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MICROWAVE TEMPERING OF BUTTER

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1.0 Introduction

The application of microwave equipment to the tempering of butter coming out of frozen storage has potential commercial applications. The frozen butter must be tempered, or raised in temperature, to a condition where it can be worked and printed. The time involved in the tempering operation is long, with up to 3 days required if still air warming is used. The tempering time is particularly long because high temperature differentials must be avoided to prevent surface melting and quality degradation. Microwave ovens have found application in the tempering of frozen meat blocks which is a similar operation except that temperatures are not raised above the freezing point. Some points regarding the capacity of the equipment and operating techniques have been considered here to provide design information.

2.0 Equipment Sizing

The energy inputs required for the tempering of frozen butter include: the specific heat of the fat, specific heat of the water, latent heats of phase change for melting the water, water-salt eutectic and crystal form changes in the fat. While it is possible to calculate the energy requirements from the individual components, it is also possible to estimate from the "mean specific heat" curve as proposed by Staph (3) and developed by Watson (3). This "mean specific heat" includes both the latent and specific heat values for the butter over the temperature range of interest (Fig. 1). Required energy may be calculated by graphical integration of the area under the "mean specific heat" curve over the temperature range from storage temperature to the final tempered value.

For a typical application the required conditions were:

Throughput of butter	3-4000 lb/hr	(1360-1815 Kg/hr)
Initial Temperature	$-20^{o}F$	$(-28.89^{o}C)$
Final Temperature	$50^{o}F$	$(10^{o}C)$

Graphical integration of the area under the curve from -29 to $+10^{o}C$ yields an area of 1494 units. From the scale values 120 units is equivalent to 1000 J Kg^{-1} C^{-1} x 10C or 10,000 J/Kg. Thus, the energy to raise butter from $-28.9^{o}C$ to $10^{o}C$ is:

$$\frac{1494}{120} \times 10{,}000 = 124{,}500 \text{ J/Kg}$$

or $(1.24 \times 10^{5}$ J/Kg) (1815 Kg/hr) = 2.36×10^{8} J/hr for the required maximum throughput. This is equivalent to 65.6 Kw of installed power in the microwave system.

Van Koughnett (2) suggests adding a 10 to 20% allowance for microwave power losses in the waveguide, tunnel walls, etc. This would suggest the necessity for a 75 Kw system to meet the 4000 lb/hr throughput.

3.0 Possible Operational Problems

The use of microwave for tempering of butter will present more problems than are encountered in the tempering of meat products. There are two reasons for this; firstly, in the meat tempering systems the temperature is not raised above the freezing point, and secondly, the composition is radically different with the meat comprising 50 to 70% water, depending on the cut and amount of fat, whereas the butter contains in the order of 16% water. Because of the high dielectric loss factor for water, a great deal of the microwave energy is absorbed by this component of the product, with less absorbed by the fat.

The problems are further compounded by the fact that water has a higher dielectric loss than ice, so thawed material will absorb more energy than the unthawed, and any free water will also preferentially heat. Because of this situation where the dielectric loss factor of the butter mass is increasing with temperature, special precautions would be required to avoid uneven heating and melting in pockets or zones of the mass.

A technique used by LMI (Les Micro-Ondes Industrielles) of France in their new micro-wave "defreezing" tunnel is to recirculate air at -30^{o}C around the product during the microwave exposure. This keeps the surface cold and prevents surface melting. Any surface melting could be a real problem, as pointed out earlier, there is preferential energy absorption in the melted areas. Also by keeping the product frozen on the surface and adding the correct total amount of microwave energy, a short period for equilibration after leaving the tunnel would complete the tempering process. With butter this procedure would help, but problems would still exist if localized melting or development of "hot spots" caused quality degradation. Localized pockets of melting are certain to occur within the butter blocks.

A second approach is to cycle the microwave power on and off with time between each power cycle to allow normal conduction to equilibrate the temperature distribution. One major drawback to this technique would be the decrease in microwave tunnel throughput in proportion to the "off" cycle time. This would result in greater equipment requirements. A similar effect could be attained by using a more complicated conveyor system in which, rather than cycling the power on and off, the product would take several passes through the tunnel with adequate time between each pass for temperature equilibration.

Such a system would allow the throughput to be maintained and yet provide for a cycled energy input into the product.

A third possibility is to use the three 25 Kw modules in individual tunnels or cavities rather than having all three in the same unit as is done with the meat. Conveyor sections between the three cavities would then provide the pauses in energy input required to allow temperature equilibration. This would have a major disadvantage in increased equipment cost.

4.0 Equipment Costs

Raytheon Corp. of Waltham, Mass., which is a major supplier of microwave equipment, has estimated the cost for tempering meat in a 50 Kw tunnel at 4000 lbs/hr to be 0.20¢/lb (1). This company estimates the cost of a tempering installation at about $60,000 per 25 Kw of installed power with an operating cost of about $3/hr per 25 Kw of power. A first estimate on the costs for a 75 Kw butter tempering system would be $180,000 in capital expenses with an operating cost of $9 per hr. This operating cost includes the cost for replacement power tubes. A rough estimate of cost for tempering is 0.225¢/lb operating cost plus an equipment cost of 0.14¢/lb using an 8 yr write-off period and assuming two shifts at 4000 lbs/hr (1.6×10^7 lb/yr).

Estimated at tempering butter for only seven hours daily on a 250 work day year (7.0×10^6 lb/yr) and amortizing the equipment over a 5 yr rather than 8 yr period the costs rise considerably. While the operating costs remain the same at 0.225 cents/lb, the amortization costs rise drastically from 0.14 cents/lb to 0.51 cents/lb. This doubles the estimated cost to 0.735 cents/lb.

A microwave system would require far less space than tempering rooms for an equivalent throughput and could possibly be competative with construction costs for a new conventional tempering system.

5.0 Summary

The theoretical energy requirement for tempering 4000 lb/hr of butter from -20°F to 50°F is 65.6 Kw. With a margin allowed for absorption of power by the tunnel, waveguides etc., an installed capacity of 75 Kw, would be required.

Because of the problems of preferential absorption of the energy by the water and the increase in energy absorption with temperature, special techniques would be required to cycle the energy input into the product with time left between energy pulses to allow for temperature equilibration. This could be done by using three 25 Kw units in series or by setting up to have the butter blocks make several passes through the cavity. Cycling of the power on and off would not appear to be a practical solution as the microwave power tubes would not be used to capacity.

Circulation of cold air through the cavity as done by LMI would help by preventing any localized surface melting.

A first estimate on the cost of the system would be about 0.365¢/lb assuming a throughput of 4000 lb/hr working two shifts and writing the equipment off over 8 yrs. Alternatively, writing the equipment off over 5 yrs and only operating one shift would result in an estimated cost of 0.735 cents/lb.

As butter tempering systems have not been previously used, it would be necessary to undertake some reasonably extensive trials with an equipment manufacturer to ascertain if the problems of localized melting could be overcome in an economic manner.

6.0 Acknowledgement

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7.0 References

1. Slater, L.E. 1974. Hormel creates self-renewing plant. Food Engineering, December, 55 - 59.

2. Van Koughnett, A.L. Fundamentals of microwave heating. Radio and Electrical Engineering Division, N.R.C., Ottawa, K1A 0R8.

3. Watson, E.L. 1974. Thermal properties of butter. Paper No. 74-501. Pres. Can. Soc. Agr. Eng., Laval Univ., Ste Foy, Quebec. August.

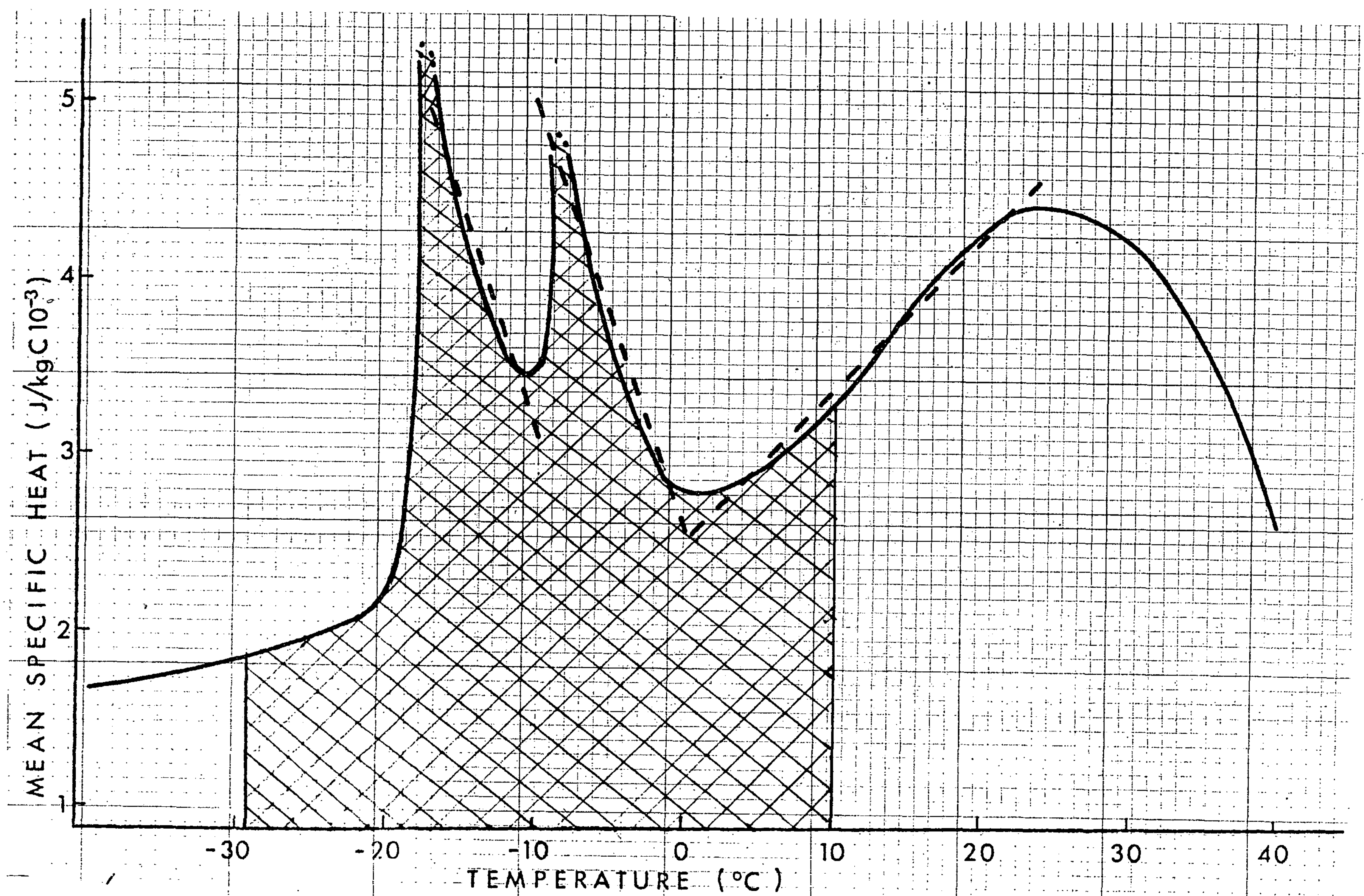

Fig. 1. Mean specific heat (including latent and sensible heat) Vs temperature for butter with 80% B.F. and 16% H_2O (From Watson, E.L., 1974).