Enthalpy and permittivity data for beef and bread

The tables below give enthalpy density data and 2450 MHz microwave permittivity data as function of temperature and are intended to be used for microwave modelling purposes. Various sources have been used; for enthalpy e.g. Rha and Riedel, and for permittivity raw and published as well as unpublished own data from SIK.

The source ("measurements and refinements by Per O Risman, Microtrans AB, Sweden) is to be stated when using the data for publication or other means of making it publicly available.

The beef data are believed to be as accurate as is reasonable, in view of the various measurement difficulties and applicability of new and unpublished extrapolation and smoothing methods for variable ice content that have been used. For all but some few entries, the inaccuracy in real permittivity is less than 5 %; for the loss factor the corresponding inaccuracy is less than 10 %. The enthalpy data are believed to be accurate within 5 %. However, the extrapolation and smoothing techniques employed here is expected to have resulted in typical inaccuracies of the data of 2 to 3 %.

Table 1. Data for raw beef between –20°C and 100 °C. No density correction; nominal density is 1.15 g/cm³, water content 65 %, with no salt added.

Temperature °C	Specific enthalpy *h* (kcal/kg)	Enthalpy density d*H*/d*V* (J/cm³)	Permittivity ε	Approx. remaining ice, weight %	Notes
–40	0,0	0.0	4.2–j0.24	88	Base (reference) zero enthalpy value
–30	4.5	21.7	4.4–j0.32	88	
–20	10.1	48.6	4.9–j0.47	87	Measured dielectric data
–15	13,0	62.6	5.5 –j0.68	—	Inserted loss factor value for proper slope
–10	17.2	83.0	6.1–j1.12	82	Measured dielectric data
–5	24,9	120	12.3–j4.2	73.3	Interpolated dielectric data using cod data
–3	33.0	159	22.0–j8.2	63.0	Interpolated dielectric data using cod data
–2.2	40.0	193	30.0–12.0	—	From the curve
–1.6	50.0	241	42.0–j15.5	—	From the curve
–1.3	60.0	289	46.0–j17.5	—	From the curve
–1.1	67,0	323	48.9–j17.8	—	Inserted data for proper curve derivatives
–1	70.0	337	49.2–j17.9	0	"Melting" temperature
10,0	79.3	382	48.9–j17.0	(0)	Interpolated dielectric data
20,0	87.0	419	48.2–j16.1	(0)	Measured dielectric data
35,0	101	486	46.9–j15.2		Interpolated dielectric data
50	115	554	45.5–j14.3	(0)	Interpolated diel. data between 40 and 60 °C
(65)	(130)	626	43.6–j14.1	(0)	Enthalpy and dielectric data extrapolation
(80)	(145)	698	41.7–j14.0		Measured dielectric data

The bread data are less accurate than the beef data, mainly due to compression errors in the sample preparation. An inaccuracy of 10 % or less applies for almost all data except those for 50 % evaporated water. The real permittivity data above 0 °C are quite accurate, however. – The many decimals in the permittivity columns are due to smoothing for improving the accuracy when using the data as piecewise linear approximations.

Table 2. Data for white bread between –20°C and 100 °C. No density correction; nominal density is 0.25 g/cm³, water content 44 %; Standard Nordic Bread recipe.

Temp-erature °C	Enthalpy density d*H*/d*V* (J/cm³)	Permittivity ε	Approx. remaining ice, weight %	Notes
–20	0.0	1.50–j0.15	49	Base (reference) zero value of enthalpy
–10	6.3	1.70–j0.25	47,5	
–5	9.9	1.82–j0.35	44	
–3.5	11.5	1.90–j0.48	42,5	
–2	13.6	2.20–j0.72	38	
–1	15.2	2.39–j0.92	35.5	
0	30.1	3.55–j1.88	0	Limit of no ice (actually about –0.2 °C)
10	37	3.89–1.68	—	
20	42,6	4.17–j1.55	—	
40	56,5	4.57–j1.35	—	
60	70,4	4.78–j1.30	—	
80	84,3	4.73–j1.30	—	
100	98,3	4.50–j1.35	—	
104	222	2.00–j0.80	—	Approximat; 50 % of the water evaporated