SciVerse ScienceDirect

Procedia Food Science 1 (2011) 1918 – 1923

Procedia Food Science

11th International Congress on Engineering and Food (ICEF11)

Food processing technology in a sustainable food supply chain

Harris N. Lazarides *

Department of Food Science and Technology, Aristotle University of Thessaloniki, Greece

Abstract

The development of sustainable process technologies was a major concern and a central idea of what Prof. W.E.L. Spiess (WELS) and his research group have tried to accomplish throughout a long and productive scientific journey. In the early sixties, Freeze Drying was considered as the process with the lowest thermal impact on quality of food. WELS recognized the importance of both freezing process and storage conditions (especially water activity) for maintaining a high product quality. His group laid the foundation for a better understanding of water sorption in food materials. In fact, their critical evaluation of the BET theory initiated fruitful discussions on water sorption in foods. Their work on freezing included studies on crystal growth conditions, the impact of Time-Temperature conditions in the Frozen Food Chain (FFC), the development of various Time-Temperature Indicators and the use of antifreeze proteins in frozen food production. They actually developed the *"mother"* of all electronic Time-Temperature Recorders; that was an electronic temperature data-logger used for the analysis of product temperatures and residence times in the FFC. The techniques they developed in their studies of the crystallization process allowed the WELS group to develop an osmotic dehydration cell attached to a Confocal Scanning Laser Microscope (CSLM). This arrangement allowed them to understand and accurately describe the mass transfer process at cellular level during osmotic dehydration. Throughout his productive scientific career Prof. Spiess coordinated several European research cooperation projects that were instrumental in the development of a European Network of Food Science/Engineering Institutions and a true *"European Food Science community"*.

Selection and/or peer-review under responsibility of 11th International Congress on Engineering and Food (ICEF 11) Executive Committee.

Keywords: sustainable food processing; minimal food processing; emerging food technologies; food quality preservation; food research leadership

* Corresponding author. Tel.: +30-2310-991633; fax: +30-2310-991632.
E-mail address:Lazaride@agro.auth.gr.

2211–601X © 2011 Published by Elsevier B.V. Selection and/or peer-review under responsibility of 11th International Congress on Engineering and Food (ICEF 11) Executive Committee. Open access under CC BY-NC-ND license.
doi:10.1016/j.profoo.2011.09.282

1. Introduction

In the long history of mankind, cooking as an original form of food processing was reportedly discovered 2 million years ago [1]. Salting, drying and fermentation were among the first processing technologies to be applied by early prehistoric communities. Cheese, bread, wine and beer were widely known fermentation products in ancient Greece or the East Mediterranean basin. The same is true with salted olives and olive oil. Christ blessed wheat ("sitos"), wine ("oenos") and oil ("eleon"), making them essential elements in the Devine Liturgy. Man has never stopped looking for better, more efficient ways of transforming perishable or inedible raw materials into stable, wholesome, appealing and nutritious food products. Thus, traditional food products and local eating habits soon became part of civilization for each and every ethnic group.

Safety and quality improvement, nutritional value, consumer convenience and acceptance, product and process cost minimization have always been fundamental aspects in the design of food processing. Conventional thermal processes have been effective in microbial and/or enzyme inactivation, but they present a severe disadvantage: heat and mass transfer depend on size and geometry, thus posing severe process limitations. The negative impact of thermal processes on sensorial quality and nutritional value has triggered extensive research on alternative, non thermal process technologies, such as High-Hydrostatic Pressure (HHP), High-Intensity Electric Field Pulses (HELPs), supercritical fluid technology, ionising irradiation, High Pressure CO_2 treatment, Ultra sound, Gas-plasma treatment and other. Emerging technologies, such as HHP and HELP, are based on instant distribution of the active principle (pressure, electric field) throughout the food item, independent of size and geometry [2]. Such technologies lead to low temperature applications that can help to achieve shorter process times and/or minimized process effects. As the above technologies require sophisticated equipment and need to be operated under special conditions in order to comply with hygienic standards, it is too early at the moment to predict which one will survive the competition against the classic, well established processes [3].

Within the frame of *"The Walter Spiess Symposium on Food Processing Technology",* held during the 11^{th} International Conference on Engineering and Food – ICEF11 (Athens, Greece, 2011), this presentation will try to underline the main contributions of Prof. Walter E. L. Spiess (WELS) and his research group in the specific scientific field, emphasizing his efforts to promote process sustainability; a short presentation of certain emerging technologies is used to describe promising process alternatives and innovative product possibilities.

2. Sustainability in the food supply chain

The food supply chain (FSC) is a complex network of activities that include farming (primary food production), processing, distribution, retailing or catering and consumer handling. Agricultural (commodity) and food logistics play a crucial role in the management of the food supply chain.

Sustainable food supply chains aim at efficient production, processing and distribution systems that:

- protect quality
- assure safety
- promote fair and transparent distribution (capturing) of created value along the FSC
- enhance consumer access to wholesome and healthy food at reasonable prices, and
- support sustainable development of rural communities, an absolute requirement for food sovereignty

Sustainable Food Processing (SFP) is an integral part of the sustainable food supply chain, which is part of what we call "Sustainable Development". Sustainable development rests on certain principles, such as:

- respect to nature

- recognition of the special role of plants as the only creatures that bind energy, entropy and pollutants (CO_2) to create order (chemical compounds)
- respect to man and human values
- use of regenerated resources
- understanding that man and nature are bound and interrelated
- respect to our roots (heredity), tradition and culture (civilization)
- social control of production, distribution and resource management

A relevant study on the origins and rationale of traditional Greek foods showed that sustainability, extension of shelf life and maximum raw material exploitation were the main drivers for the development of a large variety of traditional, local foods based on a limited number of seasonally available raw materials [4]. SFP is based on the use of low energy, low-impact processing schemes to produce food with superb quality and nutritional value, close to (or better than) that of a fresh product. Sustainable Food Processing aims to:

- promote the use of local raw materials and ingredients,
- preserve local food civilization (promote local food recipes)
- improve product acceptance and healthy food profile (quality, nutritional value)
- improve product yield (minimize raw material losses)
- minimize the use of additives, with preference to natural ingredients
- minimize environmental impact (including that of packaging)
- exploit (upgrade) food processing wastes to produce valuable by-products or ingredients
- minimize the use of water (through recovery, recycling and process modifications)
- minimize the use of energy
- maximize the use of renewable energy resources
- minimize processing and distribution costs (achieve low consumer prices)
- minimize energy demands and product losses (recalls) in the food distribution chain

The last task is greatly supported by the development of reliable, inexpensive shelf-life monitoring systems, such as Time-Temperature Indicators/Integrators (TTI's).

3. Sustainable food processing: driver for a successful scientific career

The development of sustainable process technologies was a central concern and a major driving force for what WELS and his research group have tried to accomplish throughout a long and productive scientific journey.

In the early sixties, Freeze Drying was considered as the process with the lowest thermal impact on quality of food. WELS soon recognized the importance of both the freezing process and the storage conditions (especially water activity, a_w) for maintaining a high product quality. The fundamental role of water in food was the starting point for the intensive work of his group on Water Activity, especially in the frame of COST projects, which he coordinated. Practical results of these projects included the development of a standardized procedure for measuring sorption isotherms and calibrating relevant analytical instruments, the recommendation of Micro-Crystalline Cellulose (MCC) as a reference material and an extensive collection (over 1,000) of food Sorption Isotherms, which still serves the food industry as a highly reliable reference system. In WELS's words, these isotherms were compiled and published *"in friendly competition with the group around J. Chiriffe"* [5]. The idea behind this data compilation was to find the *"ultimate sorption-isotherm formula",* so that based on the composition of a product one could calculate (draw) its isotherm. Through comparative analysis with inert gases the real physical surface area of dried products was also measured.

Over and above these fundamental achievements, together with other colleagues WELS' group laid the foundation for a better understanding of water sorption in food materials. In fact, their critical evaluation on application of the BET theory initiated constructive and fruitful discussions on water sorption in foods.

Their efforts to enhance mass (water) transfer in freeze drying by creating special crystallization conditions that favour generation of large ice-crystals resulted to major contributions in the wider area of freezing. Indeed, frozen food quality is based on creation of small ice-crystals during freezing and their maintenance throughout storage, distribution, retail and consumer handling. Thus, their work included studies on:

- crystal-growth conditions
- the impact of Time-Temperature conditions in the Frozen Food Chain (FFC)
- the development of various Time-Temperature Indicators, and
- the use of antifreeze proteins in frozen food production

They actually developed the "*mother*" of all electronic Time Temperature Recorders; that was an electronic temperature data-logger used for the analysis of product temperatures and residence times in the FFC. That data-logger was the first one of its kind (as proven by patents). It was an extremely helpful tool for monitoring the conditions in the FFC and supported the development of a stochastic model for food distribution chains at large. The model allowed statistical processing and evaluation of information regarding the quality of a product based on its residence time/temperature history in the FFC. The practical outcomes of their freezing studies were recommendations for the Food Industry and Inspection Services. In fact, their system was applied in Germany by State Food Inspection authorities and it only became obsolete when the much more reliable bar-code systems were introduced [5].

Research activities on freezing and chilling of fruits and vegetables led to the development and industrial exploitation of a sustainable, innovative blanching process that allowed to fully recycle blanching water. Besides the drastic water economy, this process helped maximize retention of nutrients and other desired components, while it discarded undesired constituents.

In the same area of research, a process for effective cleaning and disinfection of heavily soiled, fresh green salads was also developed and industrially implemented. The process uses a controlled, mild heat treatment that allows removal of bitter tasting (i.e. phenol) compounds together with a dramatic reduction of microbial load, especially regarding food pathogens.

Finally, the WELS group offered valuable insight on structure (i.e. crispness) of vegetables as it is perceived by the nerves of the human chewing system during the comminution process in the mouth; an outstanding piece of work that was dully acknowledged and awarded by the German Dental Society [6].

The techniques they developed in their studies of the crystallization process allowed the WELS group to enter a third major area of research and gain new insight on mass transfer processes in plant cells. The group developed an osmotic dehydration cell attached to a Confocal Scanning Laser Microscope (CSLM) [7]. This ingenious arrangement allowed them to understand and accurately describe the mass transfer process at cellular level during osmotic dehydration. Osmotic preconcentration of fruits and vegetables has attracted extensive research interest due to substantial advantages with respect to low energy demand, quality preservation and new product possibilities (i.e. dehydro-frozen fruit) [8]. Osmotic processing benefits arise from the fact that water is osmotically removed in liquid form (without a phase change) at ambient temperatures; thus the submerged product is protected against heat and oxygen-induced detrimental effects. Direct osmosis of prime quality liquid foods offers a minimal processing alternative in the area of liquid food dehydration (concentration) [9]. The importance of osmotic treatment as a common process step in a large variety of minimal processing schemes was dully recognized by Prof. Spiess, who coordinated a successful EU-FAIR project under the title: *"Improvement of Overall Food Quality by Application of Osmotic Treatments in Conventional and New Processes"*. The insight, which was gained into the transport of water under osmotic pressure, contributed towards a better understanding of the drying process on biological materials in general.

Beyond any doubt, Prof. Spiess' leadership in several European research projects enhanced extensive, long-term collaboration schemes among numerous academic and/or research institutions, acting as a catalyst for the creation of a *"European Food Science community"*. This must be acknowledged as his most valuable contribution to European and worldwide developments in Food Science/Engineering in the past decades and in the years to come.

4. Emerging food processing technologies – challenges and issues

High-Hydrostatic Pressure (HHP) and High-Intensity Electric Field Pulses (HELPs) constitute useful paradigms of what emerging technologies can offer to sustainable food processing, what are the challenges and the issues that need a closer look. With both technologies, low process temperatures and short processing times help protect quality and functionality, minimize use of energy and eliminate waste.

Although HHP was first applied to food more than 110 years ago [10], it attracted increased research interest 20-25 years ago, especially after the successful introduction of the first commercial products (fruit juices) in the Japanese food market. Central interest was the extension of shelf life without compromising nutrition and quality. Compared to the two thermal processing coordinates (Temperature, T-Time, t), an HHP process must be defined in a three-parameter domain that includes pressure (p-T-t). The result is an increased choice of process parameter combinations that can better serve the required process/product targets. Based on inactivation kinetics for vegetative microbes, a 3-state inactivation model was developed for *B. subtilis* cells [11] and validated for several other microorganisms in both model and real food systems. Although bacterial spores are pressure resistant, high-pressure-induced germination offers a tool for pressure-heat inactivation of spore formers [12]. Besides inactivation, metabolite production of HHP-stressed microorganisms is another interesting area of research. With respect to water in foods, HHP has been shown to promote self-ionisation of water (to lower pH). What is even more interesting is the use of HHP to control phase transitions; which offers the possibility for substantial quality improvement in frozen foods, since it allows for instant freezing with small ice crystal formation, fast thawing of frozen food by pressurization or storage of food under subzero temperatures without ice formation [2]. Thus, pressure assisted freezing and thawing opens new horizons for process innovations. HHP can physically modify structure and functions, lending itself to various applications [13]. HHP-induced gelation of proteins, polysaccharides or protein-polysaccharide mixtures offers new modes of innovation through structural interventions. HHP can also affect non-covalent bonds and induce modified enzyme activity. Finally, HHP can be used to modify the structure of plant materials, allowing for increased heat and mass transfer rates (increased drying rates), improved release of metabolites or reduced fat uptake of French fries [2]. Batch and semi-continuous equipment are now available for industrial production of HHP products (juices, purees, milk).

HELPs was originally tested in the 1960s; it recovered research interest due to its promising results on microbial inactivation. Irreversible plant membrane permeabilization has been an additional driver promoting HELPs research and development, due to its great importance in mass transfer [14] and dehydration processes (i.e. osmotic dehydration). It also helps develop low-energy modes to increase metabolite production with parallel, improved extractability. HELPs can alter protein or enzyme conformation, resulting in product protection against oxidation, off flavors and undesirable color changes [15]. Engineering aspects of HELP equipment (especially the design of process chamber) and process design (process homogeneity) are naturally receiving increased interest, in an effort to commercialise this promising technology.

5. Epilogue

According to P. E. Nelson, the 2007 World Food Prize Laureate [16]: "Just as society has evolved over time, our food system has also evolved over centuries into a global system of immense size and complexity. The commitment of food science and technology professionals to advancing the science of food, ensuring a safe and abundant food supply, and contributing to healthier people everywhere is integral to that evolution...” This commitment poses a double challenge with great impact on future developments in food process technology and food sciences in general; we need to formulate, process and label food to help the average consumer live on a healthier diet, moving away from obesity and diet related diseases; we also need to reconsider and broaden our role in the sustainable food supply chain, so as to increase our visibility, our responsibility and our impact on healthy eating and feeding the starving population groups all over the world, including our “developed” countries. The food security issue has already attracted the sincere concern and systematic efforts of Prof. Spiess. In fact, during the last IUFoST Conference (Cape Town, 2010) Prof. Spiess openly expressed his intention to lead a task-force on Food Security. In line with this commitment, his contribution to the 11th International Conference on Engineering and Food-ICEF11 (Athens-Greece, 2011) was chosen to focus on biofuel and food security.-

References

[1] Wrangham R. 2009. Catching fire: how cooking made us human. New York: Basic Books.

[2] Knorr D. 1999. Novel approaches in food processing technologies for preserving foods and modifying function. Current Opinion in Biotechnology, 10(5): 485-491

[3] Spiess W.E.L., Wolf W. & Walz E. 2003. New food technologies and processes and their impact on nutrition. Forum Nutr., 56:365-367

[4] Lazarides H. N. (Ed.). 2000. Food Technology and Sustainability. Art of Text Publications, Thessaloniki, Greece (In Greek)

[5] Spiess W.E.L. 2011. A way through the jungle of the publication list! (Unpublished)

[6] Spiess W.E.L 2011. IUFoST Life Achievement Award (Unpublished)

[7] Ferrando M. & Spiess W.E.L. 2000. Review: Confocal scanning laser microscopy. A powerful tool in food science. FOOD SCIENCE AND TECHNOLOGY INTERNATIONAL. 6(4), 267-284

[8] Lazarides H.N., Fito P., Chiralt A., Gekas V. & Lenart A. 1999. Advances in Osmotic Dehydration. In: Oliveira F.A.R. & Oliveira J.C. (Eds.). Processing Foods: Quality Optimization and Process Assessment. CRC Press. p. 175-199.

[9] Petrotos K.B. & Lazarides H.N. 2001. Osmotic processing of liquid foods. J. Food Engineering, 49:201-206

[10] Hite B.H. 1899. The effects of pressure on the preservation of milk. West Virginia Agric. Exp. Station Bull. 58:15-35

[11] Knorr D. & Heinz V. 1996. High Pressure inactivation kinetics of *Bacillus subtilis* cells by a three-state-model considering distribution resistance mechanisms. Food Biotechnol 10: 149-161.

[12] Heinz V. & Knorr D. 1998. High pressure germination and inactivation kinetics of bacterial spores. In: NS Isaacs (Ed.). High Pressure Food Science, Bioscience and Chemistry. The Royal Society of Chemistry, Cambridge, 435-441.

[13] Palou E., Lopet-Malo A., Barbosa-Canovas G.V. & Swanson B.G. 1999. High pressure treatment in food preservation. In: Rahman M.S. (Ed.) Handbook of Food Preservation, Marcel Dekker, New York

[14] Knorr D. & Angersbach A. 1998. Impact of high intensity electric field pulses on plant membrane permeabilization. Trends on Food Sci Technol, 9: 185-191

[15] Barbosa-Canovas G.V., Gongora-Nieto M.M., Pothakamury U.R. & Swanson B.G. 1999. Preservation of Foods by Pulsed Electric Fields. Academic Press, San Diego.

[16] Floros, J. D., Newsome, R., Barbosa-Canovas G.V., Fisher, W., Chen H., Dune C.P., German J.B., Hall R. L., Heldman D.R., Karwe M.V., Knabel S.J., Labuza T.P., Lund D.B., Newell-McGloughlin M., Robinson J.L., Sebranek J.G., Shewfelt R.L., Tracy W.F., Weaver C.M., & Ziegler G.R. 2010. Feeding the world today and tomorrow: The importance of food science and technology. An IFT Scientific Review. Comprehensive Reviews in Food Science and Food Safety, 5(9): 572-599

Presented at ICEF11 (May 22-26, 2011 – Athens, Greece) as paper AFT1322.