Novel Technologies for Food Processing and Shelf Life Extension

Prof. Hari Niwas Mishra
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 10
Traditional Food Preservation Technologies – Part 2

In the first part of Traditional Food Preservation Technologies, different methods that are traditionally used for preservation of food, the target factors in these methods, the objectives and the mode by which these objectives are achieved were elaborated in detail.

There are three sets: one set of technology are used to slow down microbial growth, other sets of technologies are used to kill or inactivate microorganisms and other technologies are used to reduce the contamination or restrict the access of microorganism to food. In all these processes, control of water activity, control of pH and heat treatment are the major factors which are used to preserve the food traditionally.

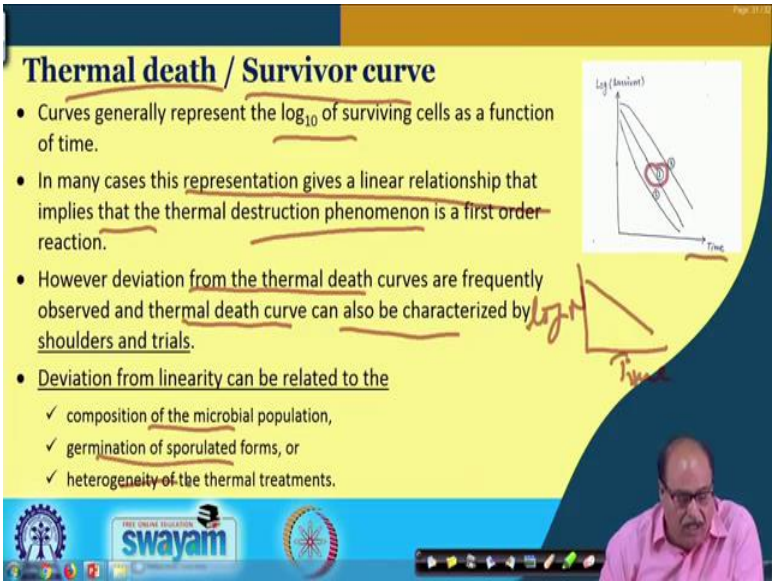
Thermally processed food constitutes a large part of the food processing industry or the products which are available in the market. This lecture basically discusses the effect of heat on the lethality of microorganisms.

The impact of heat treatment on microorganisms is estimated from the measurement of the surviving cells against heating time. The destruction profile obtained forms the basis for the designation of the operational requirement for the design of thermal process. This

is mostly based upon the total energy input that is required for the inactivation of most heat resistant form of the spore forming bacteria.

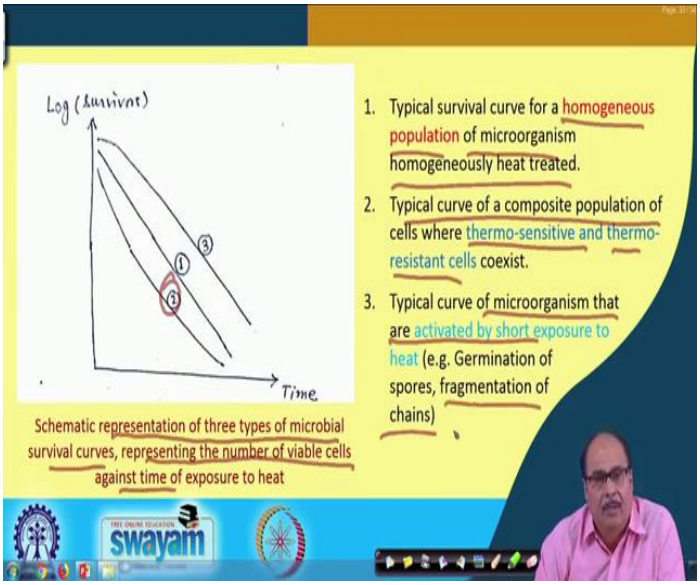
Traditional estimations of the efficiency of preservation and disinfection process are based upon the assumption that microbial death follows a known evolution. Each species of the microorganism has its own particular heat tolerance. Thermal operating conditions are determined experimentally and the data are presented as the number of surviving microorganisms or viable spores against the exposure time at a given temperature.

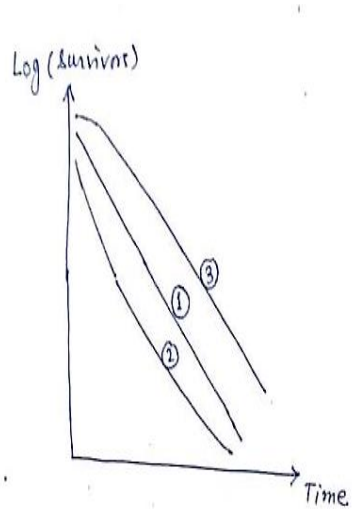
Different experiments under different temperature and time conditions are conducted and the effect of these time and temperature combinations on either killing or survival of the microorganisms are estimated. These recorded data are analyzed to find out whether the effect of change in the temperature is influencing the microorganisms and its survival in the heat process. The thermal destruction kinetics of microorganisms becomes an important subject in the thermal process design.



Thermal death kinetics or survival curve is one of the major data which are generated experimentally on the most heat resistant vegetative cell or spore of the bacteria. It is plotted in the form of a survivor curve. The log number of surviving bacteria is plotted against a time; generally a straight line is obtained. In the figure, Line 1 gives a linear relationship and this linear relationship implies that thermal destruction phenomenon is a first order reaction. However, as you could see in the figure 2 and 3, the deviation from the thermal death curves may be observed and this thermal death curve can also be

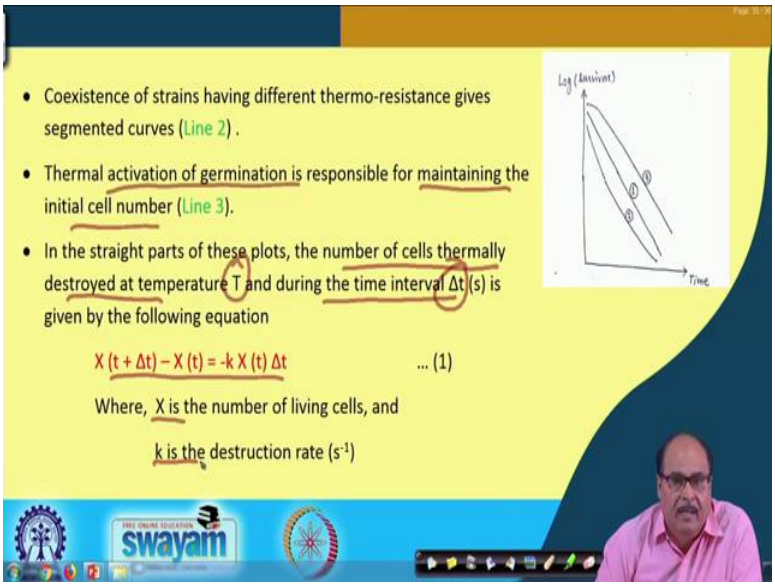
characterized by shoulders and tails. The deviation from linearity may be related to the composition of the microbial population, germination of sporulated forms, or heterogeneity of the thermal treatment.





In this graph, a schematic representation of the three types of microbial survival curves, representing the number of viable cell against the time is depicted. Line 1 which is a linear relationship, gives a straight line. This curve shows that in the population there is a homogeneous mass of microorganism and it has been homogeneously heat treated i.e. all the microorganism have received uniform heat treatment.

The line 2 is a typical curve, where composite population i.e. thermo sensitive as well as thermo resistant cells coexist in the system. The 3rd line is the curve of microorganisms that are activated by short exposure to heat. When the heat is given to the system, some of the spores might germinate or there might be certain fragmentation.



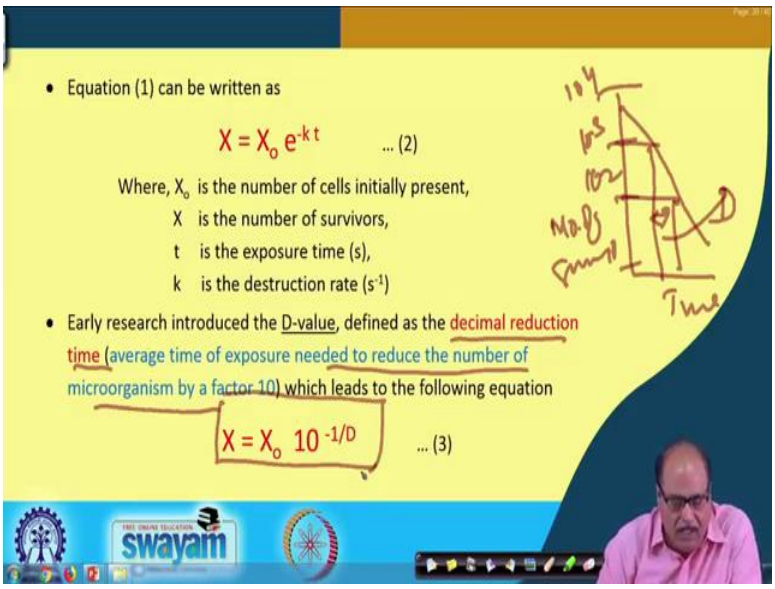
This indicates that in line 2, coexistence of strains, having different thermal resistance gives the segmented lines. Thermal activation of germination is responsible for maintaining the initial cell number which is shown in line 3.

In the straight part of these plots, the number of cells thermally destroyed at temperature T during the time interval Δt in seconds is represented by the equation 1.

$$X\ (t + \Delta t) - X\ (t) = -k\ X\ (t)\ \Delta t \qquad \ldots (1)$$

Where, X is the number of living cells, and

k is the destruction rate (s^{-1})



Equation 1 can also be written as

$$X = Xo\ e^{-k\ t} \qquad \ldots (2)$$

Where, Xo is the number of cells initially present,

X is the number of survivors,

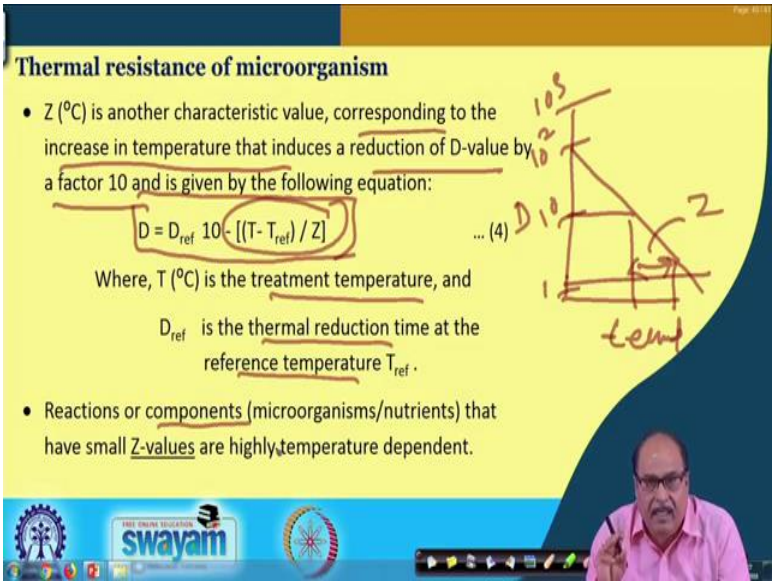
t is the exposure time (s),

k is the destruction rate ($s^{-1)}$

Early research introduced the D-value, defined as the decimal reduction time (average time of exposure needed to reduce the number of microorganism by a factor 10) which leads to the following equation

$$X = Xo\ \ 10^{-1/D} \qquad \ldots (3)$$

D value is obtained by plotting the log number of survivors (Y axis) against time (X axis) on a semi log paper. A straight line is obtained. The time required to reduce the microbial population by a factor of 10 is known as D value also called decimal reduction time. If k is replaced by D in the equation 2, equation 3 is obtained.



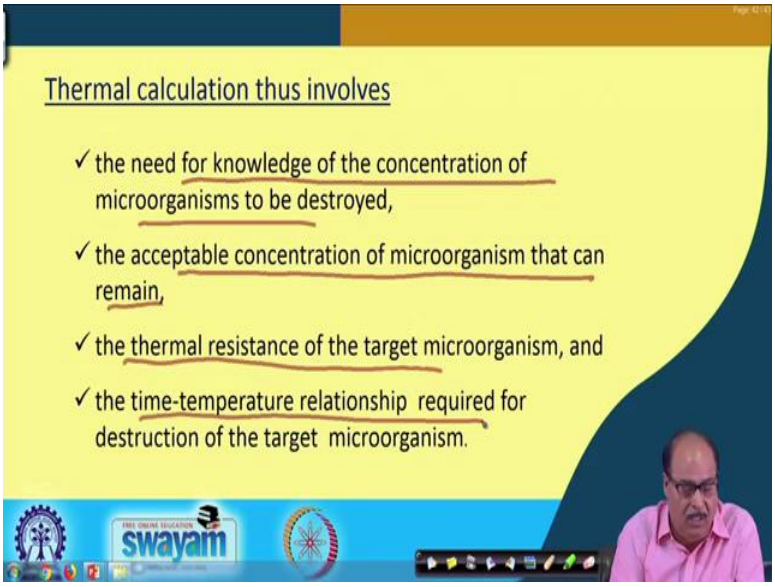
Another parameter which is used to indicate the thermal resistance of microorganism is Z value. Like in D value where, log number of survivors is plotted against time, if D value is plotted against temperature, a straight line is obtained and the slope of this curve is Z value. Z value corresponds to the increase in the temperature that induces a reduction of D value by a factor of 10 and this is given by equation 4.

$$D = D_{ref}\ 10 - [(T - T_{ref}) / Z] \qquad \ldots (4)$$

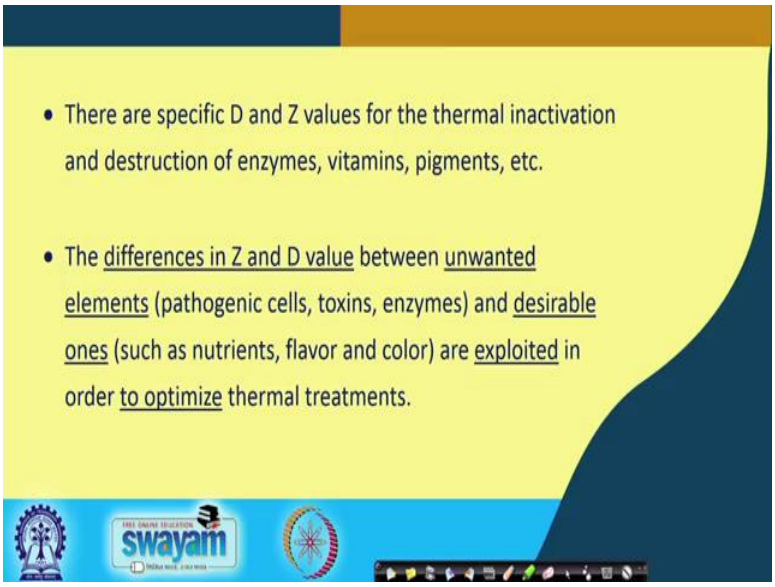
Where, T (^{0}C) is the treatment temperature, and

D_{ref} is the thermal reduction time at the reference temperature T_{ref}.

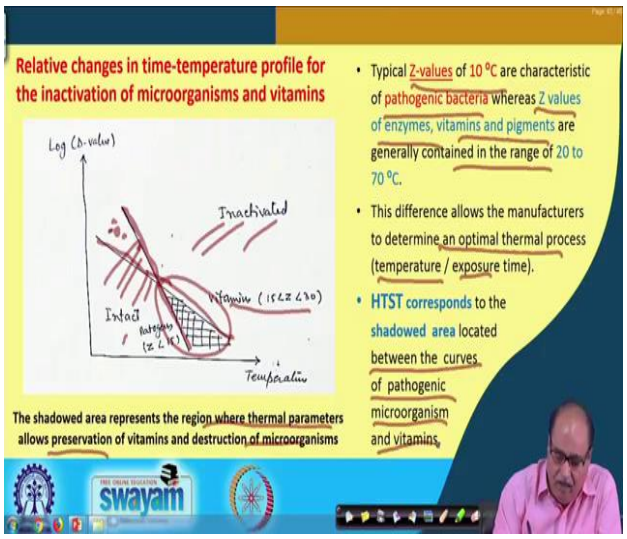
The reference temperature for pasteurization process is generally 71.7 °C and for the sterilization process it is 121 °C. Z value gives a good indication about the thermal resistance of the microorganism, for eg. consider there are two microorganisms. One microorganism has a Z value of 10°; another microorganism has a Z value of 50°. One has to increase the temperature to 50°C to get that 1 log cycle reduction in D value whereas in other case just by increasing the temperature by 10 °C, we can get a 1 log cycle reduction in D value. Reactions or components (microorganisms/nutrients) that have small Z-values are highly temperature sensitive.

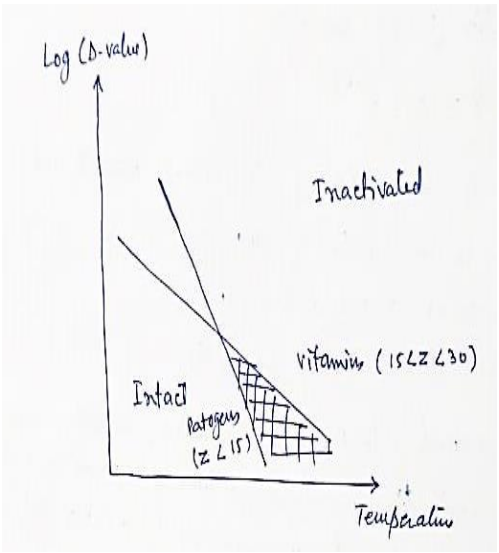


Thermal process calculations, therefore, involve the need for knowledge of the concentration of the microorganisms to be destroyed and the acceptable concentration of microorganism that can remain in the final product. It is necessary to decide whether to go for 12 or 8 or 5 log cycle reductions depending upon the number and type of the microorganisms, thermal resistance of the target microorganisms, food characteristics, and the time temperature relationship required for the destruction of the target microorganisms.



There are specific D and Z values for the thermal inactivation, destruction of enzymes, vitamins, pigment and the microorganism i.e. the unwanted elements in the food like pathogenic cells, toxins, enzymes or desirable components in the food like nutrients, flavor and color, have different D value as well as Z values. The differences of the D value and the Z values of these undesirable and desirable components on the foods are generally exploited to optimize the thermal treatments and form the main basis for the optimization of the thermal process conditions.

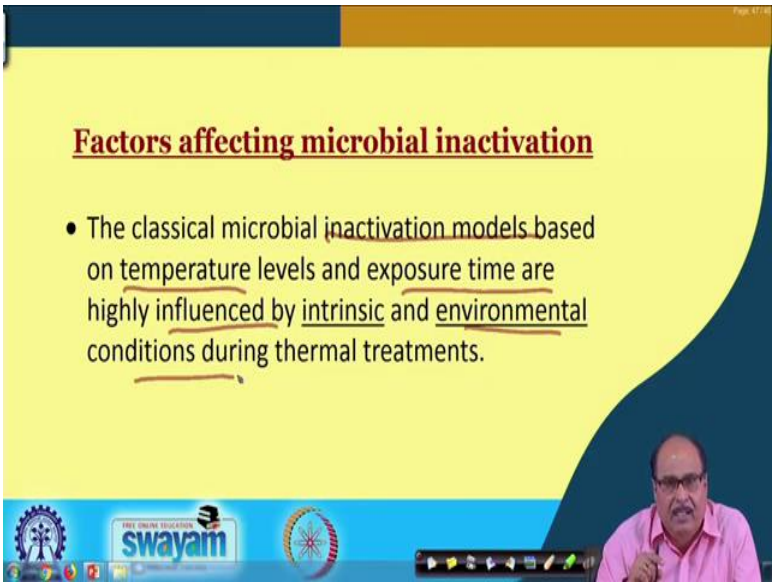




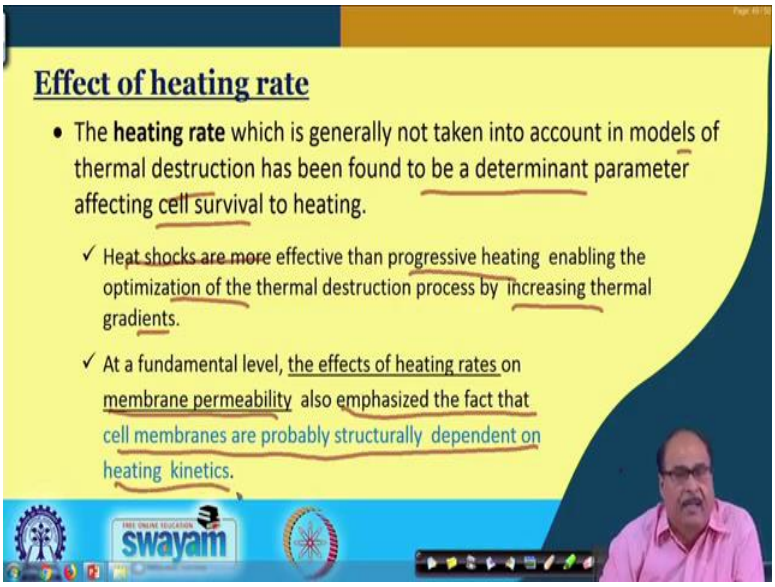
In this figure, the relative change in the time temperature profile for inactivation of microorganisms and the destruction of vitamins in the food can be observed. Z value and D value for these components differ. Z values for enzymes, vitamins and pigments

generally are found in the range of 20 to 70 °C. This difference allows the manufacturer to determine an optimal thermal process condition like temperature and exposure time. Most of the thermal process may be of low temperature long time or high temperature short time.

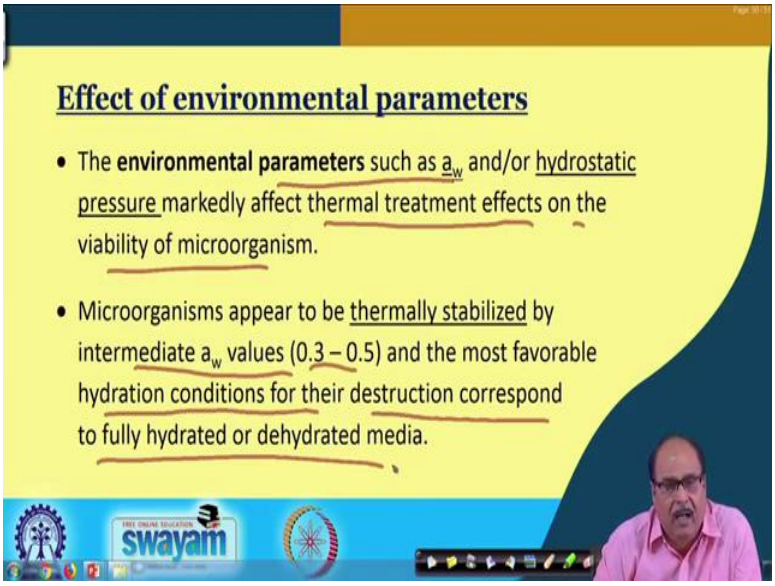
The low temperature long time methods generally lead to the destruction of the nutrient and in high temperature short time, since the exposure of the food component to the temperature is very short; it results in better nutrient retention, and high microbial destruction. It can be seen in the graph that, for the pathogens the Z value is less than 15 °C whereas, the food nutrients like vitamins color, flavor, etc. they have a higher Z value. Vitamins will remain intact for Z less than 30 °C; if the Z value reaches 30 or above, vitamins will get destroyed. So, the shaded area is the point of focus where the pathogens get inactivated and the desirable constituents of the food like vitamins, pigments, colors, etc. are also retained. The shaded area represents the region where the thermal parameters allow preservation of vitamins and destruction of microorganism through the high temperature short time treatment.



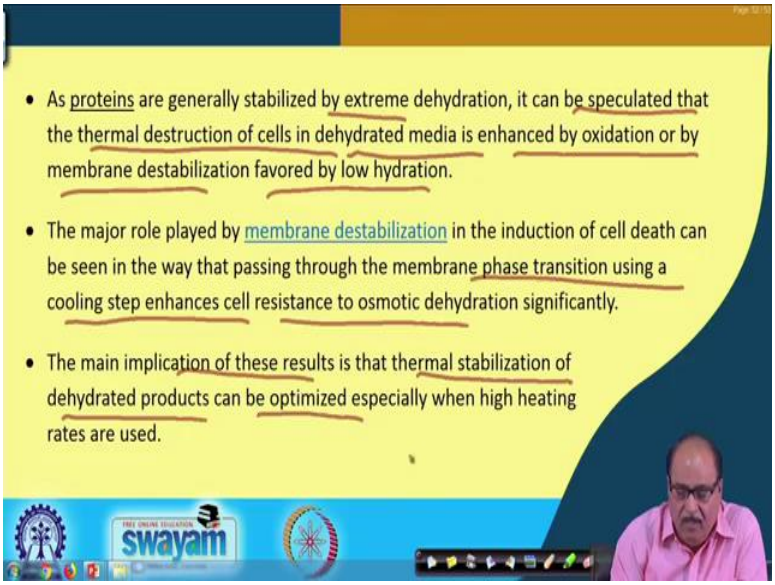
The classical microbial inactivation models based on the temperature levels and exposure times are highly influenced by intrinsic and environmental conditions during the thermal treatment. It also influences the thermal destruction kinetics of the microorganisms.



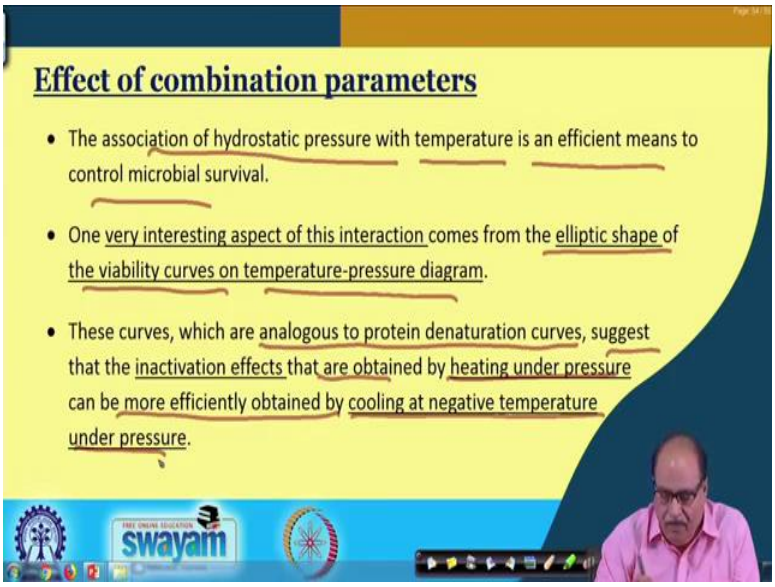
One important factor is heating rate, the rate at which heat process is applied which is generally not taken into account in the models of thermal destruction although it has been found to be a determinant parameter affecting the survival of the microorganisms. Even heat shocks are found more effective than the progressive heating. Heat shocks enable the heat optimization of the thermal destruction process by increasing the heat gradient. Instead of heating continuously if we give heat shock then it has more influence on the microbial death. At a fundamental level, the effects of heating rates on the membrane permeability also emphasized the fact that cell membranes are structurally dependent on heating kinetics.



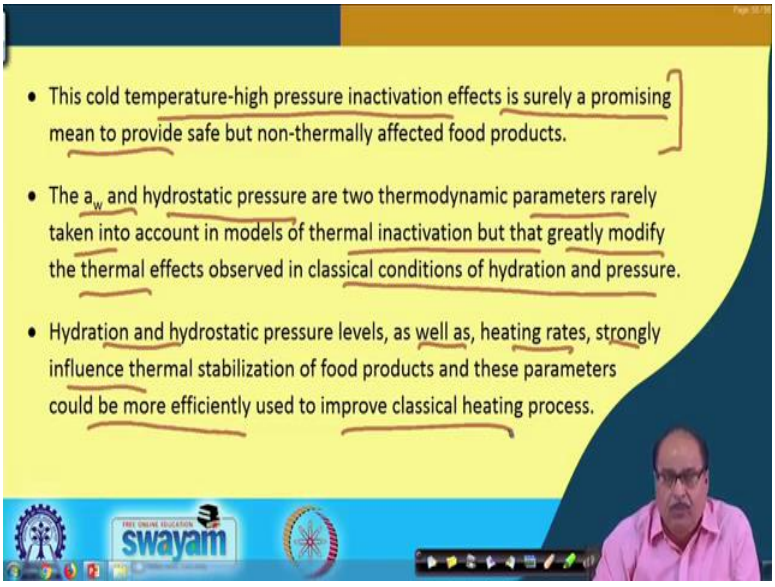
The other factors include environmental factors in which the food is heated like water activity and hydrostatic pressure. These parameters significantly influence thermal treatment effects on the viability of microorganisms. Microorganisms appear to be thermally stabilized by intermediate a_w values in the range of 0.3 to 0.5 and the most favorable hydration conditions for their destruction correspond to fully hydrated or dehydrated media.



As proteins are generally stabilized by extreme dehydration, it can be speculated that the thermal destruction of cells in dehydrated media is enhanced by the oxidation or by membrane destabilization. The major role played by membrane destabilization in the induction of cell death can be seen in the way that passing through the membrane phase transition using a cooling step enhances cell resistance to osmotic dehydration significantly. The main implication of these results is that, thermal stabilization of dehydrated products can be optimized especially when high heating rates are used.



The combination parameters also influence the heating process or thermal destruction of microorganisms in food. The association of hydrostatic pressure with temperature is an efficient means to control microbial survival. One very interesting aspect of this interaction comes from the elliptical shape of the viability curves on temperature pressure diagram. These curves which are analogous to the protein denaturation curves, suggest that the inactivation effects that are obtained by heating under pressure can be more efficiently obtained by cooling at negative temperature under pressure.



This forms the principle of hydrostatic high pressure processing i.e. the cold temperature -high pressure inactivation effects is surely a promising means to provide safe, but non-

thermally affected food products. This forms the principle of the high pressure processing of the food which is one of the emerging technologies in food processing.

The water activity and hydrostatic pressure are two thermodynamic parameters rarely taken into account in thermal process calculation models but that greatly modify the thermal effects observed in classical conditions of hydration and pressure. Hydration and hydrostatic pressure levels, as well as, heating rates, strongly influence thermal stabilization of food products and these parameters could be more efficiently used to improve classical heating process.

So, by proper control of these parameters like heating rate or by having a proper combination of the heating process as well as the environmental conditions, a better thermal process with better desired sterility level in the product can be established. A better thermal process will have the desired level of nutrients and other quality factors in the food. So, this thermal destruction kinetics becomes an important aspect in designing the thermal process parameters for a food.