IFTPS

Institute For Thermal Processing Specialists

NOMENCLATURE FOR STUDIES IN THERMAL PROCESSING

Various symbols have been employed to represent measured and derived variables in the applications of thermal processing science. The overall objective of these guidelines is to recommend a standard system of nomenclature for thermal processing applications. **The following recommendations are to be considered voluntary guidelines.** While this does not preclude the use of other symbols, these guidelines have been developed by consensus of the Institute for Thermal Processing Specialists and should be given serious consideration for adoption by individuals involved in thermal processing studies

a_w - Water activity defined as the ratio of the partial pressure of water above a food to the water vapor pressure of pure water above a food (p) to the water vapor pressure of pure water (p_o) at a given temperature ($a_w = p/p_o$)

A - Frequency factor in the Arrhenius equation, K = A exp ($-E_a$/RT) where T is expressed in Kelvin

c - Cook rate, c = 10(T - T_x)/z

C - Concentration of a nutrient or chemical component

C_T^z - Cook value used to relate a high temperature thermal process to an equivalent process at stove top temperatures, generally applied with T=100°C (212°F) and a z-value related to quality attributes

D_T - Decimal reduction time equal to the time at a given temperature, T, for a survivor curve to traverse one log cycle or equivalently, to reduce a microbial population by 90%, t = D_T(log N_o - log N)

E_a - Activation energy in the Arrhenius equation, K = A exp($-E_a$/RT), E_a= 1.8*2.303*R*T_x*T/z where T_x and T are expressed in Kelvin

f - Temperature response parameter equal to the time for the linear section of a heating or cooling curve plotted on semi-log coordinates to traverse one log cycle

f_2 - Temperature response parameter of the second straight line segment of a broken heating curve

f_c - Temperature response parameter derived from the cooling curve

f_h - Temperature response parameter derived from the heating curve

F - Time intercept from a thermal death time curve (log t_{gm}vs T) at T = T_x

F_T^z - Accumulated lethality to reflect the total lethal effect of heat applied; expressed as equivalent minutes at a specific reference temperature for a specific z-value, F_T^z = D_T(log N_o - log N_f) = $D_T Y_N$; may also be referred to as F-biological

F_c - Accumulated lethality in the cooling phase

F_h - Accumulated lethality in the heating phase

F_i - Factor relating the lethality at the retort temperature to lethality at the reference temperature, $F_i = 10(T_x - T_r)/z$

F_o - Accumulated lethality when T_x = 121.1°C (250°F) and z = 10 C° (18 F°)

F_s - Integrated lethal or degradative capacity of heat received by all points in a container during a process

F_λ - Accumulated lethality at an iso-j surface

g - Unaccomplished temperature difference, g = T_r - T_c

g_c - Unaccomplished temperature difference at the end of the heating period, g_c = T_r - T_{ic}

g_{bh} - Unaccomplished temperature difference at the intersection of f_h and f_2 for a broken heating curve

g_{ih} - Initial unaccomplished temperature difference, $g_{ih} = T_r - T_{ih}$

g_{λ} - Unaccomplished temperature difference at an iso-j surface

I_r - Ratio of the log of the straight line survivor curve zero intercept to the initial spore count (N_o)

j_c - Cooling lag factor, $j_c = (T_w - T_{pic})/(T_w - T_{ic})$

j_{cl} - Cooling lag factor associated with an iso-j surface

j_h - Heating lag factor, $j_h = (T_r - T_{pih})/(T_r - T_{ih})$

k - Reaction rate constant for base 10 logarithms

K - Reaction rate constant for base e (natural) logarithms; death rate constant in the Arrhenius model, K = 2.303/D

L - Lethal rate expressed as minutes at the reference temperature per minute at the product temperature, $L = 10(T - T_x)/z$

m - Unaccomplished temperature difference during cooling, $m = T_c - T_w$

m_{ic} - Value of m at the beginning of the cooling cycle, $m_{ic} = T_{ic} - T_w$

n - Number of samples

N - Number of surviving microorganisms

N_o - Initial number of viable spores or vegetative cells before heat is applied, initial bioburden

N_f - Final number of surviving spores or vegetative cells after heat is applied

N_{mp} - Most probable number of survivors in a thermal resistance experiment

N_s - Number of microbial cells remaining after a preservation treatment to a specified probability of finding a non-sterile unit; end point process specification

pH - The degree of acidity or alkalinity of a water solution

- Pasteurizing value used in place of F-value for pasteurizing processes

P - Pasteurizing value defined as the accumulated lethality when T_x= 60°C (140°F) and z = 10 C°(18 F°)

R - Number of negative responses in a thermal resistance experiment

R - Universal gas constant, 1.987 cal/mol×K, 8.314 J/mol×K where K refers to Kelvin temperature units

t **- Time**

t_B - Ball's process time, $t_B = t_p + 0.42\ t_c$ simple heating, $t_B = f_h(\log j_h g_{ih} - \log g_c)$ broken heating, $t_B = f_h \log j_h g_{ih} + (f_2 - f_h)\log g_{bh} - f_2 \log g_c$

t_c - Come-up time is the time between the start of heating and the time when the retort reaches processing temperature

t_D - Time when the first sample exhibiting no growth is observed in a thermal death time (TDT) experiment

t_p - Process time is the time from the end of the come-up period to the end of heating, defined as $t_p = t_B - 0.42\ t_c$ in the Ball Formula Method

t_S - Time when the last sample exhibiting growth is observed in a thermal death time (TDT) experiment

t_{bh} - Time measured from t_B = 0 to the intersection of f_h and f_2 for a broken heating curve

t_{gm} - Geometric mean time, square root of (t_S * t_D)

T - Temperature

T_c - Container center or coldspot temperature

T_{ic} - Product temperature at the start of the cooling cycle

T_{ih} - Initial product temperature measured before heating

T_{pic} - Pseudo-initial cooling temperature determined by extrapolating the linear portion of a cooling curve to the start of cooling

T_{pih} - Pseudo-initial heating temperature determined by extrapolating the linear portion of a heating curve to time, $t_B = 0$

T_r - Retort temperature

T_s - Mass average temperature

T_w - Cooling water temperature

T_x - Reference temperature

U - Sterilizing value in terms of minutes at the heating medium temperature, $U = F_oF_i = F_o/L$

Uc - Sterilizing value for the cooling phase

Uh - Sterilizing value for the heating phase

Y_N - Spore-log reduction, $Y_N = \log N_o - \log N_f$

Y_s - Spore-log reduction to reach a specified probability of finding a non-sterile unit, $Y_s = \log N_o - \log N_s$

z - Number of degrees of temperature required for the thermal death time curve (log F vs. T) or thermal resistance curve (log D_T vs T) to traverse one log cycle, $z = (T_x - T)/(\log F_T - \log F_{Tx})$ or $z = (T_x - T)/(\log D_T - \log D_{Tx})$

a - Thermal diffusivity, a =thermal conductivity/(specific heat * density), is inversely proportional to f_h where the proportionality constant is related to the container geometry

r - Fraction of total lethality delivered during heating, $r = U_h/(U_h + U_c)$ or $r = F_h/(F_h + F_c)$

- The Institute for Thermal Processing Specialists is a non-profit organization established exclusively for the purpose of fostering education and training for those persons interested in procedures, techniques and regulatory requirements for thermal processing of all types of food or other materials, and for the communication of information among its members and other organizations.

- Part of the mandate of the IFTPS Committees is to develop protocols to be used as guides for carrying out the work of thermal processing specialists. This is the first such protocol prepared by the Committee on Temperature Distribution and reviewed extensively by members of the Institute. The protocol has been approved by the Board of Directors. **This document may be photocopied in its entirety for use.**

- Single copies of the protocol, as well as information on membership in IFTPS may be obtained from: Institute for Thermal Processing Specialists, 304 Stone Rd. W. Ste. 301, Guelph, ON N1G 4W4 Phone: (519) 824 6774 Fax: (519) 824 6642, E-Mail: info@iftps.org

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