Thawing Bibliography

By
Edward R. Kolbe
Oregon State University
Food Innovation Center
1207 NW Naito Parkway, Suite 154
Portland, OR 97209
1/3/03

1. Abdalla, H., and R. P. Singh. "Simulation of Thawing of Foods Using Finite Element Method. " *Journal of Food Process Engineering* 7, no. 4 (1985): 273-86.
   Keywords: Thawing/ Calculation of thawing times
   Call Number: OSU Libraries - Guin Library Thawing file
   Abstract: "Prediction of temperature distribution in foods, subjected to freezing or thawing, is an important topic in food processing. Such knowledge is useful in the design of equipment and the evaluation of storage and handling practices. There are many formulas available for estimating transient state heat conduction in a solid body which undergoes a phase change. The most used exact solutions to predict the freezing as well as the thawing times are Plank's equation and Newmann's solution (Bakal and Hayakawa 1973; Purwadaria 1980). These solutions are limited to the fact that they assume constant thermal properties throughout the freezing and thawing processes. In addition, they assume certain boundary conditions and treat only simple geometrical shapes. Numerical solutions are obtained usually by applying either finite difference or finite element techniques. Since there are relatively few mathematical restrictions in solving equations by these techniques, they are used to obtain the solution for objects of complex geometrical shapes common to foodstuffs. Several researchers have utilized the finite difference procedure with temperature dependent physical properties to solve the freezing problem (Charm *et al*. 1973; Fleming 1973; Lescano 1973; Joshi and Tao 11974; Heldman and Gorby 1974b; Cleland and Earle 1977a; Hsieh *et al*. 1977). Comini and Bonacina (1974), DeBaerdemaeker *et al.* (1977), Singh and Segerlind (1974) and Naveh and Pflug (1983) implemented the finite element procedure for estimating the freezing time and heat conduction in foodstuffs. While the finite element analysis has proved useful in solving linear and nonlinear heat transfer problems, no investigation has been conducted to solve the thawing problem using the finite element procedure. All the previous investigations have assumed that the thawing problem is identical to the freezing problem and any solution valid for freezing should also hold for thawing. Most published models overlook the fact that during the thawing process, if the thawing environment involves condensation of water on the product, the rate of heat transfer can change dramatically. The primary goal of this study was to develop a numerical model using the finite element method to predict the rate of freezing and thawing of food products." (Author's Introduction)

2. Balaban, M., T. Henderson, A. Teixeira, and W. S Otwell. "Ohmic Thawing of Shrimp

Blocks." *Developments in Food Engineering.* eds. T. Yano, R. Matsuno, and K. Nakamura, 307-9. Vol. 1. London: Blackie Academic and Professional, 1994.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries-Valley TP 368.I51 1993, Guin Library Thawing file
Abstract: "Conventional water immersion thawing of frozen seafood blocks requires large amounts of water, causes cross-contamination problems, and loss of solids to leaching. Frozen shrimp blocks and fish were thawed by passing an alternating current through the blocks. 60 Hz and up to 480 V were used. An automated amps and voltage data acquisition system was developed. A changing current regime was used to prevent local overheating. Thawing times for different blocks for different current-voltage regimes are presented. A preliminary economic analysis and sensory tests were performed."
(Auhor's abstract)

3. Bengtsson, N. "Electronic Defrosting of Meat and Fish at 35 MHz and 2,450 MHz: a Laboratory Comparison."*5th International Congress on Electro-Heat*no. Presentation No. 414. 1963.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: "Results are presented from a laboratory investigation on meat and fish, comparing continuous dielectric defrosting of regularly shaped blocks of raw material between flat electrodes at 35 MHz and continuous defrosting in a microwave oven of parabola type at 2 450 MHz. Earlier work had shown that good results could be obtained in dielectric defrosting at 35 MHz, with a marked reduction in thawing time from 20-30 hrs in conventional coldroom defrosting to 20-30 mn. The object of the present work was to investigate whether defrosting at microwave frequencies might offer advantages over the lower frequency from the point of view of possible future large scale application in industry. The results indicate that defrosting at 2 450 MHz can, under the conditions used, result in equal product quality compared to defrosting at 35 MHz, with advantages in reduced heat treatment time and less sensitivity to raw material inhomogenities. Actual heat treatment times could be reduced in the order of 1-2 mn, since about ten times higher power density could be applied compared to the lower frequency. With individually (loose) frozen fish satisfactory results were obtained at 2 450 MHz without water immersion, whereas such immersion was found necessary at 35MHz for this material. On the negative side, low penetration was observed for the microwaves, which seemed to reduce useful sample thickness to 4 cm or less. Defrosting of fish at 35 MHz on an industrial scale is already in operation in England and possibly elsewhere. The results obtained at 2 450 MHz in the present investigation seem to justify further work at this frequency in larger scale eequipment to further assess its usefulness for industrial defrosting applications."
(Author's summary)

4. Burgess, G. H. O., M. R. Hewitt, and A. C. Jason. "A Review of Current Methods of Thawing Fish and Future Prospects."*Annual Meeting of The Institute of Refrigeration*1975.
Keywords: Thawing/ General introduction/ Alternative thawing methods

Call Number: OSU Libraries - Guin Library Thawing file
Abstract: "With the development of fleets able to freeze their catches at sea and the parallel growth of freezing and cold storage facilities on shore, fish processing industries in many countries have turned increasingly to frozen fish which is now often used in some factories as the major, or even the only, source of raw material. In these circumstances, reliable methods of thawing have become essential and a great deal of work has been carried out in many laboratories both on the theoretical aspects of thawing and also on the design and operation of plant. This paper is mainly concerned with the latter and describes factors which must be taken into account when designing equipment, discusses the methods most widely employed in the fish processing industry, indicates their limitations and points out where improvements might be made. It deals principally with large scale methods." (from Author's Introduction).

5. Calvelo, A. "Recent Studies on Meat Freezing." *Developments in Meat Science.* ed. R. Lawrie, 125-58 (chapter 5). Vol. 2. Applied Science Publication, 1981.
Keywords: Thawing/ Quality
Call Number: OSU Libraries-Valley TS1960.D481, Guin Library Thawing file
Abstract: "The morphology adopted by the ice in the frozen tissue, the size of the crystals formed and their distribution among the intra- or extracellular spaces are particularly important in a whole series of macroscopic effects which occur in frozen meat. They include:
a) A change in the water-holding capacity of muscle, once thawed. b) Changes in texture. c) Changes in surface colour.
The first of these effects is the most important, owing to the drip losses, and the changes it causes in the organoleptic properties of the meat once it is cooked. The crystallisation of ice in meat tissue has been studied mainly by cryobiologists in connection with the freezing of microorganisms and the possibilities of subsequent survival. Such studies were restricted to small systems where there were no significant temperature gradients. However, the freezing of meat under industrial conditions gives rise to important temperature gradients and this causes the local freeaing rate on the border of a meat cut to be very different from that in the centre. The presence of these temperature gradients, consequently, establishes interesting mechanisms for the formation of ice in tissue. The purpose of the present chapter is to describe a number of efforts designed to obtain a better understanding of the mechanisms involved in beef freezing, of their relationship with problems of heat transfer with a simultaneous change of phase and the consequences of these phenomena on its water-holding capacity. Since, in the industrial processing of frozen meat, the final behaviour on thawing depends on the freezing conditions, frozen storage (including transportation) and the mode of thawing itself, these three stages will be analysed in terms of the most important phenomena involved in each." (Author's Introduction, p.127-128))

6. Carver, J. H. "Vacuum Cooling and Thawing Fishery Products." *Marine Fisheries Review* 37, no. 7 (1975): 15-21.
Keywords: Thawing/ Thawing methods
Call Number: OSU Libraries-Valley SH11.A14, Guin SH11.A14

Notes: MFR Paper # 1151
Abstract: "A standard pilot plant size retort was modified for purposes of developing empirical information on dehydrocooling fresh fish and vacuum/heat-thawing (VHT) frozen fishery products. Results indicated that effective multipurpose vacuum/heat-processing systems can be constructed from readily available commercial equipment. Dehydrocooling tests indicated that small fish such as whiting can be cooled to 0 degrees Celcius in about 1/2 hour, and VHT tests showed that frozen blocks of headed and gutted (H&G) whiting and shrimp can be thawed in from 1/2 to 1 hour. The described equipment is usable both ashore and at sea. At sea, it is proposed that enough heat energy to power the equipment can be extracted from waste stack gases." (Author's abstract)

7. Chamchong, M. , and A. K. Datta. "Thawing of Foods in a Microwave Oven, I. Effect of Power Levels and Power Cycling." *Journal of Microwave Power and Electromagnetic Energy* 34, no. 1 (1999): 9-21.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries- Valley TK7876.J68, Guin Library Thawing file
Abstract: Microwave thawing is faster than other methods, but can produce significant non-uniformity of heating. The objective of this study was to perform comprehensive experimentation and heat transfer modelling to relate the time to thaw and the non-uniformity of thawing to power cycling, power level and surface heat transfer coeff. [with regard to the microwave thawing of foods]. The governing energy equation was formulated with an exponential decay of microwave flux from the surface. Surface microwave flux was obtained from the measured temp. rise using inverse heat transfer analysis. Gradual phase change was formulated as an apparent specific heat, and obtained for the experimental material tylose from DSC measurements. Temp.were measured immediately following heating with a fast response thermocouple. Dielectric properties were measured above freezing. Results show that the microwave flux at the surface and its decay are affected by the changes in the power level. Power cycling has an almost identical effect as continuous power at the reduced level of the average cycled power. As power level increases, the surface flux increases by the same fraction. At higher power levels, however, the outside thaws relatively faster. A `shield' develops due to a much reduced microwave penetration depth at the surface. This thawing time at higher power levels is reduced considerably. Temp. increases initially are non-uniform since the surface is heated at a faster rate than the interior. In keeping with the assumption that once the temp. reaches 100 degree C, all energy absorbed goes into evaporation, and subsequent temp. is maintained at 100 degree C. Thus, eventually, non-uniformity starts to decrease. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002.)

8. Charm, S. E., D. H. Brand, and D. W. Baker. "A Simple Method for Estimating Freezing and Thawing Times of Cylinders and Slabs." *ASHRAE Journal* , no. November 1972 (1972): 39-45.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TH7201.A53
Abstract: "A method is presented for calculating freezing and thawing times for

food and biological material in cylindrical or slab shapes. A computer program is provided for the case where exact solution is required and thermal properties are accurately known." (Author's abstract)

9. Chevalier, D. , A. LeBail, and J. M. Chourot. "High Pressure Thawing of Fish (Whiting): Influence of the Process Parameters on Drip Losses." *Lebensmittel-Wissenshaft Und Technologie* 32 (1999): 25-31.
   Keywords: Thawing/ Alternative thawing methods
   Call Number: OSU Libraries - Guin Library Thawing file
   Notes: KEYWORDS FROM AGRICOLA
   Abstract: : Effects of high pressure thawing parameters on the drip vol. of blue whiting (Gadus merlangus) were studied. Influence of various pressure levels (from atmospheric pressure to 200 MPa), 2 freezing rates (0.14 degree C or 0.77 degree C/min), 2 pressurization rates (42 or 100 MPa) and pressure holding time was assessed. Analyses included measuring drip loss after thawing and subsequent heat treatment, and electrophoresis of thawing drips and sarcoplasmic proteins extracted from the thawed fish flesh. Results were compared with atmospheric thawing carried out in a stirred water bath at 10 degree C. Both the high freezing and the high pressurization rates reduced drip loss at a given pressure, but minimization of drip vol. in comparison to atmospheric thawing was only achieved when pressure holding time was maintained for longer than strictly necessary for thawing. Electrophoresis showed that the 48 kDa proteins present in thawing drips and sarcoplasmic proteins underwent modification, in that their intensity decreased from 150 MPa.

10. Cleland, A. C. "Thawing Time Prediciton." *Food Refrigeration Processes: Analysis, Design and Simulation.*, Chapter 7. London: Elsevier Applied Science, 1990.
    Keywords: Thawing/ Calculation of thawing times
    Call Number: OSU Libraries- Valley TP372.2.C57 1990, Guin Library Thawing file
    Abstract: "Thawing has been included in this book because many of the mathematical models used for freezing have direct links with models for thawing. However, this is not true for microwave thawing systems which use completely different scientific principles to air--, water--, and vacuum thawing. Those interested in predicting rates of microwave thawing may find a recent paper by Taoukis et al. (1987) a useful starting point; the subject is not discussed here. Whilst thawing is the reverse process to freezing, it is too simplistic to simply try to reverse the prediction methods used for freezing. The analogy does hold in general terms, but care must be taken when considering details. An inherent difference compared to freezing is that the heat for phase change must pass through the material which has lowest thermal conductivity (whereas in freezing the heat removed passes out through the material with the highest thermal conductivity). Hence, for the same temperature driving force and surface heat transfer coefficient, thawing takes much longer than freezing. Other important differences that can occur in thawing include collapse of product structure with removal of thawed material, and greater importance of surface mass transfer effects (frosting and

condensation of the surface). As a result, the fraction of situations that closely fit the third kind of boundary condition is probably much lower than for freezing. Studies of thawing have been of two kinds--product specific studies, and studies to establish general methodology. Within the latter group Cleland (1985c) carried out a major investigation of methodology for the third kind of boundary condition. The results of this study are available as a series of published papers (Cleland et al. 1984, 1986a, b, 1987a-d) which are referred to extensively in this chapter. Tables 6.1-6.9 summarise the major published prediction methods covered in these reviews including some product-specific thawing time prediction methodologies. However, product- and shape-specific prediction methods are not considered further here because it has not been clearly demonstrated that there are situations in which the general methodologies are insufficiently precise." (Author's Introduction)

11. Cleland, D. J. "Prediction of Freezing and Thawing Times for Foods to Different Final Product Centre Temperatures."*Proceedings of the IIR Meeting* , 33-391988.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU LIBRARIES-Guin Library Thawing file
Abstract: "A correction formula that can be applied to any existing freezing or thawing time prediction method is proposed that makes the prediction methods applicable to a range of final product centre temperatures. The accuracy of the correction was tested by comparison of predicted freezing and thawing times to times calculated by an accurate numerical method over typically encountered ranges of food freezing and thawing conditions. The predictions wer within (plus or minus) 10 % of the calculated values at the 95% level of confidence for freezing and within (plus or minus) 6% for thawing. This uncertainty is sufficiently small compared with the typical inaccuracey of the best of the existing freezing and thawing time prediction methods, that use of the correction formula will not significantly increase the imprecision of freezing and thawing time predictions." (Author's abstract)

12. Cleland, D. J., A. C. Cleland, and R. L. Earle. "Prediction of Freezing and Thawing Times for Multi-Dimensional Shapes by Simple Formulae, Part 1: Regular Shapes." *International Journal of Refrigeration* 10 , no. May (1987a): 156-64.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP490.R48, Guin Library Thawing file
Notes: Keywords from the paper and some from Kolbe
Abstract: "Numerical prediction methods were used to generate data to assess and develop geometric factors taking account of the effect of product geometry on freezing and thawing time. Improved empirical formulae for two existing geometric factors were developed; these depend only on the Biot number and parameters that describe object shape. The new formulae are accurate for both freezing and thawing of an extended range of regular multi-dimensional shapes and for a wider range of conditions than the original formulae. Used in conjunction with accurate slab freezing and thawing time prediction formulae, the improved geometric factors accurately predicted a large set of experimental freezing and thawing times for various shapes. As the improved geometric factors are both accurate and generally applicable there is no need for shape-specific freezing and

thawing time prediction formulae to be developed." (Author's abstract)

13. Cleland, D. J., A. C. Cleland, R. L. Earle, and S. J. Byrne. "Experimental Data for Freezing and Thawing of Multi-Dimensional Objects. " *International Journal of Refrigeration* 10 , no. January (1987c): 22-31.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP490.R48, Guin Library Thawing file
Abstract: "Testing the accuracy of freezing and thawing time prediction methods requires accurate experimental data. To complement existing data, 175 experimental measurements, 68 for thawing of rectangular bricks and 107 for both freezing and thawing of 12 different multi-dimensional irregular shapes, were made using Tylose, a food analogue, over a wide range of conditions. Twelve additional experiments were conducted using an actual food material, minced lean beef. Details of all the experimental conditions are reported." (Author's abstract)

14. ———. "Prediction of Freezing and Thawing Times for Multi-Dimensional Shapes by Numerical Methods." *International Journal of Refrigeration* 10, no. January (1987d): 32-39.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP490.R48, Guin Library Thawing file
Abstract: "An assessment of the accuracy of numerical methods used in the prediction of freezing and thawing times was made using a comprehensive set of freezing and thawing data for both regular and irregular multi-dimensional shapes. For regular shapes, a finite difference method gave accurate predictions with reasonable computation costs. Predictions for two finite element method formulations were not always accurate. This was due to practical constraints on the computation costs which meant that time and spatial grids could not always be made sufficiently fine to ensure that the prediction method uncertainty was insignificant compared with the other sources of imprecision. Guidelines are suggested for the use of the finite element method as a freezing or thawing time predictor. These should ensure that the prediction method error is small while keeping the computation costs reasonable." (Author's abstract)

15. ———. "Prediction of Thawing Times for Foods of Simple Shape." *International Journal of Refrigeration* 9, no. July (1986): 220-228.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP490.R48, Guin Library Thawing file
Abstract: "A set of 104 experimental measurements of thawing time were made over a wide range of conditions for slab, infinite cylinder and sphere shapes of a food analogue material. These results were used to assess existing thawing time prediction methods. Versions of both the finite difference and the finite element numerical methods that accounted for continuously temperature-variable thermal properties gave accurate predictions. No previously published simple prediction formula was found that was both sufficiently accurate and expressed in a form suitable for it to be adopted as a general thawing time prediction method. Four accurate, but simple, empirical formulae based on Plank's equation were developed. These formulae predicted thawing times that were both highly correlated with those

predicted by the numerical methods and agreed with the experimental data to within (plus or minus) 10% at the 95% level of confidence. The agreement was more limited by uncertainties in the experimental and thermal property data than by inaccuracy in the prediction formulae. Significantly more accurate simple formulae are unlikely to be developed unless more accurate experimental data are available." (Author's abstract)

16. Cleland, D. J., R. L. Cleland, and R. L. Earle. "Prediction of Freezing and Thawing Times for Multi-Dimensional Shapes by Simple Formulae. Part 2: Irregular Shapes." *International Journal of Refrigeration* 10, no. July (1987b): 234-40.
    Keywords: Thawing/ Calculation of thawing times
    Call Number: OSU Libraries-Valley TP490.R48, Guin Library Thawing file
    Abstract: "Calculated and experimental data for multi-dimensional irregular shapes were used to assess various methodologies to include the effect of shpae in empirical freezing and thawing time prediction methods. The principles underlying two existing geometric factors, EHTD and MCP, were found to be valid; so there seems to be no need for other approaches. Used in conjunction with accurate slab freezing and thawing time prediction methods, the proposed empirical formulae for EHTD and MCP gave accurate predictions for all of the two-dimensional shapes and most of the three-dimensional shapes tested, except those with oval cross-sections in the third dimension. This was attributed to the lack of data for this group of shapes." (Author's abstract)

17. Code of Federal Regulations. "Current Good Manufacturing Practice in Manufacturing, Packing, or Holding Human Food.", Part 110. 2002.
    Keywords: Thawing/ Safety
    Call Number: OSU Libraries-Valley KF70 .A3
    Abstract: The U.S. Food and Drug Administration specifies procedures and temperatures for holding and thawing foods.

18. Davis, P. "Vacuum Chilling and Thawing of Fishery Products." *Australian Fisheries* , no. November (1975): 28.
    Keywords: Thawing/ Thawing methods
    Call Number: OSU Libraries-Guin Library SH131.A3
    Abstract: "The February 1975 issue of *Australian Fisheries* described a vacuum heat thawing (VHT) plant developed by APV. Reference was made to the fact that thawing times, by comparison with conventional processes, were reduced. Just how much reduction can be achieved using this type of equipment has been demonstrated by technologists working at the US National Marine Fisheries Service in Gloucester." (Author's introduction)

19. DeAlwis, A. A., and P. J. Fryer. "The Use of Direct Resistance Heating in the Food Industry ." *Journal of Food Engineering* 11 (1990): 3-27.
    Keywords: Thawing/ Alternative thawing methods
    Call Number: OSU Libraries - Guin Library Thawing file
    Notes: KEYWORDS FROM Agricola and from Kolbe's words at top of paper.
    Abstract: Direct resistance heating (DRH) offers the chance to process solid and

liquid foods at the same rate, avoiding the delay due to thermal conduction which prevents the use of HTST technologies on particulate foods. The attempts to exploit the advantages of DRH in food processing over the last century are reviewed. A successful DRH unit requires non-contaminating electrodes which have a good contact with the food material, control of the food heating rate and, if sterilisation is required, an efficient aseptic packaging process. Recent developments in these three areas mean that the advantages of direct resistance heating can now be commercially exploited. ((Abstract provided by AGRICOLA, produced by the National Agricultural Library of the United States Department of Agriculture, http://www.nal.usda.gov/ag98/)

20. Denys, S., A. M. Van Loey, M. E. Hendricks, and P. P. Tobback. "Modeling Heat Transfer During High-Pressure Freezing and Thawing." *Biotechnology Progress* 13, no. 4 (1997): 416-23.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TA164.B561, Guin Library Thawing file
Notes: Full text available online via Oasis
Abstract: An existing theoretical model for predicting product temp. profiles during freezing and thawing processes was extended for simulating high-pressure freezing and thawing processes. To take into account the influence of elevated pressure a simplifying approach is suggested, consisting of shifting the known thermophysical properties at atmospheric pressure on the temp. scale depending on the prevalent pressure. The applicability of the method to simulate high-pressure freezing and thawing profiles was tested for a food simulant (Tylose). Good agreement between experimental and predicted temp. profiles was observed for both high pressure freezing and thawing. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

21. Fikiin, K. A. "Ice Content Prediction Methods During Food Freezing: a Survey of the Eastern European Literature." *Journal of Food Engineering* 38, no. 3 (1998): 331-39.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-ValleyTP368.J681
Notes: Keywords from AGRICOLA
Abstract: The paper presents a critical synopsis of several methods for determination of the ice content in foods during freezing or thawing as a function of the temperature. Relationships established in Eastern Europe are mainly considered, including the methods of Bartlett-Tchigeov, Rutov, Latyshev and Jadan. The ability and the limits of applicability of every method are discussed and critically evaluated. On the basis of a comparative analysis recommendations are made for implementation of some of these methods in software for computer simulation of the thermophysical properties and thermal behaviour of foods during refrigerated processing, storage, transport and distribution. (Abstract provided by AGRICOLA, produced by the National Agricultural Library of the United States Department of Agriculture, http://www.nal.usda.gov/ag98/)

22. Franke, K. "A New Approach for the Numerical Calculation of Freezing and Thawing

Processes of Foods Using a Modified Fictitious Heat Flow Method." *Journal of Food Engineering* 44, no. 1 (2000): 23-29.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Notes: KEYWORDS FROM AGRICOLA
Abstract: Freezing and thawing processes play an important role in processing of aqueous foods. However, their mathematical description is difficult because of the heterogeneous, biological nature of foods. A freezing point lower than that of pure water and a broad freezing range are typical phenomena. The author proposes a new calculation approach for freezing and thawing of foods based on the fictitious heat flow model and taking into consideration the broader freezing range. The ideas of the model are presented and explained. The suitability of the model is checked using freezing/thawing processes of a whole egg product in a bucket. A good fit of temperature courses measured within the bucket could be observed. A freezing curve obtained implicitly from the model calculations shows a similar course to those measured by DSC. The model enables the simulation of both freezing and thawing processes with respect to local temperature distribution and ice content under a wide range of conditions with respect to geometry, heat transfer, temperature range and others. (Abstract provided by AGRICOLA, produced by the National Agricultural Library of the United States Department of Agriculture, http://www.nal.usda.gov/ag98/)

23. Gekas, V., I. S. Chronakis, and I. Sjoholm. "Measurement of the Heat Transfer Coefficient in a Thawing Tunnel." *Journal of Food Process Engineering.* 21, no. 4 (1998): 271-78.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP368.J66, Guin Library Thawing file
Notes: KEYWORDS FORM AGRICOLA
Abstract: A convective (air) thawing tunnel previously applied to the thawing of meat was used to measure the heat transfer coeff. of an ice model (e.g. for frozen foods or vegetables) with a geometry which could be approximated to an infinite slab. The heat transfer coeff. was deduced from the agreement between experimental data and simulated (using a commercial numerical program) data. Results could be summarized by the equation: Nu = 1.27Re-0-.-5-5-3. Thus, the dependency of the heat transfer coeff. on the Reynolds number agreed well with correlations found in the literature for similar kinds of application (freezing, thawing). In particular the Nusselt relationship was in very good agreement with the Heldman correlation for freezing of foodstuffs in the turbulent regime. [From En summ.] (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

24. Goral, D., and F. Kluza. "Comparison of Models for Predicting Thawing Times of Food." *Polish Journal of Food and Nutrition Sciences* 5/46, no. 2 (1996): 103-8.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: Six most commonly known models for predicting thawing time of food: Nagaoka's et al., Cleland's et al., Calvelo's, Pham's and Piotrovich were compared

when testing Tylose MH 1000 test substance, ground beef, and potato, and relative errors, regression and variance. The Cleland's et al. method, disregarding equivalent heat transfer dimensionality (EHTD) and mean conducting path (MCP) coefficient, was proved to be the best for predicting thawing time. The inclusion of EHTD and MCP in the computations by the Cleland's et al. method did not affect the results statistically significantly. The models of Piotrovich, Calvelo and Nagaoka et al. produced results statistically different from real thawing times. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

25. Harvey, R. A., and A. P. T. Topliss. "Thawing Rate of Fish Blocks in Water." *Annual Report. Fishing Industry Research Institute (South Africa)* 36, no. 1982/01-12 (1982): 41-42.
    Keywords: Thawing/ Thawing methods
    Call Number: OSU LIBRARIES-Guin Library Thawing file
    Abstract: The paper describes the procedure and tests to determine the time taken for blocks of frozen fish at 255 K (-18 deg C) to thaw in water at 291-293 K (18-20 deg C). Results indicated that blocks 100 mm thick could be expected to thaw in moving water in about 4 hours. The low heat conductivity of frozen flesh limits the rate of heating. Higher water temperature could result in spoilage. Plastic bags if used for holding blocks out of contact with water should be of heavy gauge. (Abstract from International Institute of Refrigeration Bulletin, 1985, v.65(1) p.58 (85-0-198)

26. Hayakawa, K. , K. R. Scott, and J. Succar. "Theoretical and Semitheoretical Methods for Estimating Freezing or Thawing Time." *Transactions of the ASHRAE* 91, no. Part 2B (1985): 371-84.
    Keywords: Thawing/ Calculation of thawing times
    Call Number: OSU Libraries-Valley TH 7201.A5, Guin Library Thawing file
    Notes: HI-85-07 No. 5
    Abstract: "Many published methods are available for predicting freezing or thawing time of conduction heating food. Based on approaches employed for developing these methods, they are classified into theoretical and semitheoretical theoretical, and empirical methods. Selected published methods of the first two groups are reviewed in this paper, with emphasis on examining their reliability by closely examining theoretical assumptions employed for the development." (Author's abstract)

27. Ibanez, E., A. Foin, P. Cornillon, and D. S. Reid. "Study of Different Thawing Methods for Frozen Fruits and Vegetables. "*1996 IFT Annual Meeting: Book of Abstracts* , 33Chicago, IL: Institute of Food Technologists, 1996.
    Keywords: Thawing/ Quality
    Notes: Abstract only
    Abstract: Frozen broccoli, spinach, lemon juice and strawberries (-69 degree C/2 h then -80 degree C until thawing) were thawed by various methods, and ascorbic acid (AA) retention and colour changes were examined. Thawing methods compared were: air at 5 or 24 degree C; water at 0 or 40 degree C; and microwave

oven on thaw mode until sample reached 1 or 40 degree C. For vegetables, which had been blanched, no significant effects of thawing method were observed for AA retention. Fruit products exhibited a large loss of AA on thawing for 24 h at room temp. (70 and 40% loss, respectively, for lemon juice and strawberries). Colour retention of fruits was equally affected by thawing temp. and time. Broccoli colour was more affected by thawing time, whereas spinach colour was more closely related to thawing temp. [From En summ. Further abstracts of presentations from this meeting are covered in electronic formats of the FSTA database and may be traced via the corporate authors (CA) field, under United States of America, Institute of Food Technologists [1996 Annual Meeting]. See also FSTA (1996) 28 11A2.]

28. Ilicali, C., and E. Ozbek. "Methods for the Thawing Time Prediction of Ellipses." *Lebensmittel Wissenshaft Und Technologie* 30, no. 6 (1997): 624-26.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: Food objects such as animal carcasses, offal, fish and some frozen foods can be represented by elliptical shapes. Accuracies of 3 equations for prediction of thawing times of elliptical foods were assessed; the equations were tested against numerical data for the thawing time (generated using a finite difference numerical model). Results showed that, with the analytical methods considered, it was possible to predict the numerical results with errors less than 5.4%.

29. International Institute of Refrigeration. *Draft Code of Practice for Frozen Fish*. Paris: 1969.
Keywords: Thawing/ General introduction
Call Number: OSU Libraries-Valley SH336.F7 I6 (in storage), Guin Library Thawing file
Notes: "Methods of thawing" on pages 57,59,61,63,65,67 (pages not consecutive)
Abstract: "There is no evidence to suggest that extremely rapid methods of thawing are essential for frozen fish. However, marginal improvements in quality have been observed as the time of thawing of 4-inch thick blocks of whole cod has been reduced from 12-14 hours (still air thawing) to one hour (dielectric thawing). Thus the choice of method will largely depend on costs and operational requirements. Thawing in water may present problems of filtration and bacterial contamination if the water is circulated in a closed system." (Author's Conclusions, p.65-70)

30. ———. "Thawing and Tempering." *Recommendations for the Processing and Handling of Frozen Foods.* 3 ed., International Institute of Refrigeration, 206-24. Paris: International Institute of Refrigeration, 1986.
Keywords: Thawing/ General introduction
Call Number: OSU Libraries-Valley TP493.5.R41 1986, Guin Library Thawing file
Abstract: "Many food processors use frozen material as a feedstock in their operations, and if thawing is not carried out carefully, quality and yield can suffer.

The importance of correct thawing is often under emphasised. Thawing is more difficult to control than freezing. This section sets out the broad principles involved in thawing and indicates some of the problem areas." (Author's introduction to section 4.5, page 206)

31. James, S. J. , and C. Bailey. "The Theory and Practice of Food Thawing." *Thermal Processing and Quality of Foods.* editor P. Zeuthen, 566-78. London: Elsevier, 1984.
Keywords: Thawing/ General introduction
Call Number: OSU Libraries-Valley TP371.2.T51, Guin Library Thawing File
Abstract: "Thawing is often considered as simply the reversal of the freezing process, and in many ways it is. However, inherent in thawing is a major problem that does not occur in the freezing operation. The majority of the bacteria that cause spoilage or food poisoning are found on the surfaces of meat and fish. During the freezing operation surface temperatures are reduced rapidly and bacterial multiplication is severely limited, with bacteria becoming completely dormant at below -10 degrees C. In the thawing operation these same surface areas are the first to rise in temperature and bacterial multiplication can recommence. On large objects subjected to long uncontrolled thawing cycles, surface spoilage can occur before the centre regions have fully thawed. For these and other reasons, thawing is not a simple operation. In this paper the theoretical considerations that govern thawing are discussed, followed by descriptions of the more important methods for thawing foodstuffs together with experimental data on thawing times for a range of products. The paper concludes with a brief discussion of the factors that need to be considered when choosing a thawing method for a particular product. Since most commercial thawing is carried out on either fish or meat only these two foodstuffs have been specifically considered. However, the majority of the points discussed would apply equally to any high water content product." (from Author's Introduction, p. 566-67)

32. Jason, A. C.Organisation for Economic Co-operation and Development. "Selection of Thawing Methods."*Fish Handling and Preservation; Proceedings* , 191-201 Paris: Organization for Economic Cooperation and Development, 1965.
Keywords: Thawing/ General introduction
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: "Categories and variant of thawing methods appropriate to various bulk forms of frozen fish are considered in relation to criteria for the selection of a suitable method for a given application. Certain pairs of categories which complement one another combine to form various hybrid methods offering distinct advantages in speed, convenience and cost over any method involving the exclusive use of only one variant. Several practicable hybrid methods are described including water/electrical resistance thawing for small scale application. A number of reasons are advanced in support of the author's preference for dielectric heating as the most suitable method of thawing large blocks of whole fish on an industrial scale." (Author's Summary, p. 191)

33. ———. *Thawing Frozen Fish*, Vol. Torry Advisory Note No. 25 (revised). Torry Advisory

Note Ministry of Agriculture and Food, Torry Research Station, Aberdeen, Scotland , 1974.
Keywords: Thawing/ General introduction
Call Number: OSU LIBRARIES-Guin Library Thawing file
Abstract: "The continuing growth of quick freezing in the fishing industry has made necessary the development of industrial methods of reversing the freezing process, that is thawing the fish for further processing, for cooking or for sale as wet fish. Rapid thawing enables the processor or distributor to meet market demands quickly, and with the minimum demand on labour and space. Methods have been developed for thawing frozen fish in the many forms now handled commercially, including large blocks of whole sea frozen fish, blocks of fillets or portions for catering use, single whole fish such as salmon, and blocks of shrimps. Frozen fish is now being used increasingly by caterers and in the home, and methods of thawing on a small scale have been devised to assist in the preparation of frozen whole fish, fillets and fish portions for immediate cooking. This note briefly describes the principal methods of thawing and discusses some of their advantages and disadvantages. There is no single procedure ideally suited to all purposes, since conditions will vary with each application. Some guidance is given about the factors to be considered when making a choice." (Author's Introduction)

34. Jiang, S. T. , M. L. Ho, and T. C. Lee. "Optimization of the Freezing Conditions on Mackerel and Amberfish for Manufacturing Minced Fish." *Journal of Food Science* 50 (1985): 727-32.
Keywords: Thawing/ Quality
Call Number: OSU Libraries-Valley TX341.F6, Guin TX341.F6
Abstract: "Optimal freezing, frozen storage and thawing conditions in preserving mackerel and amberfish for producing minced fish products were investigated. Based on assessments of extractability of 0.6M KCI-soluble proteins and actomyosin, Ca-ATPase activity of actomyosin, and gel-forming ability of kamaboko (kind of minced fish meat product), semi-dressed, dressed, and filleted samples showed stable and good quality of gel-forming ability during 3 months storage at -20 degrees C. Optimal ultimate freezing temperatures of mackerel and amberfish were -20 degrees C. and between -30 degrees C and -40 degrees C, respectively. The optimal storage temperatures for mackerel and amberfish were -20 degrees C and -40 degrees C, respectively. Appropriate thawing methods for frozen mackerel were microwave and 20 degree C running water defrosting, while those for frozen amberfish were microwave, 20 degrees C running water, and room temperature defrosting." (Author's abstract)

35. Jimenez, S. M., M. E. Pirovani, M. S. Salsi, M. C. Tiburzi, and O. P. Snyder. "The Effect of Different Thawing Methods on the Growth of Bacteria in Chicken." *Dairy, Food, and Environmental Sanitation* 20, no. 9 (2000): 678-83.
Keywords: Thawing/ Safety
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: Six chicken carcasses of approx. 3 kg each, from a poultry processing plant, were eviscerated and cooled for transport to the laboratory. 3 carcasses were used for study of growth of bacteria in uninoculated, frozen chicken during thawing

and the other 3 were used to examine growth of Salmonella hadar in inoculated, frozen samples during thawing. Thermocouples were positioned in the breast muscle and just under the skin of the thigh. Carcasses frozen to -20 degree C within 10 h were thawed in air at ambient temp. (22 degree C), in flowing water at 21 degree C or in the refrigerator at 3.5-7.2 degree C. Thawing was halted at 4.4 degree C on the breast thermocouple. Bacteria monitored were Enterobacteriaceae, Pseudomonas spp., total viable counts and Salmonella spp. Results showed that thawing chicken in air for less than or equal14 h was a safe procedure. Thawing in flowing water was also a safe and rapid procedure, but thawing in a refrigerator required a longer variable period at temp. which allowed growth of pseudomonads. Thus, controlled thawing at ambient temp., as permitted by USDA but not recommended by US FDA food codes, did not appear to lead to increased hazards. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

36. Joint FAO/WHO Codex Alimentarius Commission, and Joint FAO/WHO Food Standards Programme. *Recommended International Code of Practice for Frozen Fish*. 2 ed. Rome: Food and Agriculture Organization of the United Nations, World Health Organization, 1984.
    Keywords: Thawing/ Quality
    Call Number: OSU LIBRARIES-Guin Library Thawing file
    Notes: See pages 45-48
    Abstract: The Code of Practice for Frozen Fish offers general advice on the production, storage and handling of frozen fish and fish fillets on board fishing vessels and on shore. It also discusses the distribution, retail display and thawing of frozen fish for industrial purposes. The code is intended as background information and as a guideline for the elaboration of national quality standards, quality control and fish inspection regulations in countries where these have not been developed. It does not replace the advice or guidance of trained and experienced technologists.

37. Jul, Mogens. "Thawing." *The Quality of Frozen Foods.* Mogens Jul, 261-70. London; San Diego: Academic Press, 1984.
    Keywords: Thawing/ Quality
    Call Number: OSU Libraries-Valley TP372.3.J841 1984, Guin Library Thawing file
    Abstract: This gives a general account of the quality effects of thawing strategies. In general, variations in thawing methods have a limited but not insignificant effect on total end product quality. (Indexer's abstract)

38. Kissam, A. D., R. W. Nelson, R. Ngao, and P. Hunter. "Water Thawing of Fish Using Low Frequency Acoustics." *Journal of Food Science* 47, no. 1 (1981): 71-75.
    Keywords: Thawing/ Alternative thawing methods
    Call Number: OSU Libraries-Valley TX341.F6, Guin TX341.F6
    Abstract: "Blocks of Pacific cod (plate frozen: 91-mm thickness and 12.7 kg) were thawed in an 18 degree C circulated water bath and simultaneously exposed to 1500 Hz acoustic energy not exceeding 60 watts. A ceramic transducer was positioned

for light contact with a frozen block. A motorized belt moved the block in order to distribute the 239 cm^2 transducer over the 1500 cm^2 block surface. At 60 watts continuous input to the transducer, the block thawed in 71% less time than water-only controls. Quality analyses indicated that the flesh was not adversely affected by the acoustic waves." (Author's abstract)

39. Knorr, D., O. Schlueter, and V. Heinz. "Impact of High Hydrostatic Pressure on Phase Transitions of Foods." *Food Technology* 52, no. 9 (1998): 42-45.
Keywords: Thawing
Call Number: OSU Libraries-Valley TX599.F65, Guin TX599.F65
Notes:

Abstract: An understanding of the phase transitions occurring in water during freeze-thaw cycles in foods can be applied to process and product development. Following an outline of recent work on pressure-assisted freezing and thawing and effects on thermodynamic properties of water in the foods examined, high-pressure freezing and thawing of potato cylinders is examined. Phase transition lines for potato cylinders were established during pressure-shift freezing and pressure thawing, and results were represented mathematically. Freezing of potato at constant pressure reduced freezing time (f.p. was reduced with increasing pressure); substantial supercooling was observed prior to freezing. In frozen samples pressure-thawed at temp. lower than those applied at atmospheric pressures, an initial phase of adiabatic heating overlapped with inward heat transfer and a reduction in temp. of the solid sample was observed during pressurization. Transitions between various forms of ice are discussed. Pressure-related phase transitions may be important for food quality, but further information is required relating to kinetic data regarding formation, size, distribution and stability of ice crystals, as affecting interactions of water and other food components, and physicochemical and physiological cellular/macromolecular effects. Developments in monitoring apparatus will be required if this is to be realised, because process inhomogeneities such as temp. gradients must be catered for.(Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

40. Kristensen, J., inventor. "A Method and System for Defrosting Frozen Packed Products."Denmark, Paul Klinge Produktion DK 89-4419 (19890907). 1991.
Keywords: Thawing/ Thawing methods
Abstract: A system and method for defrosting frozen packaged food products are described. A relatively dry heated airflow sweeps around the product; the heat flow rate imparted to the airflow is controlled depending on the surface temp. of the product at a location that is expected to reach the highest temp. The plant includes a heating assembly, a blower, and a means to provide a flow duct, in which the products are piled with spaced relationships along part of the duct. A temp. sensor is located on an upstream surface of a product furthest upstream in the pile, and a microprocessor receives signals from the temp. sensor and emits a control signal to the heating assembly. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

41. Kunis, J., R. Richter, and E. Radespiel. "Effect of Rates of Freezing and Thawing on the Quality of Prerigor Frozen Beef."*Proceedings of the International Institute of Refrigeration*, 721-30Dresden: 1990.
Keywords: Thawing/ Quality
Call Number: OSU Libraries - Guin Library Thawing file
Notes: WAS THE MEETING HELD IN DRESDEN, OR IS THAT THE PLACE OF PUBLICATION? WAS THE MEETING HELD IN 1990? OR IS THAT THE DATE OF PUBLICATION? (see paper in Kolbe file)
Abstract: "In view of the present state of the art of block meat freezing and electrical stimulation /1/; studies were carried out to investigate: 1) Optimal conditions for freezing and thawing of prerigor muscle cuts; 2) Quality variations in electrically stimulated and non-stimulated prerigor-frozen muscle cuts; 3) The complex influence of electrical stimulation and rates of freezing and thawing on prerigor muscle cuts. The test conditions and results including optimum process parameters derived therefrom are presented. " (Author's Introduction, p. 721)

42. Lin, C. S., C. Hung, and C. M. Park. "Quality and Microbial Safety for Shrimp Thawed Using a Constant Temperature Thawing Chamber."*2000 IFT Annual Meeting*, 51A-1Institute of Food Technologists, 2000.
Keywords: Thawing/ Safety
Call Number: OSU LIBRARIES-Guin Library Thawing file
Abstract: "Shrimp is one of the most popular seafood items served in restaurants. Frozen shrimp is the most common form of material used by restaurants to prepare their shrimp dishes. This study was designed to evaluate the quality and safety of shrimp thawed using a constant temperature-thawing chamber. A constant temperature chamber which can maintain the temperature at 5 degrees C (FWE chamber) was used for this study. The temperature profile of the thawing chamber as well as the shrimp blocks during thawing were monitored using a Hotmux data logger equipped with T-type, 30 gauge thermocouples. Running water thawing was used to compare with the FWE thawing. Shrimp thawed in room temperature air was used as the control. All quality evaluations including drip loss, yield and moisture content as well as press juice and shear force were conducted within 2 hr after thawing. The aerobic plate count of samples was also determined. The whole study was triplicated. The FWE chamber maintained the temperature at 5 degrees C throughout the study. The FWE chamber can also provide a more uniform thawing than water thawing. Shrimp thawed using the FWE chamber had a lower drip loss, higher yield and moisture content than shrimp thawed by running water. However, the differences were not statistically significant. There were also no significant differences on press juice and shear force between control and shrimp thawed using either running water or FWE chamber. However, aerobic plate count results indicated that shrimp thawed using the FWE chamber had lower bacterial count than both control and shrimp thawed using the running water. Results obtained from this study suggest that quality and safety of shrimp thawed using a constant temperature thawing chamber were better maintained than room temperature and running water thawing processes." (IFT Abstract)

43. Lind, I. "Mathematical Modelling of the Thawing Process." *Journal of Food Engineering*

14, no. 1 (1991): 1-23.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU LIBRARIES-Guin Library Thawing file
Abstract: A review of models for the calculation of thawing time and simulation of the thawing process is presented. Aspects considered include: analytical models and simple equations; numerical methods; thermal properties; surface heat transfer coeff.; and mass transfer at the product surface, with reference to frost formation and evaporation. A new model for simulation of heat and mass transfer in thawing processes is also presented. Results on the use of this model are compared with experimental measurements on meat loaf and white bread dough; the new model simulated temp. and wt. changes during the thawing process quite well. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

44. Lucas, T., D. Flick, and A. L. Raoult-Wack. "Modeling and Control of Thawing Phenomena in Solute-Impregnated Frozen Foods." *Journal of Food Engineering* 45, no. 4 (2000): 209-18.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP368.J681
Abstract: This work designed to give a better understanding and control of the mechanisms of simultaneous thawing and mass transfer occurring in a material in isothermal contact (T<0 degrees C) with an aqueous freezant. Two models of heat and mass transport in a porous medium were developed, one solved numerically and the other analytically. Despite different levels of simplification of the phenomena, simulations using both models demonstrated similar mechanisms, including the progress of a sharp thawing front separating a frozen, non-impregnated inner layer from a thawed, highly impregnated outer (surface) layer. The work contributes not only to our understanding of the underlying mechanisms but also develops a very simple tool for predicting thawing/impregnation phenomena during cold immersion storage. The time-course changes in the thawing front and solute gain obtained experimentally with apple pieces and those predicted by the analytical model were in good agreement, with only two food structure variables being identified for this purpose. The effect of process variables predicted by the analytical model was consistent with trends previously observed with real food, for instance an absence of thawing if the food was stored in a biphasic mixture. (Abstract provided by AGRICOLA, produced by the National Agricultural Library of the United States Department of Agriculture, http://www.nal.usda.gov/ag98/

45. Mannapperuma, J. D., and R. P. Singh. "A Computer-Aided Method for the Prediction of Properties and Freezing/Thawing Times of Foods." *Journal of Food Engineering* 9, no. 4 (1989a): 275-304.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: :A numerical method, based on enthalpy formulation of heat conduction with gradual phase change, was used to develop a mathematical model to simulate freezing and thawing processes in foods of 6 geometrical shapes. Another model

was developed, to predict the thermophysical properties required by the enthalpy formulation. Several computer programs were written to implement these models. Programs were combined, to form a comprehensive package for computer-aided prediction of freezing/thawing times and properties of foods. Predictions compared favourably with published experimental data. (Abstract provided by Food Science and Technology Abstracts, IFIS Publishing, 1969-2002. All rights reserved.)

46. ———. "A Computer Program Package for the Simulation of Freezing of Foods."*Technical Innovations in Freezing and Refrigeration of Fruits and Vegetables : Proceedings of the International Conference of Davis, USA* , 223-28Paris, France: International Institute of Refrigeration, 1989.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU LIBRARIES-Guin Library Thawing file
Abstract: "A large number of methods have been proposed for the prediction of freezing time of foods. The exact analytical methods based on Neumann's solution /2/ are not easily adoptable to practical situations and often result in large prediction errors. The approximate analytical method of Plank
/21/ can be used for a number of regular geometries. This method is very simple to use but does not account for the removal of sensible heat before and after freezing thus results in under prediction of freezing times. Modified versions of this method /6/14/18/ have overcome these shortcomings of the original method and improved the accuracy of prediction but in the process have become somewhat complicated. Numerical methods can incorporate many of the complexities specific to the foods and to the freezing process thus resulting in models that emulate the real process much more faithfully than approximate analytical methods. A number of sound numerical methods /5/12/19/20/ have been proposed. However, unlike in the case of analytical methods, the user finds it hard to adopt the numerical method to suit his requirements. This is due to lack of expertise or the time necessary to develop a robust computer program. This paper presents an up to date summary of an ongoing project at the food engineering laboratory of University of California at Davis to provide the prospective users with a computer program package for the prediction of freezing of foods." (Author's Introduction)

47. ———. "Prediction of Freezing and Thawing Times of Foods Using a Numerical Method Based on Enthalpy Formulation." *Journal of Food Science* 53, no. 2 (1988b): 626-30.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TX341.F6, Guin TX341.F6
Abstract: An explicit numerical method, involving enthalpy formulation, to predict temperature distribution in foods during freezing and thawing was developed. The accuracy of the proposed method was validated using published experimental data obtained for freezing and thawing of Tylose. The enthalpy formulation avoids the problems of strong discontinuity experienced when the apparent specific heat formulation is used in predicting temperatures for situations involving phase change. The proposed method predicts temperatures in good agreement with experimental data. The computer code can be easily programmed on a desk-top computer for use in teaching and research on predicting freezing and thawing rates

in foods.
(Author's abstract)

48. ———. "Thawing of Frozen Foods in Humid Air." *International Journal of Refrigeration* 11 (1988a): 173-86.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP 490.R48<, Guin Library Thawing file
Abstract: "During thawing of foods in humid air, the ambient water vapour undergoes a phase change at the food surface. The surface phenomena during thawing were formulated into a mathematical model consisting of six stages: frost formation, frost consolidation, transition, condensation, evaporation and drying. This model was coupled with another model developed for heat conduction with phase change inside food during thawing. A numerical solution scheme for the combined thawing model was formulated and a computer program was developed for implementation. A number of experiments were conducted on the thawing of Tylose slabs to compare with the predictions of the thawing model. The predictions of thawing time agreed well with the experimental results. The model was used to simulate the growth and decay of frost, ice and water layers on the surface of the food and also to study the effect of temperature and humidity of air, convective film heat transfer coefficient, and shape and size of food on thawing time." (Author's Abstract)

49. Mascheroni, R. H. "The Use of Shape Factors to Model Multidimensional Heat Conduction. Their Application to the Prediction of Thawing Times of Foods. "*Proposals for the Generation and Use of Refrigeration in the 21 St. Century : Proceedings of the Meetings of Commission B2, C2, E2* , 248-53Buenos Aires: International Institute of Refrigeration// International Congress of Refrigeration, 1992.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: "Thawing is a usual operation in food processing during the elaboration of products from frozen raw materials or as a previous stage to the sale or consumption of frozen foods. Adequate methods for predicting thawing times should be available during equipment design as well as for the evaluation of operating conditions of existing thawers. The actual trend is the use of approximate methods, at the same time simple and of good precision over a wide range of working conditions (heating medium temperature, heat transfer coefficient, product size and shape). Besides, to be useful for practical purposes, only information of thermal properties of foods easily available from literature must be necessary for calculations. When dealing with food products of simple regular geometries, as flat plate, infinite cylinder or sphere, several well proven methods are available. .. The present work deals with the use of shape factors as developed in /5/ to predict t_t of high water content foods of any shape and composition. Four different simplified methods for the calculation of t_t of slab-shaped foods were used as a base, so as to test their precision and simplicity of use, as developed in the following paragraphs." (Author's Introduction)

50. Merritt, J. H., and Nove Scotia. Department of Fisheries. *Guidelines for Industrial Thawing of Groundfish in Air and in Water*, Report IDD-109. Halifax, Nova Scotia: Technical University of Nova Scotia, Department of Fisheries, Province of Nova Scotia. 1993.
Keywords: Thawing/ Thawing methods
Call Number: SENT TO CATALOGING
Abstract: "Freezing of fish and trade in frozen fish are major industrial activities. some fish are frozen whole and supplied for the manufacture of various products. They must be thawed before processing. Since fish processors need information and advice in order to make arrangements for thawing on an industrial scale, in this note an attempt has been made to answer some of the questions that commonly arise and set down guidelines. Attention is directed toward simple, low-cost methods of thawing groundfish in air and in water. Some information on blocks of frozen fish is appended: "Product specifications" in Appendix I and "L:ist of suppliers of frozen whole groundfish" in Appendix II." (Author's Introduction)

51. Merts, I. *A Review of Methods for Thawing Meat.* Meat Industry Research Institute of New Zealand (MIRINZ), 1999.
Keywords: Thawing/ Quality
Call Number: SENT TO CATALOGING
Notes: Publication No. 988
Abstract: This report provides an overview of the methods available for thawing meat or meat products, together with an evaluation of studies carried out by New Zealand and overseas researchers in order to optimize meat thawing processes. Individual aspects considered include: physical aspects of the thawing process; quality aspects of thawing (microbial growth and drip loss during thawing, appearance and palatability of thawed products); external heating methods used for thawing (air, water, vacuum, plate, IR, and heat-pipe thawing); internal heating methods (electrical resistance, capacitive and microwave thawing); current thawing practice and thawing requirements in the New Zealand meat industry; and methods showing good potential for application in the New Zealand meat industry (air, water, vacuum, plate and dielectric thawing). (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

52. Merts, I., C. R. Lawson, S. D. Cotter, and S. J. Lovatt. *Thawing of Meat in Water and by Direct Contact With Heated Plates*. Meat Industry Research Institute of New Zealand, 1998.
Keywords: Thawing/ Thawing methods
Call Number: SENT TO CATALOGING
Notes: Publication No. 989
Abstract: This report presents the results of studies investigating the thawing of meat by immersion in water, water spray or by direct contact with heated plates. A wide range of frozen meat was thawed by these methods and examined for effects of thawing conditions on thaw times, microbiological growth during thawing, wt. loss during thawing and appearance (colour) of the thawed meat. Results were used, together with literature data to formulate general guidelines for thawing meat by air, water and plate thawing methods. The relatively slow air thawing process is

recommended for thawing small products or for plants operating small-scale thawing operations. Water and plate thawing are suitable for thawing large or small products, although plate thawing is most suited to slab-shaped products. Water thawing is not recommended for bare meat if a pale surface colour immediately after thawing is likely to reduce acceptability. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

53. Miles, C. A. , M. J. Morley, and M. Randell. "High Power Ultrasonic Thawing of Frozen Foods." *Journal of Food Engineering* 39, no. 2 (1999): 151.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries-Valley TP 368.J681, Guin Library Thawing file
Abstract: The effectiveness of high intensity ultrasound for thawing frozen meat and fish was assessed using beef, pork and cod samples subjected to ultrasonic frequencies ranging from 0.22 to 3.3 MHz and intensities of _3 W cm---2. High intensities and frequencies at low and high ends of the range investigated were found to cause overheating near the surface. This was attributed to the onset of cavitation at low frequencies and an increase in attenuation at higher frequencies. Acceptable surface temp. was obtained using frequencies of approx. 500 KHz and ultrasonic intensities of approx. 0.5 W cm---2. These conditions resulted in complete thawing of cylindrical beef, pork and cod samples (length 76 mm, diam. 20-50 mm) within approx. 2.5 h. A theoretical ultrasonic thawing model, which assumed no cavitation, gave thawing times in close agreement with experimental results. Effects of including a fat layer and orientation of muscle fibres on direction of ultrasound transmission were also examined and found to agree with previously determined attenuation coeff. and typical acoustic impedance values. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

54. Mussa, D. M. , and A. LeBail. "High Pressure Thawing of Fish: Evaluation of the Process Impact on Listeria Innocua."*2000 IFT Annual Meeting*, 75-7Institute of Food Technologists , 2000.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU LIBRARIES-Guin Library Thawing file
Abstract: "Thawing of foods under high pressure is a new area of research interests, thanks to the depression of the phase change temperature of water under pressure. The main advantage of high pressure thawing is that it permits rapid thawing compared to atmospheric thawing. Moreover, some reports show that it may also reduce the drip volume and minimize microbial growth. Nevertheless, very few reports are available regarding the fate of microorganisms during high pressure thawing. The aim of this research was to evaluate the impact of high pressure thawing on indigenous microorganisms and on Listeria innocua inoculated on fish samples. Salmon fish samples containing indigenous microorganisms~ 104 CFU/g were obtained from Norwegian farm 4 days postmortem. Cylindrically shaped samples (50 mm diameter) were cut from the dorsal part of each fish, then were noculated with ~ 106 CFU/g of a 24 h culture of L. innocua prior to packaging in sterile plastic pouches. The pouches were frozen in air blast freezer at -20 degrees C for 4 h followed by storage in cold room (-20 degree C) for 7 days. Thawing was

realized in water bath at atmospheric pressure and under high pressure at 100 and 200 MPa. Growth of L. innocua and indigenous microorganisms was evaluated by spread plate technique using Oxford Medium and SPC respectively. Results showed that samples thawed more rapidly at 200 MPa than at other treatments. None of the studied microorganisms were affected by atmospheric thawing. High pressure thawing process reduced the number of L. innocua by 1.5 and 3 log cycles at 100 and 200 MPa respectively. Growth of indigenous microorganisms was not detected at 200 MPa while at 100 MPa the growth was reduced significantly. These results have shown additional interests to this process for thawing foods faster and improving the microbiological quality of thawed products." (IFT Abstract)

55. Myung, S. O. "Effect of Thawing Methods and Storage Periods on the Quality of Frozen Cooked Rice." *Journal of Food Science and Nutrition* 3, no. 3 (1998): 234-40.
Keywords: Thawing/ Quality
Notes: Second request ILL 1/28/03
Abstract: :Effects of various thawing methods and storage periods on the quality of frozen cooked rice were determined. Cooked rice was thawed at room temp. after 10, 30 and 90 days of frozen storage using 4 different methods (pressure cooking, conventional cooking, microwave heating and thawing). Physicochemical analysis (moisture content, dehydration rates, degree of gelatinization, colour value and texture) and sensory analysis of the frozen-thawed cooked rice were conducted. There were no significant decreases in quality characteristics of frozen-thawed cooked rice during the storage period of 90 days. However, thawing using a pressure cooker produced high moisture content, rapid dehydration rates and a high degree of gelatinization in the cooked rice. Desirability of the rice therefore diminished because of the excess moisture content and the change in appearance and texure of the rice due to high temp. processing. Similar quality characteristics were observed in the cooked rice after freezing-thawing by conventional or microwave heating. Thawing at room temp. caused a significant decrease in quality characteristics. [From En summ.](Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

56. Ohlsson, T. "Food Industry Applications of Microwave and High Frequency Heating." *Food Engineering News*, 1983, sec. Food Industry Trends, pp. 1,3-6.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: The thawing of bulk-frpzen products such as blocks of meat or fish often takes 12 to 48 hours using conventional methods such as humid air or water. The risks for loss of bacteriological quality and weight are substantial, if the surface tempertaure is not maintained low. Normally, the maximum allowable temperature is below 10 degrees C, which yields a very low driving temperature gradient. Microwaves can overcome the slow heat conduction limitations and thaw blocks of frozen meat completely in 10 to 60 minutes, depending on block dimensions and power used. However, with complete thawing, there are risks for the partial overheating of inhomogeneous material and of surface and corner parts. ..In the future, we will discover many successful microwave applications in areas where the product quality or the heat transfer properties of the material limit the tempertatures

that can used in conventional processes, and where, with microwaves, these limites can be approached much more rapidly and with better control. (Author excerpts.)

57. ———. "Low Power Microwave Thawing of Animal Foods."*Thermal Processing and Quality of Foods*, Editor P. et al. Zeuthen, and European Cooperation in the Field of Scientific and Technical Research, 579-84. EUR (Series) , no. 9038. London: Elsevier, 1984.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries-Valley TP371.2.T51, Guin Library Thawing file
Abstract: "The thawing of animal foods requires much energy to be added to the frozen product, at the same time as the surface temperatures have to be kept low. The low heat conductivity of thawed animal foods makes thawing times long when using conventional techniques. This can be overcome by using microwaves that have an ability directly to heat the interior of foods. There are however problems with uneven temperature distribution during rapid microwave thawing of large blocks of meat and fish. The effect on the thawing of different processing parameters was
studied by means of a computer calculation program for microwave thawing. The calculations show that processing in less than one hour is only possible for thicknesses below 50 mm. In such a short time thicker blocks can only be partially thawed or tempered which also is the industrial practice. With longer thawing times (5-10 hours) also thicker blocks (150-250 mm) can be successfully thawed at 915 MHz." (Author's summary)

58. Ohtsuki, T., inventor. "Process for Thawing Foodstuffs ."U.S. Patent 5,034,236 . 1991.
Keywords: Thawing/ Thawing methods
Abstract: A process for thawing foods is described. The process involves applying negative electrons to the food by the high voltage induced electrostatic method in order to thaw it rapidly at a low temp. in the range -3 to +3 degree C. The method suppresses bacterial growth and wt. loss from drip. [From En summ.] (Abstract provided by Food Science and Technology Abstracts, IFIS Publishing, 1969-2002. All rights reserved.)

59. Pham, Q. T., A. K. Fleming, and J. Willix. "Thawing of Meat Blocks in Polythene Wraps and in Cartons." *International Journal of Refrigeration* 16, no. 3 (1993): 169-74.
Keywords: Thawing/ Thawing methods
Call Number: OSU Libraries-Valley TP490.R48, Guin Library Thawing file
Notes: KEYWORDS FROM ARTICLE ITSELF INCLUDE: MEAT; THAWING, AIR HUMIDITY, WEITHT LOSS, ODOUR
Abstract: The thawing of cartoned and plastics-wrapped meat blocks, mostly 170 mm thick, in circulating air was investigated. Results showed that the thawing of large blocks of meat is a difficult process to control. Using longer times or higher temp. than strictly necessary resulted in poor product appearance and often odour problems. Effects of wrap, product position, product thickness, air temp., humidity and air velocity on thawing time, drip loss and sensory qualities were investigated. A Plank-type equation was used to correlate thawing times, but due to the complex and changing heat transfer situation at the meat surface, the heat transfer coeff. had

to be found by curve-fitting. Drip loss was lower at air velocities greater than 1 m/s. Odour and appearance were generally better at lower air temp., but could deteriorate at temp. as low as 5 degree C. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

60. Pham, Q. T., and S. L. Lovatt. "Optimisation of Refrigeration Processes by Stochastic Methods." *Food Australia* 48, no. 2 (1996): 64-69.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Guin Library Thawing file
Abstract: :Recent advances in computer hardware and in mathematical optimization methods have widened the range of problems that can be optimized and the sophistication of the mathematical models. As examples of this, 2 meat refrigeration processes and 1 meat thawing process were mathematically modelled using a novel stochastic method. A carton thawing process for meat blocks was designed to ensure complete thawing combined with the min. microbial risk. A beef chilling process was designed to ensure max. tenderness and the attainment of a 7 degree C deep leg temp. within a fixed period, while an alternative chilling process was designed to ensure that potential microbial growth did not exceed 3 generations. The rational application of automatic optimization methods led to better product quality and greater safety than conventional inflexible regulations. : Recent advances in computer hardware and in mathematical optimization methods have widened the range of problems that can be optimized and the sophistication of the mathematical models. As examples of this, 2 meat refrigeration processes and 1 meat thawing process were mathematically modelled using a novel stochastic method. A carton thawing process for meat blocks was designed to ensure complete thawing combined with the min. microbial risk. A beef chilling process was designed to ensure max. tenderness and the attainment of a 7 degree C deep leg temp. within a fixed period, while an alternative chilling process was designed to ensure that potential microbial growth did not exceed 3 generations. The rational application of automatic optimization methods led to better product quality and greater safety than conventional inflexible regulations. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

61. Pham, Q. T., P. D. Lowry, A. K. Fleming, J. Willix, and C. Fitzgerald. "Temperatures and Microbial Growth in Meat Blocks Undergoing Air Thawing." *International Journal of Refrigeration* 17, no. 4 (1994): 281-87.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Notes: KEYWORDS FROM ARTICLE ITSELF INCLUDE: MEAT, THAWING, PACKAGING, MICROBIOLOGY, MODEL
Abstract: AB: Two techniques were used to evaluate the hygienic quality of thawing cartoned meat, a temp. function integration (TFI) technique and a finite difference technique. TFI yielded microbial growth values which were usually within 1 generation of measured values. The exception was in the lower corners of cartons, where anaerobic conditions caused by the accumulation of drip led to directly determined values being much lower than those obtained in the top corners.

To ensure the success of the TFI technique, it was essential to measure the temp. where the warming of the product was quickest. The finite difference numerical model of the process was not built entirely from first principles, but involved some degree of curve-fitting against experimental data. It is suggested that numerical modelling provides a flexible design tool which allows quick evaluation and optimization of thawing and other thermal processes. It is concluded that numerical modelling is better at predicting 'worst case' microbial growth than TFI, as it does not suffer from the uncertainty of physically locating the warmest spot. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

62. Pound, J. "The Use of Dielectric Heating for Defrosting Processes and Book-Binding."*Fifth International Congress on Electro-Heat*Paris: International Congress on Electro-heat, 1964.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: "The first section of this paper describes the advantages of the rapid defrosting of deep frozen food products and the requirements for attaining this raising of temperature. With this method of heating, the first requirement is that the temperature rise in the materials is uniform throughout the mass and this can be obtained by passing it through a uniform electric field, with special design of the electrode system and method of holding the materials. Another factor affecting the successful operation of this heating system is the choice of frequency which should be as high as possible to limit the voltage between the electrodes, but as low as practical to limit standing wave difficulties and to make tuning of the load simpler. There are a number of methods of feeding the electrodes, each having their advantages and limitations which are discussed. The conditions under which the generators operate are not ideal for this type of equipment and the special requirements needed to meet these conditions are mentioned. As the equipment is to be used for food, it is necessary for the conveyor system to be kept very clean and this has to be considered in the basic design. The quantity of material capable of being handled will depend upon the temperature rise required and the power of the generators--Tables of typical commercial installations being given. Comparisons are made between this method of defrosting fish and those previously employed." (Author's abstract)

63. Ramos, M., P. D. Sanz, J. Aguirre-Puente, and R. Podado. "Use of the Equivalent Volumetric Enthalpy Variation in Non-Linear Phase-Change Processes: Freezing-Zone Progression and Thawing-Time Determination." *International Journal of Refrigeration* 17, no. 6 (1994): 374-80.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: Unlike pure substances that melt and solidify at a fixed temperature, some materials, such as the Karlsruhe Test Substance (methyl cellulose gel) freeze and thaw out over a range of temperatures. In this paper, the phase change process is studied using an equivalent volumetric enthalpy variation corresponding to the thermal field in the freezing or thawing zone instead of the latent heat appearing in

the Stefan solution for the phase change of a pure substance. In order to determine the equivalent volumetric enthalpy variation, two different temperature distributions are assumed in the freezing zone of the substance undergoing a phase change. Results obtained from calculations applying this approach are compared with experimental measurements. Measurements of freezing-zone progression were made in the course of three freezing experiments where the first kind of boundary conditions were imposed on the samples. In addition, 35 values for thawing time have been taken from the literature presenting experiments made with the third kind of boundary conditions. Comparisons showed the best agreement when a quadratic temperature distribution was adopted. The proposed method seems to be useful for many practical applications, particularly because it allows calculation of the freezing or thawing time without necessitating the use of empirical parameters in Plank's original equation. (Author's abstract)

64. Roberts, J. S., M. O. Balaban, R. Zimmerman, and D. Luzuriaga. "Design and Testing of a Prototype Ohmic Thawing Unit." *Computers and Electronics in Agriculture* 19, no. 2 (1998): 211-22.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: Frozen blocks of shrimps imported into the USA have traditionally been thawed by immersion in warm water. The purpose of the study was to design, build and test a prototype automated ohmic thawing unit to serve as a basis for modification and scale-up for industrial use. The specific objective was to design a prototype portable ohmic thawing unit, with surface temp. sensing and computer automated capabilities, that could thaw 2 shrimp blocks at the same time. Extensive testing of the operation of the unit was conducted to assure the elimination of runaway heating, and to develop guidelines and suggestions for scale-up. Ohmic thawing did not use any water, or generate much wastewater, and was more energy efficient. The test results showed that the time for ohmic thawing was comparable to water immersion time, without the incidence of hot spots. The major obstacle of ohmic thawing has been solved and the method could be used to thaw shrimp blocks. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002.)

65. Rosenberg, U., and W. Bogl. "Microwave Thawing, Drying, and Baking in the Food Industry." *Food Technology* 41, no. 6 (June) (1987): 85-91.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries-Valley TX599.F65, Guin TX599.F65
Abstract: A technical review surveys possible applications of microwave energy for thawing (and tempering), drying (and freeze-drying), and baking in the food industry, and their possible advantages and disadvantages relative to conventional processes. Each of these 3 application areas are separately discussed. Specific applications and potential technical problems and their solutions are described. A brief discussion of the basic characteristics of microwaves is included.(wz). (Abstract provided by AGRICOLA, produced by the National Agricultural Library of the United States Department of Agriculture, http://www.nal.usda.gov/ag98/)

66. Rubiolo deReinick, A. C. "Average and Center Temperature Vs. Time Evaluation for Freezing and Thawing Rectangular Foods." *Journal of Food Engineering* 30, no. 3/4 (1996): 299-311.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP368.J681, Guin Library Thawing file
Abstract: : Freezing and thawing of foods is often performed using air streams. The thermal response of rectangular foods in cooled air freezing units was modelled using the finite difference method with the heat transfer partial differential equations and equations for predicting effective heat capacities, enthalpies and thermal conductivity. Predictions made using the model of the central temp. of rectangular meat patties (used as a model food) for one- and two-dimensional heat transfer were compared with experimental results. Time taken to reach a specific temp. was generally longer than predicted times, although the difference was usually less than 10%; for most cases the difference was larger at lower temp. Differences in time taken to achieve the same average and central temp. were dependent on heat transfer rate, and could be up to 12% of the total freezing time. It is concluded that the implicit finite-difference method presented allowed prediction of freezing times in the range tested based on average temp.; the method could also be used for prediction of thawing times. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

67. Salvadori, V. O., and R. H. Mascheroni. "Prediction of Freezing and Thawing Times of Foods by Means of a Simplified Analytical Method." *Journal of Food Engineering* 13, no. 1 (1991): 67-78.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: An analytical method for the calculation of freezing and thawing times of foods of high water content was developed. This method is based on an equation relating the temp. at the thermal centre of the food to a dimensionless variable that takes into account the simultaneous influence of time, process parameters and also the thermophysical properties and size of the product. The method was developed for the most commonly found regular geometries (i.e. slab, infinite cylinder and sphere) and was compared with experimental freezing and thawing times corresponding to different types of meats (boneless beef, lean beef minced meat, mutton), fishes (cod, carp, sardine, mackerel fillets), mashed potatoes, Tylose and agar gel. The average error was plus/minus4.6%. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

68. ———. "Thawing Time Prediction for Simple Shaped Foods Using a Generalized Graphical Method." *International Journal of Refrigeration* 12, no. 4 (1989): 232-36.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TP490.R48, Guin Library Thawing file
Abstract: A graphical method is proposed for detn. of thawing times of foods with a high water content. It was developed from predictions of a numerical model [FSTA (1977) 9 3S398], which solves the heat balance for a food undergoing thawing. The

numerical model considers variation of thermophysical properties with temp. From the time-temp. graph for the thermal centre of the food, which coincides with the geometrical centre, thawing time can be calculated for any final temp. The method is valid for variously shaped foods (slabs, cylinders, spheres) and covers a wide range of working conditions encountered in industrial thawers. Thawing times predicted were compared with published experimental data, for tylose in slabs, spheres and cylinders, and for slabs of boneless beef, mackerel fillets, agar gel, sardines, cod and minced beef. Error in predicted values (results tabulated) averaged 6.5%. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

69. Sanders, H. R. "A Computer Programme for the Numerical Calculation of Heating and Cooling Processes in Blocks of Fish." *Advances in Fish Science and Technology*. Editor J. J. Connell, 263-72. Farnham, England: Fishing News Books Ltd., 1979.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley SH151.A3, Guin SH151.A3
Abstract: "In the design and evaluation of equipment for the thermal processing of food a knowledge of the temperature distribution in the material is required. The times when the whole mass of the material has passed a given temperature, and when the average temperature has reached a required value, must be established, particularly during thawing and freezing. Other quantities of interest include the instantaneous rate of energy transfer and the cumulative amount of energy transferred at any stage in the process. A means of calculating these parameters is required which, while not replacing experimental data, can be used to study the process. A number of methods varying in complexity have been devised for this purpose; they are classified by Hayakawa (1977). A method suitable for implementation on a minicomputer is in regular use at Torry Research Station and is described in this paper together with some of the results obtained thereby." (Author's Introduction)

70. ———. "Electrical Resistance Thawing of Fish."*Fifth International Congress on Electro-Heat*Paris: International Congress on Electro-heat, 1964.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: "Fish is an important source of the high-grade protein required for man's diet. As the quality of fish deteriorates rapidly at room temperature and still appreciably when stored in ice, ever increasing quantities are being frozen at some stage on the way to the consumer. By this means a product of good quality can be provided and seasonal fluctuations of supply can be evened out. Great care must however be taken during thawing to prevent deterioration at this stage. The requirements for a satisfactory thawing method are speed and avoidance of high temperatures. In the conventional methods air or water is used to transfer heat to the surface of the material, the remainder gaining its heat by conduction through the fish. As thawed fish is a poor conductor of heat, the two requirements are largely incompatible. In order to produce heat directly throughout the material, electrical resistance heating, where the fish forms part of the circuit, may be employed. In this process regularly shaped blocks of fish with even surfaces are place between

flat metal electrodes across which a controlled voltage is applied at mains frequency. The voltage is limited to avoid overheating the fish and to prevent instability. A number of layers can be thawed as they are separated by sheets of conducting material. As frozen fish has a very high electrical resistance at normal storage temperatures, it is necessary to pre-heat by some alternative method over the range of low electrical and high thermal conductivity. This is most conveniently done by immersion in or sprinkling with water. Herring and white fish, both whole and filleted, have heen thawed satisfactorily. The total processing time including water heating is about 30 m for herring, 45 mn for cod fillets and 3 h for blocks of whole cod. The electrical energy to be supplied ranges from 0.022 to 0.043 kWh/kg and represents from 30-52% of the total heat required for thawing. Thawing costs for whole herring are estimated at (English Pound) 1/7/-s/t for an 8 h daily operating period." (Author's summary)

71. Schwartzberg, H. G. "Effective Heat Capacities for the Freezing and Thawing of Food." *Journal of Food Science* 41 (1976): 152-56.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TX341.F6, Guin Library Thawing file
Abstract: Based on a modified form of the freezing point depression equation we have derived a set of rigorous, broadly applicable equations for effective heat capacity during the freezing and thawing of foods and biological materials. The equations have been integrated with respect to temperature, thereby providing a set of useful equations for enthalpy during freezing and thawing. The validity and utility of the equations are demonstrated using data from the literature. Methods for adjusting the equations to account for changes in water content and fat content are presented. The enthalpy equations are useful for calculating heat transfer loads during freezing and thawing, and the heat capacity equations can be advantageously used in differential equations for calculating freezing and thawing heat-transfer rates. (Author's abstract)

72. Sheen, S., and K. Hayakawa. "Finite Difference Analysis for the Freezing or Thawing of an Irregular Food With Volumetric Change."*Engineering and Food*, Editors W. E. L. Spiess, and H. Schubert, 426-41no. Vol. 2 title- Engineering and Food: Preservation Processes and Related Techniques . London: Elsevier , 1990.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries, Valley TP368.I574 1989, Guin Library Thawing file
Abstract: A mathematical model which includes the volumetric change for the food freezing or thawing time estimation and process simulation was developed by modifying the general heat conduction parabolic partial differential equation. Since the thermophysical properties of food are a strong function of temperature, this modified mathematical equation together with its third kind boundary condition (convective and radiative heat transfer at surface) were solved by a finite difference method for an irregular domain (two dimension). A generally applicable computer program was developed using numerical algorithms for solving the developed model. These algorithms are based on the application of an alternate direction implicit (ADI) finite difference-relaxation method coupled with a finite volume method applied to each surface node. The developed program was used to simulate

the freezing or thawing of samples of mushroom shape or spheroidal shape. Results show very good agreement with the experimental data in both cases. The influence of volumetric expansion on freezing time was examined using the developed program. (Author's abstract)

73. ———. "Parametric Analysis for Thawing Frozen Spheroidal (Prolate and Oblate) or Finitely Cylindrical Food." *Journal of Food Science* 57, no. 1 (1992): 236-40, 248.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TX341.F6, Guin TX341.F6
Abstract: A screening analysis was performed to determine influence of independent parameters (18) on thawing times of frozen spherical (prolate and oblate) and finitely cylindrical foods using a computerized simulation procedure assuming food vol. shrinkage from density changes and temp. dependent physical properties. Of 18 independent parameters, 6 were significant for both foods: thawing medium temp., initial f.p., Biot number, radiative heat exchange, a parameter for effective specific heat, and shape factor (nonsignificant influence of volumetric changes). Predictive regression equations were developed for estimating thawing time as function of significant parameters. Predictive equations were validated experimentally. A sensitivity analysis showed errors in thawing time were influenced most strongly by food dimensions, followed by operational temp., thermophysical properties and convective surface heat-transfer coeff. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

74. Skaar, G. R. , J. I. Gust, L. C. Gundlach, D. F. O'Briem, K. F. Fischer, and Oscar Meyer Foods Corporation, inventors. "Apparatus and Method for Defrosting Frozen Proteinaceous Food Blocks."USA Patent , US 5 401 520. 1995.
Keywords: Thawing/ Thawing methods
Abstract: A forced air defrost tunnel and a method for controlled defrosting of large quantities of bulk frozen foods (meat and fish) are described. The tunnel is supported and shaped by a stack (or train of stacks) of frozen proteinaceous food boxes or bundles that alternate with support spacer racks. An air containment device (preferably consisting primarily of a tarp) is closely secured over the tunnel. A supply of high pressure air at a temp. above that of the frozen food is forced through the defrost tunnel and flows through passages within the support spacer racks. The tunnel is suitable for defrosting pork, beef, lamb, chicken meat and turkey meat, as well as bacon bellies and fish. [From En summ.] (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

75. Srinivasan, S., Y. L. Xiong, and S. P. Blanchard. "Effects of Freezing and Thawing Methods and Storage Time on Thermal Properties of Freshwater Prawns (Macrobrachium Rosenbergii)." *Journal of the Science of Food and Agriculture* 75, no. 1 (1997): 37-44.
Keywords: Thawing/ Quality
Call Number: OSU Libraries-Valley S583.J6, Guin Library Thawing file
Abstract: Thermal stability of proteins in frozen and thawed freshwater prawns was

measured by differential scanning calorimetry. The onset and peak melting temperatures corresponding to myosin denaturation, as well as total enthalpy of denaturation of prawn muscle, decreased after freezing-thawing treatments. There were no significant differences in the thermal properties of prawns with changes in the rate of freezing, ie blast (fast) vs still (slow) freezing. However, the thermal properties were influenced by the rate of thawing. Rapid thawing using a combination of microwave and tap water resulted in a lower (P less than or equal to 0.05) thermal stability of prawn proteins compared to slow (refrigeration) or moderately fast (tap water) thawing methods. Keeping prawn shells intact or not intact during freezing-thawing did not alter the thermal properties of the prawn proteins. (Abstract provided by AGRICOLA, produced by the National Agricultural Library of the United States Department of Agriculture, http://www.nal.lusda.gov/ag98/)

76. Succar, J., and K. Hayakawa. "Empirical Formulae for Predicting Thermal Physical Properties of Food at Freezing or Defrosting Temperatures." *Lebensmittel-Wissenschaft Und Technologie* 16, no. 6 (1983): 326-31.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin Library Thawing file
Abstract: Empirical equations for the prediction of apparent specific heat, thermal conductivity and density during freezing or defrosting are developed by modifying or reapplying Schwartzberg's eauations. Through a nonlinear parameter estimation procedure on thermophysical properties available in the literature, constants appearing in these equations have been estimated for a wide variety of food products. Comparison to other published formulae shows that the proposed equations yield better correlation between experimental and predicted data. (Author's abstract)

77. Sweat, Vincent E., C. G. Haugh, and J. Stadelman. "Thermal Conductivity of Chicken Meat at Temperatures Between -75 and 20°C." *Journal of Food Science* 38 (1973): 158-60.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries - Guin TX341 .F6
Abstract: Thermal property data for foods, particularly at temperatures below freezing, is often not available...Th eobjectivs of this study were to determine the effect of time postmortem and temperature on the thermal conductivuty of white and dark chicken meat. ...Thermal conductivity probes having a diameter of 0.032 in. and a probe length-to-diameter ratio of 47 are suitable for measuring the thermal conductivity of meats similar to those tested in the present study for temperatures as low as -75° C. (Indexer abstract.)

78. Tanaka, T., T. Nagasake, and K. Takahashi. "Thawing of Frozen Dressed Tuna by Microwave Heating." *Transactions of the Japanese Association of Refrigeration* 1, no. 2 (1984a): 171-74.
Keywords: Thawing/ Quality
Call Number: OSU LIBRARIES-Guin Library Thawing file
Abstract: "Large sized frozen yellowfin tuna and Southern bluefin tuna in dressed

form (decapitated and gutted) were thawed by microwave (915 Mhertz) irradiation. Both frozen tunas were thawed fairly well within as short time as 30 min without any partial overheating. No changes in metmyoglobin ratio, freshness and taste component values were observed in the cases of yellowfin tuna. slight discolouration, however, occurred in Southern bluefin tuna meat during microwave thawing." (Author abstract)

79. Tanaka.T., T. Nagasake, and K. Takahashi. "Thawing of Frozen Tuna Meat. Aspect of Meat Colour and Contraction."1, no. 2 (1984b): 183-94.
Keywords: Thawing/ Quality
Notes: Second request ILL 1/23/03
Abstract: "Frozen southern bluefin tuna meat discolours easily and sometimes contracts when thawed caused by thaw rigor. Blocks of Southern bluefin tuna were thawed separately by air thawing, running water thawing and microwave thawing. Discolouration scarcely occurred in the process of running water thawing at 283 K (10 deg C) for 50 min, or at 273 K (0 deg C) for 6 hr. No contraction was observed during thawing with running water and air thawing at 291-293 K (18-20 deg C) for 6 hr. Discolouration and contraction seemed to be minimized, as for latently contractile blocks, when meat temperature passed through rapidly between 263 and 268 K (-10 and -5 deg C), and slowly (for 5-6 hr) between 268 and 272 K (-5 and -1 deg C). " (Author abstract)

80. Taoukis, P., E. A. Davis, H. T. Davis, J. Gordon, and Y. Talmon. "Mathematical Modeling of Microwave Thawing by the Modified Isotherm Migration Method." *Journal of Food Science* 52, no. 2 (1987): 455-63.
Keywords: Thawing/ Calculation of thawing times
Call Number: OSU Libraries-Valley TX341.F6, Guin TX341.F6
Abstract: "A mathematical model of microwave thawing of homogeneous food products is developed and solved numerically using the Modified Isotherm Migration Method. The model is used to predict thawing time and temperature profiles for microwave thawed meat cylinders at three frequencies (2450 MHz, 915 MHz, 300 MHz) and different power levels. Model and experimental results for thawing a lean beef cylinder heated at low microwave power using 2450 MHz frequency compare well. The advantage of using 915 or 300 MHz power over 2450 MHz power is shown by calculations. The results show that microwaves significantly accelerate the thawing rate. The mathematical model is explored as a tool for designing optimal microwave/convective heating protocols for rapidly thawing foods in desired temperature ranges." (Author's abstract)

81. Veerkamp, C. H. "Engineering Parameters for Freezing and Thawing Equipment." *Thermal Processing and Quality of Foods.* Editor P. et al. Zeuthen, 802-6. London: Elsevier Applied Science Publications, 1984.
Keywords: Thawing/ General introduction
Call Number: OSU Libraries-Valley TP371.2.T51, Guin Library Thawing file
Abstract: "The selection of the method for freezing and the optimization of the design of the equipment are nowadays the result of tradition and experience of the food manufacturer and the equipment company. The parameters used in these

procedures are analyzed. The main parameters are the state of the product, the capacity, quality changes, processing time and capital and operating costs. The specification of the product and related quality variables do not generally present a problem. The thermal properties can be calculated or measured. The methods for calculating the processing time numerical or based on an empirical analytical method are accurate within 10%. Little is known about the influences of the various parameters related to the capital and operating cost of freezing and thawing methods. Selection and optimization of procedures for freezing and thawing processes should be developed." (Author's abstract)

82. Virtanen, A. J., D. L. Goedeken, and C. H. Tong. "Microwave Assisted Thawing of Model Frozen Foods Using Feed-Back Temperature Control and Surface Cooling." *Journal of Food Science* 62, no. 1 (1997): 150-154.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries-Valley TX341.F6, Guin TX341.F6
Abstract: An apparatus was developed that combined microwave energy and cold air with different ambient temp. to reduce thawing time and avoid run-away heating during microwave assisted thawing. Effects of microwave power level, sample thickness and surface air temp. on thawing time were investigated. The microwave power was cycled on and off using 2 temp. control schemes to maintain a predetermined temp. gradient based on hot and cold points. Thawing time was reduced by as much as a factor of 7 compared to convective thawing at ambient temp. when appropriate conditions were used. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

83. Zhao, Y., R. A. Flores, and D. G. Olsen. "High Hydrostatic Pressure Effects on Rapid Thawing of Frozen Beef." *Journal of Food Science* 63, no. 2 (1998): 272-75.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries-Valley TX341.F6, Guin TX341.F6
Abstract: :Effect of application of high hydrostatic pressure (HHP) during thawing of frozen beef was investigated by measuring temp. changes in frozen beef and the pressurization fluid. Frozen ground beef [beef mince] sample variables were pressure levels (140, 210, 280 and 350 MPa), times (5, 15 and 30 min), sample diam. (55, 65 and 80mM), and initial temp. (-7, -11, -18 and -22 degree C). Properties of cooked patties were compared between beef thawed using HHP and using conventional thawing (atmospheric pressure at 3 degree C). Pressures of 210-280 MPa provided a critical processing range that effectively thawed the beef. Sample size and initial temp. did not affect thawing rate. The lowest temp. at which the beef was efficiently thawed was 24 plus/minus 2 degree C. HHP treated beef thawed much faster than controls. HHP thawing resulted in similar colour and texture to controls. (Abstract provided by Food Science and Technology Abstacts, IFIS Publishing, 1969-2002. All rights reserved.)

84. Zhao, Y., E. Kolbe, and B. Flugstad. "A Method to Characterize Electrode Corrosion During Ohmic Heating." *Journal of Food Process Engineering.* 22 (1999): 81-89.
Keywords: Thawing/ Alternative thawing methods
Call Number: OSU Libraries - Valley TP368 .J66

Abstract: A method was developed to characterize visual electrode corrosion during ohmic heating of a model system. Stainless steel 304 electrode were energized in a 2% salt solution at room temperature of 24±1C for 10 min. The effects of Alternating Current (AC) electrical frequency and current density were examined in a frequency range of 55 to 5000 Hz and current density range of 1200 to 3500 A/m^2. The ratio of colorimeter values of lightness (L)/yellowness (b) was used to quantify the degree of visual corrosion. Corrosion was most serious at low AC electrical frequencies values above 5000 Hz, corrosion reduced dramatically even as current densisty was in creased to 3500 A/m^2 and heating time extended to 1-1/2 hr.