Unit II - Topic 2

Reaction Kinetics - Decimal Reduction Time – Temperature Dependence Of Kinetics

27.1 Introduction

To establish the thermal processing schedule, the thermal destruction rate of the test micro organisms must be determined under the conditions that normally prevail in the container so that an appropriate heating time can be determined at a given temperature. Furthermore, since packaged foods cannot be heated to process temperature instantaneously, data on the temperature dependence of the microbial destruction rate are also needed to integrate the destruction effect through the temperature profile under processing conditions.

Microorganisms are destroyed by heat when microbial proteins coagulate and enzymes required for their metabolism are inactivated. The exact molecular mechanism underlying the thermal death of microorganisms is not clear, but it is believed to be due to thermal denaturation of the secondary and tertiary structures of macro-molecular cellular organizations (DNA, membrane proteins etc.) which renders them biologically inactive.

Heat treatment, necessary to kill microorganisms or their spores, varies with the kind of organisms, their state and their environment during heating. Several terms are used to denote heat resistance of the spores, viz. D-value, Z-value, Q10, sterilizing effect, etc.

27.2 D-Value (Decimal Reduction Time)

It is the time in minutes necessary at a specific temperature (?) to reduce the number of organisms to 1/10 of the original value.

27.3 Z-Value

It is an increase in temperature necessary for obtaining the same lethal action at 1/10th of the time.

27.4 F_0 Value

F is thermal death time (minutes) of an organism at 121°C and F_0 value indicates F value when Z equals 18. It is a total integrated lethal effect and is used to measure microbial severity of a thermal process. It allows the comparison of different thermal processes which have been

carried out under different operating conditions. F_0 value for low acid foods is 3 and for milk puddings is 4 to 10. Ex: F_0 value is 10 minutes at 121°C which is equivalent to 1 minute at 131°C. This is expressed as lethality (L) that is the number of minutes at a reference temperature that would have the same sterilizing effect as one minute at experimental temperature. So the higher F_0 value indicates greater heat treatment to obtain sterilization and higher Z value indicates filter slope of TDT curve and it becomes more difficult to kill the organism.

27.5 Q_{10} -Value

It refers to an increase in the kinetics of reaction (faster reaction takes places) when the temperature is increased by 10°C.

Q_{10} Values

Chemical reactions: 2 - 4
Inactivation of microorganisms: 10 and 30

Temperature range of 120 – 160°C:

Q_{10} value for Bacillus stearothermophilus --------- 13.2
Q_{10} value for Maillard reaction ---------- 3.6

Spores of Bacillus subtilis and Bacillus stearothermophilus are most common and the most resistant mesophilic and thermophilic species in milk likely to survive processing. In the 110-125°C range, the rate of spore destruction of Bacillus stearothermophilus increases about 11 times for each 10°C rise in temperature, i.e. Q10 = 11. Other Bacillus spores, such as Bacillus subtilis are more sensitive (Q_{10}=30). In the range of 95 - 120°C, the Q_{10} browning is 3. In the plot of the ratio of bactericidal (sporicidal) effect to browning effect versus temperature, the ratio does not change much until the temperature reaches about 135°C. At 140 and 150°C, the bactericidal effects are about 1,500 and 5,000 times greater, respectively. Therefore, if milk is treated in the UHT range of 135 - 150°C for a few seconds, it is possible to obtain a product virtually free from spores and with minimal browning. The color of this product is similar to that of HTST milk. Likewise these values for enzymes, nutrients and food quality are much smaller compared to that required for bactericidal effect.

Thermal Destruction Data

The results demonstrate that the range of time – temperature combinations used for UHT milk (130-150°C) are located in areas combining optimal conditions for inactivation of microorganisms with the lowest possible influence on the physical and chemical properties of

milk.

The higher the processing temperature, the shorter is the time needed for effective sterilization. The relationship between the time and temperature to have effective sterilization

Over the whole of this temperature range, the time required is short, of the order of a few seconds and cannot possibly be obtained with any in-container sterilizing process. This means that the process must be performed in a continuous flow heat exchanger. The holding time is fixed by the volume of holding tube. The mean flow time will be given by the volume of the tube divided by the flow rate of product passing through it.