Thermal technologies in food processing

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Notation

a	surface area	m^2
A	surface area	m^2
$\mathbf{A}$	coefficient matrix	$kg\ s^{-1}$
a, b	constants	
A_p	particle surface area	m^2
$Bi = hd/\lambda$	Biot number	
$\overrightarrow{B}$	magnetic flux density	
$\mathbf{B}$	flux density	$V\,S\,m^{-2}$
$\mathbf{C}$	capacity matrix	$J\ {}^{o}C^{-1}$
C	concentration of bacteria in liquid food	number of bacteria m^{-3}
C_1, C_2	constants	
C_η	turbulence constant	
c	heat capacity (Chapter 6)	$J\ kg^{-1}\ {}^{o}C^{-1}$
c, c_0	velocity of light, in vacuum (Chapter 10)	
c_a	specific moisture capacity of vapour phase	
c_P	specific heat capacity (constant pressure)	$J\ kg^{-1}\ K^{-1}$
$\overrightarrow{D}$	electric flux density	$V\,S\,m^{-2}$
$\mathbf{D}$	flux density	$V\,S\,m^{-2}$
D	decimal reduction time	min
D_{ref}	reference decimal reduction time	min
D_{p}	field penetration depth	m
D_{e}	diffusion coefficient	$m^2\,s^{-1}$
d	diameter	m
$\overrightarrow{E}$	electric field	
$\mathbf{E}$	electric field strength	$V\,m^{-1}$

F	F-value: integrated lethality (Chapter 7)	min
$\hat{F}$	volumetric average	$\mathrm{s\,m^{-3}}$
$\mathbf{f}$	thermal load vector	W
f	frequency	GHz
f_i	volumetric body force	$\mathrm{N\,m^{-3}}$
F_i	Cartesian component of particle force	N
Fo	Fourier number	
$G = SR/V - 1$	shape factor of the container	
g	acceleration due to gravity (Chapter 7)	$\mathrm{m\,s^{-2}}$
g, h	constant (Chapter 10)	
H	static enthalpy (Chapter 6)	$\mathrm{J\,kg^{-1}}$
H	specific enthalpy (Chapter 7)	$\mathrm{J\,m^{-3}}$
$\overrightarrow{H}$	magnetic field (Chapter 10)	
$\mathbf{H}$	magnetic field (Chapter 7)	$\mathrm{A\,m^{-1}}$
h	surface heat transfer coefficient (Chapter 6)	$\mathrm{W\,m^{-2}\,{}^oC^{-1}}$
h	convective heat transfer coefficient (Chapter 7)	$\mathrm{W\,m^{-2}\,K^{-1}}$
h	Planck's constant	
h_{evap}	evaporation heat density	
h_i	enthalpy of phase i	
I_i	mass sink or source density of phase i	
i	imaginary unit	
$\overrightarrow{j}$	electric current density	
K	turbulent kinetic energy	$\mathrm{m^2\,s^{-2}}$
$\mathbf{K}$	stiffness matrix	$\mathrm{W\,{}^oC^{-1}}$
k	electrical conductivity	$\mathrm{S\,m^{-1}}$
k	thermal conductivity (Chapter 7)	$\mathrm{W\,m^{-1}\,{}^oC^{-1}}$
k	Boltzmann's constant (Chapter 10)	
$\overrightarrow{k}$	wave vector	
k_{t}	reaction rate constant at temperature T	$\mathrm{s^{-1}}$
L	characteristic length	m
M	molecular weight (Chapter 6)	$\mathrm{kg\,mol^{-1}}$
M, M_l	moisture content, liquid moisture content (Chapter 10)	
m, n, o, p. q, r	exponents (Chapter 6)	
m	constant (Chapter 10)	
$\mathbf{N}$	shape function	
n	constant	
n_i	concentration of ion i	
$n_\perp$	outward normal to surface	
$\overrightarrow{P}$	polarisation	
p	pressure	Pa
Q	power dissipated per unit volume (Chapter 7)	$\mathrm{W\,m^{-3}}$

Q	volumetric heat generation (Chapter 6)	W m^{-3}
Q	rate of heat (Chapter 11)	J s^{-1}
$Q(R)$	radiant flux emitted per unit area unit increment of wavelength	W m^{-2} ηm
$\mathbf{Q}$	source term vector	units s^{-1}
Q_{em}	electromagnetic heat production density	
q_R	radiative power flux density	
R	universal gas constant (Chapter 6)	J mol^{-1} K^{-1}
R	smallest characteristic dimension of a geometry (Chapter 7)	m
r	residual (Chapter 6)	
r	radial position of a can (Chapter 7)	m
r	reflected waves (Chapter 11)	
$\Re(x)$	real part of x	
S	heat transfer surface	m^2
S_ϕ	source of quantity ϕ	units m^{-3} s^{-1}
T	temperature	ºC or K
T_{ref}	reference temperature	K
T_{m}	temperature of the heating medium	K
t	time (Chapters 6, 7, 10)	s
t	transmitted waves (Chapter 11)	
$\mathbf{U}$	velocity vector	m s^{-1}
$\mathbf{u}$	nodal temperature vector	
u	velocity in the vertical direction	m s^{-1}
u_j	Cartesian velocity component	m s^{-1}
V	volume	m^3
V	voltage (Chapter 7)	V
v	velocity in the radial direction	m s^{-1}
$\overrightarrow{x}$	local vector	
x_i, x, y, z	Cartesian coordinate (Chapter 6)	m
x, z	distance (Chapter 7)	m
Z	Z-value: slope of the lethality or cooking curve	K
Z_{q}	quality factor	K
z_i	valence of ion i	

Greek symbols

Ω	object domain	
Γ	boundary of object	
$\mathit{\Gamma}$	diffusivity of quantity ϕ	kg m^{-1} s^{-1}
α	absorbed waves	
α_M	mass diffusivity	
α_p	pressure diffusivity	
$\alpha = \lambda/\rho\ c_p$	thermal diffusivity	m^2 s^{-1}
$\chi = \epsilon - 1$	dielectric susceptibility	
δ_E	electric field attenuation length	

δ_p	pressure gradient coefficient/power attenuation length	
δ_T	thermal gradient coefficient	
ϵ	turbulent energy dissipation rate (Chapter 6)	$m^2\ s^{-3}$
ϵ	emissivity (Chapter 11)	
ϵ	permittivity (Chapter 7)	$F\ m^{-1}$
$\epsilon = \epsilon' - i\epsilon''$	relative permittivity (Chapter 10)	
ϵ_c	convergence error	
ϵ'	dielectric constant (Chapter 7)	
ϵ''	dielectric loss factor (Chapter 7)	
ϵ_0	dielectric constant of vacuum	
ϵ_V	ratio of vapour flow to total moisture flow	
ζ	ratio of vapour diffusion to total moisture diffusion (Chapter 6)	
ζ	dimensionless axial length (Chapter 7)	
η	dynamic viscosity	$kg\ m^{-1}\ s^{-1}$
$\theta = T/T_{\text{ref}}$	dimensionless temperature (Chapter 7)	
ϑ	dimensionless temperature	
κ	damping constant	
λ	wavelength (Chapter 10)	
λ	thermal conductivity (Chapter 7)	$W\ m^{-1}\ K^{-1}$
μ	relative permeability (Chapter 10)	
μ	apparent viscosity (Chapter 7)	Pa s
μ_0	permeability of vacuum	
μ_i	mobility of ion *i*	
ϕ	transported quantity per unit mass	units kg^{-1}
ρ	density (charge, mass)	$kg\ m^{-3}$
σ	Stefan-Boltzmann constant (Chapters 6 and 11)	$W\ m^{-2}\ K^{-4}$
σ	conductivity (Chapter 10)	
σ	electrical conductivity (Chapter 7)	$W\ m^{-1}\ K^{-1}$
σ_S	electrical conductivity (solid)	$W\ m^{-1}\ K^{-1}$
σ_L	electrical conductivity (liquid)	$W\ m^{-1}\ K^{-1}$
σ_e	electrical conductivity (effective)	$W\ m^{-1}\ K^{-1}$
ω	circular frequency	

Subscripts

0	initial condition
∞	ambient condition