

Wolfram Demonstrations: Free Interactive Software for Food Engineering Education and Practice

Mark D. Normand · Uri Lesmes ·
Maria G. Corradini · Micha Peleg

Received: 4 March 2010 / Accepted: 9 March 2010 / Published online: 30 March 2010
© Springer Science+Business Media, LLC 2010

Abstract The Wolfram Demonstrations Project on the web offers a freely downloadable interactive program, ‘Mathematica Player’, which can be used to view and manipulate about six thousands Demonstrations to date. They have been contributed by professionals and amateurs from around the world and include many that elucidate scientific and engineering principles through graphical displays. Some can also be used to do actual engineering calculations, and of these, about forty have been developed specifically for food and food engineering applications. The Project’s Demonstrations are all esthetically attractive, give brief written explanations of the displays and provide short descriptions of the theory behind them. Each also gives typical or representative examples, which are shown with their corresponding parameter settings. Once a Demonstration is downloaded, the user can enter and modify the display parameters using sliders on the screen and watch the effect almost instantaneously. This makes the Demonstrations a powerful teaching and learning tool and an effective aid to professionals in routine engineering calculations. In this review, the food-related Demonstrations are briefly described and their potential role in Food Engineering education and practice is assessed.

Keywords Unit operations · Mass balance · Heat transfer · Particulates · Flow · Microbial growth · Microbial inactivation · Risk assessment · Kinetics

Introduction

Engineering Calculations with the Internet Aid

As in other engineering and scientific disciplines, many basic food engineering calculations can be automated. Perhaps the best example is units-conversion, which many web sites offer. Programming a unit conversion is simple because all that is needed is choosing the appropriate factor and its multiplication by the user’s entered value. No wonder, therefore, that “converters” of many types can be found on the Internet. Currency convertors are perhaps the most widely known, but similar web pages enable the user to convert engineering parameters from British units to metric and scientific or vice versa.

The next stage in complexity involves the use of an algebraic equation for the conversion. Perhaps the simplest is the conversion of °C to °F or vice versa. With the high speed of today’s computers and the Internet, elaborate mathematical operations can also be performed so that even complicated functions can be calculated and plotted. Calculators that allow the user to write one or more algebraic equations and have the program plot them in 2D and 3D displays are perhaps the best known. Some can be freely downloaded while others can be used online. An example of an online calculator can be found by opening http://www.walterzorn.com/grapher/grapher_e.htm. There is also free software on the Internet that generates and plots statistical distribution functions, performs a Fourier transform and more.

M. D. Normand · U. Lesmes · M. Peleg (✉)
Department of Food Science, Chenoweth Laboratory, University
of Massachusetts, Amherst, MA 01003, USA
e-mail: micha.peleg@foodsci.umass.edu

M. G. Corradini
Instituto de Tecnología, Facultad de Ingeniería y Ciencias
Exactas, Universidad Argentina de la Empresa, Cdad. de Buenos
Aires, Argentina

Interactive Programs

Some of the mathematical and engineering programs that do conversions or more elaborate mathematical calculations allow the user to change the function parameters through sliders on a screen. Zooming on maps provided with driving instructions is a most familiar example. Web sites that offer this kind of software add a ‘game-like’ element to their use. Adding the option to change a parameter or a set of parameters continuously also enables the user to generate and examine several scenarios or patterns within a very short time and with hardly any effort.

Animation

Many web sites include display of a system having a ‘movie-like’ feature. The richest and best known in Food Engineering and Food Technology is the collection of animated graphical displays and interactive calculation tools developed and posted on the Internet by Professor R. Paul Singh of UC Davis which are used in his courses— See [3, 11, 12] and <http://www.rpaulsingh.com/animated%20figures/animationlist.htm>. Professor Singh’s posted web pages cover almost all the standard processes and unit operations in food production, processing and preservation. They explain, in a most vivid and colorful way, how major types of food processing equipment work and the physical principles on which unit operations are based. The web pages have been an immensely effective teaching aid and learning tool. Software in related scientific and engineering fields, such as heat transfer, fluid dynamics and distillation, can also be found on the web. Such software comes at

different levels of sophistication, written for users at different levels of preparation. Certain programs are very basic making them appropriate as a teaching tool while others are more suitable for trained professionals and practitioners in a field.

Commercial Software

Much of the software to do specific engineering calculations is not free. There exist a large variety of such programs, and it would be difficult to survey them all. However, very few of these have been designed specifically for food engineers or food engineering students. A notable exception is Professor Singh’s eFoodSolver [12], examples of which can be viewed at <http://www.rpaulsingh.com/problems/problemsbyname.htm>. It offers user-friendly calculators for almost all unit operations that are pertinent to food processing. The programs to calculate heat transfer in food containers and the (microbial) lethality of commercial thermal preservation processes (e.g., [10]) are another notable exception. However, most of the sterility calculation software is based on log-linear inactivation kinetics and other assumptions whose validity ought to be treated with caution. A few interactive sites allow the user to retrieve numerical data on isothermal microbial growth and inactivation from large data bases created from published material. These sites, some listed in Table 1, also enable the user to view isothermal survival and growth curves based on the retrieved parameters. The displayed curves, however, are generated with traditional inactivation and growth kinetics models, whose applicability cannot be always taken for granted.

Table 1 Free on-line software and teaching aids for food engineering education and practice

Name	Brief description and source	Web link
Food engineering	Lecture notes for Introduction to food engineering, relevant animations and calculation examples (Prof. Singh, University of California-Davis, USA).	http://www.rpaulsingh.com/teachingfirstpage.htm
Food engineering applications	A package of 21 free downloadable Microsoft Excel applications for food engineers (Prof. Peleg, University of Massachusetts- Amherst, USA).	http://www.people.umass.edu/aew2000/ExcelLinks.html
Pathogen modeling program	A package of models to predict the growth and inactivation of food-borne bacteria, primarily pathogens, under various environmental conditions. (United States Dept. of Agriculture, USA).	http://www.arserrc.gov/mfs/PMP7_Start.htm
Growth predictor	Growth models of microorganisms as a function of environmental factors, such as temperature, pH and water activity.	http://www.ifr.ac.uk/Safety/GrowthPredictor/
Microfit	Extraction of growth parameters from challenge test data and comparison between data sets	http://www.ifr.ac.uk/microfit/
Seafood spoilage and safety predictor	Software to predict shelf-life and growth of bacteria in fresh and lightly preserved seafood.	http://www.dfu.min.dk/micro/sssp/Home/Home.aspx

The Wolfram Demonstrations Project

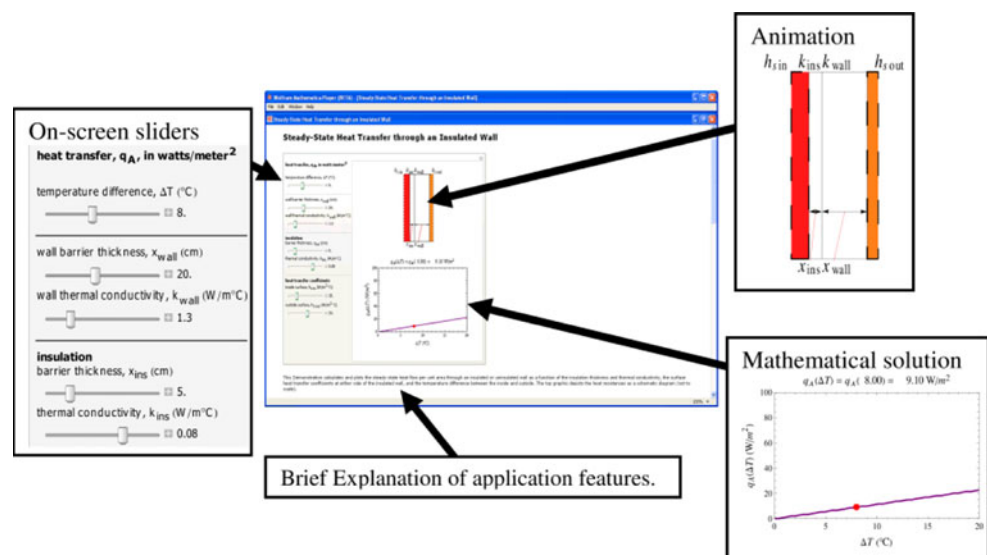
Wolfram Research (Champaign, IL) is the commercial company, named after its founder Stephen Wolfram that has developed and is marketing the program Mathematica®. It has launched and is now hosting the ‘Wolfram Demonstrations Project’ (<http://www.demonstrations.wolfram.com/>). The ‘Wolfram Demonstrations Project’ contains a very large collection of interactive software written and contributed by Mathematica® users around the world. Prior to posting on the Project’s web site, each contributed Demonstration is reviewed and edited by the company’s experts, to avoid errors in contents and guarantee smooth crash-free running. Almost all the ‘Demonstrations’ can be previewed in an animated form by clicking on the ‘watch web preview’ button on each Demonstration’s web page (shown in green letters at the top right corner of the display). The Mathematica Player program, which runs the Demonstrations, can be downloaded free of charge by following the instructions on the screen. Once saved in the user’s computer, it will run any of the nearly 6,000 Demonstrations in the project to date. Each Demonstration has one or more sliders or other controls, see Fig. 1, which are used to vary the particular Demonstration’s parameters manually or automatically. Once a slider is moved or a setter bar clicked, the displayed function, image, calculated values or any other object adjust almost instantaneously on the screen to reflect the new parameters’ setting. [The same is true for the emitted sound in the acoustic and musical Demonstrations]. In almost all the Demonstrations, the user can also type in the parameters’ values in order to perform a specific calculation. In addition, each parameter can also be varied continuously to produce an animated display of its effect. The direction and speed of the chosen parameter alteration

are chosen by a set of animation controls adjacent to the particular parameter’s slider. Where pertinent, generated 3D objects can be rotated with the mouse so that they can be viewed from different angles. The Demonstrations, whose number grows almost daily, cover a very large variety of fields, from mathematics, the physical sciences, biology and engineering to economics and business or music and the arts. The Demonstrations are aimed at users at different levels of preparation. Some explain concepts, mathematical theorems or physical principles at the most rudimentary level. Examples are siphon action, the Pythagorean theorem or the leverage of pulley arrays. Other Demonstrations show the inner operation of machines, such as an internal combustion engine (linear and radial) with a different number of cylinders, transform color coordinates, process images or even show visual illusions. But many Demonstrations deal with advanced and modern mathematical concepts, such as fractional derivatives, functions of complex variables, cellular automata and fractals. Many of the Demonstrations are presented as strikingly beautiful colorful displays. The aforementioned list of the Demonstrations attractive features is by no means exhaustive, and the interested reader will find many enlightening, esthetically appealing and even entertaining Demonstrations by simply performing a random search, another option offered by the project.

Wolfram Demonstrations for Food Engineering and Processing

With less than a handful number of exceptions, the Food Engineering and Processing-related Wolfram Demonstrations to date have been contributed by a mathematical modeling group at the University of Massachusetts at

Fig. 1 Calculating heat transfer through an insulated wall—a typical display of a Wolfram Demonstration designed to aid in Food Engineering



Amherst. At the time this article is written, they total over 40 different Demonstrations in areas that include basic principles of rheology, mass balance, thermal properties, heat balance and transfer, fluid flow, microbial inactivation and growth kinetics, general kinetics, particulate technology and risk assessment. Although their layout varies, almost all the Demonstrations have a slider or a group of sliders to adjust the parameter(s) and set the scales for the calculated plot or plots. Many of the Demonstrations also display the numerical values of the calculated result and those of related parameters. An example is the calculated pressure drop in a pipe shown together with the Reynolds number and friction factor or the surface to volume ratio of a cube or sphere of a given length or diameter accompanied by the actual areas and volumes. Every demonstration contains a brief explanation of the system and, where appropriate, the equations used for the calculation and plot(s) generation. The Demonstrations can be used as a teaching or learning tool. They provide visual presentation of the principles involved or the system's features and allow the user to change the pertinent parameters in a 'game-like' fashion and instantaneously watch the effect. The Demonstrations also allow a teacher to compose homework and exam questions and check the correctness of the answers, again instantaneously. The student can do the same, of course. Many of the Demonstrations can be used by professional engineers and technologists to carry out routine engineering calculations on the job, such as mass or heat balance, in a speedy and reliable manner. Several Demonstrations, such as those dealing with microbial growth and inactivation, can be used to examine, almost instantaneously, the potential consequences of contemplated changes in processing or storage conditions. Two other Demonstrations can be used to estimate the risk of a mishap on the basis of existing Quality Control charts or subjective probabilities. What follows is a list of examples of Food Engineering and Processing Wolfram Demonstrations grouped by subject.

General and Basic Principles

This group has Demonstrations showing:

- How the size of an object or size reduction affects its surface to volume ratio.
- How a line's jaggedness (that of the mechanical signature of brittle foods, for example) is affected by resolution using the Mandelbrot–Weierstrass function as a model. The "true" jaggedness is controlled by this function's fractal dimension D_f ($1 \leq D_f < 2$), and the resolution by the number of points and terms. 'Moving' the curve illustrates that the perceived jaggedness does not depend on the curve's general morphology.

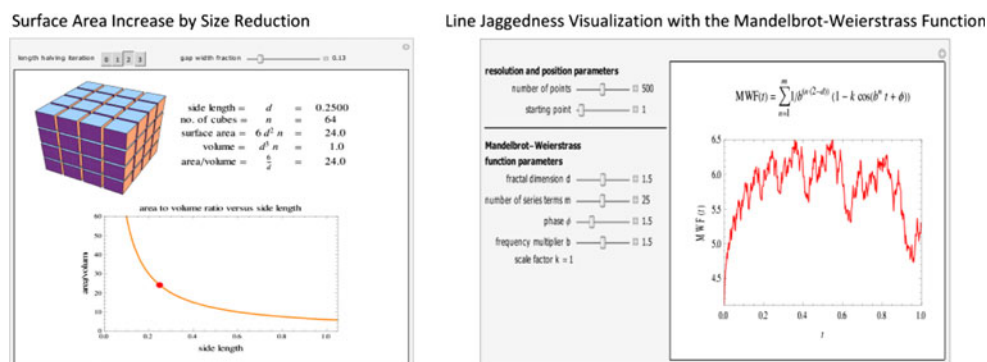
The interactive displays of these two Wolfram Demonstrations are shown in Fig. 2. Like Fig. 1 and the rest of the figures in this article, the figure only shows the layout of the sliders and the plots themselves, but not the snapshots. These, which in the actual Demonstrations are shown on the screen below the interactive display, represent typical or representative cases created with selected parameters settings. The snapshots are followed by an explanation of how the plots were created and/or the displayed values calculated. Although the explanation and snapshots are an integral part of every Demonstration, they will not be shown in subsequent figures because of space limitations.

Mass Balance

This group has Demonstrations that allow the user to:

- Calculate the amount of cream produced by centrifugation from a chosen amount of milk where the variables are the milk, cream and skim's butterfat contents or the amount of milk needed to produce a chosen amount of cream having the chosen butterfat content.

Fig. 2 Demonstrations showing how the surface area to volume ratio changes with size reduction (*left*) and how a fluctuating signature's apparent jaggedness is affected by resolution (*right*)



- (b) Calculate the amount of concentrate and vapor produced in a single-stage evaporator, given the feed and concentrate’s total solids weight fraction. Or, alternatively, calculate the amount of feed needed to produce a chosen amount of concentrate having a given solids concentration.
- (c) Calculate the needed amounts of ‘rich’ and ‘lean’ ingredients in order to make a binary mixture of given composition, or alternatively, the amount of binary mixture produced for a chosen amount of the ‘lean’ or ‘rich’ components. The sliders’ layout and settings are shown in Fig. 3 (top). All the calculations are based on the assumption that there is no accumulation in the mixer and that losses are insignificant.

Heat Balance and Transfer

This group has Demonstrations that allow the user to:

- (a) Calculate the logarithmic mean temperature difference of ideal heat exchangers with the streams’ entry and exit temperatures as well as their flow directions (parallel vs. countercurrent) chosen by the user.

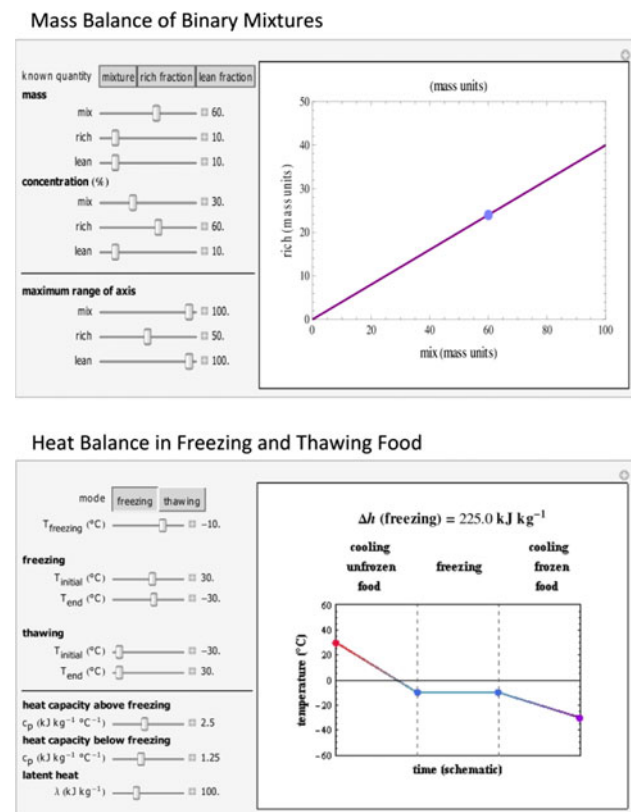


Fig. 3 Calculating mass balance in mixing two food components (top) and heat balance in freezing and thawing of foods (bottom)

- (b) Calculate the heat transfer in Wm^{-2} through an ideal heat exchanger wall of chosen wall thickness and thermal conductivity, surface heat transfer coefficients in the two streams and the logarithmic mean temperature difference between them.
- (c) Calculate the amount of heat in Wm^{-2} transferred through an insulated wall as a function of the wall and insulation’s thickness and conductivity, the surface heat transfer coefficients at the two sides of the wall and the temperature difference between them, all chosen and set by the user—See Fig. 1.
- (d) Estimate the net amount of heat to be removed from 1 kg of a food during ideal freezing as a function of its initial and final temperatures, heat capacities below and above freezing, freezing point and latent heat, all chosen and set by the user. Or alternatively, estimate the amount of heat needed to thaw 1 kg of food with these chosen parameters. The assumptions are that the freezing/thawing occurs at a constant temperature, the thermal properties are not significantly affected by temperature in the pertinent range and that heat losses during the process are negligible—See Fig. 3 (bottom).
- (e) Calculate the heat in Wm^{-2} or in kWm^{-2} radiated from a hot body having a chosen temperature (in $^{\circ}C$ or $^{\circ}K$) and emissivity to an environment of a chosen temperature according to the Stefan–Boltzmann law—See Fig. 4.
- (f) Estimate a food’s thermal conductivity below and above freezing ($J kg^{-1} ^{\circ}C^{-1}$) and latent heat ($kJ kg^{-1}$) from its moisture contents. The displayed table gives realistic estimates to foods that are primarily composed from water, carbohydrates and

Stefan-Boltzmann Law

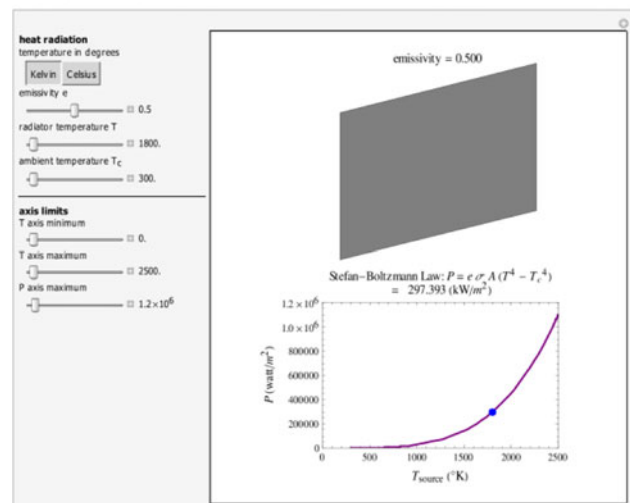


Fig. 4 Calculating heat radiation using the Stefan-Boltzmann law

protein. This demonstration should not be used for foods containing a large amount of fat or salt.

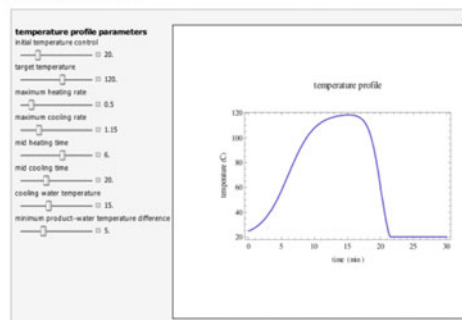
- (g) Calculate the coefficient of performance (COP) of an ideal refrigeration cycle using the refrigerant's Pressure-Enthalpy diagram. The refrigerant's enthalpies at each of the cycle's critical points are entered and can be altered by the user.

Kinetics of Microbial Inactivation

There is growing evidence that microbial survival during lethal heat treatments (and the application of non-thermal preservation methods) only rarely follow first-order kinetics as has been traditionally assumed and that there is no reason that it should (e.g., [5, 13]). Most microbial survival curves, including those of bacterial spores, follow the Weibullian or “power-law” model of which log-linear inactivation is just a special case where the power is equal to one. Notable exceptions are the survival curves of *Bacilli* spores, which frequently exhibit an ‘activation shoulder’, see: <http://www.demonstrations.wolfram.com/SurvivalCurvesOfBacilliSporesWithAnActivationShoulder/>, and the rare sigmoid survival curves, which might indicate a mixed population [5].

A group of Demonstrations allows the user to create a temperature profile that emulates the time–temperature relationship recorded at the coldest point in a food during its industrial thermal processing in a retort or its preparation by cooking, baking, roasting or grilling (Fig 5—top). Once the temperature profile has been chosen, the process's settings can be transferred to the inactivation calculation Demonstrations to generate the corresponding survival curve (Fig. 5—bottom) using the Weibullian-log-logistic (WeLL) model [5]. They can also be used to calculate the ‘equivalent time at a reference temperature’ curve, as shown in Fig. 6. In order to create plots of the kind shown in Figs. 5 (bottom) and 6, the user has to enter the targeted organism or spore's *three* survival parameters directly or with their sliders. They are n , assumed to be constant, which accounts for the curvature of the isothermal semi-logarithmic survival curves, T_c , a temperature that marks the lethal regime's onset and k the slope of the Weibullian ‘rate parameter’, $b(T)$, at temperatures well above T_c . [The temperature dependence of $b(T)$ can be created with another demonstration, not shown]. The WeLL model is a replacement of the traditional log-linear model, which had produced the ‘ z value’, and the Arrhenius equation based on a temperature-independent ‘energy of activation’, whose applicability to microbial survival is highly questionable on theoretical grounds as well as practical considerations [4, 5]. To calculate and plot the process's equivalent time curve (Fig. 6), the user sets the reference

Simulating Temperature versus Time Relationships in the Thermal Preservation of Foods



Log Survival Ratio as a Function of Time

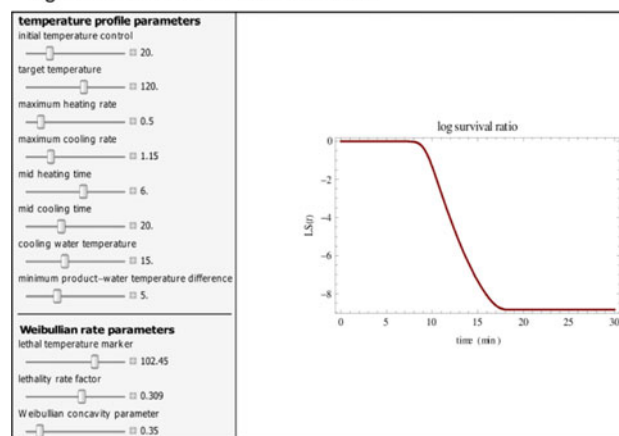


Fig. 5 Simulating the temperature profile during thermal processing of foods (*top*) and calculating the corresponding dynamic microbial inactivation curve using the Weibull-log-logistic (WeLL) equation as the targeted organism's survival model (*bottom*)

Equivalent Isothermal Time at a Reference Temperature as a Function of Time

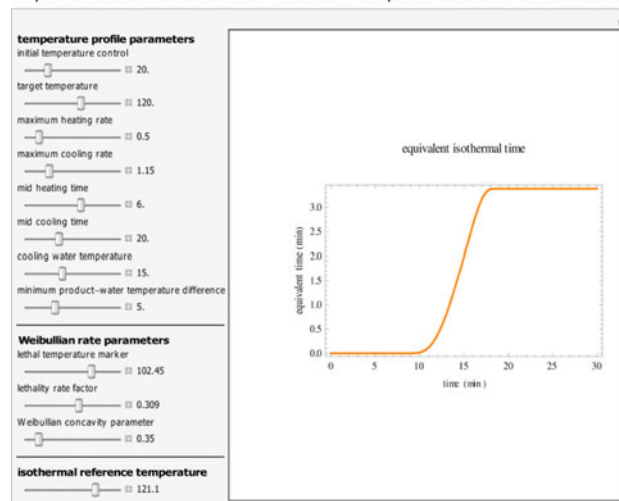
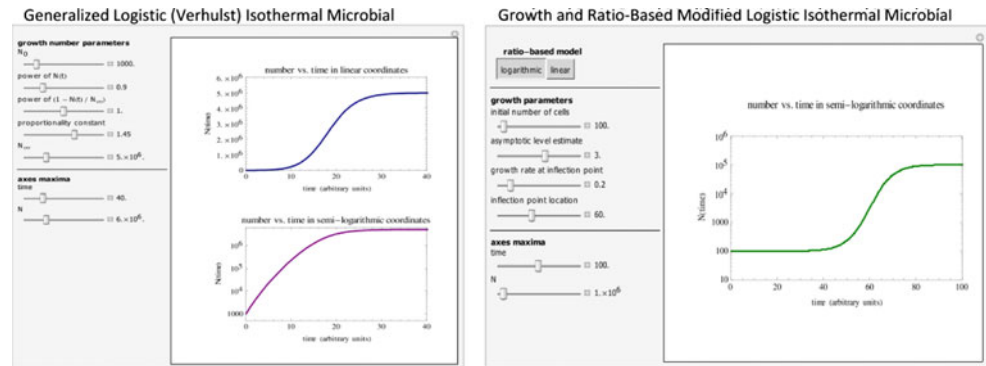


Fig. 6 Calculating the equivalent time at a reference temperature curve during thermal processing of foods using the Weibull-log-logistic (WeLL) equation as the targeted organism's survival model

Fig. 7 Simulating sigmoid microbial growth curves with the generalized Verhulst (logistic) model (left) and the ratio-based shifted logistic equation, which allows for long logarithmic ‘lag time’ (right)



temperature, e.g., 121.1 °C (250°F) in the traditional sterility calculation of low acid foods, by entering its numeric value or by slider, in addition to the temperature profile settings and the targeted organism’s three survival parameters. The equivalent time curve is a proposed replacement of the traditional $F_0(t)$ curve [2], which is only valid when all the organism or spore’s isothermal survival curves are log-linear and so is the temperature dependence of their slope. Notice that if the power n in the WeLL model is set to one ($n = 1$), the resulting survival ratio and equivalent time plots will be for an organism having first-order inactivation kinetics. In such a case, the ‘rate parameter’, $b(T)$, would be the exponential rate constant, k in the traditional log-linear model. Thus, by moving the n slider around the value of one, one can examine the potential effect of deviations from log-linearity on the survival pattern in an industrial thermal preservation process.

Sigmoid Microbial Growth Curves

A Demonstration to generate sigmoid growth curves that follow the generalized continuous logistic (Verhulst) model is shown in Fig. 7 (right). As in Verhulst’s original model, the momentary growth rate is proportional to the momentary population size and the amount of remaining resources in the habitat that are available for exploitation. The difference is that the rate’s scaling with these two factors (the powers α and β in the generalized model) need not be unity. In other words, the generalized model allows for situations where the population’s growth rate can exceed that which the exponential model entails ($\alpha > 1$), as well as for situations where it fails to reach its full growth capacity ($\alpha < 1$). The generalized model also allows for situations where the organism is over-sensitive to resource shortage, crowding and/or habitat pollution ($\beta > 1$), or less so, at least to a certain extent ($\beta < 1$). The scaling parameters, α and β , as well as the population’s initial size (N_0) and growth rate constant, k , are entered and can be altered directly or through sliders on the screen. Setting $\alpha = \beta = 1$ will produce a growth curve governed by Verhulst’s original model. Notice though that regardless of

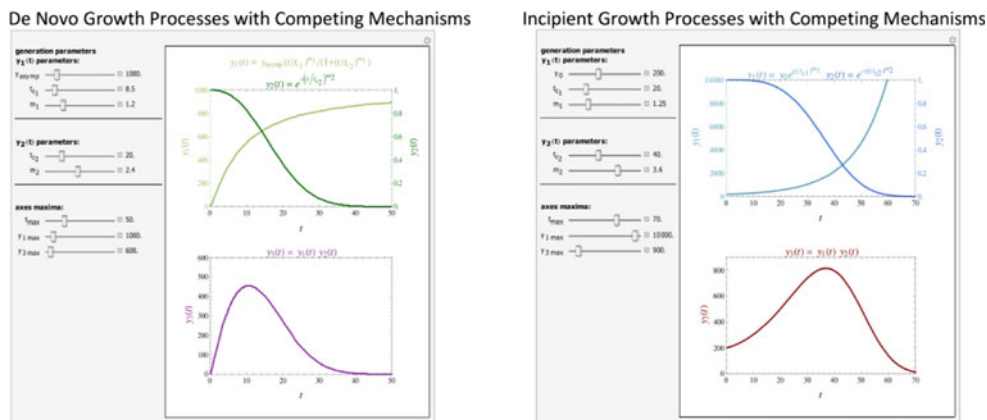
the settings (of α , β and the other parameters), the growth curve produced by this model does not have a long ‘lag time’ of any appreciable duration when the curve is plotted on semi-logarithmic coordinates.

One way to overcome this problem and create isothermal sigmoid growth curves with a ‘lag-time’ of any length is to express the logarithmic or net growth ratio, $R(t)$, i.e., $R(t) = \log [N(t)/N_0]$ or $[N(t) - N_0]/N_0$, respectively, and plot it versus time using the three parameter *logistic function* as a model [1, 5]. An example is shown in Fig. 7 (right). Here too, the plot type (i.e., on linear or semi-logarithmic coordinates) can be chosen with a bar setter, and model parameters can be entered and adjusted with sliders on the screen.

Chemical and Biological Processes Governed by Competing Mechanisms

Most of the kinetic models used in food science, technology and engineering are for systems where the process’s product concentration rises or falls monotonically. Typical examples of the former are browning or microbial growth and of the latter a vitamin degradation and microbial inactivation. However, there are systems where the product’s concentration initially rises and then falls. Typical food examples are peroxides formation during lipid oxidation, acrylamide formation during baking or frying and microbial growth followed by mortality as in a pickling process. An observed concentration (or number) rise and subsequent fall is a common outcome of processes of the general kind $A \rightarrow B \rightarrow C$ [13], where B is the monitored product. Peleg et al. [8] have recently discussed the phenomenology of such processes. They divided them into two types: those where the product’s initial concentration is measurable (e.g., the Peroxide Value of a partly oxidized oil), or zero (e.g., the acrylamide concentration in yet to be fried potatoes or yet to be baked wheat dough). The distinction was necessary in order to set a proper boundary condition for the rate versions of the model, which can be used to simulate such processes under non-isothermal (‘dynamic’) conditions. Two Demonstrations, which only

Fig. 8 Simulating processes governed by competing mechanisms, starting from zero and non-zero product concentration (left and right, respectively)



describe isothermal generation and decay curves, are shown in Fig. 8. By moving sliders, the user can generate peaked concentration curves of different heights, widths and degrees of symmetry. With proper choice of the parameters, the user can also generate monotonically rising curves, within the specified time range, such as those encountered in lipid oxidation at room temperature or lower, for example, at which a peak Peroxide Value is not usually observed.

Risk Assessment

A Wolfram Demonstration that computes the most likely number of food poisoning victims based on an expanded

version of the Fermi Solution [7] is shown in Fig. 9. It allows the user to set the assumed range of the number of exposed individuals and the probability range of the main factors, which determines whether a person will come down with acute poisoning symptoms. Examples are the lower and upper limits of the probability that a food portion has been actually contaminated, the lower and upper limits of the probability that a large enough portion has been consumed, the lower and upper limits of the probability that the immune system will be unable to neutralize the pathogen, etc. The program that generates the Demonstration uses a Monte Carlo method to draw the histogram of the number of affected persons and compute the lognormal distribution that theoretically should describe it. The mode of this lognormal distribution—see figure—is

Fig. 9 Estimating the most probable number of food poisoning victims or faulty product units using the Expanded Fermi Solution method

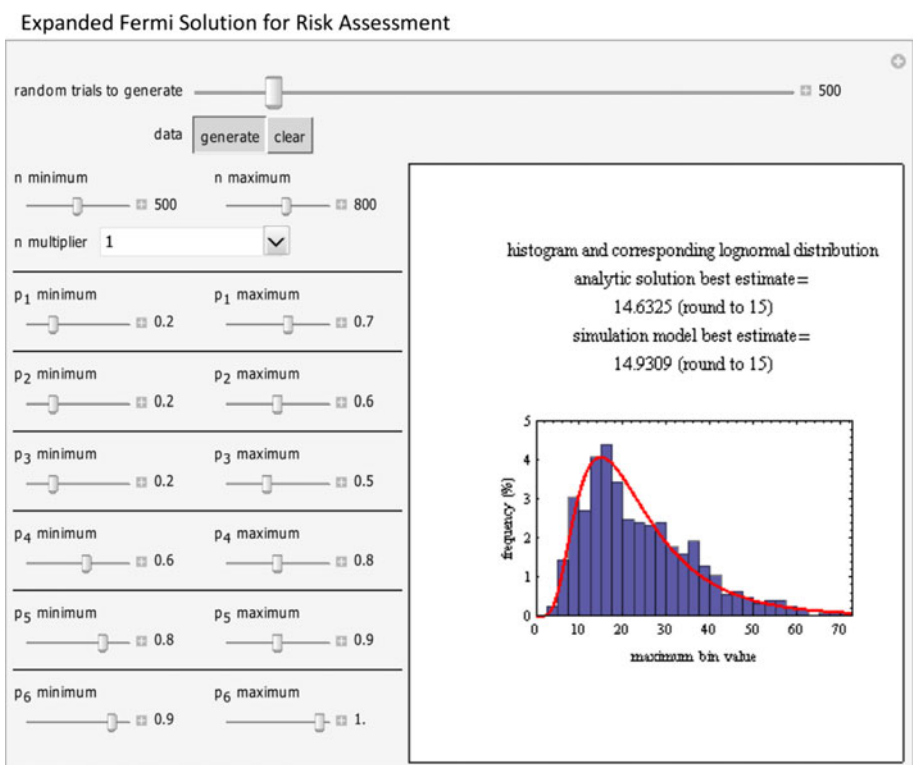
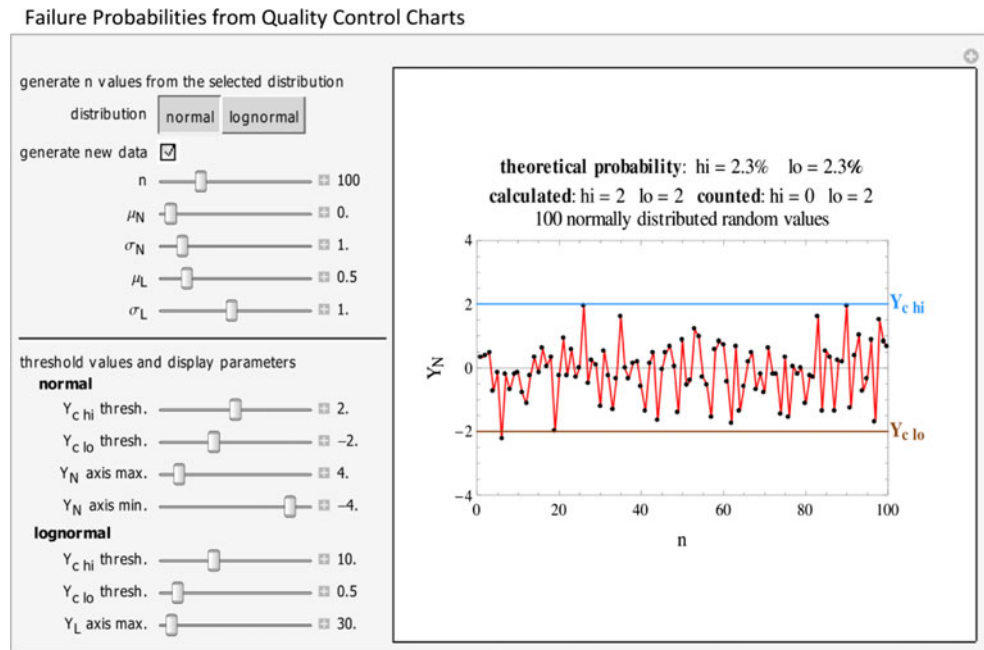


Fig. 10 Estimating the probability or frequency of future problems from a randomly fluctuating Quality Control record, using the normal and lognormal distribution functions



the best estimate of the number of victims. For random ‘guessed parameter values’ having a uniform distribution (“maximum ignorance”), the most probable number can also be calculated analytically with a formula. This result is displayed below the one calculated by the Monte Carlo method to show the agreement between the two estimates. The same Demonstration can be used to assess the most probable number of other kinds of mishaps by entering the lower and upper limits of the number of potentially affected units and of the probabilities of up to six major factors that determine the risk. [An MS Excel[®] program that allows the user to set the limits of the number of potentially affected individuals or units and the ranges of up to 29 probabilities can be downloaded free of charge at <http://www-unix.oit.umass.edu/~aew2000/FermiRisk/FermiRiskEst.html>].

Figure 10 shows a Demonstration that enables the user to simulate randomly fluctuating entries in a quality control (QC) or quality assurance (QA) chart and translate them into a probability or future frequency of mishaps, i.e., of too high or low exceeding the user’s set tolerance limits. The simulations are based on the assumption that the entries have a normal (Gaussian) distribution as is frequently found in chemical analysis records, e.g., protein or fat in a meat product, drained weight in canned or jarred fruit segments, etc., or on a lognormal distribution, which is frequently found in microbial count records [5]. In the latter, the asymmetry arises because microbial counts can be very large but never negative. The Demonstration allows the user to choose the distribution type by clicking on a setter bar and to adjust its parameters (mean or logarithmic mean and standard deviation or logarithmic

standard deviation) by moving sliders on the screen. In the same manner, it also allows the user to set the upper and lower bounds of the tolerance and the plot axes’ range. At each new setting, the Demonstration generates and plots a new random series with the chosen parameters, and it counts and displays the number of entries that are above or below the tolerance upper and lower limits, respectively, which have been set by the user. It also displays the corresponding theoretical probabilities and calculated numbers for comparison. [A free MS Excel[®] program that calculates the probabilities of exceeding *five* chosen limits can be found at <http://www-unix.oit.umass.edu/~aew2000/MicCountProb/microbecounts.html>. Unlike the Wolfram Demonstration, this MS Excel[®] program allows the user to paste his or her own record for analysis. Once the record is entered, the program tests the entries’ independence and the normality or log-normality of their distribution. It then calculates the two distributions’ parameters and estimates the probabilities that an entry will exceed any of the five chosen upper limits of the tolerance.]

Miscellaneous Demonstrations

The list of Demonstrations of potential interest to Food Engineers is not limited to those already discussed and is continuously growing. Here are a few examples:

Food Engineers working on the storage and discharge of cohesive food powders can find a Demonstration—see Fig. 11, which calculates the principal stresses in sheared compacts and the Effective Angle of Internal Friction (Peleg et al. [9]). [These parameters are used to quantify

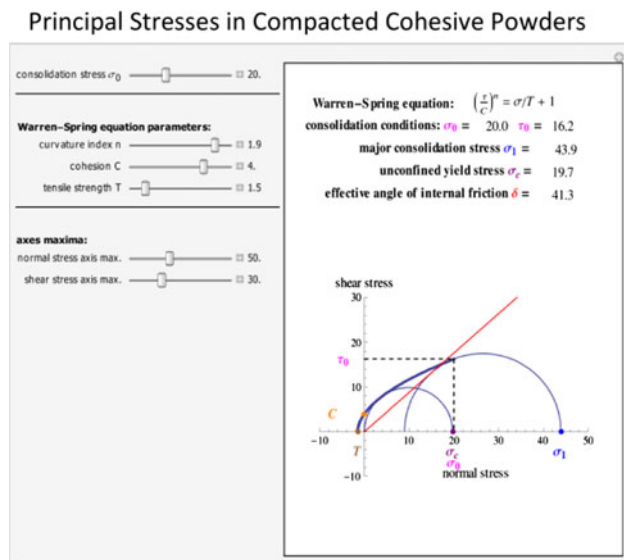


Fig. 11 Calculating the principal stresses and effective angle of internal friction from experimental shear data of consolidated cohesive powder specimens using the Warren-Spring equation as the yield loci curve's model

the flowability of cohesive powders and play a major role in bin design.]

Another Demonstration shows how moisture in a binary mixture of foods stored in a sealed container is redistributed to reach equilibrium water activity. It is primarily intended to be a teaching aid providing visualization of the principle [6]. A more flexible program to estimate the equilibrium water activity of a dry mixture of up to 15 different ingredients is available in both an MS Excel® and a Mathematica® version. [Both have been posted on the Internet as freeware and can be downloaded at <http://www-unix.oit.umass.edu/~aew2000/WaterAct/Excel/excelwateract.html> and at <http://www-unix.oit.umass.edu/~aew2000/WaterAct/Mathematica/mathwateract.html>, respectively].

Yet another Demonstration shows the difference in the forces that develops during ideal lubricated and frictional squeezing flows. It also shows how the array's geometry and the applied displacement rate forces are affected by the force in these two flow regimes.

There is also a Demonstration that allows the user to examine bimodal distributions by modifying their two component's mean, standard deviation and relative weight and identify combinations that produce what appears to be a unimodal distribution, either symmetric or skewed.

And finally, calculations of frictional pressure drop in pipes can also be automated and performed with a Wolfram Demonstration as shown in Fig. 12. This demonstration allows the user to enter and alter the volumetric flow rate, the pipe's diameter, length and degree of roughness, and the liquids density and viscosity by sliders. The program will then calculate and display the Reynolds number, the

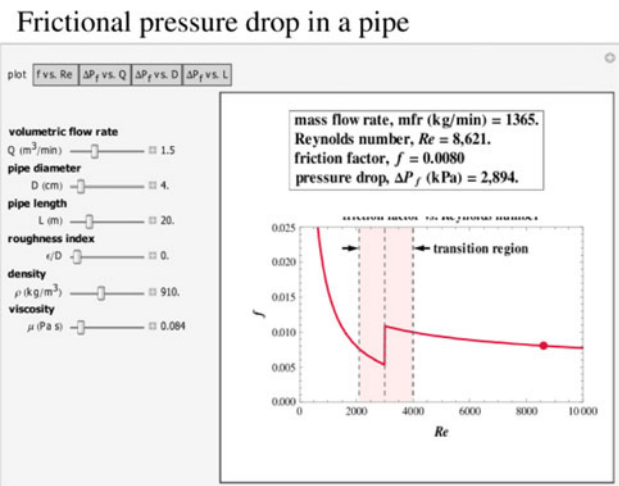


Fig. 12 Calculating the Reynolds number, friction factor and frictional pressure drop in laminar and turbulent flows through a pipe

friction index (f) and the pressure drop. The user can also choose the kind of plot, i.e., f versus Reynolds number (see figure), pressure drop versus flow rate, pressure drop versus the pipe's length or pressure drop versus the pipe's diameter, by clicking on a setter bar.

The Wolfram Demonstrations Project also posts several Food Engineering-related Demonstrations contributed by other authors. In one (in English and Portuguese versions), the user can move a point on a psychrometric chart to generate a numeric display of the corresponding dry and wet bulb temperatures and the absolute and relative humidity, see <http://www.demonstrations.wolfram.com/PsychrometricChart/>.

Another Demonstration is a 'nutritional value indicator'—see <http://www.demonstrations.wolfram.com/StylizedPieAndBarChartsForFastFoodNutrition/>. It plots the protein, total fat, total carbohydrates, sodium and cholesterol contents of several common food items in the form of a pie chart. In an adjacent plot, the contents of the last four in 100 g of the chosen food are calculated as percent of the suggested daily value, which is displayed in a bar chart. There is also a Demonstration, which allows the user to 'create' a fruit salad from apples, oranges and bananas and estimate its total cost (up to \$10). The cost of each fruit can be entered and varied through sliders, see <http://www.demonstrations.wolfram.com/MaximumFruitSalad/>.

General Science and Engineering

Many Demonstrations allow the user to manipulate statistical distribution functions and learn or perform statistical analyses. A variety of Demonstrations illustrate classic and modern mathematical concepts. The former include proofs

of the Pythagorean theorem, for example, and the latter cellular automata, auto correlation functions, fractals and more.

Physical phenomena such as those involving molecular motions (in gases, liquids and solids), phase transition and diffusion can also be found in the Project's collection. There are also Demonstrations of colors displays (and their coordinates) that might be of interest to Food Engineers, see for example <http://www.demonstrations.wolfram.com/CartesianColorCoordinateSpaces/> and <http://www.demonstrations.wolfram.com/SelectViewAndCompareNamedColors/>.

Chemistry Demonstrations present molecular structure, reactions kinetics, (including enzymatic). Rheology is represented by Demonstrations of fluid flow and viscosity. [For visualizing the shear rate-dependent viscosity of a Herschel–Bukley fluid, see <http://www.demonstrations.wolfram.com/FlowCurvesOfAHerschelBulkleyFluid/>.

On the “engineering side”, there are Demonstrations that describe or aid in calculating, transient heat and mass transfer, distillation, controllers and control systems. Although not specifically intended for Food Engineers, they can be very helpful in Unit Operations classes and some in routine work in industry or in plant design.

There are also many Demonstrations that deal with business and finance, an important aspect of technology to which most Food Engineering students are rarely exposed during their academic training.

The listings in this article by no means cover all the Demonstrations that are pertinent to Food Engineering. And, as already mentioned, the number of Demonstrations posted on the web is growing almost daily. We hope that practicing Food Engineers and Food Engineering students and teachers will take advantage of this extremely useful and free tool. We also want to take the opportunity to congratulate Wolfram Research for originating the idea and supporting the Demonstrations Project. However, the project's success would have been impossible without the many individual contributors, too numerous to be thanked individually, who have taken the time and effort to share their technical and scientific knowledge with the public,

and make it available to all in the form of attractive interactive Demonstrations.

Acknowledgments The authors own participation in the Wolfram Demonstration Project has been largely supported by the University of Massachusetts Center of Learning, under the PMYR program, and by the Massachusetts Agricultural Experiment Station at Amherst.

References

1. Corradini MG, Peleg M (2005) Estimating non-isothermal bacterial growth in foods from isothermal experimental data. *J Appl Microbiol* 99:187–200
2. Corradini MG, Peleg M (2009) Direct calculation of the survival ratio and isothermal time equivalent in heat preservation processes. In: Simpson R (ed) *Engineering aspects of thermal food processing*. CRC Press, Boca Raton
3. Feng H, Morgan M, Balasubramanian VM, Singh RP (2007) Virtual laboratory modules for food processing education. Institute of Food Technologists, 2007 Annual Meeting, Chicago
4. Peleg M (2003) Microbial survival curves: interpretation, mathematical modeling and utilization. *Comments Theor Biol* 8:357–387
5. Peleg M (2006) *Advanced quantitative microbiology for food and biosystems: models for predicting growth and inactivation*. CRC Press, Boca Raton
6. Peleg M, Normand MD (1992) Estimation of the water activity of multicomponent dry mixtures. *Trends Food Sci Tech* 3:157–160
7. Peleg M, Normand MD, Horowitz J, Corradini MG (2007) An expanded fermi solution for microbial risk assessment. *Int J Food Microbiol* 113:92–101
8. Peleg M, Normand MD, Corradini MG (2009) Isothermal and non-isothermal kinetic models of chemical processes in foods governed by competing mechanisms. *J Agr Food Chem* 57:7377–7386
9. Peleg M, Normand MD, Corradini MG (2009) Interactive software for calculating the principal stresses of compacted cohesive powders with the warren-spring equation. *Powder Technol* 197: 268–273
10. Simpson R (2009) *Engineering aspects of thermal food processing*. CRC Press, Boca Raton
11. Singh RP (1999) Conducting laboratory experiments via the internet. *Food Technol* 53:54–59
12. Singh RP, Erdogdu F (2008) *Virtual experiments in food processing*, 2nd edn. RAR Press, Davis
13. van Boekel MAJS (2009) *Kinetic modeling of reactions in foods*. CRC Press, Taylor and Francis, Boca Raton, London