Novel Technologies for Food Processing and Shelf Life Extension
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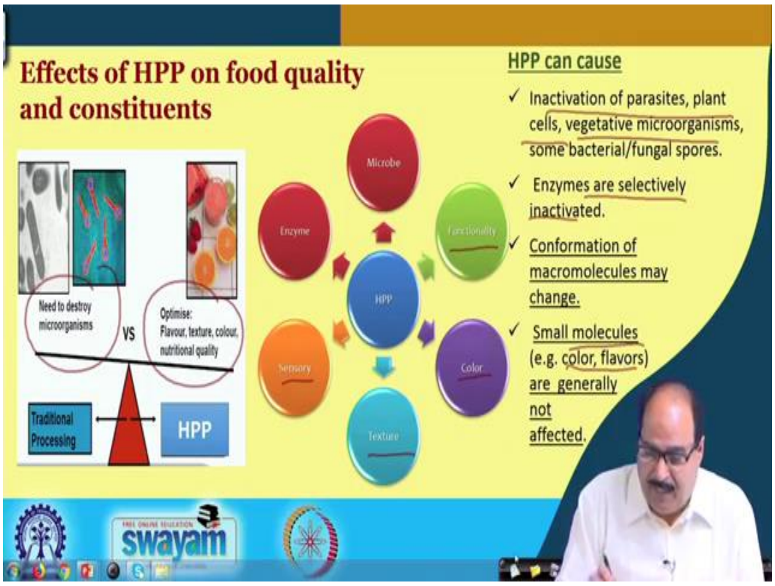
Lecture – 12
High Pressure Processing of Food (Part - 2)

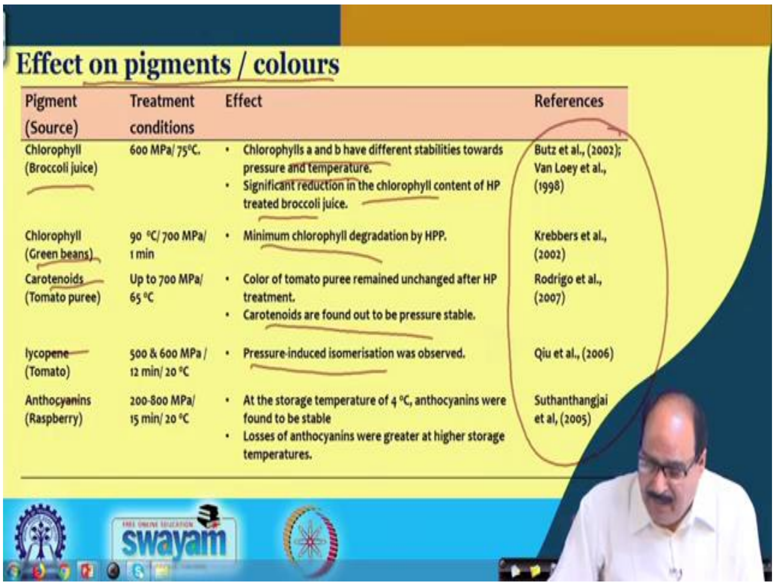


In the second part of the lecture on High Pressure Processing of Food, the effect of HPP on the constituents of food and ultimately its quality is discussed. Also at the end of lecture, the focus on the product and process applications of high pressure processing is elaborated.

Depending upon the process applications, in general to extend the shelf life of the food materials, the microorganisms or enzymes or such other causative agents, which result in the spoilage of food need to be destroyed. During optimization of the process, care should be taken so that there will not be any significant change or alteration or reduction in the quality attributes.

In the earlier lecture, the effect of high-pressure processing on inactivation of parasites, plant cells, vegetative microorganism, and spores of bacteria or fungi is well discussed. Simultaneously, the effect of high-pressure process parameters on sensory, texture, color, functional properties, enzymes & microbiological characteristics of the food must be analyzed.

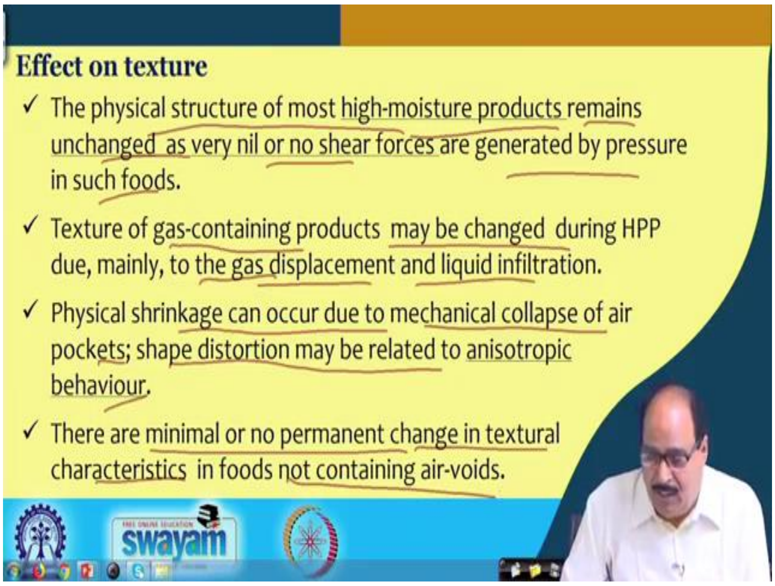
During HPP, the confirmation of the macro molecules may change depending upon the process conditions i.e. the pressure and other factors. Small molecules, such as color and flavor, etc. are generally not affected.



Effects on Pigments and Color

Several researchers have studied and reported the influence of varying ranges of pressure, temperature, and other factors such as acidity, etc. on major pigments present in food like chlorophyll, carotenoids, lycopene, anthocyanin, etc. The observations made by them are listed in the Table. It can be seen that chlorophylls a and b have different stability towards pressure and temperature. The significant reduction in the chlorophyll content was found for the high-pressure treated juice in broccoli. However, in the case of green beans; minimum degradation was reported. Similarly, the carotenoids are found to be pressure stable. Even the pressure induced isomerization was also obtained in certain case e.g. lycopene in tomato. Anthocyanins also were more or less influenced by the high-pressure conditions.

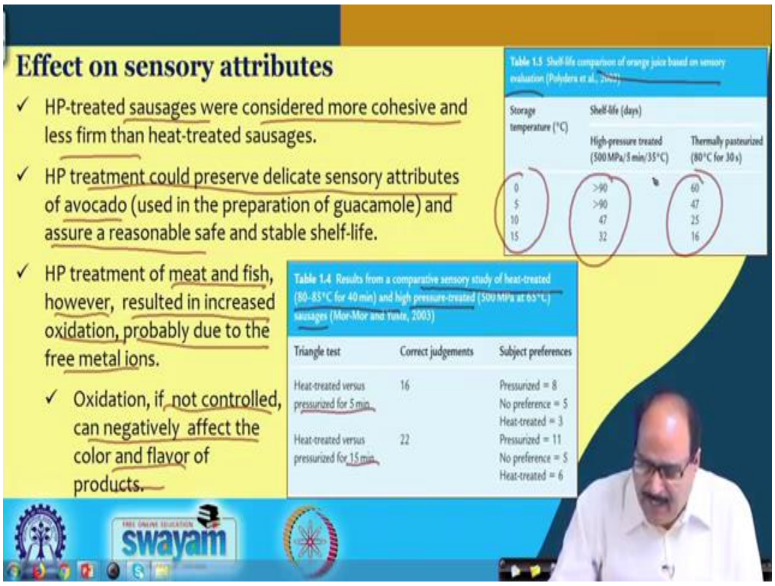
The actual appeal or final colour of the food product is not much influenced during high-pressure processing (see Fig.). The food products such as salami, milk, strawberry did not show any change in the colour. However, other products like salmon, chicken, beef and pork meats had shown significant change in the color before and after processing. It means that depending upon the characteristics, composition of the food material, extent of pressure applied, temperature of the medium & other factors such as pH, acidity, etc. during the high-pressure processing, influence the color to a less or great extent.



Effect on texture

The physical structure of most high-moisture products remains almost unchanged, as very nil or no shear forces are generated by pressure in such foods. Texture of gas-containing products i.e. the foods having air pockets or which have gas may be changed during high-pressure processing mainly because of the gas displacement as well as liquid infiltration.

Physical shrinkage can occur due to mechanical collapse of air pockets; shape distortion may be related to the anisotropic behavior. There are however minimal or no permanent change in textural characteristics in food not containing air-voids.

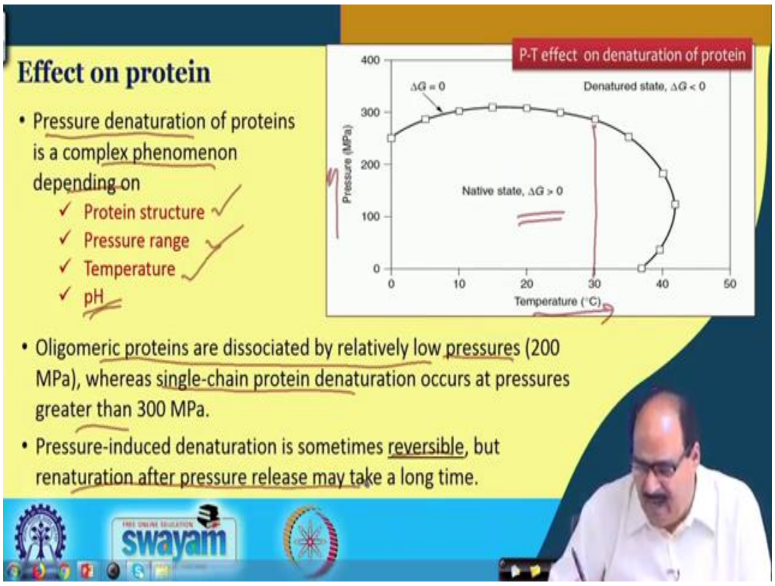


Effect on sensory attributes

The high pressure treated sausages were considered more cohesive and less firm than heat-treated sausages. High pressure treatment could preserve delicate sensory attributes of avocado, and assure a reasonable safe and stable shelf-life.

High pressure treatment of meat, fish, however resulted in the increased oxidation, probably due to the release of the metal ion from the myoglobin and hemoglobin. The oxidation if not controlled, can negatively affect the colour and flavour of the products.

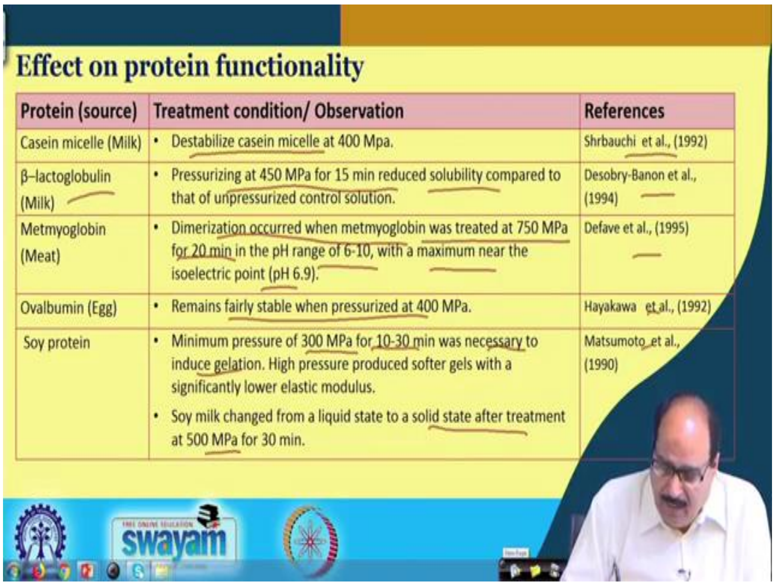
Some researchers conducted the comparative sensory study of heat treated, and high-pressure treated sausages (see Table). They found that pressurized or high-pressure treated sausages were liked by more judges in both case studies i.e. 5 & 15 minute high pressure treatment. Also the shelf-life comparison of orange juice was made, based on the changes in sensory characteristics of the juice during storage. It was found again that for storage temperature from 0 to 15 °C, the high-pressure treated juices were stable for longer period than the thermally pasteurized juices.



Effect on protein

Pressure denaturation of proteins is a complex phenomenon, and it depends mainly on the structure of protein, range of pressure applied, temperature, and pH of the system. In this figure, the effect of pressure and temperature on denaturation of the protein is shown. It can be seen that in most of the food, the proteins remain in its native state up to 250 MPa i.e ΔG value = 0. When the food protein is exposed to a pressure of 300 MPa or so at 30 °C temperature, it may get denatured which is indicated by ΔG value < 0.

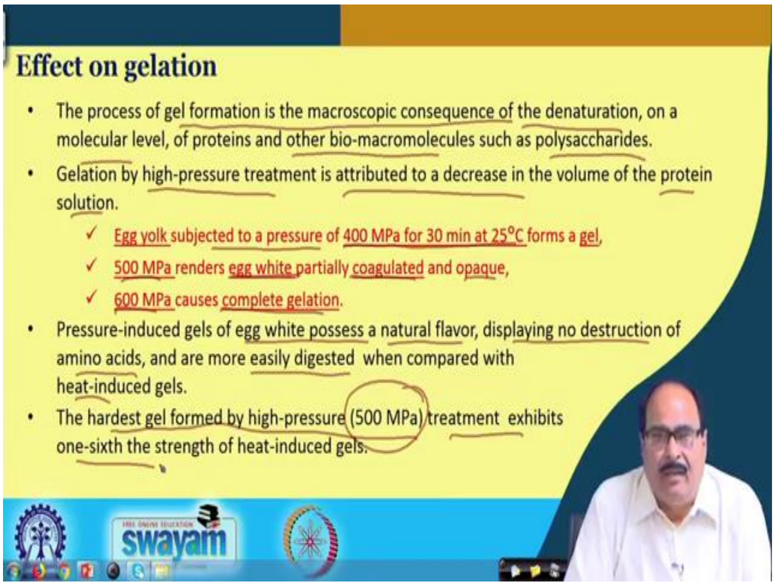
Oligomeric proteins are dissociated by relatively low pressure (200 MPa), whereas single-chain protein denaturation occurs at pressure greater than 300 MPa. Pressure-induced denaturation is sometimes reversible, but renaturation after pressure release may take a long time.



Effect on protein functionality

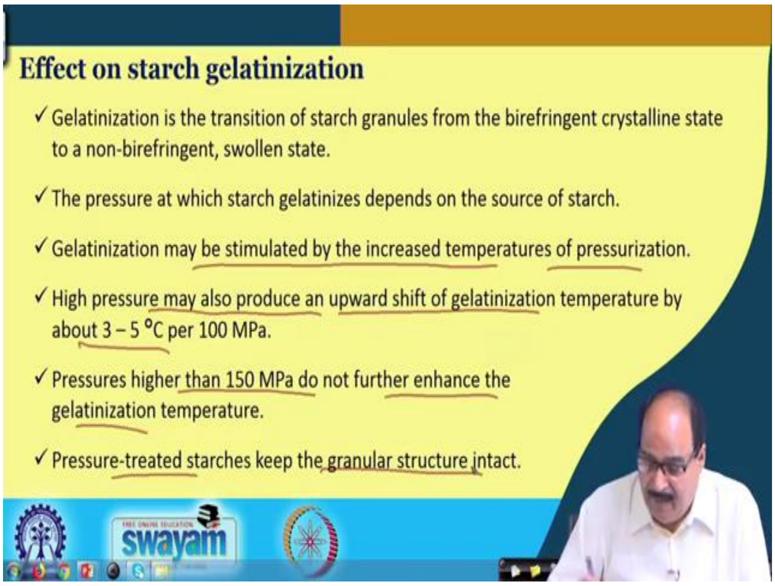
The effect of high pressure on functionality of the protein has been studied by several researchers. Many reports are available in the literature depending upon the pressure and temperature. The functionalities of protein are improved sometimes or at very high pressure, may have some adverse effect.

Casein micelle in milk get destabilized at 400 MPa pressure while 450 MPa & 15 min HP treatment reduced solubility of beta-lactoglobulin in milk in comparison to the unpressurized or control milk. Similarly, dimerization occurs, when met myoglobin is treated at a comparatively higher pressure like 750 MPa for 20 min in the pH ranges of 6 to 10 with a maximum near the isoelectric pH (6.9). Ovalbumin in egg remains fairly stable when pressurized at 400 MPa. In soy protein, a pressure of 300 MPa for 10 to 30 min was necessary to induce gelation. High pressure produces softer gel with a significantly lower elastic modulus. Soy milk change from a liquid state to solid state after treatment at 500 MPa for 30 min; that means under this condition, the proteins are completely coagulated or precipitated.



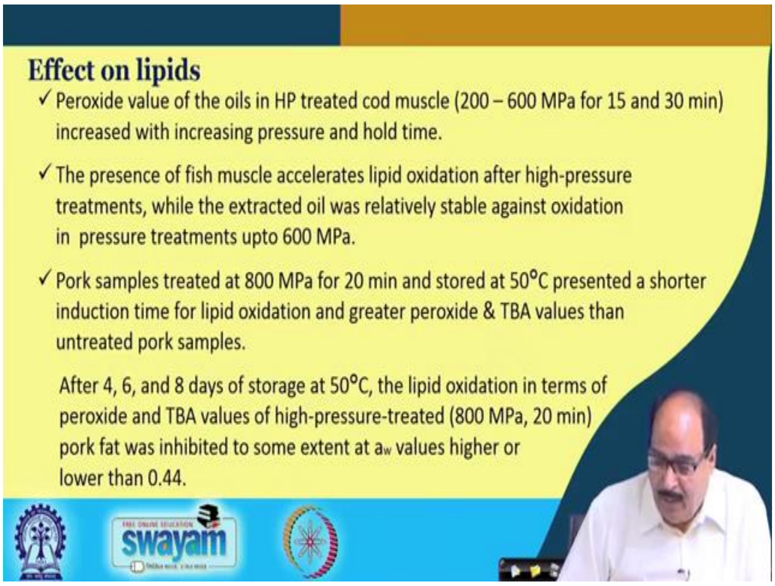
Effect on gelation

The process of gel formation is the macroscopic consequence of protein denaturation on a molecular level of proteins and other bio-macromolecules such as polysaccharides, etc. Gelation by high-pressure treatment is attributed to the decrease in the volume of protein solution. Egg yolk subjected to a pressure of around 400 MPa for 30 min at 25 °C forms a gel. At 500 MPa, egg white gets partially coagulated, and it becomes opaque and if the pressure is made little higher 600 MPa, the complete gelation of the protein takes place. So, these pressure-induced gels of egg white possess a natural flavor, displaying no destruction of amino acids, and have a better digestibility, when compared with the heat-induced gel. The hardest gel formed by high-pressure (500 MPa) treatment exhibit one-sixth the strength of heat-induced gel.



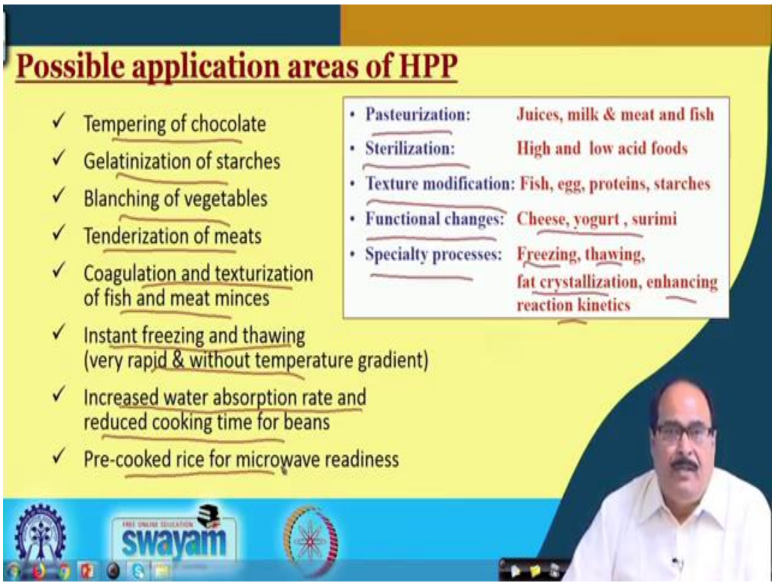
Effect on starch gelatinization

Gelatinization is the transition of starch granules from the birefringent crystalline state to non-birefringent swollen state. It may be stimulated by the increased temperatures or pressurization. The pressure at which starch gelatinizes depends upon the source of starch. High pressure may also produce an upward shift in the gelatinization temperature of the starch by about 3-5 °C per 100 MPa. Pressures higher than 150 MPa do not further enhance the gelatinization temperature. Interestingly, the pressure-treated starch keeps the granular structure intact and this gives a very good application in the high-pressure or pressure parboiling of the paddy and other starch containing materials.



Effects on lipids

Peroxide value of the oil in high-pressure treated cod muscle (200-600 MPa for 15 and 30 min) was increased with the increasing pressure and hold time. The presence of fish muscle accelerates the lipid oxidation reactions after high-pressure treatment while the extracted oil was relatively stable against oxidation in pressure treatment up to 600 MPa. Pork samples treated at 800 MPa for 20 min and stored at 50°C presented a shorter induction time for lipid oxidation and greater peroxide and TBA values than untreated pork samples. After 4, 6, and 8 days of storage at 50°C, the lipid oxidation in terms of peroxide and TBA values of high-pressure-treated (800 MPa, 20 min) pork fat was inhibited to some extent at a_w values higher or lower than 0.44.

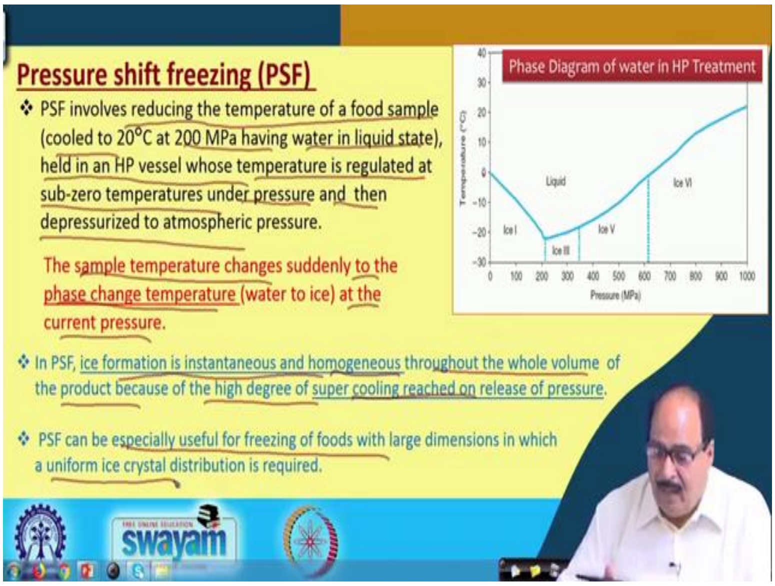


Possible application areas of HPP

The application of HPP is wide ranging. It can be applied for both the product preparation for having good functional and other characteristics as well as for extension of the shelf-life. HPP can be used for pasteurization, sterilization, texture modification, functional changes and some specialty processes such as freezing, thawing, fat crystallization, enhancing reaction kinetics, etc.

The high pressure processing has a good potential for its application such as

- ✓ Tempering of chocolate
- ✓ Gelatinization of starches
- ✓ Blanching of vegetables
- ✓ Tenderization of meats
- ✓ Coagulation and texturization of fish and meat minces
- ✓ Instant freezing and thawing (very rapid & without temperature gradient)
- ✓ Increased water absorption rate and reduced cooking time for beans
- ✓ Pre-cooked rice for microwave readiness

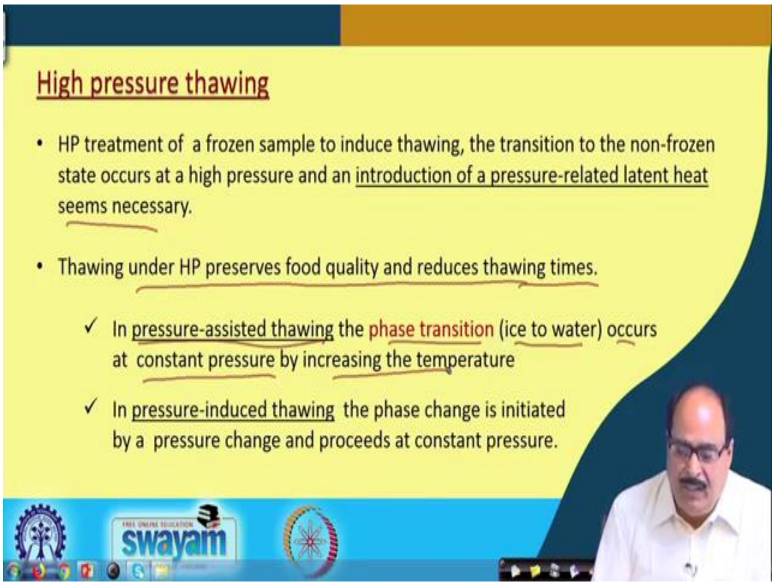


Pressure shift freezing (PSF)

The pressure shift freezing involves reducing the temperature of a food sample (cooled to around 20 °C at 200 MPa having water in liquid state), held in a high-pressure vessel which temperature is regulated at sub-zero temperature under pressure, and then depressurized to atmospheric pressure.

So, when it is depressurized, the sample undergoes temperature changes i.e. sudden change in the temperature of the sample to the phase change temperature (water to ice) at the current pressure.

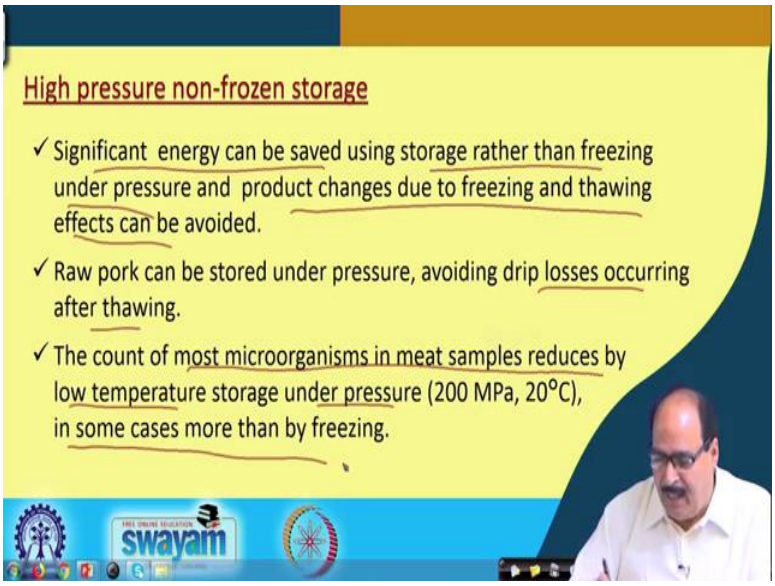
In PSF, ice formation is instantaneous and homogeneous throughout the whole volume of the product because of the high degree of super cooling reached on release of pressure. PSF can be especially useful for freezing of foods with large dimensions in which uniform ice crystal distribution is required.



High pressure thawing

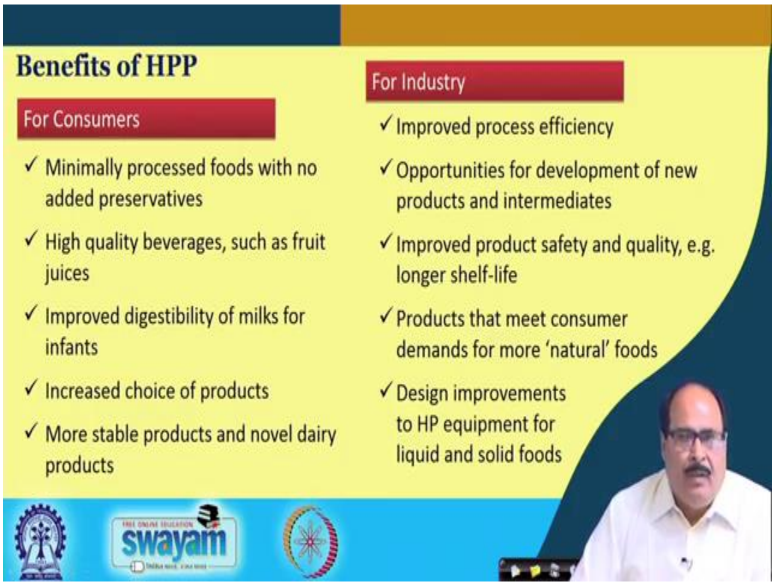
High pressure thawing is the reverse of the freezing. A frozen food is taken out of the frozen environment, and put to certain conditions to change the ice into water. Normally, heat treatment is used but it is associated with the changes in the characteristics of the food material. So, in this case, high pressure processing becomes very good useful tool. High pressure treatment of a frozen sample to induce thawing, the transition to the non-frozen state occurs at a high pressure and an introduction of a pressure-related latent heat seems necessary. Thawing under high pressure preserves food quality and reduces thawing times.

- ✓ In pressure-assisted thawing, the phase transition (ice to water) occurs at constant pressure by increasing the temperature
- ✓ In pressure-induced thawing, the phase change is initiated by a pressure change and proceeds at a constant pressure.



<u>High pressure non-frozen storage</u>

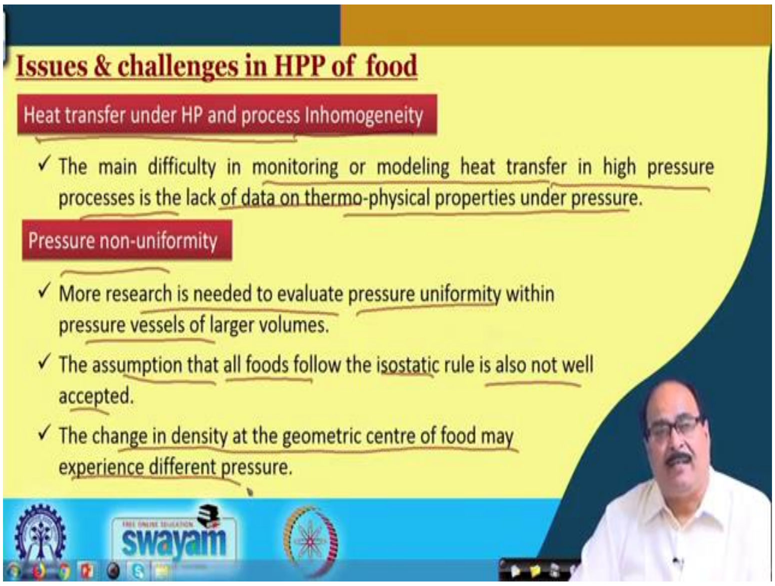
Another application is the high pressure non-frozen storage. In this process, significant energy savings can be done using storage rather than freezing under pressure and the product changes due to freezing and thawing effects can be avoided. Raw pork can be stored under pressure avoiding drip losses occurring after thawing. The count of most of the microorganisms in meat samples reduces by low temperature storage under pressure (200MPa, 20°C) in some cases more than by freezing.



Benefits of HPP

Now, at the end of the lecture the benefits of the high-pressure processing for both the consumers as well as the industry must be summarized.

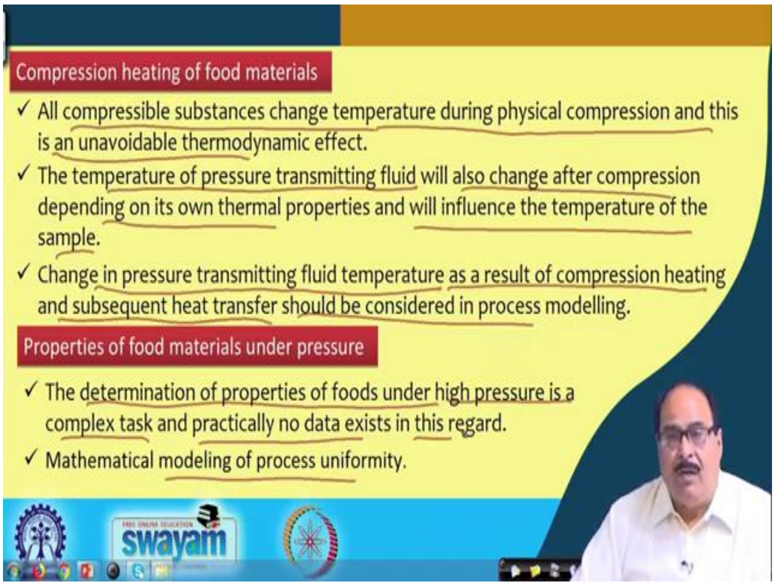
For Consumers	For Consumers
✓ Minimally processed foods with no added preservatives ✓ High quality beverages, such as fruit juices ✓ Improved digestibility of milks for infants ✓ Increased choice of products ✓ More stable products and novel dairy products	✓ Improved process efficiency ✓ Opportunities for development of new products and intermediates ✓ Improved product safety and quality, e.g. longer shelf-life ✓ Products that meet consumer demands for more 'natural' foods ✓ Design improvements to HP equipment for liquid and solid foods



Issues & challenges in HPP of food

There are certain issues and challenges in the high-pressure processing, and of course, the interest has generated among the world academic fraternities & the industry and definitely these issues will be resolved.

The important issue is the heat transfer under high-pressure and process inhomogeneity. The main difficulty in monitoring or modeling heat transfer in high pressure processes is the lack of data on thermo-physical properties under pressure. The pressure non uniformity is another important issue that invites more research to evaluate process at higher handling volumes in larger pressure vessel. The assumption that all foods follow the isostatic rule is also not well accepted, because the change in density at the geometric centre of food may experience different pressure.



The other important issue is the compression heating of the food materials. All compressible substances change temperature during physical compression, and this is an unavoidable thermodynamic effect. The temperature of pressure transmitting fluid will also change after the compression depending upon its own thermal properties and it will influence obviously the temperature of the sample. So, change in the pressure transmitting fluid temperature as a result of the compression heating and subsequent heat transfer should be considered in the process modeling. Not many literature reports are found where these are considered during modeling of microbial inactivation or enzymatic inactivation.

Properties of food materials also become a very important issue during high pressure processing. The determination of properties of foods under high pressure is a complex task and practically no data exists in this regard. Mathematical modeling of process uniformity needs to be properly understood for the destroying undesirable factors in food for improving its functionality and extending the shelf-life of the food without causing any alteration in the sensory and other attributes.