Novel Food Processing & Emerging Technologies & its impact on Food Safety & Nutrition

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Introduction

- Consumer demand for very high organoleptic and nutritional qualities - search for new alternatives
- For many years thermal processing was the main technology

Disadvantages: Flavour & nutrient loss, physicochemical properties affected

Desirable feature of a technology
- Minimum losses of flavor and food quality
- Low processing temperatures
- Lower cost and fewer environmental impacts.
- Superior to traditional technologies
- Avoids or reduces the detrimental changes of the sensory and physical properties
- Inactivation of microorganisms and enzymes
Emerging technologies:

- High hydrostatic pressure
- High intensity pulsed electric field
- Ultrasound
- Supercritical CO2 extraction
- Ozone processing
- UV radiation
- Gamma- irradiation
High Pressure Technology

- High pressure kills microorganisms and preserves food - the fact was discovered in 1899
- Food Technologist accepted recently in 1980 that HPT has many things to offer to Food Industries.
- Promise of becoming new and revolutionary unit operation - Potential for new generation foods
- HPT can replace/supplement conventional thermal processing and addition of chemical preservatives
- HHP treatment is an athermic decontamination process which consists in subjecting packaged food to water pressures from 100 to 900 MPa.
- The pressure applied is isostatically transmitted inside a pressure vessel.
How Much High Pressure Is?

- Range of pressure
  100 MPa to 1000 MPa
  100 MPa = 1000 Atmospheric Pressure

- Two elephants standing on a platform connected to a piston of cross section one cm²
HP Processing Principles

• **Iso-static principle**
  Application of pressure is instantaneous and uniform throughout the sample

• **Le Chateliers’s Principle**
  Reactions resulting in a volume change are influenced by high pressure applications
  – Reactions with a volume decrease are accelerated
  – Reactions with a volume increase are suppressed
How High Pressure Can Preserve Foods?

• Similar to high temperature
• Death MO due to permeabilization of cell membranes
• Changes – reversible at low pressure and irreversible at high pressure.
• Reduction of enzymes activity ensures high quality and shelf stable products
• Only non covalent bonds are affected - organoleptic properties are unaltered
• Combination methods for baro-resistive micro-organism /bacterial spores
• Little, if any, effects on organoleptic and sensorial characteristics
Saccharomyces cerevisiae

- 400 MPa - structure and cytoplasmic organelles deformed and intracellular material leaked out

- 500 MPa – nucleus could not be recognized loss of intracellular material was complete
Advantages

- Uniform penetration of pressure - uniform quality
- Instant transmittance of pressure throughout system
- Elimination or reduction of heat damage to food
- Elimination of chemical additives
- Creation of new functional properties
- Improve the overall quality of foods
- Very low use of energy
- No residues: uses only tap water
- Safe for workers
- Accepted by consumers and retailers
Other Advantages

• Independence of size and geometry of the samples
• Possibility to perform processing at ambient temperature or even lower temperatures
• Waste free, environmentally friendly and energy efficiency technology
• Depending on the operating parameters and the scale of operation, the cost of high pressure treatment is typically around US$ 0.05–0.50/L or kg, the lower value being comparable to the cost of thermal processing
HP Application Areas

- **Pasteurization**: Juices, milk & meat and fish
- **Sterilization**: High and low acid foods
- **Texture modification**: Fish, egg, proteins, starches
- **Functional changes**: Cheese, yogurt, surimi
- **Specialty processes**: Freezing, thawing, fat crystallization, enhancing reaction kinetics
Food that can be HP treated

Solid foods, mainly vacuum packed
- Dry-cured or cooked meat products
- Cheeses, Fish, seafood, marinated products
- Ready to eat meals, sauces
- Fruits, marmalades / jams, Vegetables

Liquid foods, in flexible packaging
- Dairy products
- Fruit juices
- Nutraceutical formulations

Food that can not be HP treated
- Solid foods with air included: Bread, Mousse
- Packaged foods in completely rigid packaging: In glass or canned
- Foods with a very low water content: Spices, Dry fruits
Opportunities for High Pressure Processing of Foods

- High Pressure Blanching:
- High Pressure and Dehydration:
- High Pressure and Osmotic Dehydration:
- High Pressure and Rehydration
- High Pressure and Frying:
- High Pressure & Solid Liquid Extraction
- High Pressure and Gelation
- Pressure freezing & pressure thawing
- Pressure Assisted Thermal Processing HP Sterilization
High Pressure and Gelation:

- HP induces gels of proteins and polysaccharides
- These gels could be created even at low temperature storage of Kiwi or strawberry purees

Gel formation of pressurized strawberry puree during cold storage

Egg (left: boiled egg; right: 700MPa, 20C, 10min)
Pressure freezing & pressure thawing

Pressure shift freezing
• Pressure helps in super cooling to \(-20\, ^{\circ}\text{C}\) resulting in rapid and uniform nucleation and growth of ice crystals on pressure release

Pressure assisted thawing
• Frozen sample pressurized to 300 MPa and temperature increased and then pressure is released
Pressure Assisted Thermal Processing
HP Sterilization

- Yields a shelf-stable product
- Spores of both spoilage and public health concern need to be destroyed
- Spore destruction requires high pressure and high temperature combination
- High pressure can accelerate the destruction. Therefore, permits the use of milder processing conditions: Quality advantage
  - Higher quality product compared to conventional retort.
Pressure assisted thermal processing
HP sterilization

1. Packing in flexible pouch
2. Preheating (80-90°C)
3. High pressure (500-700 MPa)
   Temp. reaches to 105-121°C due to compression heating
4. Depressurize
   Cooled to 90°C

PATP product
Rapid heating & cooling - High quality product
Some commercially-available HP-processed food products

<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jams, fruit sauces, yoghurt and jelly</td>
<td>Meida-Ya</td>
<td>Japan</td>
</tr>
<tr>
<td>Mandarin juice</td>
<td>Wakayama Food Industries</td>
<td>Japan</td>
</tr>
<tr>
<td>Tropical fruits</td>
<td>Nishin Oil Mills</td>
<td>Japan</td>
</tr>
<tr>
<td>Beef</td>
<td>Fuji Ciku Mutterham</td>
<td>Japan</td>
</tr>
<tr>
<td>Guacamole, salsa dips, ready meals and fruit juices</td>
<td>Avomex</td>
<td>USA</td>
</tr>
<tr>
<td>Hummus</td>
<td>Hannah International</td>
<td>USA</td>
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<tr>
<td>Fruit and vegetable juices</td>
<td>Odwalla</td>
<td>USA</td>
</tr>
<tr>
<td>Ham</td>
<td>Hormel Foods</td>
<td>USA</td>
</tr>
<tr>
<td>Processed poultry products</td>
<td>Purdue Farms</td>
<td>USA</td>
</tr>
<tr>
<td>Oysters</td>
<td>Motivatit Seafoods</td>
<td>USA</td>
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<td>Goose Point Oysters</td>
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<td>Oysters</td>
<td>Joey Oysters</td>
<td>USA</td>
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<tr>
<td>Orange juice</td>
<td>Ultifruit</td>
<td>France</td>
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<td>Fruit juices</td>
<td>Pampryl</td>
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<td>Apple juice</td>
<td>Frubaca</td>
<td>Portugal</td>
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<tr>
<td>Sliced ham and tapas</td>
<td>Espuña</td>
<td>Spain</td>
</tr>
<tr>
<td>Fruit juices and smoothies</td>
<td>Orchard House</td>
<td>UK</td>
</tr>
</tbody>
</table>
HHP Products

Ready meals

Cooked rice
HHP Products

Fruit juices, sauces and smoothies
The high pressure processed products
Ulti developing a range freshly pressed, stabilized cold high pressure (HP) with a lifespan of 16 days. Bottles already packaged and sealed are subject for a few minutes at a pressure equivalent to several times the seabed.
Various Applications of High Pressure in Food Industry
Fruits and Vegetables Industry

Orange juice (600 MPa, 1 min):
- Microbiologically stable juice up to 12 weeks at 4°C, retained freshness, nutritional values and increased flavor retention, high consumer acceptability
- Inactivation of PME leading cloud stabilization
- No change in colour, browning index, concentration, acidity, AIS, ascorbic acid, β-carotene, folates, antioxidant activity

Grape fruit (160 MPa, 20 min):
- Naringin (bitter) to naringenin (tasteless) using naringinase (α-rhamnopyranosidase immobilized on calcium alginate) increased from 35% to 75% by application of high pressure

Lemon juice (300 MPa):
- No fungi were detected in pressure-treated lemon juice
- Satisfactory shelf life without any significant change in constituents and physicochemical properties.
Mango pulp or slices (522 MPa, 5 min):
- No microbial growth was observed at 3°C for 1 month.
- Addition of ascorbic acid and phosphoric acid prior to HPP resulted in reduced rates of browning.
- Flow behavior index for fresh pulp decreased with pressure treatment, whereas it increased for canned pulp.

Guava puree (600 MPa, 15 min):
- Sterilized microbes and partially inactivated enzymes.
- Puree stored up to 40 days at 4°C did not change in color, cloudiness, ascorbic acid, flavor distribution and viscosity.

Pineapple (300 MPa):
- Reduction in the hardness of HP treated pineapple due to cell permeabilization - reduction in drying / osmotic dehydration time.
- HP pretreatment resulted in lower loss of nutrients during rehydration.
- HPP fresh cut pineapple was found to microbiologically stable.
Avocado puree (700 MPa, 10 min) Guacamole
- SPC as well as yeast, mold counts were < 10 CFU/g for 100 days at 5°C
- PPO inactivation - acceptable color, sensory property for 60 days.

Lychee (600 MPa, 60 °C, 20 min):
- less loss of visual quality in both fresh and syrup-processed lychee compared to thermal processing.
- HPP led to extensive inactivation of PPO and POD
Strawberry and black berry purees (400-600 MPa, 15 min):

- HPP results in inactivation of enzymes responsible for degradation of food quality (PPO, POD)
- No significant change in ascorbic acid, anthocyanin and antioxidant activity. Color change was less, redness was retained.

Grape (500 MPa, 3 min):

- Red and white grape must could be sterilized by HPP with little changes. HP increased antioxidant activity and anthocyanin.
Jam manufacture: (400 MPa, 5 min)

- Freeze concentration and sterilization by HP – yielded strawberry jam with better color (stable anthocyanin) and sensory properties than heat-treated one.
- Texture was similar to conventional jam, product retained all the original flavor compounds.
National Forge Europe, Belgium

Working Volume 700 ml, Maximum working pressure 600 MPa
Stansted Fluid Power, UK

Working Volume 2.0 liter, Maximum working pressure 900 MPa
Stansted 5L HP ISO-Lab Processing System

Operating pressures 0 to 700 MPa, temperatures from -20 to 120°C
Large-scale high pressure processing equipment

Avure Technologies, USA
Large scale high pressure processing equipment, Avure Technologies, USA
Practical Challenges in high pressure processing

- Thermal effects during high pressure processing
  Temperature increase depends upon the initial temperature, material compressibility and specific heat, and target pressure

Heating may lead to gelling of food components, stability of protein, migration of fat
• **Compression heating**
  Water 3°C for every 100 MPa
  Fats & oils 6-8.7°C per 100 MPa

• **Appearance of temperature gradient with the food**
  Surface at less temperature then that of center

\[ T_P > T_L \]
• **Pressure nonuniformity**
Challenging the assumption that all foods follow the isostatic rule.

• **Appearance of cold surfaces**
Water $3^\circ C$ for every 100 MPa
Fats & oils 6-8.7$^\circ C$ per 100 MPa

$$T_{product} < T_{Liquid}$$

$$T_{product} > T_{Liquid}$$

Time

Cold point

Thermal processing

High pressure processing

Cold surface
Recent Developments in High Pressure Processing of Foods

Navin K. Rastogi

Foreword by Dietrich Knorr, Berlin
High Intensity Pulsed Electric Field
High Intensity Pulsed Electric Field

- Microbial cells exposed to few $\mu$s resulted in cell breakdown and permeabilization.
- Minimum losses of flavor and food quality.
- Low processing temperatures and short processing time allows energy efficiency.
- Lower cost and fewer environmental impacts.
- Avoids or reduces the detrimental changes of the sensory and physical properties.
Enhancing the efficiency of many processes such as extraction, dehydration or osmotic dehydration

PEF processing offers fresh like minimally processed foods with little loss of color, flavor and nutrients.

Method of Applying Current in Food Processing
- Ohmic Heating
- Microwave Heating
- Low Electric Field Stimulation
- High Voltage Arc Discharge
- Low Voltage Alternating Current
- HIGH INTENSITY PULSED ELECTRIC FIELD
Features

• Short burst of high voltage to a food placed between two electrodes.
• Electric current is passed only for microseconds (short pulses) through the food.
• Destroys cell membrane by mechanical effects without heating
• Inactivates enzymes

Traditional Method: Electric current converted into thermal energy causing inactivation

Economic & Efficient energy use

  ➢ Microbiology safe
  ➢ Minimally processed
  ➢ Nutrition
  ➢ Fresh

Application: Cold Sterilization of liquid foods: Juices, cream soups, milk & egg products
PEF Processing System:

- **Major component** - Voltage power supply, capacitor, treatment chamber, discharge switch
- **High voltage generator** supercharges capacitor and then it is **discharged** through food material placed between electrodes
- **Pulse duration and frequency** is controlled by a switch
- **Temperature control** by circulating water through the electrode

General design of high pressure equipment:
1. High voltage generator
2. Switch
3. Capacitor
4. Medium
5. Electrodes, R,S,T,M connector points for the main supply
• **Pulse form** may be exponential or square decay
• Generation of pulse involve slow charging and fast discharging of the capacitor
• Voltage and current waveforms can be recorded via digital data acquisition system.
• Pulses duration and voltage monitored with an oscilloscope

The energy stored in the capacitor is given by

\[ Q = 0.5 \ C_0 V^2 \ ; \ C_0 = \frac{t}{R} = t\sigma A/d \]

Specific energy input

\[ Q = n \frac{E_{max}^2 Kt}{10\rho} \text{ [J/kg]} \]

\[ E \text{ (field strength)} = \frac{V \text{ (Voltage)}}{d \text{ (distance between the electrodes)}} \]
Fig 1. A simple circuit for producing exponential decay pulses.

Fig 2. A simple circuit for producing Square pulses.
High Intensity Electric Field Pulse Generator

Pure Pulse Technologies Inc., USA
Working Principles of PEF:

- Liquid foods – conductors due to ions, to generate pulses large amount of current should pass in a short time

- Application of electric field to cells results in transmembrane potential, which in turn leads to the pore formation or electroporation (primary event)

- Membrane acts as an insulator shell to the cytoplasm (conductivity 6-8 times higher than membrane)

- Cell membrane regarded as a capacitor filled with low dielectric constant material.
Exposure of cell to electrical field results:

- Movement of ions inside the cells until they are held back by the membrane.
- Free charges accumulate at both membrane surfaces.
- Accumulation increases the electromechanical stress or TMP.
- Induced potential is many orders greater than applied electric field.
- Induced potential is greater for large cell - larger cells are more susceptible to damage.

Fig. Induction of transmembrane potential in a cell exposed to an external electric field.
• Attraction of opposite charges induced on inner or outer surface of cell membrane, compression pressures occur resulting in decrease in the membrane thickness

• Further decrease in resistance leads to irreversible breakdown

• Fig shows transmembrane voltage during pulsation for fish, apple tissue, plant and yeast suspension reaches critical value of approx 0.7-0.22 V within less than 1 μs after initiation of pulse.
• Cell permeabilization increases with specific energy input and pulse number

• Permeabilization can be performed with 1 pulse with high specific energy input

• Post treatment condition are very important because injured microorganisms may recover and reproduce during storage

Fig 4: Relationship between specific energy input per pulse and cell disintegration index
Effect of HELP on Enzymes

- Preservation technique based on microbial inactivation as well as inactivation of enzyme
- If the enzymes are not inactivated, it will lead to detrimental effect on food quality.
- 3D molecular structure of globular proteins (secondary, primary & tertiary) is stabilized by hydrophobic interactions, hydrogen bonding, van der Waal interactions, ion pairing, electrostatic forces and steric constraints
- Conformational state of proteins results in inactivate enzymes
- Limited effect of HELP on enzymes can be overcome by combining HELP with other preservation factors such as mild heat treatment or cold storage.
Opportunities of HELP Treatment in Food Processing:

HELP Treatment and Preservation:
- PEF treatment preserves the quality of the foods and improves the shelf life

Processing of Apple Juice:
- 50 kV/cm, 10 pulses, 2 μs, 45 °C increased shelf-life of 21 days of fresh squeezed apple juice
- No significant difference in ascorbic acid, sugars, sensory qualities

Processing of Orange Juice:
- 15 kV/cm reduced natural microflora by 3 log cycles quality not affected. Vit C loss was marginal and color was improved
- 32 kV/cm reduced aerobic counts by 3-4 log cycles and shelf life of juice stored at 4 °C was about 5 months.
Processing of Milk:
- 40 kV/cm, 40 pulses, 2 μs of raw skimmed milk resulted in shelf-life of 2 weeks stored at 4°C
- 80°C for 6 s + PEF treatment increased shelf-life up to 22 days.

Processing of Liquid Whole Eggs
- Reduced viscosity & increased the color as compared to fresh eggs. No difference in sensory quality

Processing of Green Pea Soup:
- 2 steps of 16 pulses at 35 kV/cm
- Shelf life of soup stored at refrigeration temperature was more than 4 weeks.
HELP Treatment and Extraction

**Extraction of secondary metabolites:**

- *Useful method for the recovery of desired substances from plant cells without the use of chemical or thermal treatment.*
- *Application of HELP treatment resulted in complete release of red pigment from Cheopodium rubrum cells.*

**Extraction of apple juice:**

- *Increase in juice yield (10-12%) by subjecting apple mash to HELP*
- *Juice was lighter in color and less oxidized than the enzyme or heat treated samples.*
Extraction of carrot juice

- HELP treatment resulted in increase carrot juice yield
- In case of finely ground carrot juice yield was increased from 51.3 to 76.1%
- Whereas this increase was from 30.0% to 70.3% in case of coarsely ground carrots

Extraction of sugar beet juice

- As a processing step in the extraction of sugar beet juice.
- HELP resulted in increase in dry matter of the pulp from 15.25 to 24.91%, which indicates the enormous potential in sugar industry.

Application in coconut processing

- 20% increase in the yield of coconut milk due to HELP pretreatment with 50% and 58% of protein and fat content, respectively.
HELP Treatment and Dehydration:

- HELP reduced drying time by 25%
- HELP treatment resulted in higher drying rates, heat and mass transfer coefficients compared to control

HELP treatment could reduce drying time to 1/3 in case of drying of potato cubes as shown by moisture profiles

HELP treatment could also reduce dehydration time in case of dehydration of coconuts

Current Limitations:

- Non-availability of commercial units
- Presence of **bubbles** may lead to non uniform treatment as well as operational and safety problems
- Limited application - homogeneous fluids with low electrical conductivity provide ideal condition for PEF treatment
- Particle size must be smaller than gap between the electrodes.
Conclusion

• Exciting emerging technology
• Wide application range from increasing the efficiency of the process to food preservation processes
• Most ideal for heat sensitive fluid foods
• Non fluid food and food containing particles can also be processed.
• Technology option for food and drink industry, pharmaceutical or biotechnological applications.
• Continuous application and the short processing time makes HELP treatment an attractive candidate as a novel non-thermal unit operation.
• Still substantial research and development activities are required to understand, optimize and apply this complex process to its full potential.
A glimpse of large scale PEF plant at Ohio State University, USA
Dense Phase Carbon Dioxide: A Non-thermal Processing Technique for Food Processing
Dense Phase Carbon Dioxide (DPCD)

- CO$_2$ is non-toxic, non-flammable, inexpensive and easily accessible gas and has GRAS status.

- Cold pasteurization method inactivates microorganisms and enzymes through molecular effects of CO$_2$ under pressure below 50 MPa. “Better than fresh”

- Food is not subjected to adverse effect of heat and retains fresh like physical, nutritional, and sensory qualities.

- Fraser (1951) - “Bursting bacteria by release of gas pressure” Later, work to extended to pathogenic and spoilage organisms, vegetative cells and spores, yeasts, molds, enzymes and their activities, and food quality attributes.

- Feasible pasteurization technique especially for juices containing heat labile phytochemical, antioxidant, and flavor compounds.
What is DPCD?

- Dense with respect to gaseous CO$_2$

- Dense phase of matter includes liquid & supercritical regions

- At these states, CO$_2$ alters its physical properties
  - Increased density, becoming a more effective solvent.
  - Decreased viscosity
  - Increased diffusivity, which should facilitate penetration through a bacterial cell membrane.
Technological aspects

• Ability to inactivate endogeneous enzymes and microorganisms

Commercial aspects

• Equipment designed by Praxair Inc and technology provided by University of Florida, USA (Patent held by Praxair)
• Capacity 1.5 LPM (lab level); 150 LPM (Pilot plant level)
• Parxair developed combined DCPD + thermal process for longer shelf life with better sensory and nutritional properties
• Mitsubishi Co. Japan – 5.8 L vessel (3 kg/h CO₂, 20 kg/h Food) (Patent held by Shimadzu)

Regulatory aspects

Data collection, modeling of the process, kinetics of inactivation, process optimization, proper sale up, simulating and calculating process economics, sensory and shelf-life data, quality assurance, compliance with existing regulations, hygiene standards
Properties of some supercritical fluids at critical point

<table>
<thead>
<tr>
<th>Fluid</th>
<th>$T_c$ (°C)</th>
<th>$P_c$ (MPa)</th>
<th>Density (g/ml)</th>
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<tbody>
<tr>
<td>CO$_2$</td>
<td>31.0</td>
<td>7.11</td>
<td>0.47</td>
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<tr>
<td>N$_2$O</td>
<td>36.5</td>
<td>7.10</td>
<td>0.45</td>
</tr>
<tr>
<td>H$_2$O</td>
<td>374.2</td>
<td>21.5</td>
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<table>
<thead>
<tr>
<th>State</th>
<th>Density (g/cm$^3$)</th>
<th>Viscosity (cP)</th>
<th>De (cm$^2$/s)</th>
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<tr>
<td>Gas</td>
<td>0.002</td>
<td>0.014</td>
<td>0.01</td>
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<tr>
<td>Super critical</td>
<td>0.467</td>
<td>0.02-0.12</td>
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</tr>
<tr>
<td>Liquid</td>
<td>1.0</td>
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</table>

- N$_2$O has been effective at killing bacteria,
- CO$_2$ is most preferable gas due to its low toxicity, nonflammability, and low cost
- CO$_2$ is acceptable due to the familiarity with products such as carbonated beverages.
Advantages

• No loss of flavor
• No denaturation of nutrients
• No toxic side reactions
• No changes in the physical and chemical properties
• Preserves food quality and enhance safety
• Elimination or reduction of heat damage to food
• Elimination of chemical additives
• Improve the overall quality of foods
• Very low use of energy
• Leaves no residues
• Adaptable to continuous processing
Mechanism of microbial inactivation

pH lowering effect

- CO₂ penetrates cell membrane consisting of phospholipid layers and lowers internal pH

- Reduction in pH by forming H₂CO₃, which dissociates to HCO₃⁻, CO₃²⁻ and H⁺ ions - lowering extracellular pH

Inhibitory effect of molecular CO₂ and bicarbonate ion

- Sorption of CO₂ into enzyme molecules and at low pH - protein-bound arginine may interact with CO₂ to form a bicarbonate complex, inactivating the enzyme.

- Inactivation of decarboxylases, alkaline protease, lipase, glucoamylase and acid protease
Inactivation of enzymes

• pH lowering, conformational changes of the secondary structure of enzyme ($\alpha$-helix, $\beta$-sheet, $\beta$-turn, random coil), and inhibitory effect of molecular CO$_2$

• Changes in isoelectric profile and protein pattern

• Inactivates certain enzymes at temperatures where thermal inactivation is not effective

• Good potential in F&V juice processing where the following food quality related enzymes are inactivated
  
  ▪ Pectinesterase causes cloud loss in some fruit juices  
  ▪ Polyphenol oxidase causes undesirable browning  
  ▪ Lypoxygenase causes chlorophyll destruction and off-flavor development in frozen vegetables  
  ▪ Peroxidase has an important role in discoloration of foods and used as an index of heat treatment efficacy
Other enzyme

- α-Amylase
- Acid or alkaline protease
- Glucoamylase
- Lipase
- β-galactosidase
- Pectin esterase
- Pectin methyl esterase
- Polyphenol oxidase
- Tyrosinase
- Lipoxygenase
- Peroxidase
- Alkaline phosphates
- Glucose oxidase
- Glucose isomerase
- Thermolysin
- Alcohol dehydrogenase
Ongoing work at CFTRI

Combination of ultrasound and ozone for the processing of liquid foods

Project Funded by

Department of Science & Tech., New Delhi
Introduction

- Consumer demand for very high organoleptic and nutritional qualities with natural flavor, taste and fresh appearance - search for new alternatives

- For many years thermal processing was the main technology
  Disadvantages: Flavour & nutrient loss physicochemical properties affected

- Ozone processing of liquid food is one such alternative. Active against bacteria, fungi, viruses, protozoa, and bacterial and fungal spores pertinent to fruits and vegetables and their products.
What’s Ozone?

- Tri-atomic oxygen (O₃), Molecular weight of 48
- Bluish gas (at high concentrations)
- Pungent characteristic odor
- Low solubility in water
- Half-life: Gas: ~12 hr (at ambient)
  Aqueous: Short, varies by medium
Advantages

• Ozone is a powerful antimicrobial agent
• Reacts faster than chlorine with many organic materials and produces fewer decomposition products.
• Meets the USFDA’s requirement of a mandatory 5-log reduction of the most resistant pathogens (E. coli, Salmonella, Listeria monocytogenes)
• Excess ozone auto-decomposes rapidly to produce oxygen (half-life 20 – 30 min at ~20 °C), and thus it leaves no residues in food.
• Ozone processing results in color change for fruit juices such as apple cider and orange juice, blackberry juice, strawberry juice.
Combined treatment (Ozone and Ultrasound)

• Efficacy of can be increased by synergistic effect
• Disaggregating effect of ultrasound upon solid matter and on gas bubbles - increasing surface area
• Accelerates sedimentation of oxidizable organic matter - reducing ozone demand.
• Microorganisms exposed to ultrasound become more sensitive to lower concentrations of ozone
• Ultrasound: Very rapid localized changes in P and T cause shear disruption, caviation, thinning of cell membranes, localized heating, and free radical production, which have a lethal effect on microorganisms.
Mechanism of action of Ozone

- Both molecular ozone and the free radicals produced by its breakdown play a part in inactivation.
- Double bonds, sulfhydryl groups, and phenolic rings are destroyed. Membrane phospholipids, intracellular enzymes, and cell components are targeted.
- Attacks numerous cellular constituents including proteins, unsaturated lipids and enzymes in cell membranes.
Typical ozonator to be developed for liquid foods

\[
\frac{dC}{dt} = K_L a (C_s - C) - d_i
\]

Oxygen flow rate
125 ml/min

Ozone concentration
75-78 μg/mL
(7.8% w/w oxygen)
Nonthermal technologies has potential to economically and efficiently energy uses, as well as provide consumers with microbiologically safe, minimally processed, nutritious, and fresh like foods.
I would like to thank

- Director CFTRI
- Dr, Shashi Kant, CII
- Research Supervisors:
  - Prof. Dr. Dietrich Knorr, Technische Universitat Berlin, Germany
  - Prof. K. Niranjan, Reading University, England
  - Prof. V. M. Balasubramaniam, Ohio State University, Columbus, OH, USA
- All the participants for their presence
Solicit the blessings of Almighty to reveal and unravel the mysteries of nature...

Thank you