JMBFS
Journal of Microbiology, Biotechnology and Food Sciences
International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

THERMOPHYSICAL PROPERTIES AND WATER ACTIVITY OF TRANSFERRED CHEESE (UF)

*Mohsen Dalvi Esfahan**[1], *Yasamin Jahangiri*[2], *Mehdi Kaviani*[2], *Lukáš Hleba*[4], *Mohammad Ali Shariati*[3]

Address(es):
[1]Department of Food Science, College of Agriculture, Isfahan University of Technology, Iran.
[2]Department of Food Science and Technology, Ferdowsi university of Mashhad, Mashhad, Iran.
[3]Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[4]Department of Microbiology, Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture in Nitra, Slovakia.

*Corresponding author: mohsen.dalvi@gmail.com

doi: 10.15414/jmbfs.2015.4.6.550-553

ARTICLE INFO

Received 18. 3. 2015
Revised 7. 4. 2015
Accepted 16. 4. 2015
Published 1. 6. 2015

Regular article

OPEN ACCESS

ABSTRACT

Few data are available on the thermophysical properties of cheese in the ripening process.The main objective of this work was to investigate the effects of brining and temperature on the thermophysical properties, i.e., thermal conductivity, specific heat, density and water activity of UF cheese and finally we measure surface heat transfer coefficient .Then we develop models for thermophysical properties based on physical and multiple regression concept .

Keywords: UF cheese, thermophysical properties, modeling

INTRODUCTION

In fact, a very little data concerning thermophysical properties of cheese have been published in the literature. And extensive literature search revealed that there is no data were available for UF cheese but In Iran, white brined cheese is a major item in the diet and the consumption per capita per annum is about 5.4 kg and UF cheese Provide main part of it The knowledge of the thermophysical properties of cheese are necessary for the simulation of heat and mass transfer phenomena and the prediction of temperature profiles .Temperature profiles during the ripening stage is one of the most important operating parameters governing the final organoleptic and textural properties of cheese, because associated with water and NaCl concentration profiles, they govern mainly the fermentation activity during the manufacturing process**(Pajonk *et al*, 2003).** Thermophysical properties of matter can be divided in two categorize: 1) Transport properties: thermal conductivity, kinematic viscosity and diffusion coefficient , 2) Thermodynamic properties, relating to equilibrium state of a system, such as density, and specific heat **.** Thermal conductivity is measured in 3 categorize techniques(steady state ,quasi-steady state , transient state) and each technique have different method **(Rahman,1995)** but the most popular techniques is transient because they are fast ,cheap ,and reliable. This techniques have two different method 1) line-source, like thermal probe and hot wire 2) pulse (or flash) theory **(Urbicain and Lozano, 1997).** thermal conductivity of some cheese with using modified hot wire method was reported by Tavman and Tavman **(Tavman and Tavman, 1999).** Specific heat measurements can be done by the method of mixture, comparison.Method, adiabatic method and differential scanning calorimetry (DSC). The temperature of the sample in DSC cell increased at a constant heating rate and heat flow rate in to the sample of known mass is measured and specific heat of the sample is determined according the following equation **(Rahman, 1995)**

$$C_{sa} = \frac{d_{sa}}{d_{re}} \frac{W_{re}}{W_{sa}} C_{re}$$

Where d_{sa} and d_{re} are the deflection from the base line of thermogram for sample and reference respectively (mW) , W_{sa} and W_{re} are the mass of sample and reference and sample respectively (kg) and C_{sa} and C_{re} are the specific heats of sample and reference respectively (kJ/ kg °C) A precise knowledge of the Water activity is essential for the control of the ripening process as for the control of the final organoleptic properties and the safety standards of Cheese **(Carson *et al*, 2006).**

Surface heat transfer coefficient

Methods for measurements of heat transfer coefficients within convection ovens have been reviewed by **Carson *et al*.(2006)**. Surface heat transfer coefficient can be predicted with transient temperature measurement or lumped capacitance method, which can be used for solids within Experimental

Dairy product samples

UF cheeses were supplied by PEGAH Dairy product inc., Isfahan, Iran before and after the brining treatment and kept refrigerated at 4°C until tested . The composition of cheeses tested is given in Table 1, as percent by weight. Fat content of the samples was determined by Gerber's method and water content with the oven method. The Kjeldahl method was used for protein determination. For ash content, the sample was first dried in an oven at 105 °C before being transferred to a muffle furnace at 550°C, until a white or light gray ash resulted and then volhard method was used for determination of NaCl content**(A.O.A.C , 1996).**

Table 1 Composition of UF cheese (%by weight)[a]

Cheese	Water	Fat	Protein	Ash	Carbohydrate*	salt
Salted	63.41 (0.31)	17.07 (0.10)	11.12 (0.049)	3.89 (0.11)	4.51	3.14 (0.216)
Non-salted	67.11 (0.061)	17.125 (0.176)	11.16 (0.049)	1.47 (0.11)	3.135	0.27 (0.11)

* Carbohydrate content was calculated as 100% (moisture%+fat%+protein%+ash%).
[a] Values given in parenthes is represent standard deviations.

Thermal conductivity

Thermal conductivity measurement

Thermal conductivity of cheese samples was measured by the transient method using a thermal conductivity probe described by sweat **(Sweat , 1986).** This is based on a linear heat source of infinite length and infinitesimal diameter. It essentially consisted of a thermocouple with a constantan heater wire running along its length, which is the heat source and a thermocouple (type K) as the temperature recorder. The entire assembly was then enclosed in a 21 gage stainless steel tubing 4.6 cm long and 1 mm outer diameter. Each wire being carefully insulated with an epoxy resin. The heater wire and thermocouple wires were insulated from each other and from the hypodermic tubing. Aversion of the thermal conductivity measurement system developed by **McGinnis.(1987)** was used to supply power, measure current and record temperatures and voltage (Figure 1). The probe was inserted longitudinally into sample. In this experiment, the probe with cheese sample was packed in a polyethylene bag and assumed to have negligible contact resistance. The sample was equilibrated to the desired temperature by a Programmable Incubator. The accuracy of the current measurement in the heater circuit was $\pm$0.1 mA.The temperature-time and voltage-time data were continuously collected by a digital recorder (Delta-T Devices Ltd, Cambridge, England) which was bi-directionally interfaced with a PC so measurement could be programmed on a computer. The record of voltage was used to find the initial time of the heating. The slope of the linear portion of the plot of the temperature vs. ln (time) is equal to Q/ ($4\lambda\pi$). Thus, thermal conductivity of the sample was calculated by using the following equation:

$$\lambda = \frac{Q}{4\pi S}$$ **(Pajonk et al, 2003)**

where Q is calculated by:

$$Q=I^2R$$

Before measuring the samples, the probe was calibrated with 0.5% agar gel and glycerin at selected temperatures between 5°C and 25°C. This calibration permitted to determine the heater wire resistance (R=185.2 Ωm^{-1}) which is used in the heater power calculation. Data for thermal conductivity measurement of cheeses was collected at 1 s intervals for over 20 s and to obtain satisfactory linearity of temperature vs ln(time) plot, the procedure was standardized by (1) choice of a power level to increase the temperature up to 10 °C (initial temperature basis), (2) using a duration of 10 s, and (3) accepting thermal conductivity values measured only when r^2>0.98 **(Hamdami *et al*, 2003)**. The comparison thermal conductivity between salted and non-salted cheese, are given in Fig.2 The UF cheese thermal conductivity were determined at different temperatures between 1°C and10 °C which correspond usually to the temperature range encountered during the industrial ripening process.

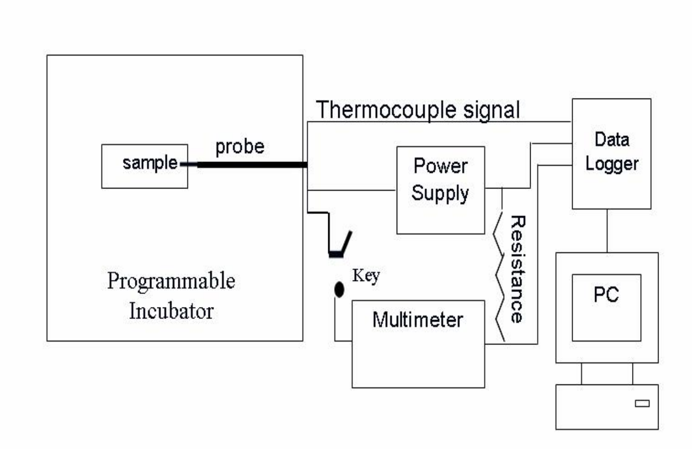

Figure 1 Set-up of the thermal conductivity measurement system.

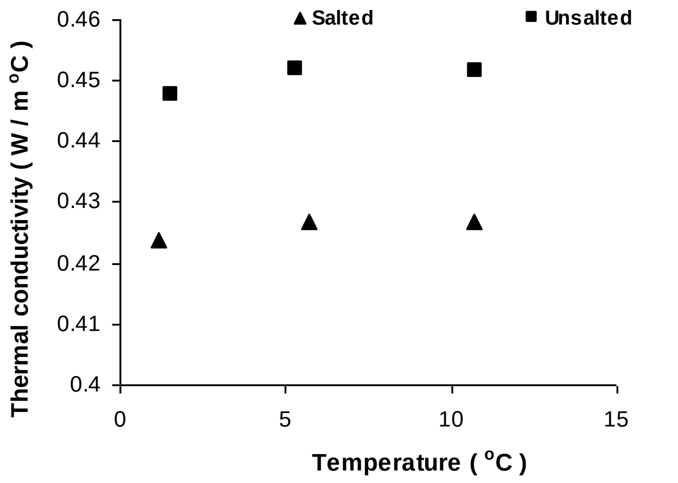

Figure 2 Thermal conductivity of salted and non-salted UF chees

Thermal conductivity model

In this study we Developed model based on composition and structure of UF cheese in three stages for predicting thermal conductivity of cheese as a function of composition and temperature .In addition, several theoretical thermal conductivity models such as serie , parallel ,modified maxwell and Krischer's (Krischer's model parameters were estimated by fitting the model to experimental ones) were evaluated and their predictive ability was compared with experimental values. In the first step we considered ,Without protein, the cheese was represented as a two-phase material, which consisted of a fat dispersed in a continuous phase and component of this phase are water, ash, carbohydrate. The thermal conductivity of this continuous phase was modelled with the parallel model by using the intrinsic thermal conductivity values of each main component and their volume fractions estimated from their weight fraction and their density. Then based upon Modified Maxwell model (second step), two phases were considered: (1) continuous solid phase, (2) discontinuous fat phase. and eventually(third step) we modelled protein and continuous phase (water-ash-carbohydrate-fat) with parallel model (parallel correction) (Figure 3) **(Hamdami *et al*, 2003; Cogne *et al*, 2003).**

Specific heat

DSC (Mettler TA 4000 SYSTEM) has been used to measure specific heat of cheese. Nitrogen gas was continuously flushed through the cell to eliminate problems associated with water condensation. The instrument was calibrated for specific heat capacity (Cp) with sapphire as standard reference. The reference value for cp was obtained from the manufacturer. Samples (3-5 mg) was weighed and hermetically closed in aluminum pans. An identical empty aluminum pan, used as a reference, was exposed to the same temperature rate increase of 2°C/min for all the experimental runs with samples **(Hamdami et al, 2004)**. The specific heat of a cheese at temperatures above its initial freezing point, can be obtained from the mass average of the specific heats of the cheese components.This model give a more generalized equation for specific heat which takes into account the composition of the solid **(Urbicain and Lozano1997).**

$$Cp = \sum_{i}^{N} Cp_j w_j$$ **(Rahman, 1995)**

where the subscript i represents the major components (lipid, protein, carbohydrate, water and ash), w_i their mass fraction, Cp_i their intrinsic specific heat values as published by **Choi and Okos.(1986)** Figure 4 show the typical curves of apparent specific heat of cheese and comparison with model as a function of temperature.

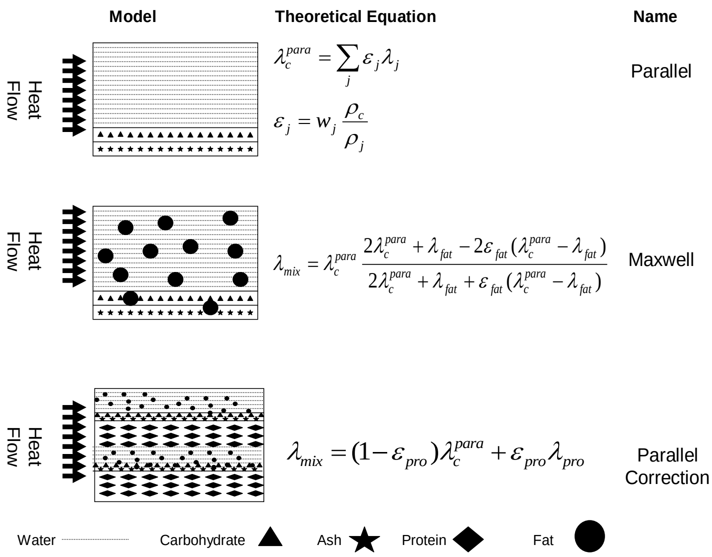

Figure 3 Thermal conductivity model.

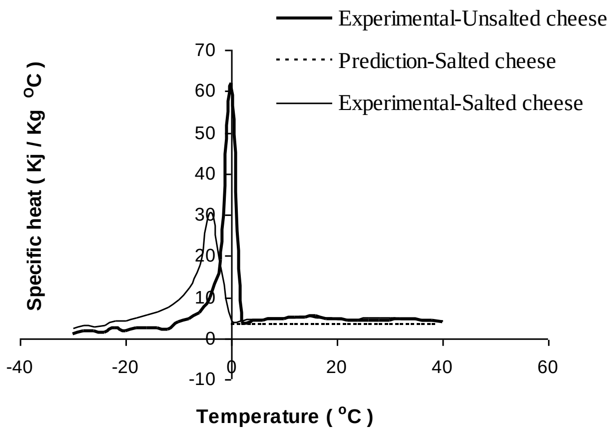

Figure 4 Specific heat values obtained from the DSC and comparison with model

RESULTS AND DISCUSSION

Composition of salted and non-salted UF cheese are listed in Table 1 this values obtain in three replicates . Their moisture content is usually higher and the fat content is lower than those of cheese made by traditional techniques due to the high water holding capacity of whey proteins retained in UF cheeses and for this reason thermal properties are greatly affected **(Erdem, 2005).**

Thermal conductivity

The thermal conductivity of cheeses with different NaCl content (salted & unsalted) increased with increasing temperature (Figure 2). The thermal conductivity values of salted cheese were slightly less than that of the thermal conductivity of unsalted cheese because the difference in osmotic pressure between brine and cheese causes some moisture to be expelled with its dissolved components, including whey proteins, lactic acid and minerals, in exchange for NaCl in the other words the unsalted cheese have higher moisture content and since higher thermal conductivity .

Thermal conductivity model

As described in a experimental method , the thermal conductivity was modelled model in 3 step .Figure5 shows the comparison between the experimental and predicted effective thermal conductivity values with different model but parallel correction models were able to predict very precisely the experimental data obtained with the probe method at different temperatures .

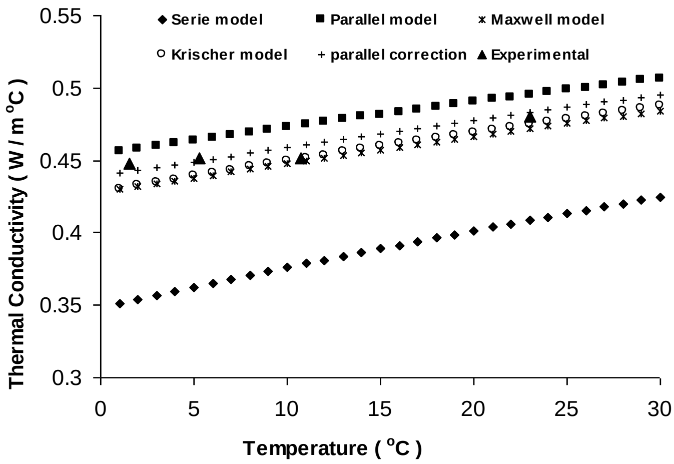

Figure 5 Experimental and predicted thermal conductivity values

Specific heat

As can be seen,in the Figure 4. the predicted specific heat values of cheese by model are not in good agreement with the experimental values in all case and experimental values had fluctuation above 0°C and significantly higher than the values estimated from the model this variation being related to the melting enthalpy of the different fat components between 15 and 30 °C but in the model didnt considered fat latent heat of fusion This problem was observed when pajonk and etal measured specific heat of emmental cheese in the tmperatures varying from 0°C to 40°C.(2) The experimental data on thermal properties are compared with the values calculated from model in Table. 3. (parallel correction for thermal conductivity and values calculated from Choi and Okos correlations for specific heat prediction).

Table2 Thermal conductivity and specific heat of experimental and predicted data for different temperature

Sample	λ (W/ m °C)				Cp (kJ/ kg °C)	
	T = 1 °C	T = 5 °C	T = 10 °C	T = 23 °C	T = 2 °C	T = 40 °C
cheese	0.4475	0.4517	0.4517	0.4801	3.871	4.005
Model	0.4408	0.4488	0.4587	0.4829	3.433	3.452

CONCLUSION

Physical models and empirical equations have been compared to experimental data to predict the thermal properties of industrial UF cheese with or without salt. the effective thermal conductivity of a UF cheese at selected temperatures and water contents was measured by a line-source heat probe . The principal results are the following: thermal conductivity increases with temperature, and water content . The models based on parallel correction have shown a quite good accuracy for correlating the effective thermal conductivity data as a function of temperature.

Acknowledgement: This work was funded by European Community under project no 26220220180: Building Research Centre „AgroBioTech".

REFERENCES

A.O.A.C. (1996). Official methods of analysis of AOAC international. P. Cunniff. Maryland, AOAC International.

CARSON, J. K., WILLIX,J., NORTH,M.F. (2006). Measurements of heat transfer coefficients within convection ovens. *Journal of Food Engineering*, 72, 293-301. http://dx.doi.org/10.1016/j.jfoodeng.2004.12.010

COGNE, C., ANDRIEU, J., LAURENT, P., BESSON,A.,NOCQUET,J. (2003). Experimental data and modelling of thermal properties of ice creams. *Journal of Food Engineering*, 58, 331-341. http://dx.doi.org/10.1016/s0260-8774(02)00396-5.

ERDEM, Y. K. (2005). Effect of ultrafiltration, fat reduction and salting on textural properties of white brined cheese. *Journal of Food Engineering*, 71, 366-372. http://dx.doi.org/10.1016/j.jfoodeng.2004.10.040

HAMDAMI, N., MONTEAU,J., BAIL,A (2003). "Effective thermal conductivity of a high porosity model food at above and sub-freezing temperatures. *International Journal of Refrigeration*, 26, 809-816. http://dx.doi.org/10.1016/s0140-7007(03)00051-3

HAMDAMI, N., MONTEAU, J, Y., .(2004). "Thermophysical properties evolution of French partly baked bread during freezing." Food Research International 37(7): 703-713. http://dx.doi.org/10.1016/j.foodres.2004.02.017.

HERTOG,M., NICOLI,B.M., CRC Press:Boca Rayton. http://dx.doi.org/10.1533/9781855736375.1.60

MCGINNIS, D. (1987). Automated line-heat source system for the measurement of thermal conductivity and diffusivity. *Can Agric Eng*, 29:201-207. http://dx.doi.org/10.1016/s0315-5463(86)71599-x

PAJONK, A. S., SAUREL,R.,ANDRIEU,J., LAURENT,P.,BLANC,D. (2003). Heat transfer study and modeling during Emmental ripening.*Journal of Food Engineering*, 57,249-255. http://dx.doi.org/10.1016/s0260-8774(02)00305-9

RAHMAN, M. S. (1995). Food properties handbook, CRC Press:Boca Raton.

SAUREL, R., PAJONK, A., ANDRIEU, J. (2004). Modelling of French Emmental cheese water activity during salting and ripening periods. *Journal of Food Engineering*, 63(2), 163-170. http://dx.doi.org/10.1016/s0260-8774(03)00295-4

SWEAT, V. E. (1986). Thermal Properties of Foods. Engineering Properties of Foods. M. A. Rao, Rizvi,S.S.H., New York: Marcel Dekker.

TABIL, L. G. Specific Heat of Agriculturral and Food Materials. Agricultural and Bioresource Engineering. Saskatoon, University of Saskatchewan: 29. http://dx.doi.org/10.7451/cbe.2013.55.3.19.

TAVMAN, I. H., TAVMAN,S. (1999). Measurement of thermal conductivity of dairy products. *Journal of Food Engineering*, 41, 109-114. http://dx.doi.org/10.1016/s0260-8774(99)00079-5

URBICAN, M. J., LOZANO,J.E. (1997). Thermal and Rheological Properties of Foodstuffs. Handbook of Food Engineering Practice. K. J. Valentas, Rotstein,E.,Singh .R.P. New York, CRC Press : Boca Raton : 736. http://dx.doi.org/10.1201/9781420049077.ch11