pressure (and temperature) with subsequent means for the product to do work during decompression followed by aseptic or clean filling of packages.

Conventional heating. Heating of a substance by transfer of thermal energy from a heating medium to a low temperature product.

Converter Plate. A heavy metal (usually Pb) plate that converts an electron beam into Bremsstrahlung X-rays with a broad-band photon energy spectrum.

Critical process factor. Any specified process condition and specified limit (see process deviation) required to achieve a desired/specified residual level of activity of a specified pathogen. For instance in HPP critical process factors can include, but not be limited to, process pressure, product IT, process temperature, pH, A_w , product composition, compression time, and process pressure hold time.

Cross-field. An ohmic heating system where the electric field is aligned across the product flow path.

Cyclotron. An accelerator in which particles move in spiral paths in a constant.

Cyclotron resonance. Phenomenon that occurs when the frequency of revolving ions induced by a specific magnetic field intensity is similar to the frequency of that magnetic

field and parallel to it. In these instances, energy may be transferred to the ions, affecting cell metabolic activities.

D.C. power supply. Electrical device to deliver direct current to the capacitor bank

Decompression time. Recorded time to bring a mass of food from process pressure to 37% of process pressure. If decompression time is 0.5% or less of process pressure hold time it may be neglected in process determination calculations (seconds).

Density. Mass per unit volume of a material.

Dielectric constant. Property of a material representing the ability to store electromagnetic energy.

Dielectric loss. Property of a material representing the ability to dissipate electromagnetic energy as heat.

Dipole. For oscillating magnetic fields, a magnetic particle that contains a *north* and *south* magnetic pole.

D-value, decimal reduction time. Time required for a one-log cycle reduction in the microbial population, at a specific temperature, pressure, or electric field intensity. For the D-value to be meaningful, the semi logarithmic survivor curve must be a straight line.

Electric field intensity, E. A force on a stationary positive charge per unit charge in an electrical field. For ohmic heating and PEF, this can be calculated in an average sense as the voltage divided by the distance between the electrodes.

Electric field strength. See electric field intensity

Electrical breakdown. An abrupt rise in electric current in the presence of a small increase in voltage. As a consequence, rupture of bacterial cell membranes may occur with the application of an electric field. This effect is more pronounced in pulsed electric field treatment. In microwaves, this can happen if operating at very low pressures, as in freeze-drying.

Electrode gap. Distance (cm) between the inner and outer electrode.

Electroheating. See ohmic heating

Electrohydraulic treatment. A rapid discharge of high voltage electricity across an electrode gap below the surface of aqueous suspensions.

Electroporation. Phenomenon in which a microbial cell exposed to high voltage electric field pulses temporarily destabilizes the lipid bilayer and proteins of cell membranes.

Energy density or fluence. Energy delivered from a light source per unit area (Joules/cm²).

Focussing. Concentration of electromagnetic waves inside a food due to its curved surface, much like a lens focussing light waves. It leads to enhanced heating at the interior.

Gyrofrequency. Frequency at which the ions revolve in a magnetic field.

Heterogeneous magnetic fields. Magnetic field that exhibits a gradient depending on the nature of the magnet

High pressure processing (HPP). Adiabatic compression, hold, and decompression of foods at pressures in the range of 100 to 800 MPa for hold times of 0.001 to 1200 seconds or longer.

High voltage electrical impulse. Application of high voltage discharges to a liquid medium in a very short time.

High voltage switch. Device used to trigger the delivery of high intensity light pulses to foods or packaging materials.

Homogeneous magnetic fields. Magnetic field with a constant strength over space.

Homogeneous material. Material which does not exhibit spatial variation in composition

Inclusion particle. A food particle of significantly different electrical conductivity than its surroundings.

Inhomogeneous material. Material which exhibits spatial variation in composition

In-line field. An ohmic heating system where the electric field is aligned along the product flow path.

Input voltage. Voltage (kV) supplied from a DC power source.

Intensifier. Device for delivering high pressure process liquid generally by using a large diameter low pressure piston to drive a small diameter high pressure piston. The ratio of intensification is directly proportional to the ratio of the area of the large diameter piston divided by the area of the small diameter piston. A 20:1 intensification ratio is common. The pressure in the low pressure cylinder may be used to estimate the pressure of the high pressure process liquid. Intensifiers may be operated as single or multiple stroke devices. Single stroke intensifiers may be used to control the decompression rate of an HPP system.

Internal energy generation. Heat generation within a material and throughout its volume due to the presence of an energy source that is dissipated throughout the volume (see also volumetric heating).

Interstitial fluid motion. The motion of fluid in the spaces between solid particles.

Irreversible breakdown. Irreversible generation of pores in the bacterial cell membranes.

k, reaction rate constant (first-order). The slope of the logarithm of survivor ratio (log S) versus time of treatment for the microbial population.

LIEA. Linear Induction Electron Accelerator

Liquid crystals. Materials, which have properties that are useful for thermal sensing. Liquid crystals typically change color with temperature.

Magnetic flux density. Force that an electromagnetic source exerts on charged particles. Magnetic flux density is measured in Telsa (1 Telsa =104 gauss).

Magnetron. The physical component of a microwave system that generates the microwaves.

Microwaves. Electromagnetic waves at frequencies 915, 2450, 5800, and 24225 MHz.

Non-thermal effects. Effects due to the exposure to a process that are not of thermal origin, i.e., cannot be explained by measured temperature changes.

Oscillating magnetic fields. Magnetic fields generated with electromagnets of alternating current. The intensity varies periodically according to the frequency and type of wave in the magnet.

Pasteurization. A process designed to reduce the population of pathogenic bacteria in a product, sufficient to ensure product safety but with modest impact on the nutritional properties and flavor of the product. Traditionally, this term has been applied to thermal processes but it can also refer to emergent alternative technologies with the purpose of pathogens inactivation.

Peak voltage. Maximum voltage (kV) delivered by PEF system.

Penetration depth. The distance the electromagnetic waves (of a certain frequency) travel in a material before it loses 63% of its energy.

Power cycling. The process of the microwave source turning on and off .

Process deviation. Any critical process factor which differs outside an specified value and limit or range limit during the treatment and subsequent handling of a treated food.

Process pressure (PP). Constant holding pressure for any HPP treatment (MPa) (psi). Process pressure should be controlled to +/- 0.5% and recorded to the same level of accuracy. (+/- 500 psi at 100,000 psi) or (+/- 3.4 MPa at 680 MPa).

Process pressure hold time. Recorded time from end of compression to beginning of decompression (s).

Product composition. Specified percent by weight and range limit of stated product ingredients (%).

Product initial temperature (IT). Product IT can be specified as a critical process factor. For HPP processes, IT must be not less than 0.50°C below value-value in all food locations from start of compression time to end of decompression time (°C).

Product pH. Value of pH measured at product IT at atmospheric pressure.

Product process temperature. Temperature at which the process is performed (°C). Initial temperature and process temperature must be monitored at all points of the process if it is an integral condition for microbial inactivation. With some processes, such as HPP, foods will increase in temperature as a function of the imposed treatment and their composition. Final product temperature at process pressure is independent of compression rate as long as heat transfer is negligible.

Pulse rate. Number of pulses per second or input frequency (1/s).

Pulse width. Duration of the pulse. In PEF and for exponential decaying pulse, pulse width can be calculated as the resistance of the food times the capacitor capacitance. This is also called time constant.

Pulsed treatment. Treatment of a food using more than one treatment cycle of specified conditions such that each cycle element is accurately and precisely reproduced until a specified number is achieved. Cycle parameters (i.e. pressure, electrical field) may display a square, ramp, sinusoidal, or other waveform when recorded.

Radio frequency. Electromagnetic waves at frequencies of 13.56, 27.12 and 40.68 MHz.

Rate of inactivation or survival ratio, S. Initial number of viable microorganisms (N_0) divided by the number survivor microorganisms after treatment (N).

Residence time distribution. The distribution of times spent by the various components of a food product through a process vessel.

Resonance. Electromagnetic wave patterns formed due to superposition of oncoming and reflected waves, leading to very high rates of heating. Resonance can occur inside a food for specific combinations of size, shape, and food property.

Reversible breakdown. Formation of reversible pores in the bacterial cell membranes.

Runaway heating. A cycle of increasing temperature in food causing increasing rate of energy (microwave/ohmic) absorption that further increases the rate of temperature rise. It is more prominent in foods undergoing phase change from ice to water and in foods containing significant salt and other ions.

Semi-continuous HPP. Treatment of liquiform products using one or more chambers fitted with a free piston to allow compression, hold, and decompression with discharge under clean or sterile conditions.

Sinusoidal wave. A mode of propagation of the magnetic field.

SOS. In X-rays technology, solid state opening switch that can deliver pulses in the gigawatt range.

Specific heat. The ability of a material to store heat. Described technically as the amount of energy required to raise the temperature of unit mass of an object by a unit increment in temperature.

Static chamber. Chamber that processes a given volume of food at a time.

Static magnetic field. Magnetic fields that have constant intensity (B) over time and whose field direction is constant. The intensity varies periodically according to the frequency and type of wave in the magnet.

Sterilization. Any process, physical or chemical, which will destroy all forms of life; applied especially to microorganisms, including bacterial and mold spores and the inactivation of viruses.

Surrogate Microbe. A non-pathogenic species and strain responding to a particular treatment in a manner equivalent to a pathogenic species and strain. The surrogate allows biological verification of the treatment without introducing pathogens into a food processing area. For example, PA 3679 is used as a surrogate microbe for *Clostridium botulinum* in thermal process validation. *Listeria innocua* is a possible surrogate for *L. monocytogenes*.

Tesla. Unit to express magnetic flux density (B). 1 Telsa (T) = 104 gauss.

Thermophysical properties. Properties that influence the heating rate of a material. Examples of thermophysical properties are thermal conductivity (the ability of the

material to conduct heat), specific heat (the ability of the material to store heat), and density (the mass per unit volume of the material).

Thyristor. Charging unit used to convert three-phase power to direct current.

Treatment time. Time that a food product is subjected to a process. For instance in PEF, it is calculated as the product of the number of pulses times the duration of the pulses.

Ultrasonic. Term used to describe a vibrating wave of a frequency above that of the upper frequency limit of the human ear; it generally embraces all frequencies above 16 kilocycles/second.

Variable frequency. Sweeping over a range of frequencies during the microwave heating process to improve uniformity.

Volumetric heating. Heating by internal energy generation throughout the volume of a material (see also internal energy generation).

Water Activity, a_w . Qualitatively, a_w is a measure of unbound, free water in a system, available to support biological and chemical reactions. Water activity affects microorganisms survival and reproduction, enzymes, and chemical reactions. The water activity of a substance is quantitatively equal to the vapor pressure of the substance divided by the vapor pressure of pure water (both measured at the same temperature).

Waveform/Waveshape. Type of electric or pressure pulses generated by the high voltage pulser.

Waveguide. The physical component of a microwave system that guides the microwaves from magnetron to the cavity where the food is heated. When applied in the form of pulses, it reverses the charge for each pulse and pulse intensity gradually decreases.

$z(T)$ [$z(P)$ or $z(E)$]. Thermal (pressure or electric field) resistance constant (z) is the temperature ($^{\circ}C$) (pressure or electric field) increase needed to accomplish a one-log cycle reduction in the D-value.

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