Food preservation by high temperature

The high temperature preservation of food is based on destructive effect of heat on microorganisms, thereby extending shelf life of foods. High temperature refers to any temperature higher than ambient temperature applied to food. Preservation of foods by heat treatment can be done by two methods viz. pasteurization and sterilization.

Pasteurization

Pasteurization refers to use of heat at the range of 60~80^{o}C for a few minutes for the elimination/ destruction of all disease causing microorganisms, and reduction of potential spoilage organisms. Pasteurization is commonly used in the preservation of milk, fruit juices, pickles, sauces, beer etc. Pasteurization process which is commonly employed in milk preservation can be achieved by heating the milk at 63^{o}C for 30 min, called low temperature long time (LTLT) process; or 72^{o}C for 15 sec, called high temperature short time (HTST) process. This process destroys most heat resistant non-spore forming pathogens (Ex. *Mycobacterium tuberculosis*), all yeasts, molds, Gram negative bacteria and most Gram positive bacteria.

Sterilization

Sterilization or appertization refers to destruction of all viable organisms in food as measured by an appropriate enumeration method. This process kills all viable pathogenic and spoilage organisms. However, organisms that survive are non-pathogenic and unable to develop in product under normal conditions of storage. Thus, sterilized products have long shelf life. Commercially sterile or commercial sterility is often used for canned foods to indicate the absence of viable microorganisms detectable by culture methods or the number of survivors is so low that they are of no significance under condition of canning and storage.

Processing of food for preservation using high temperature depends on the physical nature of the food. Foods (solid or semisolid) are generally processed by packing in cans, sealing and then sterilized. Most liquid foods are sterilized, packed in suitable containers and sealed aseptically. Temperature and time of sterilization given to a food depends on the nature (pH, physical state, nutritional type etc) of the food being processed.

Heat resistance of microorganisms

- Heat resistance of microorganisms is related to their optimal growth temperature.
- Psychrophiles are most sensitive and thermophiles are most resistant to heat treatment.
- Spore forming microorganisms are most resistant than non spare formers.
- Gram positive bacteria are more resistant than Gram negative bacteria.
- Yeasts and molds are fairly heat sensitive
- Spores of molds are slightly more heat resistant than vegetative cells.

Heat resistance of spores

Bacterial spores are more heat resistant than vegetative cells. Thermophiles produce more heat resistant spores. Since spore inactivation is the main concern in canned foods, high process temperature is used to achieve this. The heat resistance of bacterial endospore is due to their ability to maintain very low water content in the DNA containing protoplast. Presence of calcium and dipicolonic acid in high concentration in spores helps to reduce cytoplasmic water. Higher the degree of spore dehydration greater will be its heat resistance.

Factors affecting heat destruction of microorganisms

Several factors associated with microorganisms as well as their environment affect heat destruction of microorganisms.
Water: Heat resistance of microorganisms increases with decrease in moisture/ water activity and humidity. This is due to faster denaturation of protein in presence of water than air.

Fat: Heat resistance increases in presence of fat due to direct effect of fat on cell moisture. Heat protective effect of long chain fatty acids is better than short chain fatty acids.

Salts: Effect of salt in heat resistance of microorganisms is variable, and depends on type of salt, concentration used, and other factors. Some salts (sodium salts) have protective effect on microorganisms and others (Ca^{2+} and Mg^{2+}) make cells more sensitive. Some salts (Ca and Mg) increase water activity, while others (Na^{+}) decrease water activity there by affecting heat sensitivity.

Carbohydrates: Presence of sugars in suspending medium increases heat resistance of microorganisms due to decreased aw. Different sugars show varying effect. Heat resistance decreases in the order of; sucrose>glucose>sorbitol>fructose>glycerol.

pH: Microorganisms are most heat resistant to heat at their optimum pH for growth (about pH 7-0). Increase or decrease in pH reduces heat sensitivity. Thus, high acid foods require less heat processing than low acid foods.

Proteins: Proteins have protective effect on microorganisms. As a result high protein foods need a higher heat treatment than low protein foods to obtain similar results.

Number of microorganisms: Larger the number of microorganisms, higher the degree of heat resistance. This is due to the production of protective substance excreted by bacterial cells, and natural variations in a microbial population to heat resistance.

Age of microorganisms: Microorganisms are most resistant to heat in stationery growth and least in logarithmic growth phase. Also old bacterial spores are more resistant that young spores.

Growth temperature: Heat resistant of microorganisms increases with increase in incubation temperature, especially in spore formers. This is mainly related to genetic selection favoring growth of heat resistant forms. Cultures grown at 44°C are known to have three times more heat resistance than those grown at 35°C.

Inhibiting compounds: Heat resistance of most microorganisms decreases in the presence of heat resistant microbial inhibitor such as antibiotic (nisin), sulfur dioxide etc. Heat and inhibiting substances together are more effective in controlling spoilage of foods than either alone.

Time and temperature: Generally believed that the longer the heating time, greater the killing effect. But higher the temperature, greater will be the killing effect. Thus, as temperature increases, time necessary to achieve the same effect decreases. Also, the size and composition of containers affect heat penetration.

Thermal destruction of microorganisms

The preservative effect of high temperature treatment depends on the extent of destruction of microorganisms. Certain basic concepts are associated with the thermal destruction of microorganisms.These include;

- Thermal death time (TDT)
- D- value
- Z- value
- F- value
- 12D concept

Thermal death time (TDT)

TDT is the time required to kill a given number of organisms at a specified temperature. Here, temperature is kept constant and the time necessary to kill all cells is determined. Whereas, thermal death point is the temperature necessary to kill given number of organisms in a fixed time, usually 10 min. But it is of less importance.

TDT is determined by placing a known number of bacterial cells/spores in sealed containers, heating in a oil bath for required time and cooling quickly. The number of survivors from each test period is determined by plating on a suitable growth media. Death is defined as the inability of organism to form viable colonies after incubation.

D-value (Decimal reduction time

D-value is the time in minutes required at specified temperature to kill 90% of microorganisms thereby reducing the count by 1 log units. Hence D – value is the measure of death rate of microorganisms. It reflects the resistance of an organism to a specific temperature and can be used to compare the relative heat resistance among different organisms/spores. D-value for the same organism varies depending on the food type. D -value is lower in acid foods and higher in presence of high proteins.

Example: D 250^{o}F (121.1^{o}C) for *B. stearothermophilus:* 4-5 min

C. botulinum: 0.1 – 0.2 min.

D 95^{o}C for *B. coagulans*: 13.7 min

B. licheniformis: 5.1 min.

Z – Value

Z-value refers to degrees of Fahrheit required for the thermal destruction curve to drop by one log cycle. Z value gives information on the relative resistance of an organism for different destruction temperature. It helps to determine equivalent thermal process at different temperature. Example: If adequate heat process is achieved at 150^{o}F for 3 min and Z -value was determined as 100F, which means the10^{o}F rise in temperature reduces microorganisms by 1 log unit. Therefore, at 140^{o}F , heat process need to be for 30 min and at 160^{o}F for 0.3 min to ensure adequate process.

F – Value

F- value is the better way of expressing TDT. F- is the time in minutes required to kill all spores/vegetative cells at 250^{o}F (1210^{o}C). It is the capacity of heat process to reduce the number of spores or vegetarian cells of an organism.

F – Value is calculated by F_o = Dr (log a-log b)

Dr = Decimal reduction time (D value)

a = initial cell numbers

b = final cell numbers

12D concept

12D concept is used mainly in low acid canned foods (pH >4.6) where *C. botulinum* is a serious concern. 12D concept refers to thermal processing requirements designed to reduce the probability of survival of the most heat resistant *C. botulinum* spores to 10-12. This helps to determine the time required at process temperature of 121^{o}C to reduce spores of *C. botulinum* to 1 spore in only 1of 1 billion containers (with an assumption that each container of food containing only 1 spore of *C. botulinum*).