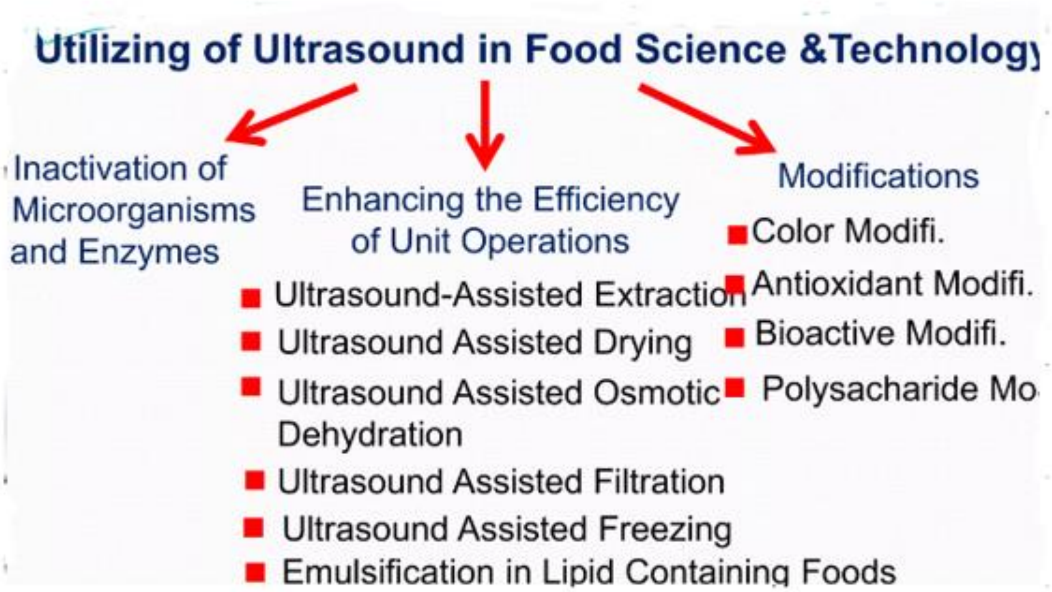
ULTRASOUND IN FOOD PROCESSING

Ultrasound waves are similar to sound waves but, having a frequency above 16 kHz, cannot be detected by the human ear. Ultrasound refers to sound waves, mechanical vibrations, which propagate through solids, liquids and gases with a frequency greater than the upper limit of human hearing. Use of ultrasound in food processing includes:



Utilizing of Ultrasound in Food Science &Technolog

Inactivation of Microorganisms and Enzymes

Enhancing the Efficiency of Unit Operations
- Ultrasound-Assisted Extractio
- Ultrasound Assisted Drying
- Ultrasound Assisted Osmotic Dehydration
- Ultrasound Assisted Filtration
- Ultrasound Assisted Freezing
- Emulsification in Lipid Containing Foods

Modifications
- Color Modifi.
- Antioxidant Modifi.
- Bioactive Modifi.
- Polysacharide Mo

Mixing and homogenization, Defoaming, Crystallization of fats, sugars etc, Cutting and Degassing

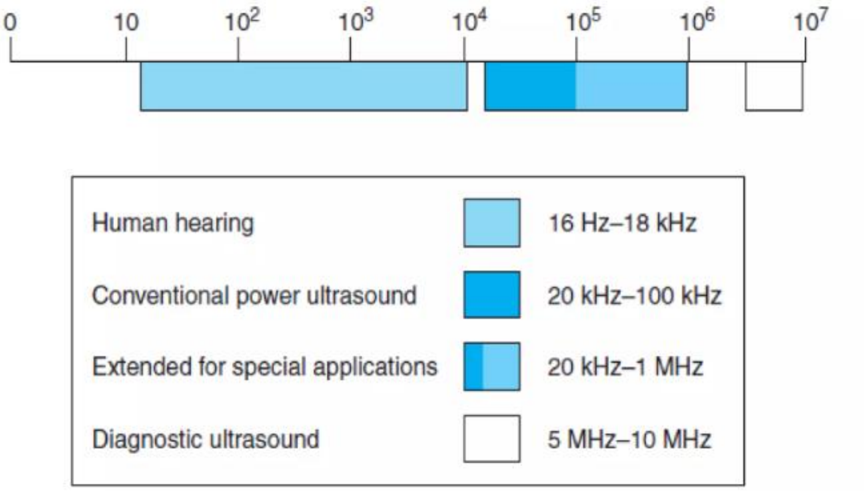
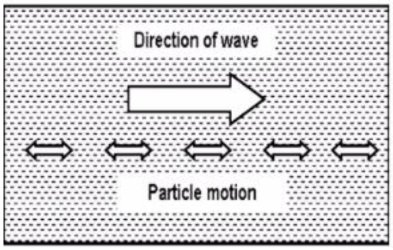


Figure . Frequency ranges of sound

Sound waves can propagate parallel or perpendicular to the direction of travel through a material. Since the propagation of sound waves is normally associated with a liquid medium.

- Parallel waves are known as longitudinal waves.
- Perpendicular waves are also known as shear waves.



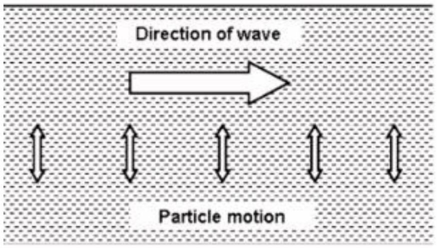


Figure . longitudinal wave Figure . shear wave

Longitudinal waves are capable of traveling in solids, liquids, or gases. And have short wavelengths with respect to the transducer dimensions, producing sharply defined beams and high velocities.

Shear waves The particle motion is perpendicular to the direction of wave propagation and liquids and gases do not support stress shear under normal conditions, shear waves can only propagate through solids. The velocity of shear wave is relatively low compared to longitudinal waves.

Ultrasound generation

Ultrasonic wave producing system contains the generator, transducer and the application system.

- Generator: It produces mechanical energy.
- Transducer: It converts mechanical energy into the sound energy at ultrasonic frequencies.

There are 3 types of transducer

1) Fluid-driven
2) Magnetostrictive
3) Piezoelectric

1)Fluid-driven Transducer: The fluid-driven transducer produces vibration at ultrasonic frequencies by forcing liquid to thin metal blade which can be used for mixing and homogenisation systems.

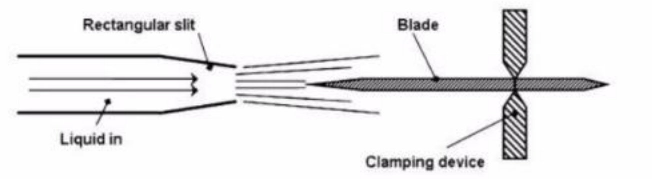


Figure . fluid-driven

2**) Magnetostrictive Transducer**: The magnetostrictive transducer is made from a kind of ferromagnetic materials such as iron or nickel. The frequency of the oscillator can be adjusted by changing the capacitance of the condenser C.

- A magnetostriction generator produces ultrasonic waves of comparatively low frequency. up to 200 kHz.

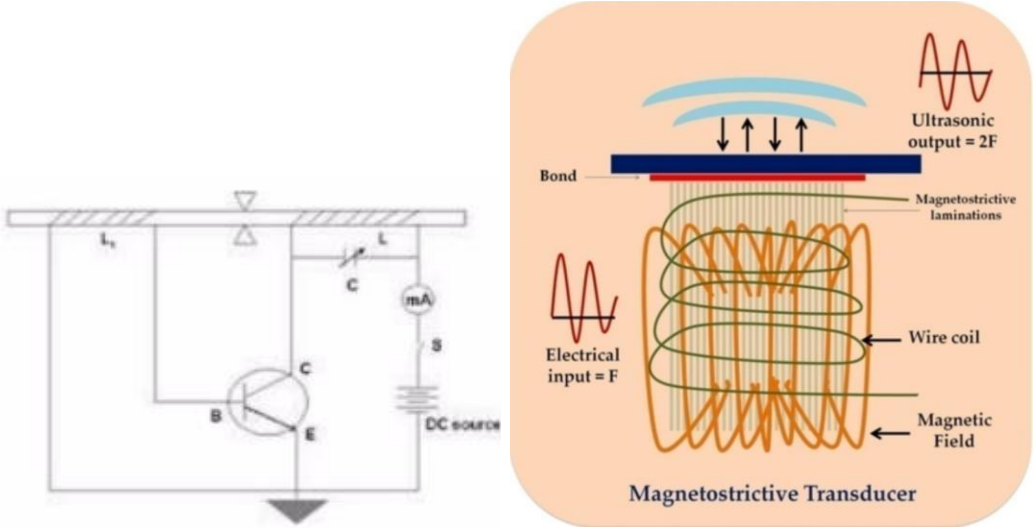
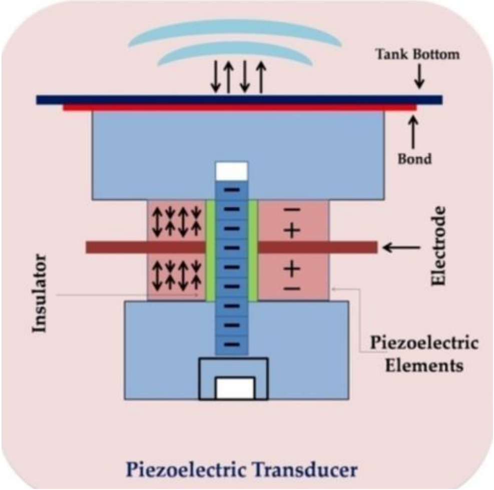


Figure .Magnetostrictive Transducer

3) **Piezoelectric Transducer:**

- Some naturally piezoelectric occurring materials include Berlinite, cane sugar, quartz, Rochelle salt, topaz, tourmaline, and bone.
- man-made piezoelectric materials includes barium titanate and lead zirconate titanate.
- Piezoelectric Transducer produces ultrasonic waves more than 300kHz.



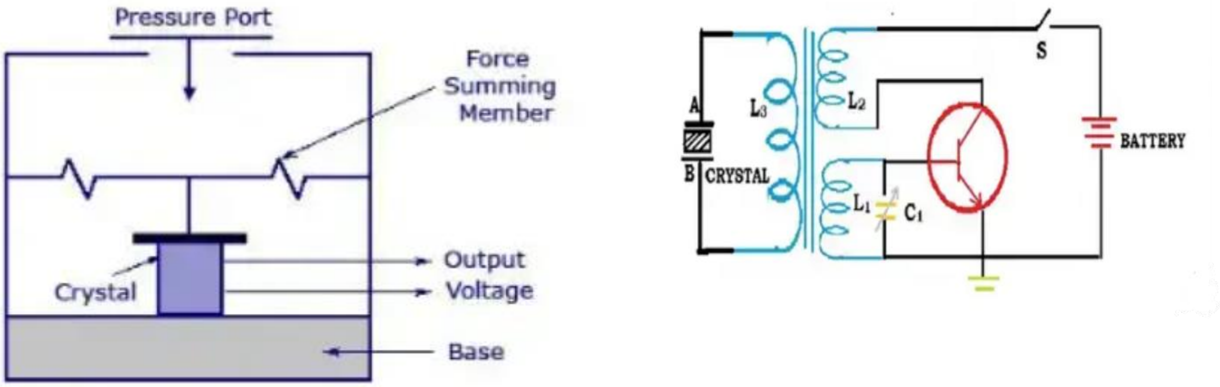
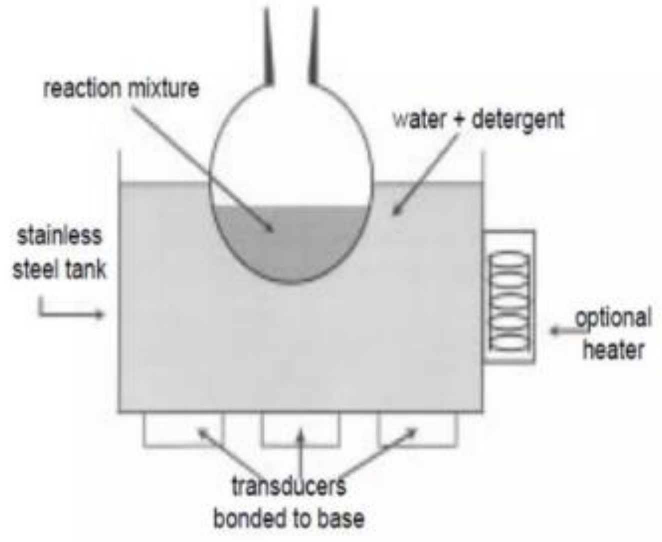


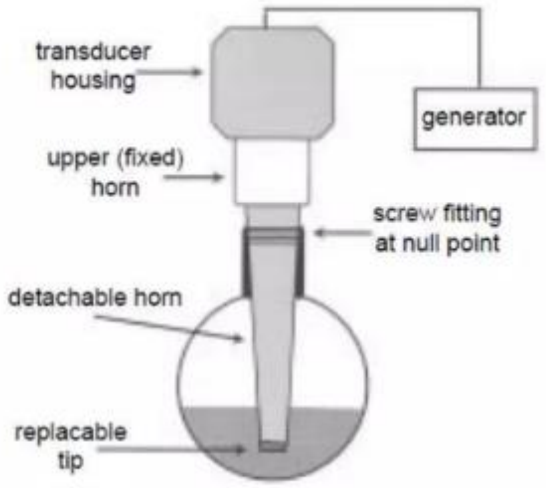
Figure . Piezoelectric Transducer:

In application system a coupler device is used to transfer ultrasonic vibrations to the sample.

- probe system
- ultrasonic bath



Simplest – ultrasonic baths



Ultrasonic probe system

Ultrasound in food preservation

- Microbial inactivation mechanism: By cavitation phenomena. During the cavitation process it changes the pressure and temperature cause break- down of cell walls, disruption and thinning of cell membranes and DNA will be damage.

Cavitation can be divided into two types

1) Transient Cavitation: The bubbles oscillate in a irregular fashion and finally implode. This produces high local temperatures and pressures that would disintegrate biological cells and denature enzymes.

2) Stable Cavitation: • The bubbles that oscillate in a regular fashion for many acoustic cycles.

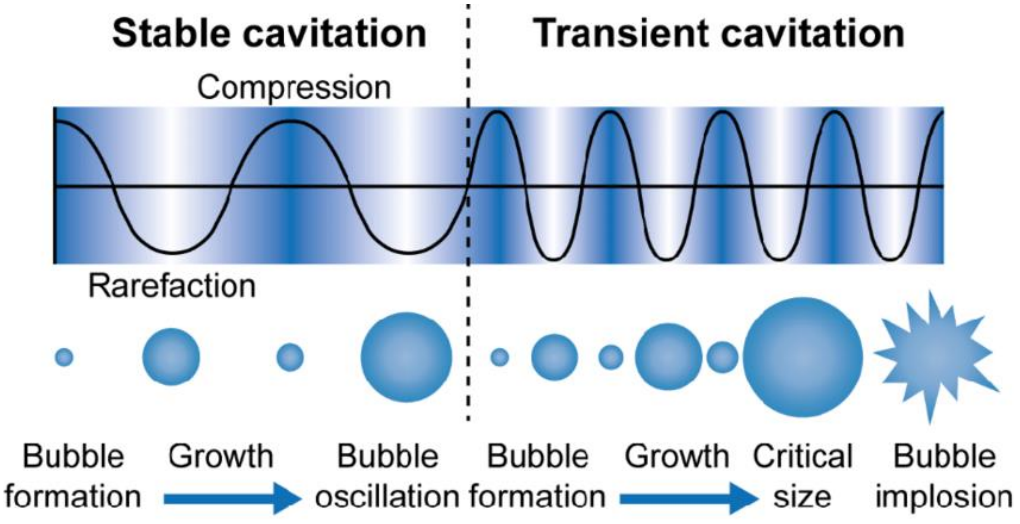


Figure . stable Cavitation and transient Cavitation

- The inactivation effect of ultrasound has also been attributed to the generation of intracellular cavitation and these mechanical shocks can disrupt cellular structural and functional components up to the point of cell lysis.

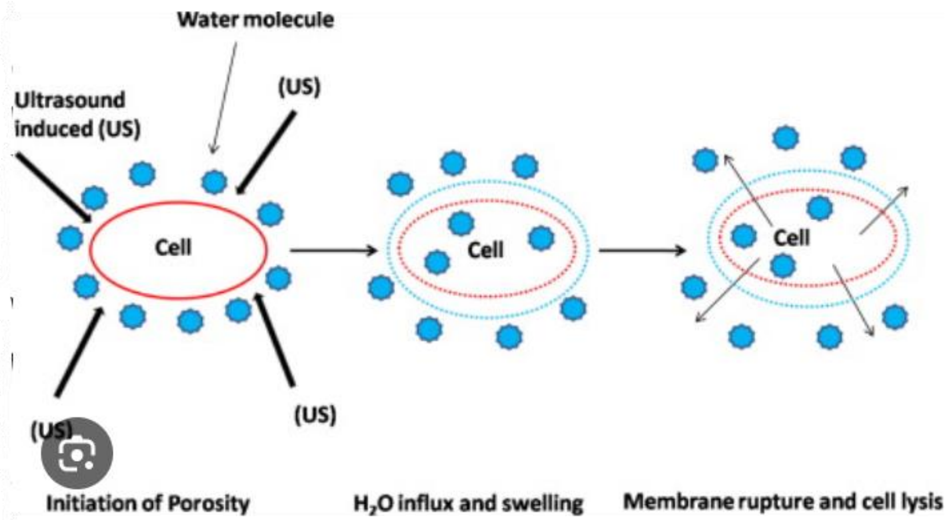


Figure . Mechanism of ultrasound-induced cell damage

Methods of ultrasound:

a) Ultrasonication (US): • it is the application of ultrasound at low temperature. • it requires long treatment time to inactivate stable enzymes and microorganisms which may cause high energy requirement.

b) Thermosonication (TS): • It is a combined method of ultrasound and heat. The product is subjected to ultrasound and moderate heat simultaneously. This method produces a greater effect on inactivation of microorganisms than heat alone.

c) Manosonication (MS) : • It is a combined method in which ultrasound and pressure are applied together. • Manosonication provides to inactivate enzymes and microorganisms.

d) Manothermosonication (MTS) : • It is a combined method of heat, ultrasound and pressure. • MTS treatments inactivate several enzymes at lower temperatures and/or in a shorter time than thermal treatments at the same temperatures

Microbial Inactivation

Different kinds of microorganisms have different membrane structure.

- Gram-positive bacteria have a thicker cell wall and also Gram- negative bacteria have a thinner cell wall.
- Factors affecting the effectiveness of microbial inactivation are.

¬ Amplitude of ultrasound waves.

¬ Exposure or contact time.

¬ Volume of food processed.

¬Treatment temperature.

- The inactivation of Listeria monocytegenes by high-power ultrasonic waves (20 kHz) at ambient temperature and pressure has been found to be low with decimal reduction values in 4.3 min.

- By combining sub lethal temperatures and higher pressures of 200kPa the decimal reduction value will be over 1.5 min to 1.0 min.
- Spore Inactivation • Microbial spores are resistant to extreme conditions such as high temperatures and pressures, high and low pH and mechanical shocks. • The endospores of Bacillus and Clostridium species are very resistant to extreme conditions.
- Manosonication treatment at 500kPa for 12min inactivated over 99% of the spores. Increasing the amplitude of ultrasonic vibration of the transducer. The increasing the level of inactivation.
- For example 20 kHz probe at 300 kPa, 12 min sonication at 90µm amplitude inactivated 75% of the spores.
- By raising the amplitude to 150µm resulted in 99.5% spore inactivation. • Finally increasing the thermal temperature of the treatment resulted in greater rates of inactivation certainly at 300kPa compared to thermal treatment alone.

Enzyme inactivation

- The study of enzyme inactivation by ultrasound has received less attention than microbial inactivation.
- Ultrasound creates continuous vibration and produce stable cavitation bubbles which collapse due to the extreme local increase in pressure (1000 P) and temperature (5000 K).
- Due to high pressure and temperature the secondary and tertiary structure will breakdown. And also loss of many enzymes.
- Application of MTS treatments to model enzymes relevant to the food industry in model buffer systems proved to be much more efficient than heat treatment for inactivating these enzymes, especially those which are more thermally labile (lipoxygenase and polyphenol oxidase).

Effect of ultrasound on food quality

- Effects of Ultrasound on Dairy Products
    i. Serum proteins are lactalbumin and lactoglobulin are denatured more extensively when ultrasound is combined with heat than with these two treatments performed separately.
    ii. Similar results were obtained in fat globule homogenization when applying continuous manothermosonication. \
    iii. This also results in a slight change in milk colour.
- Effect of ultrasound on juices

i. vitamin C retention of orange juice after ultrasonic treatment is higher when it is compared to thermal processing.

ii. The effects of ultrasound and temperature on vitamin C content of tomato extract. It was found that there is no significant effect of ultrasound whereas heat treatment significantly reduces vitamin C content of tomato extract.

iii. MTS treatments of pure pectin solutions yielded molecules with lower apparent viscosities due to a size reduction.

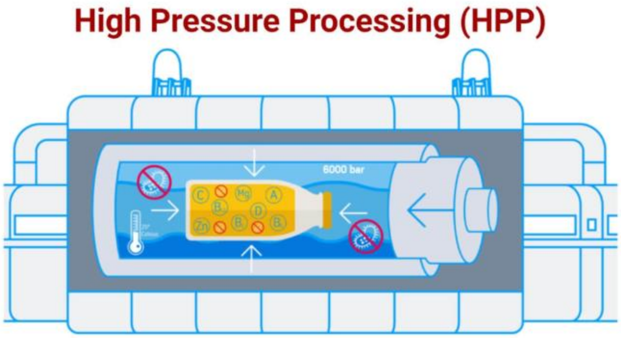
References

- Songul Sahin Ercan and Cigdem soysal. (2013) Use of ultrasound in food preservation. Natural Science, (5), 5-13.
- Farid Chemat, Zill-e-Huma, Muhammed Kamran Khan. (2011) Applications of ultrasound in food technology: Processing, preservation and extraction. Ultrasonics Sonochemistry, (18), 813– 835.
- Emerging Technologies for Food Processing. Edted by Da-Wen Sun. 323-351.

HIGH-PRESSURE TREATMENT OF FOODS.

Principles of High- Pressure processing

The idea of using high hydrostatic pressure (HHP) as a method of food processing is not new. Bert Hite, from West Virginia University, reported in 1899 that high-pressure treatment at ambient temperature could be used to preserve milk. In later studies he also reported that some micro-organisms, such as lactic acid bacteria and yeasts, associated with sweet, ripe fruit were more susceptible to pressure than spore-formers associated with vegetables. Research did not progress as the equipment was not available to routinely subject foods to the necessary pressures. However, in recent years there has been renewed scientific and commercial interest in the process.


High Pressure Processing (HPP)

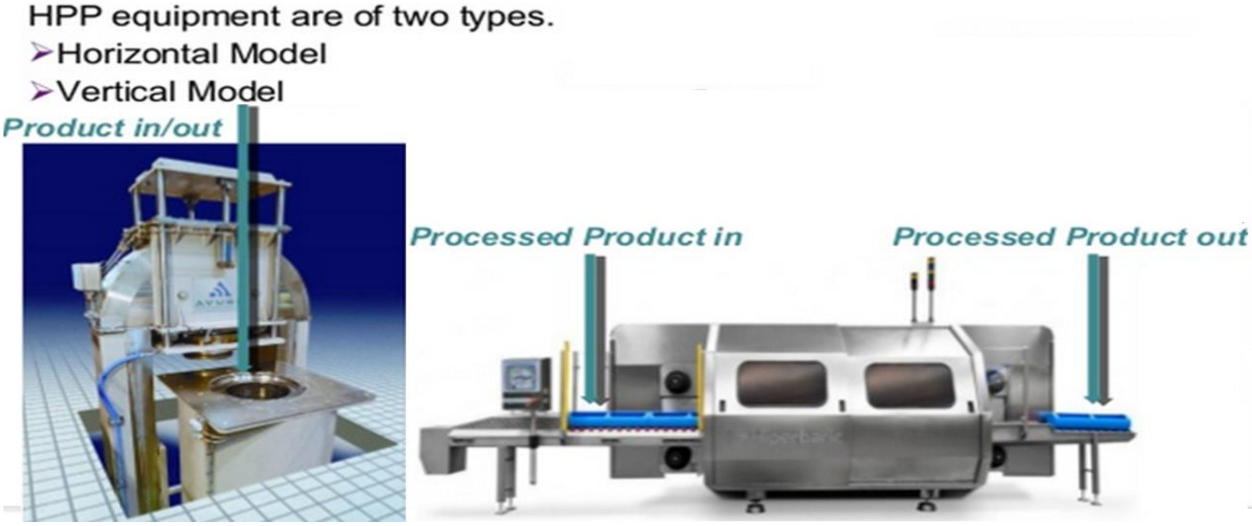
HHP- is a method of preserving and sterilizing food, in which a product is processed under very high pressure, leading to the inactivation of certain microorganisms and enzymes in the food.

¬Also known as Pascalization.

¬High Pressures applied at short periods of time (20minutes).

The High Hydrostatic Pressure (HHP) treatment is an athermic decontamination process which consists in subjecting packaged food to water pressures from 100 to 900 MPa.

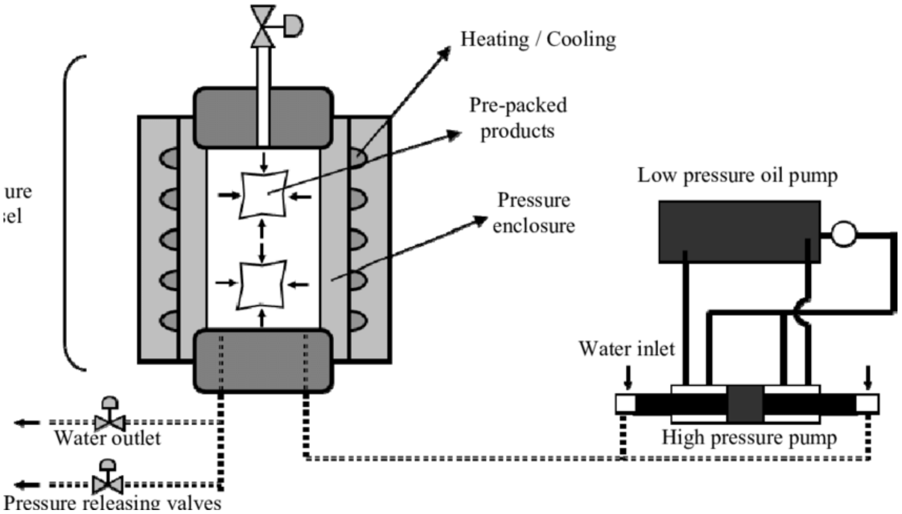
High-pressure is generally a semi continuous bulk process for liquid foods and a batch process for solid foods.



HPP equipment are of two types.

- ➢Horizontal Model
- ➢Vertical Model

A typical high-pressure system consists of a pressure vessel and a pressure generator. Food packages are loaded into the vessel and the top closed. The pressure transmission fluid, usually water, is pumped into the vessel from the bottom. Once the desired pressure is reached, the pumping is stopped, valves are closed and the pressure is held without the need for further energy input.



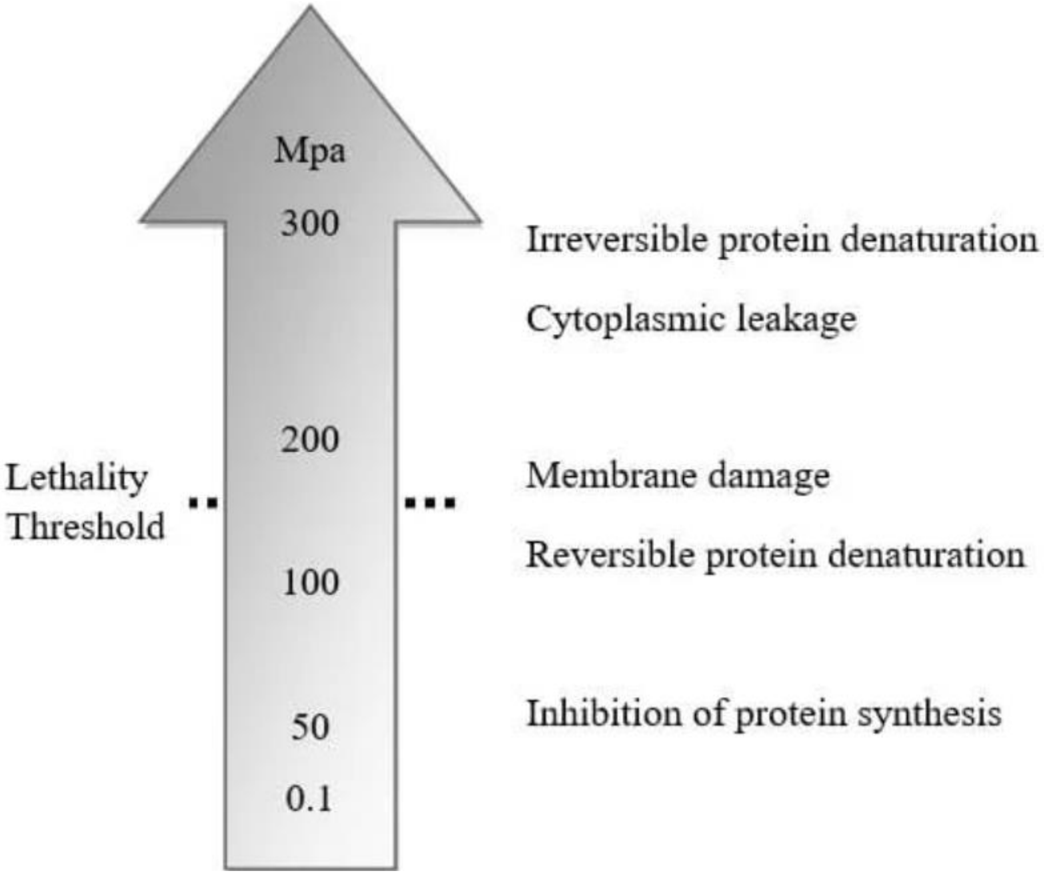
- ➢ Hydrogen bonding tends to be favoured while ionic bonds are broken. Hydrophobic interactions are disrupted below 100 MPa but can be stabilized at higher pressures. Covalent bonds appear to be unaffected by high pressure, so low-molecular-weight molecules – such as those responsible for the sensory and nutritional qualities of food

– are left intact. However, the structure of high-molecular-weight molecules can be significantly affected and this can result in altered functionality of proteins and carbohydrates. These changes result in micro-organisms being killed, as well as the possibility of producing foods of improved sensory and nutritional quality.

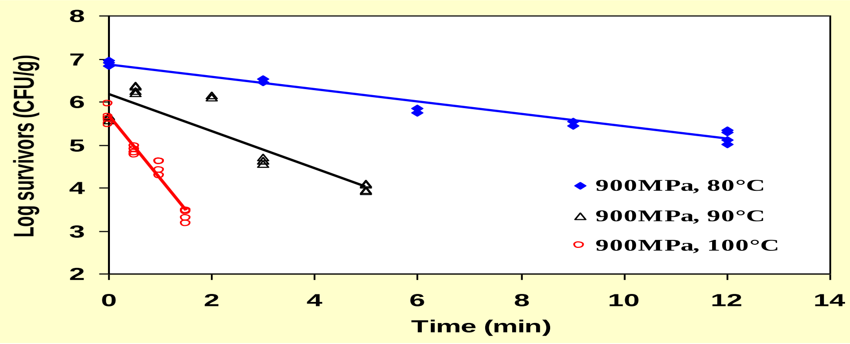
- High Hydrostatic Pressure treatments affect the non-covalent links (ionic, hydrophobic, and hydrogen links) of proteins.
- Sensitivity of different bonds to HHP is in the order of ;

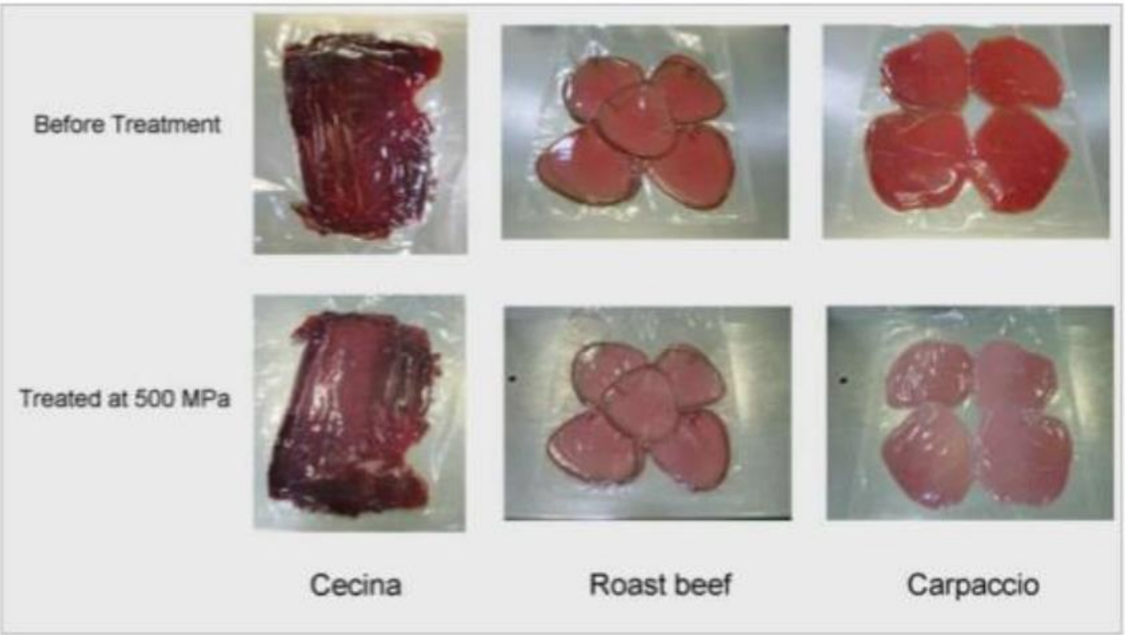
Hydrophobic > Electrostatic bonds > Hydrogen bonds > Covalent bonds.

- The secondary, tertiary, and quaternary structures can be unfolded and dissociated while the primary structure remains stable.
- Enzymes will at sufficiently high pressure undergo conformational Changes and thus lose activity.



Effect of Pressure on Biomolecules There are two main principles involved in high-pressure processing: the isostatic principle and the Le Chatelier principle. The former states that pressure is transmitted uniformly and instantaneously throughout the sample. This process is independent of the volume or geometry of the sample. This property gives HHP an important advantage over conventional thermal processing. The Le Chatelier principle states that the application of pressure to a system in equilibrium will favour a reduction in volume to minimize the effect of pressure. Thus, reactions that result in a volume decrease are stimulated, while those causing a volume increase are disrupted.





Commercial beef products before and after HHP treatment

Industrial applications

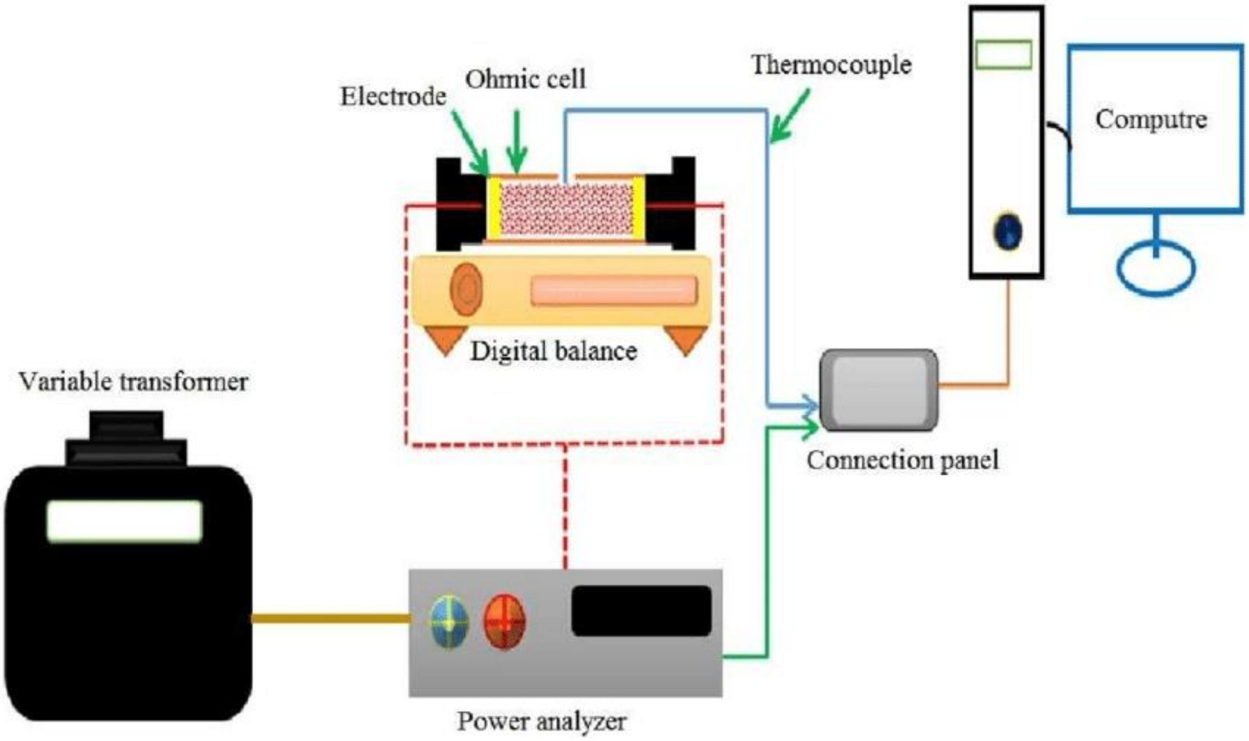
Industrial applications of h.- p. technology The first commercial high-pressure processed product was a high-acid jam, launched in 1990 by the Meida-ya Food Factory Co., Japan. Since then several other pressure-treated products have been launched in the Japanese market, including fruit sauces, juices and jellies. A high-pressure processed orange juice is also available in France and a pressure-treated avocado dip is available in the USA. Pressurized fruit products are normally given a treatment of around 400 MPa at 20°C.

It is claimed that the color and flavor of the fresh fruit is maintained and there is only a slight decrease in vitamin C content. Yeasts and moulds, which are the main cause of spoilage in fruit products, are relatively sensitive to pressure, so the microbiological quality of the products can be improved. However, enzymes such as polyphenoloxidase, which causes browning, are resistant to pressure and therefore can limit the shelf life.

For these reasons the current commercial applications of HHP as a preservation method have been limited to high-acid, chilled foods where spore-forming bacteria are unlikely to be a problem and enzymatic activity is retarded by refrigerated storage. However, extensive research and development programmes are in progress in Japan, Europe and the USA and it is likely that other foods, including fruit, dairy, meat and fish products, will be launched into the international market.

OHMIC HEATING

Ohmic heating principle Ohmic heating is the term used to describe direct electrical resistance heating of food product by the passage of mains frequency (50-60Hz) electric current through the continuous flow of product (Fig.).



Depth of penetration is virtually unlimited and the extent of heating is determined by the spatial uniformity of electrical conductivity throughout the product and its residence time in the heater. The applicability of Ohmic heating is dependent on product electrical conductivity. Most food preparations contain a moderate percentage of free water with dissolved ionic salts and hence conduct sufficiently well for the Ohmic effect to be applied.

Processing applications The Ohmic heater was originally developed by the UK Electricity Research and Development Center and in 1984, APV Baker, secured a license for the heater system and since then has undertaken substantial further development with respect to the following specific applications within the food processing industry: - Aseptic processing of high added value ready prepared meals for storage and distribution at ambient temperatures.

- Pasteurization of particulate fruit products for hot-filling. - Pre-heating of food product prior to in-can sterilization. - The hygienic production of high added value prepared meals for storage and distribution at chilled temperatures.

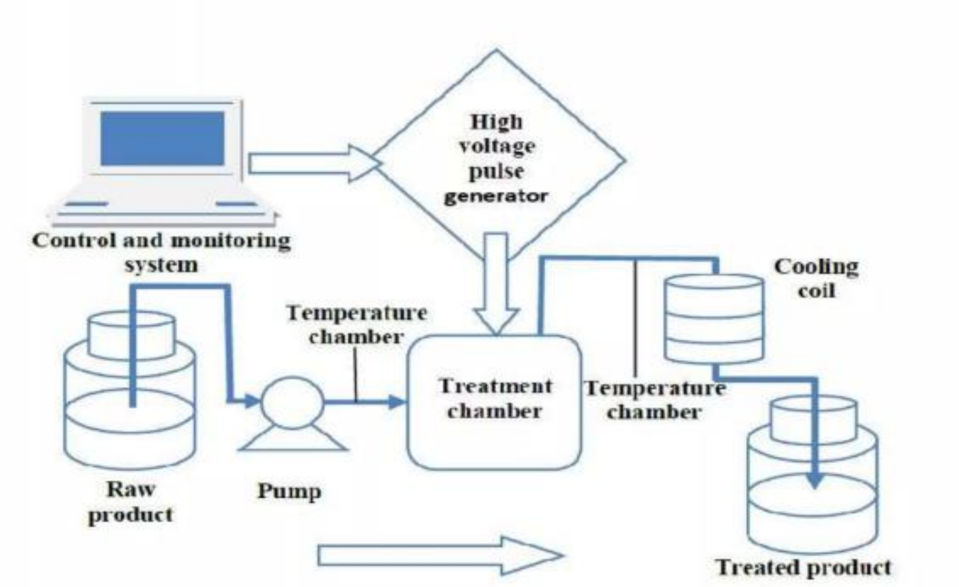
A number of commercial systems are now operating in the production of a range of high added value food products .

-Fresh tasting, high quality products with increased nutrient retention due to minimal thermal and mechanical damage. High levels of product safety due to minimum residence time differences between liquids and particulates. Low flow velocities and virtual absence of moving parts make Ohmic heating the ideal process for delicate, shear sensitive products. Low maintenance costs. Continuous flow without hot heat transfer surfaces, thereby eliminating plant fouling. Rapid and even heating of both liquid and particles, minimizing heat damage and giving vastly superior organoleptic properties. Quietness of operation giving a better working environment. Easy to control with fast start-up and shut down minimizing product losses. A turndown facility is also available. When combined with an aseptic filling system, product can be stored and distributed at ambient temperatures, avoiding the need for costly refrigeration.

DIELECTRIC HEATING

Dielectric heating: the techniques of Microwave and radio frequency (RF) heating. Both are forms of electromagnetic energy Selection of RF (3 kHz-300 GHz) or Microwave (300 MHz-300 GHz) heating: depends on product physical properties and process conditions.
Basic principle: If a material is placed in an electric field alternating at radio or microwave frequencies, heat is generating throughout the mass of the material by the rapid reversal of polarization of individual molecules.

Pulsed electric field (PEF) processing is a new food pasteurization method that uses short bursts of high voltage electric fields on foods to achieve desired microbial inactivation or modification of food structure.
PEF processing applies high voltage pulses (20–80 kV/cm) with a duration of milliseconds to microseconds to treat liquid foods placed between two electrodes (Zhang et al. 2010; Toepfl, Heinz, and Knorr 2006). For solid foods, 1–8 kV/cm is used due to the large gap in the treatment chamber and the power limit of the pulse generator. The electric field may be applied as exponentially decaying, square wave, bipolar, or oscillatory pulses at ambient, sub-ambient, or slightly above-ambient temperatures. The pulses are applied at high repetition rates (up to 3,000 pulses per second) so that the entire volume of the food sample can be treated.



PEF processing applies a series of short, high-voltage pulses. These pulses rupture the cell membranes of vegetative microorganisms by creating pores or by expanding existing pores (electroporation). The ruptures cause leak of intracellular contents, resulting in the concomitant loss of cellular metabolic activity such as growth and division, thus causing microbial inactivation (Buckow, Ng, and Toepfl 2013).

The inactivation of microbial populations by PEF depends on a variety of PEF equipment process parameters and treatment chamber geometry (Jin, Guo, and Zhang 2015):

- electric field strength
- treatment time
- pulse frequency
- pulse width
- treatment temperature

Microbial efficacy of PEF treatment is also influenced by various product parameters:

- acidity
- presence of antimicrobial and ionic compounds
- conductivity
- medium ionic strength

PEF treatment has limited effect on bacterial and mold spores, enzymes, and viruses.

To date, PEF is primarily used as a pasteurization technique. The technology does not inactivate bacterial spores. Ongoing research suggests that PEF in combination with heat may inactivate bacterial spores, but more comprehensive research is needed before PEF can be used as a sterilization method. To increase the degree of microbial inactivation and extend the shelf life of food, PEF processing can be combined with mild heating or other nonthermal processing and antimicrobial packaging (Jin 2017).

What Are Current Applications of PEF in the Food Industry?

PEF processing is used for food pasteurization. In 2005, PEF-processed organic fruit juice products were sold in the commercial market in Oregon, United States. PEF-pasteurized foods include liquid food (fruit juice, beverage, milk, liquid egg, etc.) and semi-solid food (yogurt, applesauce, salsa, pudding, etc.).

In recent years, PEF technology has been used for extraction and dehydration of foods where lower field strength (<10 kV/cm) is employed (Yu, Jin, Fan, and Wu 2018). PEF pretreatment facilitates the release of nutrients from fruits, vegetables, and herbs, thus increasing the extract yields. PEF pretreatment also promotes liquid diffusion inside food. The pretreatment significantly reduces food dehydration time and enhances the quality of dry or semi-dry food products (Yu, Jin, Fan, and Xu 2017).

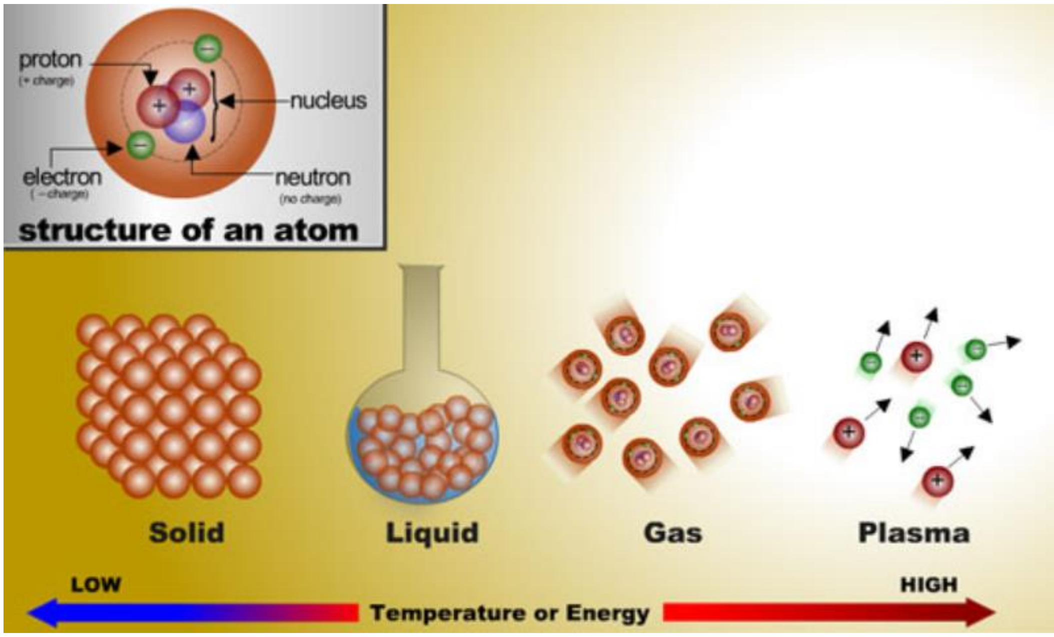
Potato processors from the United States, Canada, Europe, and Australia use PEF pretreatment to improve cut quality and reduce French fry breakage as an alternative to preheaters.

- ✓ PEF pretreatment of potatoes has many advantages:
- ✓ reduces water and energy consumption
- ✓ shortens drying and pre-frying times
- ✓ reduces frying oil absorption and fat content up to 50%
- ✓ enhances extraction of juice yields from fruits
- ✓ reduces the solid volume (sludge) of wastewater

COLD PLASMA TECHNOLOGY IN FOOD PROCESSING

Introduction Conventional states of matter

Solid, Liquid, Gas and Plasma



As materials acquire energy (such as by heating), they change state, from solid (lowest energy) to liquid and then ultimately to gas.

Plasma is an ionized gas that consists of a large number of different species such as, electrons, free radicals, positive and negative ions.
It was first discovered by Irving Langmuir in 1923.
Cold Plasma Technology
Cold plasma is a novel non thermal food processing technology
It uses electricity and a carrier gas, such as air, oxygen, nitrogen, or helium. Energetic and Reactive gases results in inactivation of contaminating microbes .

Applied in meat, poultry, fruits, and vegetables.

Cold Plasma Discharge Systems Three types

1) Glow Discharge
2) Radio Frequency Discharge
3) Dielectric Barrier Discharge (Becker et al. 2005)

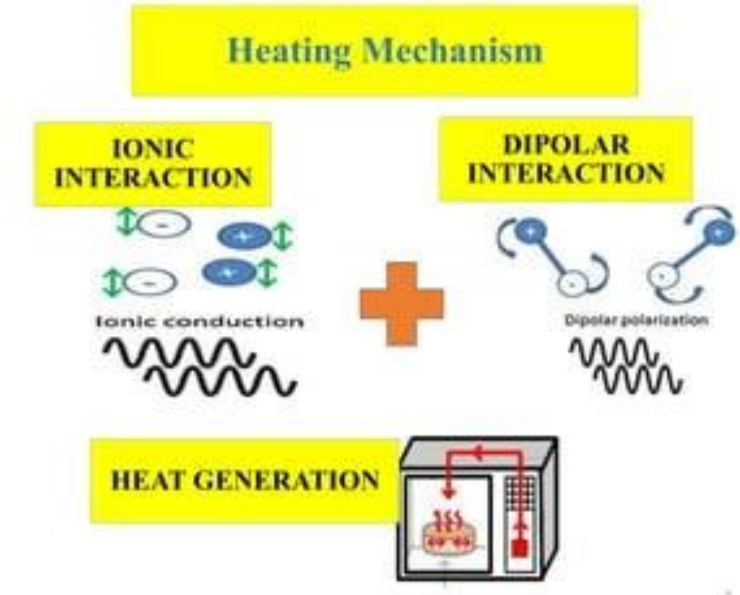
Application of Cold Plasma in Foods

1. Microbial decontamination of foods.
2. Modification of the Functionality of Food Materials .
3. Sterilization of Food Packaging Material .

Microwave Food processing

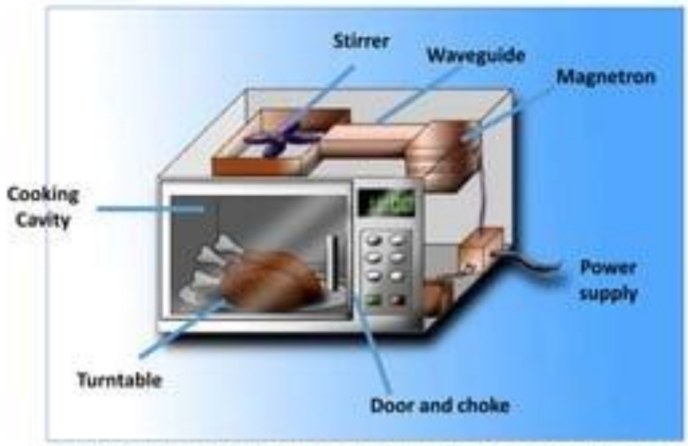
Microwaves (very short wave) Electromagnetic waves whose frequencies range from about 300 MHz – 300 GHz or wavelengths in air ranging from 100 cm –1 mm.
The shortest wavelength region of the radio spectrum and a part of the electromagnetic spectrum.
History • The first continuous magnetron was invented by Randall and Boot, who worked on producing a radar source to power radar sets for the British military during World War II.
• A patent was issued in 1950 for "a method of treating foodstuffs" in which a closed microwave oven was described for the first time.
The first major applications:
1. Drying of potato chips
2. Pre-cooking of poultry and bacon
3. Tempering of frozen food and
4. Drying of pasta (Decareau, 1985).

While the first patent describing an industrial conveyor belt microwave heating system was issued in 1952 (Spencer, 1952) Cont..



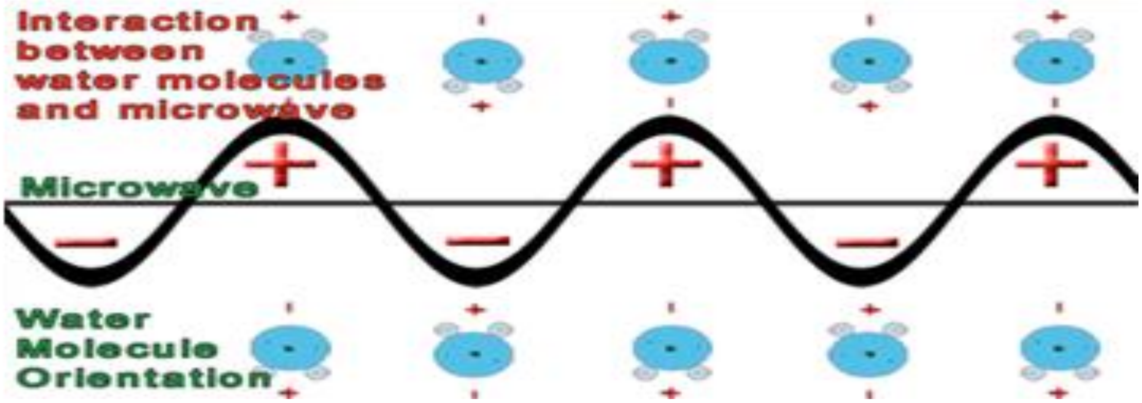
A microwave oven // is a kitchen appliance that cooks or heat food by dielectric heating.

WORKING



BASIC STRUCTURE OF MICROWAVE OVEN

It is accomplished by using microwave radiation to heat water and other polarized molecules in the food.



MICROWAVE HEATING DEPENDS UPON MOISTURE CONTENT

- High moisture content generally translate into greater microwave absorption and decreased penetration depth.
- Moisture content is high, product will heat more efficiently due to larger dielectric loss factor
- Products of lower moisture content may also heat well due to lower specific heat capacity

FREQUENCY

- The frequency of microwave greatly influences the depth of penetration. • Frequency increases and depth of penetration decreases.
- The surface heating effect is more prominent in 2450MHz whereas center heating effect in more prominent in 915MHz.

PRODUCT PARAMETER

- A direct relationship exists between the mass and the amount of absorbed microwave power.
- Density affects microwave heating; direct relationship exists between density and dielectric constant.
- It affects the depth of microwave penetration, and the heating rate and uniformity

Applications of Microwave

- Detect speeding cars
- Send telephone, radio communication
- Cure rubber
- Food processing

APPLICATIONS IN FOOD PROCESSING INDUSTRY

Baking and Cooking Case Study Microwave Cooking

Thawing and Tempering

Microwave Drying Microwave Assisted Freeze Drying Microwave-Assisted Vacuum Drying Microwave

Microwave Assisted Air Drying (Md)

Microwave Assisted Freezing Drying (Mfd)

Microwave Assisted Vacuum Drying (Mvd)

Microwave Blanching

Microwave Pasteurization and Sterilization

REFERENCES

- Microwave (and RF) Heating in Food Processing Applications. Juming Tang, Ph.D. Professor of Food Engineering Department of Biological Systems Engineering Washington State University, Pullman WA
- June 2005 Food and Environmental Hygiene Department The Government of the Hong Kong Special Administrative Region MICROWAVE COOKING AND FOOD SAFETY Risk Assessment Studies Report No. 19
- A.C. Metaxas Microwave heating IEE (1991). Power Engineering Journal 5(5) in September
- Venkatesh M.S & Raghavan G.S.V. (2004). An Overview of Microwave Processing and Dielectric Properties of Agri-food Materials Biosystems Engineering 88 (1), 1–18.
- Kouchakzadeh A& Safari. A. (2015). Studies on microwave energy absorption of fresh green bell pepper (Capsicum) AgricEngInt: CIGR Journal 17(2): 105.
- YuanY, Xiong S L Q. Jiaqi Zhong Yuzhe Zhang Jiannan L. (2015). Temperature Control Using Hybrid Control with MRAC and ECS into a MIMO Microwave Heating Process. Journal of Microwave Power and Electromagnetic Energy, 49 (1): 46-54. 39