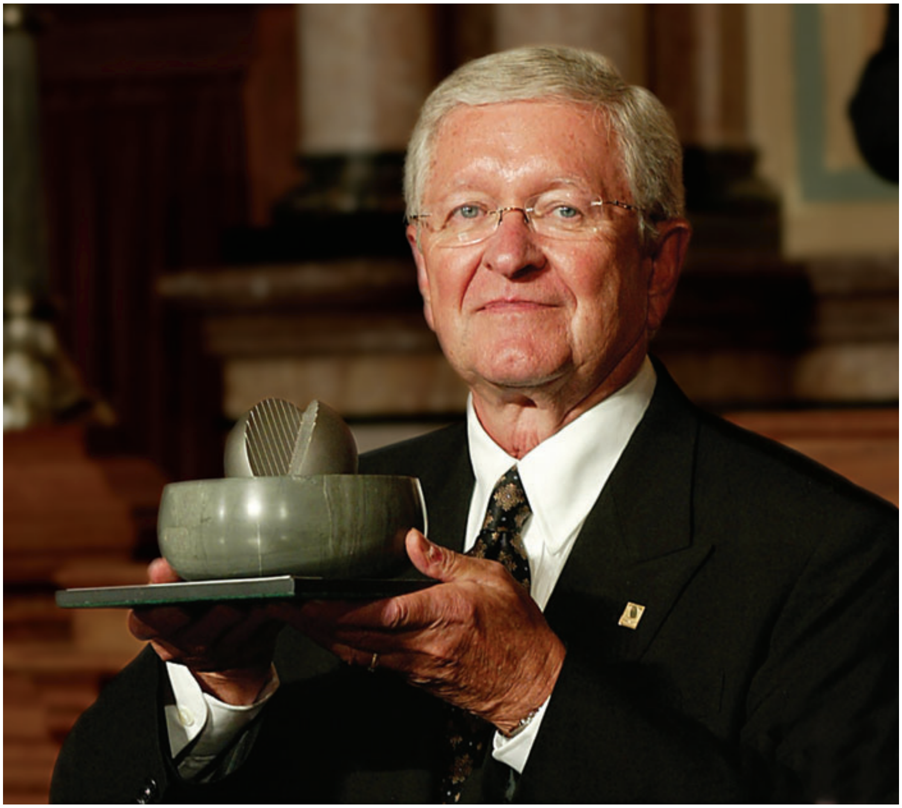

Philip E Nelson

From Tomato King to World Food Prize Laureate

Philip E. Nelson

Department of Food Science, Purdue University, West Lafayette, Indiana 47907; email: pen@purdue.edu

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Abstract

This autobiographical article describes my early years, education, and career at Purdue University. Helping form and expand the Department of Food Science at Purdue was exciting and gratifying, and working with students in the classroom and on research projects was rewarding and kept me feeling young. My research on bulk aseptic processing allowed me to help solve problems relevant to the tomato industry, but I learned later that it had much broader relevance. I certainly never expected the impact and visibility of the work to result in my being awarded the World Food Prize. Being the first food scientist to win this award has enabled me to focus increased attention on the need to reduce food losses.

INTRODUCTION

To say that my career was influenced by my upbringing is certainly an understatement! I was born in 1934 into a tomato processing family. I've always said that the red in my veins is not blood, but rather it's tomato juice! I never imagined that my research on tomatoes and aseptic processing would eventually bring me the honor of winning the World Food Prize.

GROWING UP IN THE TOMATO INDUSTRY

I grew up on my family's 500-acre Meadowbrook Farms near Morristown, Indiana. I worked with my two older sisters and a brother during planting and harvesting seasons on the farm and in my family's tomato canning factory, the Blue River Packing Company. Our factory employed approximately 300 workers in the months following tomato harvest. However, the canning operation was always subject to the seasonal nature of the production and the perishability of the tomato crop. If the processing of tomatoes following harvest could have been spread out, it would have been better for my family and our employees.

I developed an interest in horticulture as a result of working with my family on the farm and in the tomato cannery. A 4-H project I had to do when I was 15 involved the production and display of 24 perfect tomatoes. Winning top prize for this project earned me the title of "Tomato King" at the Indiana State Fair. My prize included lunch with the governor of Indiana, a gold watch, and a drive around the Indianapolis Motor Speedway. Little did I know that decades later I would be honored at a luncheon hosted by another Indiana governor, after winning the World Food Prize!

YEARS AT PURDUE UNIVERSITY

I've always said that I bleed the colors of Purdue University, where I earned my college degrees and spent my entire 50-year career. My upbringing led me to pursue an undergraduate degree in general agriculture at Purdue University, which I completed in 1956. One of the best things that came from those early years at Purdue was meeting the woman who would become my wife. As a junior at Purdue, I met Sue Bayless in 1954 in the halls of the Purdue Memorial Union on her first night on campus as a freshman. Back then, the male-to-female ratio was 6 to 1, so I had to move fast. We were married two years later during Sue's sophomore and my senior year.

Upon graduation from Purdue, Sue and I went back home to Morristown, Indiana, where I was plant manager of our family-owned tomato cannery for three years. My father always said to me, "You don't have to be crazy to be a tomato canner, but it helps." We had only eight weeks to get everything harvested and into cans. We prayed that it didn't rain during that time, which would cause many problems with harvest and processing. There were so many opportunities for spoilage and loss of product. In 1958, our plant closed, like more than 200 other Indiana canneries, as a result of the tomato industry moving to the rain-free harvest season of the West Coast. I initially planned to work on my family farm, raising hogs, corn, and soybeans, but I became very discouraged with the death of hogs due to a respiratory virus. Sue and I planned our "great escape" to leave the family farm. I planned to return to school, and Sue landed a first-grade teaching position in Lafayette, paying $4,200/year. It didn't take us long to pack. My return-to-school wardrobe consisted of a couple shirts, two pairs of khaki slacks, and one pair of shoes. We also had our two-year-old daughter, Jenny.

In the fall of 1960, I returned to Purdue University in West Lafayette, Indiana, originally intending to attend veterinary school. However, soon after getting back to Purdue, I met

Dr. Norman Desrosier, a professor in horticulture doing research in food processing, who convinced me to pursue a graduate degree with him. He offered me a graduate assistantship in horticulture (paying $1,200/year), serving as an instructor and doing research on the protein value of algae. Coursework like organic chemistry didn't come easy to me, given that I had been out of an academic environment for almost four years. In that class, I dropped a beaker with sulfuric acid in lab, and it ruined my only pair of shoes and one pair of pants. Between Sue's salary as a teacher and my assistantship, it was hard to buy new clothes, let alone pay $15 for the glassware I had broken and pay a babysitter. I wanted to leave but Sue said, "Where will we go?" So we stayed.

When Dr. Desrosier left for a job with Beech-Nut, my research on algae ceased, and I had to find another major professor. I started work with Dr. Milton Workman, a postharvest physiologist working on irradiating potatoes so they wouldn't sprout. My research was interrupted for a second time when Dr. Workman left for Colorado State. Finally, I completed my PhD in 1967, working with Dr. Johan Hoff on a project that was perfect for me—the volatile flavor components of tomatoes.

As I neared graduation, I began interviewing for positions in the food industry. I interviewed at one university and with several companies across the US and received job offers from four companies. However, an important conversation led me to stay at Purdue. During a flight for one of those job interviews, I met Dr. Earl Butz, who at the time was Purdue's dean of the College of Agriculture, and who later became the US Secretary of Agriculture under Presidents Nixon and Ford. Dr. Butz advised me to talk with him first before accepting a job in the food industry. When I later went to his office for that purpose, Dr. Butz offered me a tenure-track faculty position in the Horticulture Department at Purdue, with a salary of $11,000/year. That offer led to a 50-year career at Purdue! Dr. Butz told me there were many opportunities in academia and that I could always go to industry later. He appealed to my common sense and my heart as an Indiana son with a loyalty to Purdue.

THE FOUNDING AND GROWTH OF THE DEPARTMENT OF FOOD SCIENCE AT PURDUE

I went through the faculty ranks as a member in the Department of Horticulture, teaching and doing research in aseptic processing (described in more detail below). I became part of the Food Science Institute formed on campus, with Dr. Bernie Liska as director. When Dr. Liska became dean of the School of Agriculture in 1975, I became director of the restructured Food Science Institute. Liska was a food dairy scientist who saw the value of food science as a stand-alone department; as such, he oversaw the creation of the Department of Food Science at Purdue in 1983. I served initially as interim head and in 1984 was named department head. Now as a full-fledged department, we could really grow the Food Science program at Purdue. The good news was that we had a department; the bad news was that there was no money to support our programs. However, we had a vision to be THE leading food science department in the world. During my 20 years as department head, we grew from a small department (9 faculty, 10 graduate students, and 30 undergraduate students) to one of the largest and strongest food science departments in the US (peaking at 19 faculty, 50 graduate students, and 150 undergraduate students) (Stadelman et al. 1986).

As department head of Food Science, I was a "big picture" guy and wanted to do some nontraditional things. Years before becoming department head, I had seen the need for our students to be better trained for entering the food industry, where most of our graduates took jobs. In the late 1970s, I created a product development course as a capstone course for food science majors. The value of such a course for food science majors led to its being adopted as a model capstone course by food science programs all across the US. The nature of my research and teaching convinced me that our new food science department needed to be closely linked to the food industry, to better inform our research and train our students. With the help of Dr. Arnold "Bud" Denton, retired Executive Vice President of the Campbell Soup Co., and Dr. John Nelson, retired Vice President of Research at McCormick, we developed an industrial associates group to keep the department linked to the food industry. We also introduced into the department the concept of total quality management. These principles were common practice in industry, and during lunch meetings for faculty, we discussed how to incorporate them into our department and the training of our students.

I got the idea to establish centers of excellence in the department, and the first one we pursued was associated with carbohydrate research. We didn't have a single carbohydrate chemist in the department when we started. However, Dr. Roy Whistler, an emeritus professor in the Department of Biochemistry, was a well-known starch chemist, and he was willing to lend his name to the center. We began to gather faculty members with expertise in carbohydrate chemistry, which led to what is now the world-renowned Whistler Center for Carbohydrate Research. A real strength of that center is its strong linkage to the member companies that help support the research and together help determine research priorities. Over time, we established three additional centers associated with the department. The most recent is the International Center for Food Technology, focused on reducing food losses in developing countries and creating processed food products with increased value. Winning the World Food Prize (see the Recognition Based on Research in Aseptic Processing section below) gave me the opportunity to obtain funding for the center focused on this important area.

The year the Department of Food Science was created, we also started teaching a workshop on aseptic processing and packaging, thinking that we would offer it once or twice, if there was enough interest. In 2013, we taught the 30th annual Aseptic Processing Workshop with a record number of attendees and several countries represented. We've taught that workshop not only on campus but also on-site at many food companies, for employees in various positions (researchers, product developers, line operators, equipment manufacturers) (**Figure 1**). We've published three editions of our *Principle of Aseptic Processing and Packaging of Foods*, the most recent in 2010 (Nelson 2010). Our Aseptic Processing Workshop has resulted in the training of thousands of individuals in aseptic processing techniques. More than 20 different companies have hired us over the years to tailor the workshop for their specific needs, providing additional training for their staffs. TetraPak and PepsiCo, China; Kikkoman's, Japan; Citrosuco, Brazil; and Aleuropa, Germany, are a few of the companies we worked with. These workshops have been held all over the world, further allowing the successful adaptation of aseptic processing.

Since I was not only serving as department head but also as faculty representative to the athletic program at Purdue, I saw how athletes were being recruited. I thought we could learn something from athletics about how to recruit students into food science. We adopted some of their practices (e.g., contacting select high school juniors, strong advising, tutoring) into our department and grew to become the largest undergraduate food science program in the US (Stadelman et al. 1986). It seems that many food science departments across the US have adopted some of these recruiting and retention practices, to the benefit of the departments, the students, and the reputation of food science as a discipline within universities.

Part of what I could do for the Department of Food Science at Purdue was linked to my serving for 20 years as Purdue's faculty representative to the Big Ten and National Collegiate Athletic Association. In this role, I served as chair of Purdue's Athletic Affairs Committee; chaired the search committees for Purdue's athletic directors; and was involved in hiring many coaches, all of which gave me a chance to influence Purdue's athletic program over a 30-year period. As a big

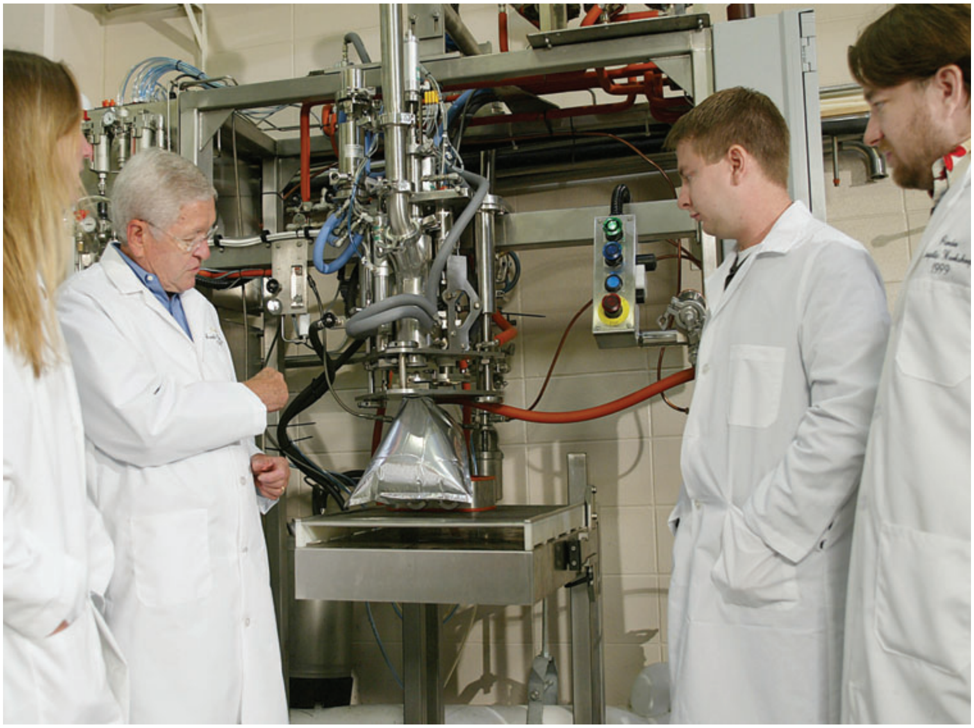

Figure 1

Phil Nelson teaching at the 30th annual Aseptic Processing Workshop.

sports fan, these roles made it even more enjoyable to attend athletic events on and off campus. Our two sons, Andy and Brad, enjoyed the benefits of attending the Rose Bowl several times, and both later became Purdue graduates. However, the benefit to the Department of Food Science from my role as faculty athletic representative came from my having occasions to be on flights with our university president. When the president asked about my work and department, I often talked about our need for more space for a rapidly growing department. There is no question that this helped lead to our department getting a new building in 1998.

It was exciting to help design and to witness the construction of our new 120,000-square-foot Food Science Building. The building was designed to house both the food science faculty and the food process engineers from the Department of Agricultural and Biological Engineering. You can imagine how excited I was in 2010, when I retired, to learn from the dean of the College of Agriculture that the Food Science Building was to be renamed the Philip E. Nelson Hall of Food Science (**Figure 2**)!

INVOLVEMENT WITH STUDENTS

My wife, Sue, always saw that I cherished my role as an educator and that I was most proud of the success of my students. I enjoyed working with young adults my entire career, and recognized that this helped keep me young. While I was department head, our department's motto was "Training the best." This not only brought the top young minds into food science, but it also attracted numerous employers to develop internships and recruitment programs within the department.

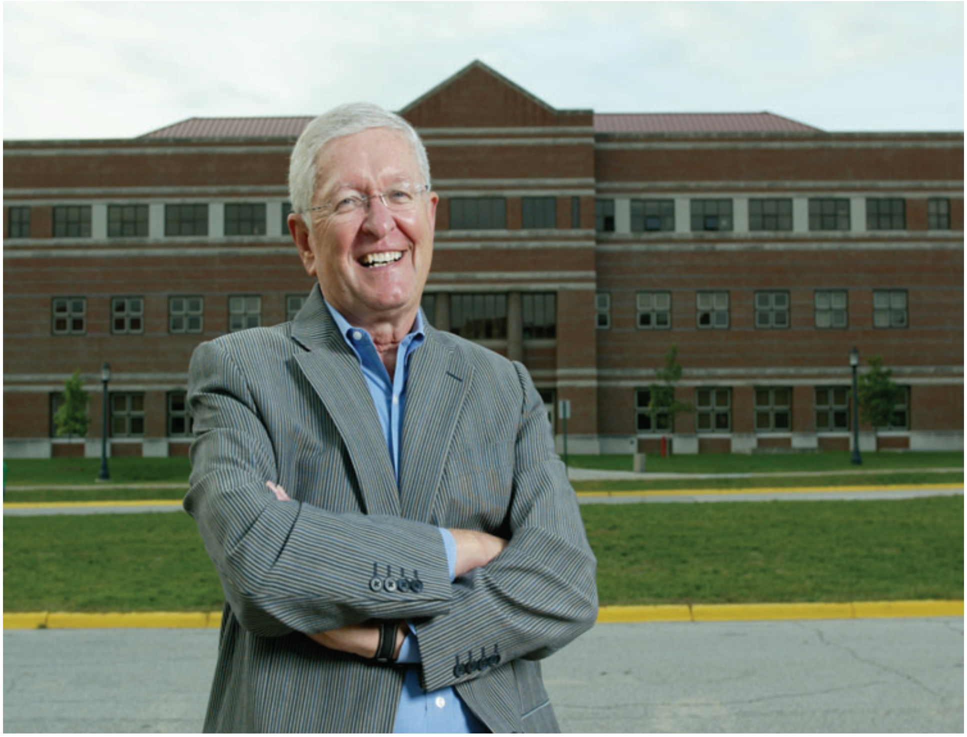

Figure 2

Phil Nelson, in front of the Philip E. Nelson Hall of Food Science.

I especially enjoyed working closely with graduate students. I am very pleased to say that I trained 32 graduate students at Purdue and sat on the advisory committees of another 35 graduate students. Those graduate students helped me establish the academic record of 70 peer-reviewed articles, 12 US patents, and 28 international patents. I was able to maintain an active role in graduate education during my years as department head. Along with shaping the next generation of researchers in the area of aseptic processing, I considered it important to develop leaders. I encouraged them to prepare themselves for whatever might come along. I'm pleased that many of my former students have led research programs in numerous companies (e.g., Rich-SeaPak, FMC, PepsiCo, etc.) and at other academic institutions (e.g., Illinois Institute of Technology, National Taiwan University, etc.). Several of the faculty members that I hired have gone on to become heads of food science departments and deans of agriculture.

A few years ago I was asked to create a list of my priorities for involvement with graduate students. I created the following list:

- Create opportunities for research, free of charge, allowing intellectual exploration while providing guidance;
- Place the needs of graduate students first;
- Make introducing students to industry and their leading scientists a high priority;
- Create spontaneous brainstorming sessions with students via an open-door policy, providing ideas but allowing the students to answer their own questions;
- Use my own expertise to point out the practical applications/implications of ideas and research directions;

- Provide students with the skills needed for independent scientific inquiry;
- Instill leadership qualities in students and provide them tools to become leaders in their respective organizations;
- Encourage students to participate in professional organizations such as the Institute of Food Technologists (IFT); and
- Encourage and facilitate presentations by graduate students at national and international meetings.

As head of the Department of Food Science, a key effort of mine was to create opportunities for faculty and students to interact with industry, to help them understand the application of their research to the real world. As mentioned above, I created the Industrial Associates program, which brings the students in contact with industry representatives and provides the connection to the practical applications of their ongoing research. The program helps incorporate industry application, stimulates interest in the research, and promotes novel and innovative research directions by identifying and addressing the industry's needs. Pointing out the applications and implications of research increases the potential of students for securing industry jobs. Former students have commented on how, with these industry interactions, they learned to translate research topics into important real-world situations. Interactions with industry resulted in employment opportunities for students with these companies.

I encouraged many of my graduate students to consider academic careers, and a number of them did so. Showing the students a decision-making approach helped them address their research problems and interpret research findings, and helped prepare them for careers in academia. I hope that my enthusiasm for knowledge was instilled in the students who worked with me; this became a motivating factor not only in the lab, but also in life. I used my knowledge of food processing to help create a lasting excitement in my students for future inquiry. An example of my impact became clear to me when I visited Taiwan. One of my former students became a professor at the National Taiwan University. I was identified as "the Grand Professor," he was designated the "Professor," his students that went on in academia became known as "my Grand Students," and their students were known as my "Great-Grand Students"—a family tree of more than 40 individuals having an impact on our global food supply.

When I received the World Food Prize in 2007 (described below), some of the especially meaningful notes of congratulations were from my former graduate students, some of whom had gone on to work for companies that commercialized our research and technology in aseptic processing, to create the global impact that was the basis for the award. During the announcement of the World Food Prize award in Washington, D.C., in 2007, Administrator of the United States Agency for International Development Henrietta Fore said, "Nelson has answered the important call, made to all great educators, to broadly share what they have learned with others. He has spent his career educating food scientists, worldwide."

Educating students, both graduate students and undergraduates, was the most important thing I did as a faculty member!

PROFESSIONAL INVOLVEMENT

I was fortunate to be called upon to provide leadership to the profession of food science and the food industry through its professional organization, IFT. By serving as a diligent volunteer of many IFT committees, I became prepared for leadership roles on various committees (e.g., Long Range Planning, Research, Nominations, Awards, Expert Panel, Constitution, and Bylaws). On the Long Range Planning Committee, I took part in creating a strategic planning process that for the first time involved the immediate-past and current IFT presidents, as well as the president

Figure 3

Phil Nelson with other former Institute of Food Technologists (IFT) presidents and the executive director in 2007 when he won the World Food Prize. (*row 1*) Al Clausi, Sheri Schellhaass, Margaret Lawson, Phil Nelson, Barbara Byrd Keenan. (*row 2*) John Floros, Richard Hall, David Lineback, Chuck Manley, Dennis Heldman, Ann Hollingsworth. (*row 3*) Mark McLellan.

elect. We aggressively looked to the future of IFT and adamantly insisted on strong stewardship to accompany the planning process. Committee leadership roles helped prepare me for serving as president of IFT in 2001–2002. This was a critical time, especially because of 9/11. Although most other association-type organizations tumbled to all-time lows in personnel and fiscal health, fortunately, IFT enjoyed only a soft decline and had a resilient recovery. Presidents of IFT before and after my time (many of whom were in attendance when I received the World Food Prize in 2007; see **Figure 3**) have worked very hard for the organization.

In addition to professional involvement with IFT, I was pleased to be involved with Phi Tau Sigma, the Honorary Society for Food Science and Technology. I still strongly believe in the goals of Phi Tau Sigma: to recognize excellence in our students and our profession. After becoming a charter member of the Purdue Phi Tau Sigma Chapter, I became the National Membership Chairman in 1976, and later served as National President of Phi Tau Sigma.

Having had leadership roles in a food science professional organization, I was fortunate to be called on to serve on food science–related committees of the National Academy of Sciences and within the US Department of Agriculture (USDA). It has been important for food science to have a "voice at the table" in important conversations related to human health and agriculture. It was really educating for me to serve as a member of the National Academy's Subcommittee on the

World Food and Nutrition Study (1974–1977), the Additives Used in Food Processing Committee (1979–1981), and the Food Additives Survey Data Committee (1980–1991). The service to USDA, representing food science professional organizations as a member of the Secretary of Agriculture's National Agricultural Research, Extension, Education and Economic Advisory Board, was more recent (2002–2005).

Serving as a member for their Study on Postharvest Conservation, in New Delhi, India, in 1974 was my first real exposure to the magnitude of food loss problems in developing countries. Indian officials I met with included M.S. Swaminathan, who was then Minister of Agriculture, but in 1987 was awarded the first World Food Prize for introducing high-yielding wheat and rice varieties to India's farmers. That meeting in India started me on a path to explore ways bulk aseptic processing technology could be used in developing countries, to preserve food for both domestic distribution and for export.

WORK IN ASEPTIC PROCESSING

After receiving my PhD from Purdue University in 1967 through the Department of Horticulture, my focus as a faculty member became food science; however, it always remained grounded in the food industry (Caradec et al. 1985, Floros et al. 1992). My interest was always fruits and vegetables—the topic of the only major book I published (Nelson & Tressler 1980). Very early in my career, I understood the industry needs for year-round processing of seasonal vegetables like tomatoes. I wondered if tomatoes could be stored aseptically for a long time period at ambient temperatures without spoiling or becoming contaminated. I knew that if we could discover and successfully implement a method that would reduce postharvest spoilage, it would be a great boon to the food processing industry and the consumer. If we could hold large amounts of tomato product beyond harvest then process it throughout the year into various products (e.g., ketchup, juices, sauces), we would help the tomato industry be less seasonal. I saw aseptic processing as a way to extend the processing season for vegetables. Of course, we would need to maintain the nutritional value and flavor of the final product. My work on bulk aseptic storage was initially applied to just tomato processing, but fortunately it could be applied to a multitude of seasonal products. With bulk aseptic processing systems, the vegetable and fruit packing industry was transformed from a fresh pack system of putting up product once a year to making a variety of products year round in a remanufacturing industry. I was happy to see that immediate applications of the research helped stabilize the canning industry in the Midwest, but I didn't realize until much later the global impact.

Aseptic processing is a way to sterilize a product and maintain that sterility through storage, further processing, and/or packaging. In aseptic processing, the product is commercially sterilized and cooled outside the package, the package is sterilized separately, then the two are combined under sterile conditions. The system uses highly efficient heat exchangers and high-temperature, short-time and ultrahigh-temperature processes. Because of the shortened times and high temperatures, aseptic processing has a number of advantages. With rapid heating and cooling of the product, we save more nutrients and flavor in the product compared to the longer heating process involved in canning. Aseptically processed products are safe, usually more fresh tasting, and can be stored, packaged, and shipped at a reduced cost. Consumers now recognize such products as juice boxes, pudding in a cup, fruit-on-the-bottom yogurt, and wine in a box.

Time has proven that seasonal processing of fruits and vegetables has greatly benefited from aseptic processing, extending seasonal work to year-round work. Shipping container costs were minimized as containers went from disposable, tin-lined drums to plastic bags. In some product forms, foods previously had to be shipped in a frozen form. Aseptic processing allowed those products to be packaged, and the temperatures during shipping could be higher than the frozen forms.

When we started our research, aseptic processing was in its infancy. Successful applications in the US were limited to two companies, and they were closely guarding the technology. In 1968, we launched a program to develop a low-cost, simple, aseptic, bulk storage system that could be readily introduced into existing processing lines. The basic process included (*a*) heat sterilization and cooling of the product; (*b*) sterilization of the container; (*c*) filling of the sterile container with the cooled, sterile product; and (*d*) maintaining asepsis while in storage. Before our work, no system existed that could do this. No existing equipment could accomplish this task. To do research in this area, we needed close ties with industry. I had been advised as a junior faculty member not to take any money from industry, that as a researcher you had to be pure. I ignored that advice and became an early example of industry and university working together. I'm convinced that the bulk aseptic processing system we developed would not have been successful without collaboration with industry.

As I prepared a short review article on aseptic bulk processing for *Food Technology* in 1990 (Nelson 1990), it was easy to look back over the past 20–30 years at our early work and the work of others who helped guide our research approach. I could describe how the seasonal production constraints of fruits and vegetables were indeed being overcome with aseptic bulk processing, storage, and transportation. To give a historical perspective, I referred in the article to the US patent filed in 1958 by Dixon et al. (1963) for the aseptic transfer of tomato products into large tanks. Sterilizing bulk tanks with hydrogen peroxide was the basis of a patent filed by Buitoni & Buitoni (1971). Industrial procedures for storing large volumes of grape juice under refrigeration were described by Friedman (1971), and Neogrady & Szody (1972) had reported the mechanical challenges of aseptic storage for vegetable preserves in large containers. Lemarine et al. (1970) had reported improved quality of aseptically stored grape juice, compared to conventionally processed juice, along with decreased production costs by eliminating the need for refrigerated storage. About this same time, we started research on storing tomato products aseptically in tanks (Nelson 1971, 1973).

In our research at Purdue in the 1970s, we focused first on storing products in pilot tanks (100 gallons). We scaled up over time, testing larger tank sizes up to 15,000 gallons. In 1976, Purdue University and Bishopric Products received the Industrial Achievement Award from IFT for technological developments that included large-tank aseptic storage and adaptation of railcars for aseptic transportation (IFT 1976). By now, large tanks have become the norm, ranging from 40,000 to more than 2 million gallons. Those million-gallon tanks are six stories tall and six stories wide.

In our early work, we developed several patentable parts of the tank and filling system (**Figure 4**). We found that a carbon steel tank coated with an epoxy resin was easier to clean and sanitize than was a stainless steel tank. The move to epoxy-coated steel greatly reduced installation costs. Bishopric/Enerfab, a tank manufacturing company in Cincinnati, Ohio, worked with me to perfect and build the tanks that we first used for processed tomatoes, but were later applied to not-from-concentrate orange juice and other fruit juice products. In early studies with tomato sauce, we had made five 100-gallon tanks, with different linings, and tested them to determine the best tank for product storage. When I brought in representatives from Heinz, Hunts, and Campbell's to look at the technology, they said, "Great project, but way too small; we'd fill that size tank in minutes." We scaled up to a 1,000-gallon tank that my graduate students and I filled with chopped tomatoes (Dale et al. 1981). The product stored for 18 months had good vitamin C content, color, and flavor, but again industry said it wasn't big enough. I couldn't find a company in Indiana or Ohio to work with on a bigger tank but found a willing collaborator in Pennsylvania. In the summer of 1972, we put in two 15,000-gallon tanks and filled them with pizza sauce for

Figure 4

Tanks for storing aseptically processed products.

that collaborator. I'll never forget when in the fall I got a call saying, "We hate to tell you, Dr. Nelson, but all 30,000 gallons of your product is spoiling." I was glad that was in Pennsylvania, rather than near Purdue, because we had to spread that red wasted tomato all over the hills of Pennsylvania. Fortunately, we had kept good records to identify the process temperature as the source of the problem, which had allowed some microorganisms to grow. The processor let us come back the second year. We filled those tanks again, and fortunately we were successful. An Indiana processor asked me, "Will it work?" With my fingers crossed, I said, "I think so." He installed six 40,000-gallon tanks and was successful.

We discovered in our work with tanks that to sterilize the air in a tank, the entire tank had to be flooded with sanitizer. Aseptic filters were designed and built to allow sterile, inert gas to flood tanks and force out the sanitizer, and to force out partial volumes of sterile product from the tank (Wilson & Nelson 1979). We also designed and built patentable aseptic valves to prevent recontamination of the sterile product. The key was the valve's ability to prevent microorganisms from moving through the valve stem into the sterile system. A secure cavity around the valve stem permitted this area to receive steam or a sanitizing solution that could act as a barrier against the possibility of recontamination.

Our work focused on bulk aseptic processing systems: from the tanks and linings to the fillers and valves; from processing to storage and from storage to packaging. We went on to research and apply a storage and shipping system (bag-in-box) that would allow others to export and import new, cheap, and safe food products. Others had applied aseptic packaging on the consumer scale, but we focused on creating the bulk aseptic system. Over a three-year period, we identified other critical

Figure 5

Phil Nelson in Japan, at Nippon DelMonte, a site with aseptic tanks.

parts of the system, and a complete system was designed, built, and tested first in the laboratory, then in the field. After test results came back positive, industries worldwide began investing in major commercial installations. The first systems were built in the US and were followed by systems in Japan, Russia, Morocco, and other countries (**Figure 5**). Bulk aseptic processing and storage was getting a lot of international attention (Hulsey 1971, Nelson et al. 1974). In 1975, the technology was featured as the key exhibit at a conference in Bulgaria.

We found success with pilot studies of aseptic bulk storage, but we also pursued developing a similar system for smaller-scale, in-bag storage. Our research led eventually to processors filling aseptically processed products into multilayer, sterile flexible package material, in bags ranging from 1 gallon to more than 300 gallons. The research on these small-scale systems resulted from a visit to my office by William Scholle, an entrepreneur from Chicago, who had a chemical engineering degree from Purdue University. He approached me and asked if my technology developed for aseptic bulk storage could be used with a small-scale aseptic processing system. At that time, the Scholle Corporation was shipping and storing battery acid in collapsible bags. Bill Scholle was willing to "roll the dice" with me and try this technology with food. Working with the Scholle Corporation, we carried out in our pilot laboratory a testing and development program that resulted in the establishment of a low-cost system for preserving and transporting foods worldwide at ambient temperatures (Nelson 1984). As with bulk aseptic processing, this system had to produce an aseptic product, but in addition, the fitment used to fill bags required treatment to prevent recontamination of the product during filling. In the case of the Scholle research, this fitment would be taken off and steamed during filling then reapplied. After we successfully tested the process on several food products, this technology was rapidly commercialized and became the leading method for moving products globally. Because this method was relatively inexpensive, it could be used in countries where metal containers were economically out of reach. The flexible packaging materials of the collapsible bags increased the need for research in oxygen permeation using this aseptic system (Sadler & Nelson 1985, 1988; Sadler et al. 1988).

My research continued with Fran Rica Manufacturing (now JBT) to develop an aseptic fitment that was used on the aseptic bag. This fitment, the fitting that allows aseptic products to be introduced into a sterile bag without recontamination, was engineered as a membrane that was ruptured during the fill then resealed with a foil cap. Again, after successful development, this system was adopted worldwide. In subsequent years, other companies worked with our laboratories at Purdue University to test, develop, and prove the concepts behind their technology before going commercial.

In 1984, representatives from Tropicana came to my office and said, "Marketing wants us to be able to put on the label 'not from concentrate.' Do you think your technology will work for orange juice?" I said hesitantly, "I think so." I think it's fair to say that we actually changed the citrus industry, making possible not-from-concentrate orange juice (**Figure 6**). Bulk aseptic storage and transportation have made it possible to distribute not-from-concentrate orange juice on a wide scale year round.

During my career, I consulted with many companies worldwide. One notable event for me was working with a Norwegian shipbuilder that installed our technology in the hull of a ship. The first two ships held 3.2 million gallons, but ships built more recently have a capacity of 8 million gallons.

Figure 6

Phil Nelson with Tropicana aseptically processed orange juice.

Figure 7

Phil Nelson with a model ship for transporting aseptically processed orange juice.

The ships are more than the length of two football fields, six stories tall, and contain 16 tanks each of half a million gallons. These vessels are used to move aseptically processed, single-strength orange juice from Brazil to the US and Europe. I was honored when the Norwegian shipbuilder built me a model ship scaled to one one-hundredth of the actual size. I intended the model to sit on my fireplace mantel in my home, but the 8-ft model built was too big for that. The ship model now finds its home in the main office of the Department of Food Science at Purdue (**Figure 7**).

Our published papers and presentations helped bring our research success into the public domain, and the Aseptic Processing Workshop we offered through Purdue helped train scientists and operators from around the world (Nelson 2010). Although our early research was focused on aseptic processing of liquids, some later work focused on aseptic processing of particulates (Berry et al. 1990). Likewise, our early work on sterilizing tanks was focused on iodophor (Wilson & Nelson 1979, Chung et al. 1979), and more recent work focused on using chlorine dioxide to sterilize tanks and inactivate microorganisms on fruits and vegetables (Han et al. 1999, 2000, 2001, 2002, 2003, 2004). This work continues. I would like to think that we helped move aseptic processing from being a novel process to becoming one of the fastest-growing segments of food processing.

IMPACT OF WORK ON ASEPTIC PROCESSING

In 1991, IFT rated the top 10 innovations in food technology. The list ranked aseptic processing and packaging as number one, above juice concentrates, safe canning processes, freeze drying, and food fortification. Aseptic processing has become a mainstay in safe and economical food processing, shipping, and storage. I'm glad to see that our research in aseptic processing in the 1970s and 1980s contributed to the advances in, and championing of, this technology, and to its global impact.

While my graduate students and I were doing research on bulk aseptic processing technology, I had no idea that aseptic processing would become one of the fastest-growing segments of food processing and that bulk aseptic processing would have such a global impact. The argument for that impact was the basis of the nomination for the World Food Prize (discussed below). The scientific contributions to bulk aseptic processing technology resulted in advancements that made preserved foods more accessible and safer throughout the world. Our successes included a majority of the bulk aseptic processing system, including the filters, valves, fillers, tanks, and their linings (including bag-in-box containers). The preparation for the World Food Prize nomination documented my impact of bulk aseptic processing technology. Breakthroughs in that technology revolutionized the food industry, particularly in the area of large-scale storage and transportation of fresh fruits and vegetables using bulk aseptic food processing. The advancements significantly reduced postharvest waste and spoilage, and greatly increased the availability and accessibility of nutritious food worldwide, particularly in emergency situations.

It seemed that prior to our work, research and development in aseptic processing were progressing slowly. Aseptically processed products were more expensive than their traditionally processed competitors. This clearly prevented this processing method from becoming mainstream. We developed the bulk aseptic process that has become economical enough to use almost anywhere in the world. The process works for both fruits and vegetables and was adapted to work in portable units. These breakthroughs drastically cut transportation costs, given that metal drums and/or refrigeration are not needed, while they alleviated food safety concerns. They allow countries around the globe to import and export foods that otherwise could never enter the world market. Prior to these breakthroughs, many farmers and food businesses in remote areas could sell only to local consumers, and as such many products spoiled. By using bulk aseptic technology, any cargo vehicle that can carry a wooden crate (bag-in-box) can ship processed foods from remote areas within countries to heavily populated areas.

Also, aseptically processed and packaged products have an advantage of being more easily imported and exported. The Foreign Agriculture Service of the USDA estimated that 30–50% of fresh food products that are imported into a developing country are lost at the port of entry due to improper handling and storage; aseptically packaged foods and canned goods only suffer a 5% loss.

Another impact of successful bulk aseptic processing has been the change to year-round work for what was once only seasonal work. Packaging fresh produce previously meant that companies could only operate at capacity during harvest times, so companies would fluctuate their numbers of employees with those harvests. With bulk aseptic storage, companies can have steady employment and continue to make value-added products year round. For example, data available in 2006 showed that more than 90%, or between 20 and 21.6 million tons of the 22 to 24 million tons, of fresh tomatoes harvested globally were aseptically processed and packaged for off-season remanufacture into various tomato-based food products.

Our aseptic technology was shown to work on both a tremendously large scale and a small scale. It has been used to create 8-million-gallon, ocean-going aseptic tankers. It has also been used to create small-scale consumer packages. The aseptic bag-in-box technology we developed in cooperation with industry is used both for consumer packaging and for transport of bulk products, the latest being a 3,000-gallon bag with contents destined for individual consumer packaging. The cost-effectiveness of these shipping packages has opened the way for new markets.

Other equipment manufacturers have used our patents and concepts to develop their own aseptic processing and packaging equipment and are utilizing them in their own systems worldwide. One example is the Dry Pea and Lentil Council, which began field testing aseptically packaged lunch products in the Indonesian School Lunch Program. Lunches are processed this way to provide a low-priced, nutritious food product that does not need local water (which is of poor quality) or refrigeration.

Though more costly than bulk aseptic processes, transportation and storage of bag-in-box products is still more economical than storing and shipping in metal drums. Data available in 2006 showed that in comparison to frozen storage costs estimated at 20 cents per liter, bag-in-box estimates were 14 cents per liter (a 25% savings, equivalent to $700 million per year based on Scholle Corp. market size estimates), and bulk storage costs were approximately 6 cents per liter (a 75% savings). These savings illustrate how developing markets have benefited from these technologies.

The systems, valves, and equipment developed for bulk aseptic processing have benefited both developing and developed countries by providing an inexpensive packaging and shipping system for both importing and exporting food stuffs. In 1989 in Senegal, a new aseptic processing and packaging endeavor was developed to process local fruits into juices. This endeavor, at its height, accounted for a $4,000,000/year impact to the Senegalese economy. This is equivalent to a $7 billion impact on the US.

Of the companies we directly worked with, Enerfab substantiated in 2006 that nearly 500 million gallons of juice were processed annually with our bulk aseptic processing technology. Enerfab produced the tanks and systems for this and had a 95% share of the global market for juice producers. In addition, in 2006, Scholle Corporation produced and sold 3,251,857,000 liters worth of aseptic bag-in-box in 138 countries each year. Scholle held at that time a 60% share of bag-in-box production. That approximated to an annual usage well exceeding 5 billion liters worth of aseptic bag-in-box. Since 2006, new and emerging uses for these processes have been introduced.

Aseptically processed and packaged milk has been part of a humanitarian feeding program funded by the USDA and managed by Land O'Lakes since 2000. The program provides milk and biscuit products as part of school nutritional programs in Bangladesh, Pakistan, Indonesia, Vietnam, and the Philippines. Safe and nutritious products can be delivered to remote regions, with minimal loss, due to the durable sterile packages. In 2005 and 2006, less than 0.2% of the school-feeding products were lost in the Philippines.

For most of us, it is hard to appreciate the value of safe water until disaster strikes. When the tsunami hit Southeast Asia in 2004, and when Hurricane Katrina hit the Gulf Coast in 2005, potable water was transported to these areas in packaged flexible materials. Although these applications were not aseptic, I'm told that our research in aseptic processing contributed to such flexible packaging that is convenient and cost-effective, finding use in relief programs.

RECOGNITION BASED ON RESEARCH IN ASEPTIC PROCESSING

I certainly didn't anticipate the visibility and awards that would come from my research on bulk aseptic processing. Our research and its impact were recognized by IFT (Industrial Achievement Award and the Nicholas Appert Award), the food industry (Food Processing Putman Food Award, Food Processors' Hall of Fame, Forty Niner Service Award, and H.D. Brown Food Processing Person of the Year Award), and the USDA (USDA Secretary's Award for Personal and Professional Excellence).

Of course, the most surprising recognition that came from our research in bulk aseptic processing was being selected to receive the 2007 World Food Prize. The World Food Prize was created by Nobel Peace Prize winner Dr. Norman Borlaug and often is referred to as the "Nobel Prize for Agriculture." The presentation that year was unique in that it was the first time the award was given to someone in the area of food science/food processing (i.e., a value-added segment of agriculture). It was also unusual that the award went to an individual (versus a group) and to someone in the US.

Dr. Norman Borlaug, referred to as the "father of the Green Revolution," won the Nobel Peace Prize in 1970 for his humanitarian efforts. In the 1940s and 1950s, he developed wheat varieties with increased yield, thus preventing starvation of millions in developing countries. Borlaug asked the Nobel Foundation to create a special award category for food and agriculture, to bring more attention to the issue of agriculture and hunger. When they declined, Borlaug sought financial sponsors and created the World Food Prize in 1986. The annual World Food Prize ceremony is held each October in the State Capitol building of Iowa—the home state of Dr. Borlaug and John Ruan, the philanthropist who donates the prize of $250,000 (**Figure 8**).

The Department of Food Science at Purdue University and IFT nominated me for the World Food Prize. An argument was made by them that our work in bulk aseptic processing was "an innovative breakthrough technology that revolutionized the food industry, particularly in the area of large-scale storage and transportation of fresh fruits and vegetables." The advancements significantly reduced postharvest waste and spoilage, and greatly increased the availability and accessibility of nutritious food worldwide, particularly in emergency situations.

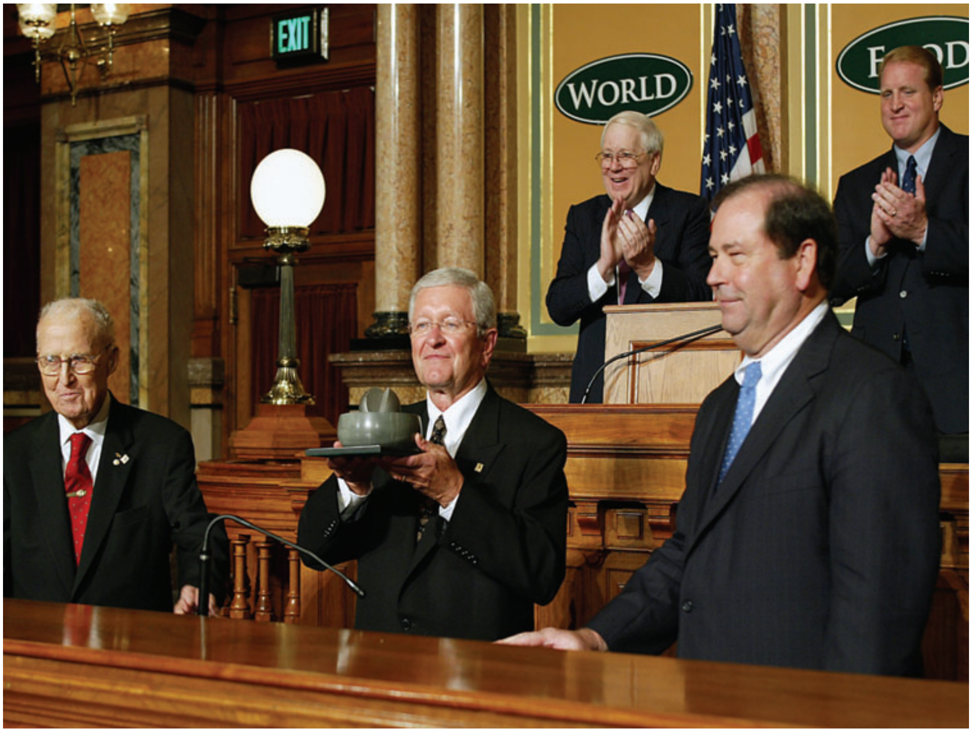

Figure 8

Phil Nelson (*center*) holding the World Food Prize. (*row 1*) Dr. Norman Borlaug, Dr. Phil Nelson, Mr. John Ruan. (*row 2*) Ambassador Kenneth Quinn, Mr. Chuck Culver (Governor of Iowa).

A FOCUS ON REDUCING FOOD LOSSES

In 1974, I attended a conference on reducing food losses that was held in New Delhi, India. At that time, it was reported that 20–40% of food produced in India was lost due to spoilage, contamination, improper storage, or other causes before it reached the consumer. A call was made to reduce these losses to help alleviate hunger.

Today, 40 years later, little improvement has been made, as food losses are still reported at the same or higher levels throughout parts of India and Africa. Food losses represent a tremendous waste of resources, including water, land, energy, labor, and capital. Needlessly and unfortunately, little attention has been paid at the national and international levels to this part of the food chain. The dilemma of food losses continues to hold our attention as an unrealized opportunity. Fortunately for me, my winning the World Food Prize in 2007 gave me a platform on which to stand in pushing this agenda. I was also fortunate that the Department of Food Science at Purdue also had other faculty members with a history of working in developing countries and focusing on technologies that could help reduce food losses and promote economic development.

A report issued in 2011, sponsored by the Food and Agriculture Organization of the United Nations (Gustavsson et al. 2011, p. 15), stated that "tension between production and access to food can also be reduced by tapping into the potential to reduce food losses." The report continued, "Given that many small holders live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods" (Gustavsson et al. 2011, p. 1).

It is critical now to focus on reducing food losses and expanding markets for local food crops, to help reduce hunger and poverty and to stimulate rural economic growth. Making food loss reduction a mainstream component of research and development programs is essential to improving food security and enhancing the livelihoods of populations in developing countries. Scientific and technological innovations in areas of food preservation, storage, distribution, and market development will help reduce hunger, create demand for commodities, and contribute to food loss reduction.

Our recently initiated International Food Technology Center (IFTC) at Purdue University, which I helped initiate after winning the World Food Prize, is focused on reducing food losses. The IFTC began an action plan to reduce on-farm losses and develop the capacity for small- to medium-scale entrepreneurs and women's groups to provide markets for farmers. Efforts to develop and provide training opportunities to researchers, extension personnel, entrepreneurs, student exchanges, and others through short-term training on improved processing and preservation, food safety, health and nutrition, and technology development will provide sustainable solutions to the problems of food losses and market development. Food scientists' efforts, through the IFTC at Purdue University and other partner organizations, look to reduce food losses as a key component in reducing hunger and poverty and to stimulate economic growth.

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