Isothermal Calorimetry for Food Science - References and Research Papers

Instruments to which this note applies: Biocal 2000, Biocal 4000

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Target use: Research, Development and Innovation in Food Science and other Life Sciences. Process Control in Food processing and technology

Introduction

Isothermal calorimetry is an effective method to follow processes in living materials like fresh vegetables, products under fermentation or foodstuffs being spoiled by microbial activity. This Application Notes contains a collection of papers from the scientific literature in which isothermal calorimetry has been used to study life processes in foodstuffs. This is a non-exhaustive list, but there are quite a lot more studies of food biology made with isothermal calorimetry.

The term "isothermal calorimetry" is used for the measurement of thermal power and heat at constant temperature. Other terms for this type of measurements are "microcalorimetry" (indicating that measurements are made at the μW-level, but not necessarily at isothermal conditions), (heat) conduction calorimetry (indicating how these instruments work), and "isoperibol calorimetry" (a somewhat confusing term).

Note that isothermal calorimetry is in most cases distinctly different from the more common differential scanning calorimetry (DSC), which monitors thermal events caused by the change in temperature. Isothermal calorimeters are used to study processes that take place at constant temperature, such as the biological processes discussed in this literature review. They usually have a better temperature stability, are suitable for much larger samples, and have much higher specific sensitivity than DSC instruments run in the isothermal mode. Isothermal calorimetry and DSC are complementary techniques in the food laboratory. This is exemplified in the following mainly non-biological food calorimetry references:

Le Parlouër, P. and L. Benoist, Methods and applications of microcalorimetry in food, in Calorimetry in food processing, G. Kaletunc, Editor 2009, Wiley-Blackwell: Ames, Iowa, USA. p. 15-49.

Gaisford, S., M. O'Neill, and A. Beezer, Shelf life prediction of complex food systems by quantitative interpretation if isothermal calorimetric data, in Calorimetry in food processing, G. Kaletunc, Editor 2009, Wiley-Blackwell: Ames, Iowa, USA. p. 237-263.

General references

Wadsö, L. and F. Gómez Galindo, Isothermal calorimetry for biological applications in food science and technology. Food Control, 20 (2009) 956-961.

This paper discusses isothermal calorimetry and gives examples of its use to study vegetable respiration, fermentation and shelf life issues.

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Respiration

Gómez, F., et al., Isothermal calorimetry approach to evaluate tissue damage in carrot slices upon thermal processing. J. Food Eng., 65 (2004) 165-173.

Gómez Galindo, F., et al., The potential of isothermal calorimetry in monitoring and predicting quality changes during processing and storage of minimally processes fruits and vegetables. Trends Food Sci. Technol., 16 (2005) 325-331.

Gómez Galindo, F., R. Toledo, and I. Sjöholm, Tissue damage in heated carrot slices. Comparing mild hot water blanching and infrared heating. J. Food Eng., 67 (2005).

Gómez Galindo, F., et al., Exploring metabolic responses of potato tissue induced by electric pulses. Food Biophysics, 3 (2008) 352-360.

Peredes Escobar, M., et al., Effect of long-term storage and blanching pre-treatments on the osmotic dehydration kinetics of carrots (Daucus carota L. cv. Nerac). J. Food Eng., 81 (2007) 313-317.

Rocculi, P., et al., The potential role of isothermal calorimetry in studies of the stability of fresh-cut fruits. LWT - Food Sci. Technol., 49 (2012) 320-323.

Rocculi, P., et al., Effects of the application of anti-browning substances on the metabolic activity and sugar composition of fresh-cut potatoes. Postharvest Biol. Technol., 43 (2007) 151-157.

Panarese, V., et al., Isothermal and differential scanning calorimetries to evaluate structural and metabolic alterations of osmo-dehydrated kiwifruit as a function of ripening stage. Innovative Food Sci. Emerging Technol., 15 (2012) 66-71.

Gómez, Wadsö and co-workers have made several studies in which they use isothermal calorimetry to quantify activity changes in vegetables being exposed to different unit operations in the food industry. Generally, the aim of these studies has been to find indications of conditions that would cause minimal damage to the tissue and thus a processed product that keeps as much of its original texture, flavor etc. as possible.

Tortoe, C., et al., Potential of calorimetry to study osmotic dehydration of food materials. J. Food Eng., 78 (2007).

This paper shows that isothermal calorimetry can be used to divide the osmotic dehydration of fruits or vegetable into different parts; however, the authors do not interpret the observed thermal power regimes in terms of biologically produced heat, but only discuss it in physical terms.

Fermentation and yeast studies

Dubrunfaut, M., Note sur la chaleur at le travail méchanique produits par la fermentation vineuse. C. R. Hebdomadaires Seances Acad., 42 (1856) 945-948.

This is the first study of the heat production from a fermentation process, but it was not made in a calorimeter; instead the heat balance of a whole fermentation vat was assessed.

Calvet, E. and H. Prat, Recent progress in microcalorimetry (1963) Oxford: Pergamon Press.

An example of the result from a one day study of beer fermentation is given in this interesting book with examples of microcalorimetric measurements in many fields.

Riva, M., et al., Growth and fermentation activity of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* in milk: a calorimetric investigation. Annali di Microbiologia ed Enzimologia, 47 (1997) 199-211 (paper is in English).

The cultures were injected into the milk and a pH-meter placed in the vial enabled simultaneous determinations of thermal power and pH. The study confirmed the cooperative action of a mixed yogurt culture.

Riva, M., et al., Calorimetric characterization of different yeast strains in doughs. J Thermal Anal, 52 (1998) 753-764.

The growth of three yeast strains in a dough system was investigated by calorimetry and other methods, for example image analysis, to determine the volume expansion. Significant differences were found between the three strains.

Schäffer, B., et al., Examinatio of growth of probiotic microbes by isoperibolic calorimetry. J. Thermal Anal. Calorim., 102 (2010) 9-12.

Schäffer, B., S. Szakály, and D. Lorinczy, Examination of the growth of probiotic culture combinations by the isoperibolic batch calorimetry. Thermochim Acta, 415 (2004) 123-126.

Two papers that show calorimetric thermal power curves for different probiotic bacterial cultures in milk.

Seratlić, S., et al., Behavior of the surviving population of Lactobacillus plantarum 564 upon the application of pulsed electric fields. . Innovative Food Sci. Emerging Technol., 17 (2013) 93-98.

This study shows that, although a pulsed electric field (PEF) treatment inactivates the majority of the bacteria, the remaining bacterial population showed higher resistance to further PEF treatment

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Kabanova, N., I. Stulova, and R. Vilu, Microcalorimetric study of growth of Lactococcus lactis IL1403 at low glucose concentration in liquids and solid agar gels. Thermochim. Acta, 559 (2013) 69-75.

Calorimetric measurements of microbial growth at different glucose concentrations and different inoculation densities made it possible to construct a multistage growth model.

Kabanova, N., I. Stulova, and R. Vilu, Microcalorimetric study of the growth of bacterial colonies of Lactococcus lactis IL1403 in agar gels. Food Microbiol., 29 (2012) 67-79.

An interesting study where the difference in colony morphology and colony size is seen both in calorimetric and microscopy results.

Kazarjan, A., N. Kabanova, and R. Vilu, Microcalorimetric study of extruded dog food containing probiotic organisms. Adv. Microbiol., 2 (2012) 436-440.

Isothermal calorimetry is shown to be a method to check the activity of probiotic organisms under low pH (stomach conditions) in a dried foodstuff.

Stulova, I., et al., Fermentation of reconstituted milk by Streptococcus thermophilus: Effect of irradiation on skim milk powder. Int. Dairy J., 31 (2013) 139-149.

Isothermal calorimetry is well suited to assess differences between the growth kinetics of different systems; here between two different substrates: reconstituted milk from irradiated and non-irradiated skim milk powder.

Shelf life, predictive microbiology and spoilage

Sacks, L.E. and E. Menefee, Thermal detection of spoilage in canned foods. J Food Sci, 37 (1972) 928-931.

The first mentioning of the possibility of detecting microbial activity (and possibly also other types of processes) with calorimetry in sealed packages without opening them. In this case the temperature increase of the canned food was monitored.

Lampi, R.A., et al., Radiometry and microcalorimetry - techniques for the rapid detection of foodborne micro-organisms. Food Technology, (1974) 52-58.

The authors show that it is possible to detect microbial growth in soy broth after only a few hours. Higher inoculation levels gave shorter detection time.

Gram, L. and H. Sögaard, Microcalorimetry as a rapid method for estimation of bacterial levels in ground meat. J. Food Protect., 48 (1985) 341-345.

A fundamental study in which ground meat was inoculated with different concentrations of bacteria. The resulting thermal power profiles corresponded well with the inoculation densities.

Nunomura, K., K. Ki-Sook, and T. Fujita, Calorimetric studies of microbial activities in relation to water content of food. J. Gen. Appl. Microbiol., 32 (1986) 361-365.

The authors used isothermal calorimetry to show that the growth of both a mold fungus and a bacterium were dependent on the water content of skim milk powder.

Iversen, E., E. Wilhelmsen, and R.S. Criddle, Calorimetric examination of cut fresh pineapple metabolism. J. Food Sci., 54 (1989) 1246-1249.

Isothermal calorimetry was found to be a good method to detect microbial activity in cut pineapple. The effect of a preservative at different concentrations was also tested and it was easy to see which preservative levels that caused an inhibition of the microbial activity.

Riva, M., D. Fessas, and A. Schiraldi, Isothermal calorimetry approach to evaluate shelf life of foods. Thermochim. Acta, 370 (2001) 73-81.

Calorimetric measurements were made on three food systems (eggs, milk and a salad) at different (constant) temperatures. The time of an increase in the measured thermal power – indicating the onset of degradation processes – correlated well with other measures used to determine shelf-life.

Alklint, C., L. Wadsö, and I. Sjöholm, Effects of modified atmosphere on shelf-life of carrot juice. Food Control, 15 (2004) 131-137.

Alklint, C., L. Wadsö, and I. Sjöholm, Accelerated storage and isothermal microcalorimetry as methods of predicting carrot juice shelf-life. J. Sci. Food Agric., 85 (2005) 281-285.

In these two papers the microbiological spoilage of carrot juice is investigated. Carrot juice is an interesting spoilage model as it has a short shelf life because of its non-acidic nature and its high content of soil microorganisms.

Seed germination

Calvet, E. and H. Prat, Recent progress in microcalorimetry (1963) Oxford: Pergamon Press.

In the third part of the English translation of this interesting book Prat describes several measurements on germinating seeds, for example the influence of temperature of the germination of wheat grain (several references to Prat's original work are given).

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Dymek, K., et al., Effekt of pulsed electric field on the germination of barley seeds. LWT - Food Sci. Technol., 47 (2012) 161-166.

Exposure of germinating barley to a pulsed electric field treatment affects radicle emergence without significantly affecting the seeds' metabolic activity, as quantified by isothermal calorimetry.

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