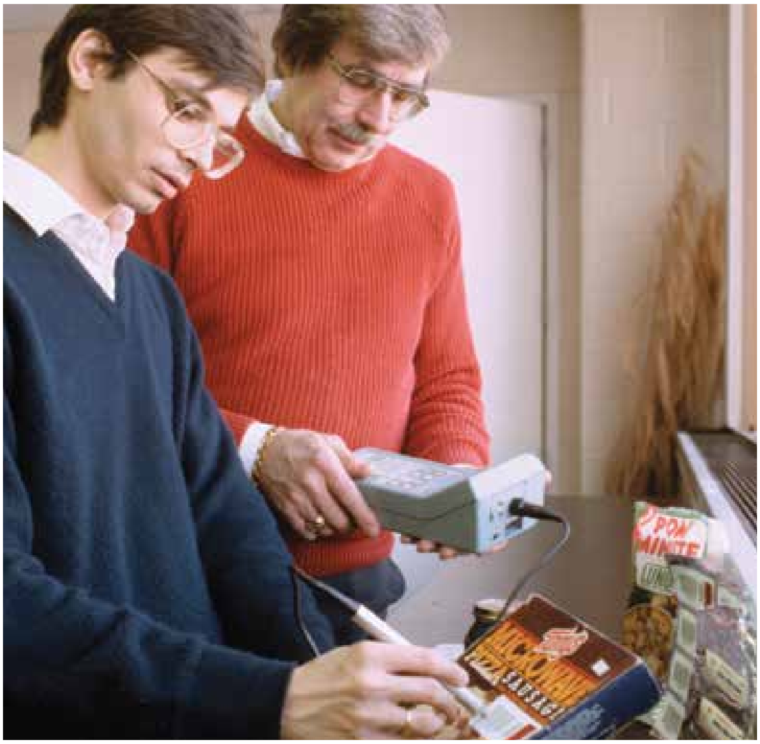
by Claire Koelsch Sand

Ted Labuza Talks Reaction Rates and Packaging



Ted Labuza, right, in 1989 with postdoctoral student Petros Taoukis, who is now a professor at National Technical University of Athens.

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VETERAN FOOD SCIENTIST Ted Labuza's research has been instrumental in understanding how packaging can be used to stall degradative reaction rates in foods.

Central to Labuza's research is water activity (a_w), which was a new concept when he and his PhD advisor, Marcus Karel, related it to foods at the Massachusetts Institute of Technology in the 1970s. For nearly 50 years, Labuza has taught the food and packaging industry how to look at food through the lens of water activity, impacting the next generation of food packaging scientists and inspiring in-depth research in the field. His work on understanding reaction rates, and how we can use intelligent packaging to predict deteriorative reactions and active packaging to stall them, continues to be an area of intense research in the quest to ensure food safety and quality and reduce food waste.

Vital Statistics

Credentials: BS and PhD, food science and engineering, Massachusetts Institute of Technology

Career Highlights: Internationally recognized expert on reaction kinetics related to food quality and safety and the packaging solutions that stall and inhibit these reactions. IFT Fellow and recipient of numerous IFT awards. IFT president 1989. Mentor for 110 MS and PhD students and 24 postdoctoral and undergraduate students. Author or coauthor of 295 publications, 18 textbooks, 78 book chapters, and eight patents.

Fun Fact: Labuza's family cars have sported the license plates NTROPY and KINETIC.

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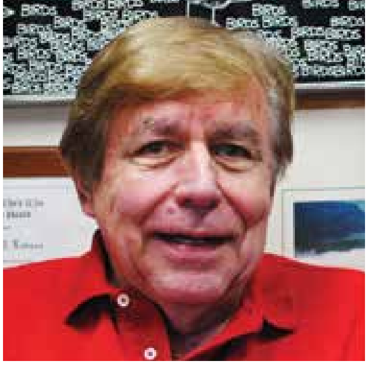
Recently retired from his position as Morse Alumni Distinguished Teaching Professor of Food Science and Engineering at the University of Minnesota, Labuza spoke with *Food Technology* about his research and its real-life applications. This interview was edited for clarity and brevity.

Q: The classic Labuza, Karel, and Tannenbaum "food quality and safety as a function of water activity map" pinpoints the importance of water activity on food reaction rates and packaging. What motivated you to look at food chemistry this way?

Labuza: [In the 1960s], degradative reactions in food chemistry lacked a fundamental explanation. Marcus Karel and I wanted to look at different degradative reactions in food and what drove their comparative reaction rates. [As part of our work], in 1965 we met with a group of researchers on water and food at a conference in Aberdeen, Scotland.

We understood that water was complex and multifaceted related to the concentration of nutrients and food safety, and that physical chemistry could explain the various phenomena. By looking at the chemical potential, the



standard first equation $(G = G_o + RT\ln a_w)$ in physical chemistry, we could explain the potential for the degradative reactions in food and the reaction rate in foods under certain conditions.

Using this concept and existing data, we began to test our hypotheses. We considered two foods at different water activities, and we saw that the energy moves from the high energy to the low until equilibrium is reached. This is a physical chemistry concept: If there is no difference in chemical potential, then nothing happens. But no one had understood how this concept related to deteriorative reactions in food.

Q: Based on your enormous body of research and writing throughout your career, what's the biggest takeaway for the food industry?

Labuza: For real direction in food and packaging choices, simplicity is key. Simple models with two or three parameters are preferred because the effects of food and packaging changes can be made more evident. This is the Occam's razor rule of simplicity. The connection to packaging and the simplicity of the equation make them applicable.

We predicted food shelf life and water activity based on ingredients, temperatures, and the relationship between water and moisture contents. For example, one of the things we did was take 15 ingredients and predict what the water activity would be and what reactions would happen. This allowed for the rapid fine-tuning of food formulations and food packaging decision-making, and it helped industry a great deal then and now.

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For example, we were able to predict a_w and shelf life of MREs [Meals, Ready-to Eat] in a hot and dry desert using these concepts and package geometry. This work eventually led to understanding degradative reactions in the dry state for proteins and the need for an extensive water barrier for protein bars. This work was rapidly applied in the industry to define the need for water vapor barriers to inhibit degradative reactions and enhance food safety.

Often complex equations based on fundamental concepts explain moisture and the water activity relationship. A linear isotherm with boundary conditions from initial water activity to the water activity at the end of shelf life can allow for a rapid understanding of the impact of changes in packaging and the food system. In contrast, when the early analysis on modified atmosphere packaging was done, nobody in the fruit and vegetable business could understand the research into applications. It was a shame. It took 20 years for this work to be applied.

Q: Do you think more research on reaction rates is still needed?

Labuza: Certainly, reaction rates continue to fascinate me because of the complex interactions within foods. Most of the research is not coming up with new principles but applying fundamental concepts to explain what is happening and then addressing how to stop the degradative reactions. With computer modeling done well, this is fascinating. But the equations need to apply, and especially for systems with multioxidation, it's hard to make a good model.

There is even more research on reaction rates needed now because of new packaging materials and new ingredients. And more accurate shelf-life predictions based on correct degradative pathways are needed. I still enjoy researching these complex food systems.

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Q: When did you develop the idea for Q_{10}—the temperature sensitivity of a reaction—for shelf-life predictions?

Labuza: I was exposed to the concept of reaction rates as a function of temperature when I was an undergraduate. I was searching for a way to explain why reactions were happening and how this knowledge could be applied to understand the influence of oxygen and moisture to the degradation of food.

Q_{10} is the change in reaction rate for every 10 degrees' change in temperature. Critically, the reaction itself does not change over the temperature range of concern, and the reactions need to be understood in order to understand potential reaction changes due to temperature. Using the Q_{10} concept, if we have shelf life as a function of temperature at different temperatures, we can predict the shelf life at different temperatures.

Q: What do you see as the top five challenges facing the food packaging industry?

Labuza: The No. 1 challenge is cancer-causing chemicals in packaging material that can and do migrate into food. But funding to fuel the analysis needed for rapid detection is missing.

The second issue facing the industry is ensuring that nutritional labels are accurate. This is a growing concern as the lines between nutraceuticals, food, and drugs blur. For example, people want a nutraceutical bar that is the size of a granola bar to be a meal replacement. So you've got nutrients in close contact with each other, and you've got some water activity differentials in there as well as different structures. When we researched the degradation of 10 nutrients in milk, for example, we found the nutrient degradation and the reactions between degradative byproducts. This is not being addressed by the FDA and should be regulated more closely as nutraceuticals should be more controlled for many foods. The real critical point is how much nutrient actually is metabolized.

The third issue is that the food packaging industry needs to provide the basic direction for consumers on when food is unsafe to eat. TTI (time temperature integrators), pH, and other indicators are available at reduced costs. They can prevent food waste and address food safety. We need to move forward with implementation.

The fourth issue is the need for increased industry funding of research at universities. This allows graduate students to research industry problems and channels their efforts to address relevant problems.

The fifth issue is the need to focus on protecting food shelf life. Essentially, suppose decision-makers have limited knowledge of the fundamentals of food packaging and do not have a science background. In that case, it is hard to sell the shelf-life problem, let alone the package solution. But as decisions are made and costs allocated, the packaging is often compromised and does not adequately protect food.

Q: You've taken your work home with you over the years—how did you teach your children about water activity when they were young?

Labuza: I started them early in the humid summers in Minnesota. We would go to the Minnesota State Fair on a humid day and buy two cotton candies for each of them. I told them to eat one in pieces and watch the other one, and I asked them what was happening. We would also go into a building with good air conditioning and notice the difference in the cotton candy. Again, they watched, and I explained the glass vs. rubbery state of food and water activity. As a result, each of our kids placed first in their division in the Minnesota State Science & Engineering Fair, some presented posters at IFT, and one went on to an international science competition.

The No. 1 challenge [for the food packaging industry] is cancer-causing chemicals in packaging material that can and do migrate into food.

Claire Koelsch Sand, PhD, contributing editor, is the owner of Packaging Technology and Research, and an adjunct professor, Michigan State Univ. and California Polytechnic State Univ. (claire@packagingtechnologyandresearch.com).