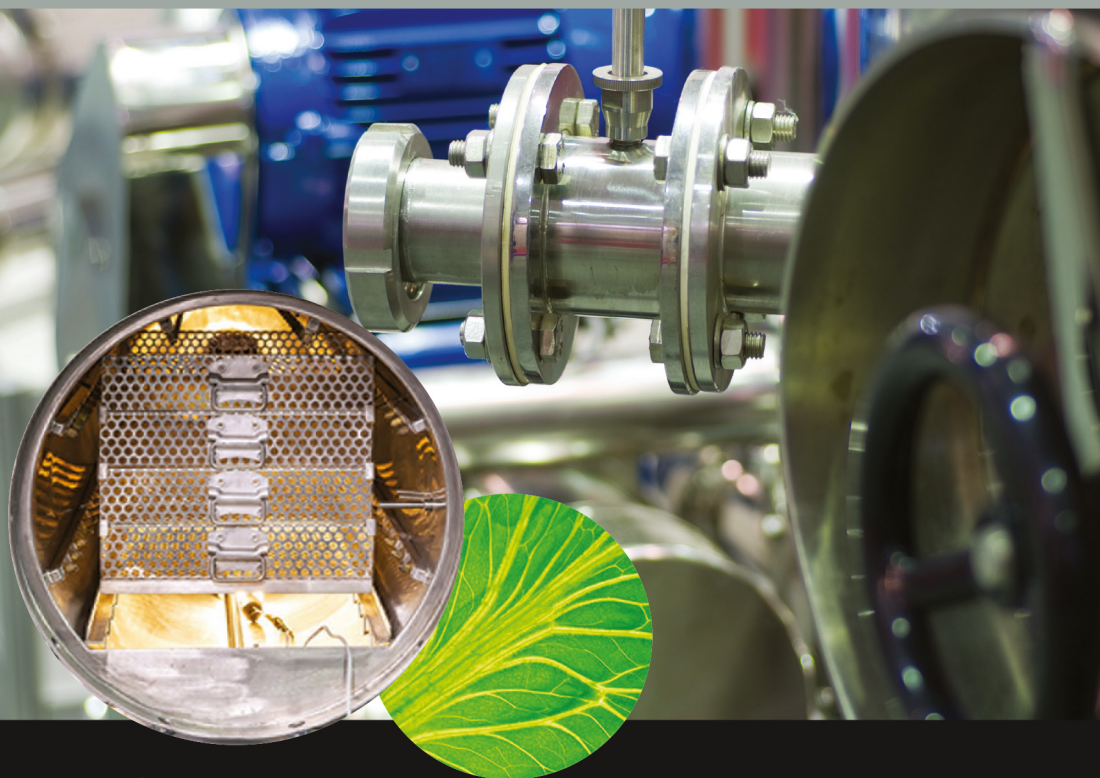


BIOPROCESSING IN FOOD SCIENCE

NONTHERMAL FOOD ENGINEERING OPERATIONS

Editors

Nitin Kumar, Anil Panghal *and* M.K. Garg



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Nonthermal Food Engineering Operations

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Bioprocessing in Food Science

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Scope: Bioprocessing in Food Science a series of volumes covering the entirety of food science, unit operations in food processing, nutrition, food chemistry, microbiology, biotechnology, physics and engineering during harvesting, processing, packaging, food safety, and storage and supply chain of food. The main objectives of this series are to disseminate knowledge pertaining to recent technologies developed in the field of food science and food process engineering to students, researchers and industry people. This will enable them to make crucial decisions regarding adoption, implementation, economics and constraints of the different technologies. Bioprocessing has revolutionised the food industry by allowing for more efficient and sustainable production methods. This comprehensive series focused on microbial fermentation, enzyme technology, genetic engineering, microbial transformations, and bioreactor design. As we continue to face challenges such as population growth and climate change, bioprocessing will play an increasingly important role in ensuring a sustainable food supply for future generations.

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Nonthermal Food Engineering Operations

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Preface

The book, *Nonthermal Food Engineering Operations*, in the “Bioprocessing in Food Science” series is an up-to-date and comprehensive overview of this area. Written and edited by a team of experts in the field, this book covers topics such as artificial intelligence usage in food industry, ultrasound, biosensors, cold plasma, extrusion process, image processing, active packaging, membrane processing, nanotechnology, supercritical and subcritical fluid extraction, utilization of ultraviolet rays in technological processes, and food safety concerns. The engineering and science aspects of these technologies are significant component of the undergraduate and postgraduate degree programs in Biological and Agricultural Engineering, Food Engineering, Food Science & Technology, and Nutrition & Health Science throughout the world. These novel technology operations in food processing are considered as one of the core competencies for these programs and in industries as well. Researchers around the globe will be able to use the information as a guide in establishing the direction of future research on nutritional properties during food processing. The main reason for writing this book now is to disseminate the wealth of knowledge on novel processing and its effects on food products. It is envisioned for scientists; technologists/engineers working in the area of food processing, process equipment design, and product development; and students of food science, technology, nutrition, health science, and engineering. It will enable them to make informed decisions regarding adopting appropriate processing technology, implementation, economics, and constraints of different technologies. As the demand for healthy, nutritious, and safe food increases, manufacturers are looking for new possibilities to occupy a growing share of the rapidly changing food market. The book covers a range of emerging topics, from concepts to applications of different non-thermal processes in food engineering operations and their implications in nutritional sciences, nanotechnology in food systems, applications of nano-materials in the food system, emerging techniques in food preservation, and food safety and quality assurance in the food chain. The book also

provides insights on advances in nonthermal technology for healthy and safe nutrition with illustrations of how to ensure public health safety. The authors and editors discussed the need for innovative food products, contamination in the food chain, risk assessment, regulatory frameworks, and their challenges within the context of the food engineering in the global food market.

Thanks are due to all authors for contributing their knowledgeable chapters in this volume and helping us to complete the book. We also thank the authorities of Chaudhary Charan Singh Haryana Agricultural University, Hisar (India) for their help and support. Finally, we also express indebtedness and thankfulness to Scrivener Publishing and Wiley team for their unfailing guidance and helpful assistance.

Editors

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Artificial Intelligence (AI) in Food Processing

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Abstract

The food processing sector holds a significant place among other business sectors globally that support high employability. The efficient production and packing of food products depend greatly on the human workforce. Owing to the involvement of the human workforce, the food industries are not only unable to maintain food safety but also the demand-supply chain. Food is a basic human need. Reducing food waste, streamlining the supply chain, and improving food delivery, logistics, and safety are imperative. The most efficient approach to address these problems in the food industry is through industrial automation. Artificial Intelligence (AI) plays a significant role in achieving these goals. AI is defined as a branch of study that mimics human thought processes, learning abilities, and knowledge storage systems. AI has become an integral part of technological advancements in the food industry in recent years as a result of growing food demands spurred on by a growing world population. The food industry is becoming more and more in need of these intelligent systems due to their versatility for performing tasks like food quality assessment, quality control, classification of foods, food processing, and forecasting. The numerous applications of artificial intelligence in the food sector will grow as a result of ongoing technological advancements and a wider range of application scenarios. This chapter helps to shed light on cutting-edge AI and its

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technologies in the food processing sector. The first part of this chapter explains what is AI, its components, techniques, and the ways forward its popularity in various sectors. The second part of this chapter provides insight into the various food processing applications of different AI technologies including Machine learning, Expert systems, Fuzzy logic systems, and machine vision, etc., It also discusses their benefits, drawbacks, and approaches to provide guidance for choosing the best approaches to advance future developments related to AI and the food industry. Furthermore, it also explains the efficiency of the use of combinations of two or more AI techniques to make tedious process and applications simple. In day-to-day life, the application of AI continues to grow because of its ability to improve waste management and maintain food quality, hygiene, and safety. In the future, AI significantly changes the food processing sector by producing more reasonable and healthier productivity for the growing population.

Keywords: AI, emerging technologies, expert system, neural networks, fuzzy logic, food industry, quality assessment, food safety

1.1 Introduction

With the advancement of mechanization, the processing sector and current industry have reached productivity peaks in a matter of decades. The processing sector was the first to be transformed by technology developments and many other industries followed (Volter, 2013). In the early 1900s, the thought of automation performing jobs with more precision and eliminating human labor in all disciplines was a vision of hope for a better future. Artificial Intelligence, popularly known as AI, has risen to prominence in recent times, surpassing humans in activities such as object identification and data analysis (Cohen & Feigenbaum, 2014). While learning systems and processing capacity improve, this scenario appears to make a significant step forward. The origins of automation may be traced back to the early 1800s when it enabled the manufacturing sector, which eventually led to current technical advancements (MacLeod, 2002). Automation has now infiltrated nearly all fields and is outperforming market trades by a wide margin (Frohm *et al.*, 2008). The majority of equipment in the 18th century was designed to do simple operations like welding, spinning, and repetitive activities, allowing human workers to focus on more sophisticated activities (Mantoux, 2013). From the early 1900s until the present, various forms of automation have appeared in a few instances, ultimately turning their attention to a wide range of sectors. Nevertheless, recent advances in AI have caused humanity to reconsider the potential of learning and

ask, “What might be the depths of AI when machines can learn?”. AI is a collection of various approaches and phenomena, amid which two fundamental principles, Neural Networks (NN) and Deep Learning (DL), are credited for AI’s remarkable progress (Norvig, 2002). AI is a term used to describe computer-generated intelligence that can develop to analyze, plan, comprehend, and interpret human language (Wang, 2008). It is the study and creation of digital systems capable of doing activities that would ordinarily need human intellect, such as vision, speech identification, strategic planning, and language processing (Kumar, 2018). The pioneer of AI, John McCarthy, described it as the science and engineering of creating intelligent devices, particularly intelligent computer programs. Artificial intelligence can be divided into two categories: strong AI and weak AI. The weak AI principle states that the computer should be built to serve as an intelligent element that mimics human decisions, but the strong AI concept states that the machine should be able to reflect the human brain (Borana & Jodhpur, 2016). AI has a range of algorithms to pick from including reinforcement learning, Expert Systems (ES), Fuzzy Logic (FL), Swarm Intelligence, Turing Test, Cognitive Science, Artificial Neural Networks (ANN), and logic programming (Borana & Jodhpur, 2016). AI’s seductive potential has earned it the most popular tool to use in fields such as decision-making and process optimization, intending to lower total costs, improve quality, and increase profitability (Ge *et al.*, 2017; Mahadevappa *et al.*, 2017). Food demand is expected to increase from 59 to 98% by 2050, as the world’s population grows (Elferink *et al.*, 2016). Consequently, AI was used to meet this food demand in areas such as supply chain management, food sorting, production development, food quality enhancement, and adequate food hygiene (Funes *et al.*, 2015). ANN was used to assist complicated problem-solving in the food industry (Funes *et al.*, 2015), and the classification and prediction of variables are simple and easier when using ANN (Correa *et al.*, 2018), which has resulted in a growing demand for ANN over the past year. In addition, FL and ANN were performed as controllers in the areas of food safety, quality management, yield increase, and reducing costs (Kondakci & Zhou, 2017; Wang *et al.*, 2017).

1.2 Evolution of Artificial Intelligence

For scientists, Artificial Intelligence is not a new term or technique. This technique is much older. In Ancient Greek and Egyptian mythologies, there are even tales of mechanical men. The achievements in the history

of AI that outline the route from AI formation to current development are listed below (McCorduck & Cfe, 2004):

- Warren McCulloch and Walter Pitts published the first study on artificial intelligence in 1943, which is today known as AI. They presented an artificial neuron approach.
- In the year 1949, Donald Hebb developed an updated rule for altering the intensity of neuron connections. He named the rule Hebbian Learning.
- In the year 1950, Alan Turing, an English mathematician, invented the machine learning system. In his paper “Computing Machinery and Intelligence,” Alan Turing proposes a test. A Turing test can be used to determine whether or not a machine can demonstrate intelligent behavior comparable to human intelligence.
- In the year 1955, Allen Newell and Herbert A. Simon built “Logic Theorist,” the “first artificial intelligence program.” This program verified 38 of 52 mathematical theorems, as well as discovered new and more concise solutions for several of them.
- At the Dartmouth Conference in 1956, John McCarthy, an American computer scientist, coined the term “Artificial Intelligence.” AI became a recognized academic discipline for the first time. High-level computer languages such as FORTRAN, LISP, and COBOL were created during the period. There was a lot of interest in AI during this period.
- In the year 1966, the focus of researchers was on inventing algorithms that could solve mathematic problems.
- In the year 1972, Japan produced WABOT-1, the world’s first intelligent humanoid robot.
- The first AI winter took place between 1974 and 1980. The AI winter represents a duration when computer scientists faced a severe lack of government support (funds) for AI research. Throughout AI winters, there was a drop in public interest in AI.
- After a brief hiatus, AI returned with Expert System. Expert systems have been built to mimic the abilities of a human expert to make decisions.
- Between 1987 to 1993, the AI Winter lasted for the second time. Investors and the government have once again halted funding for AI research, citing excessive costs and ineffective

results. XCON, for example, was a very cost-effective expert model.

- In the year 1997, IBM Deep Blue defeats Gary Kasparov, the global chess champion, and becomes the first computer to defeat a world chess champion.
- In the year 2002, AI made its first appearance in the house in the Roomba vacuum cleaner.
- In the year 2006, artificial intelligence (AI) was introduced into the business world.
- In the year 2011, IBM's Watson won Jeopardy, a game show in which it had to tackle difficult questions and puzzles. Watson demonstrated that it could comprehend plain language and solve complex problems fast.
- Sophia is a robot that resembles a human. It is a humanoid robot that was designed in Hong Kong by American company Hanson Robotics and has been operational since April 19, 2015. Even though she does not yet demonstrate the most remarkable features that are anticipated of AI, she has already been accepted as the First World Citizen Robot by Saudi Arabia in the year 2017, based on her language performance, conversational abilities, and expressive externalizations in her brief existence. Sophia's key technological feature is her ability to understand human behavior through her interactions with others. Because of this, it has been granted as the latest breakthrough in AI due to its mastery of a complicated sequence of predictive algorithms based on computational statistics, a fluid artificial phonation, quick interpretation of the data she absorbs, and a wider ability to detect faces and voices (Retto, 2017).

Now, AI has progressed to a stunning level. The conception of deep learning, neural networks, expert systems, machine learning, computer vision, big data, and data science all have a major impact in all fields (McCorduck & Cfe, 2004).

1.3 Artificial Intelligence in Food Processing

Over the years, AI has been used in the food sector for a variety of reasons, including food sorting, selection, categorization, quality parameter

forecasting, quality control, and food safety. Common approaches in the food industry include:

- Artificial Neural Networks (ANN)
- Fuzzy logic model
- Expert Systems (ES)
- Adaptive Neuro-Fuzzy Inference Systems (ANFIS)
- Machine Learning (ML)

Before the introduction of AI, food research was conducted for many years to raise awareness in the community about food knowledge and to optimize the end outputs connected to food attributes and production (Rahman *et al.*, 2012). The AI approach can provide numerous advantages and its use in the food business has been popular for decades and continues to grow today (Corney, 2002).

1.4 Artificial Neural Network (ANN)

There has been significant growth in interest in ANNs over the last 15 years. ANNs have been extensively used to solve complicated issues in a variety of domains, including the ones listed below (Sozen & Akcayol, 2004; Sozen & Arcaklioglu, 2007):

- Pattern correlation and pattern recognition
- Associative recollections
- Development of new emerging patterns
- Function approximation

Some tasks are well-suited to ANNs, whereas others aren't. They are particularly well-suited to jobs involving inadequate data sets, ambiguous or missing information, and very complicated and ill-defined situations where humans typically make decisions based on perception. They are capable of learning from investigations and dealing with nonlinear challenges. They also have a high level of reliability and are fault tolerant. The activities that ANNs cannot do well are those that need a lot of precision and efficiency, such as logic and arithmetic (Menlik *et al.*, 2009). By identifying the needed information from the input data, ANNs circumvent the shortcomings of traditional methods. A very precise equation form is not required for an ANN. Instead, it requires enough input-output data. It can also be trained regularly so that it can easily respond to fresh data (Sozen &

Ozalp, 2003). An ANN is made up of several layers: an input layer, an output layer, and several hidden layers. The training process of a neural network occurs when an input and target output are given to the network and the weights are modified so that the network tries to create the required outcome. The weights include useful information after the training phase, whereas before they were unpredictable and had no value. Once a suitable level is attained, the network ends training and utilizes the weights to make judgments, discover patterns, and describe correlations in test data (Satish & Setty, 2005). There are a variety of learning algorithms to choose from. The back-propagation algorithm, which has various versions, is a prominent algorithm. Furthermore, the algorithms' performance is dependent on user-dependent variables, learning rate, and momentum constant.

1.4.1 Fats & Oils Quality Evaluation

Vegetable oils come in a wide range of flavors and trademarks. Vegetable oils have a lot of similarities in terms of color, odor, and flavor and it's difficult to tell them just by looking at them. Methods for classifying these oils are frequently expensive and time-consuming and they frequently rely on analytical and mathematical methods to enhance their effectiveness. Because of the diverse range of products, more advanced techniques for qualifying, characterizing, and classifying these products are required, as the final cost would represent the quality of the product that reaches the purchaser.

Da Silva *et al.*, 2015 proposed a model for identifying canola, sunflower, corn, and soybean oils from different manufacturers. To acquire the spectra of induced fluorescence in diluted oil samples, a simplified math approach, a light-emitting diode, and a CCD array sensor were used. An ANN with 3 layers, each of which has four neurons, performs spectrum categorization. They observed that this model enables quick network training while only requiring a few mathematical operations on the spectrum data. From the aspect of vegetable oil quality management, this is an efficient technique that can be utilized to conduct future research concentrating on the resolution of genuine blends of oils from various cultivars, namely for corn and soybean oils. More research on sunflower and canola oils is needed to increase categorization precision. This novel technique emphasizes the requirement for careful analysis of the characteristics that characterize the regions of interest over the fluorescence spectrum by employing the most related variables of the fluorescence spectrum as input data for ANN. As a result, it was concluded that this approach was capable of identifying vegetable oil and enabling rapid network training with a 72% success rate, utilizing only a few statistical manipulations in the spectral data (Da Silva *et al.*, 2015).

Groselj *et al.*, 2008 used the Counter-propagation Artificial Neural Networks (CP-ANN) approach to detect the presence of refined hazelnut oil in refined olive oil. FT-MIR spectroscopy was used to examine oil samples. They were divided into three categories: pure olive oil (Class 1), pure hazelnut oil (Class 2), and two types of adulterated olive oil samples: one with more than (or equal to) 10% hazelnut oil (Class 3) and the other with less than 10% hazelnut oil (Class 4). Furthermore, FT-MIR was used to assess an external set of blind samples. Five CP-ANN models were created and tested for classification performance using varied numbers of specified infrared spectral areas. The best models were chosen and utilized for blind sample estimation using the leave-one-out cross-validation approach. The results revealed that the ANN model has successfully classified pure olive oil and hazelnut oil and divided it into various groups. Furthermore, an acceptable distinction was established between mixes and pure oils (Groselj *et al.*, 2008).

Due to the high expense of manufacturing compared to other oils on the market, Extra Virgin Olive Oil (EVOO) has always been vulnerable to deception and complexity. Spectral and Volatile Organic Compound (VOC) parameters are crucial in determining the authenticity of an EVOO. Violino *et al.*, 2021 used an open-source UV VIS (Ultraviolet-Visible)-Near-infrared spectrophotometric observation, as well as a VOCs analyzer to determine different levels of sophistication. A total of 96 samples were examined. Pure EVOO, complex olive oil, pure seed oils, and olive oil samples adulterated with 7 different seed oils at different ratios were among the samples. To detect adulterations in the spectrum and VOC data, an artificial intelligence algorithm was used. Both the models, that is the models based on spectral and VOC data, exhibited faultless categorization (100%) of pure EVOO samples in comparison to complex ones. The most relevant spectral values and Volatile Organic Compounds (VOCs) were extracted. ANN models were created with the goal of not only identifying complex samples but also understanding the most relevant spectra and VOCs to design specific anti-fraud systems (Violino *et al.*, 2021).

Fish oil deteriorates mostly due to oxidation, which results in significant quality and nutritive value losses. Chemical analysis is currently the only tool available for monitoring lipid oxidation in foods (Bhagya Raj & Dash, 2020). FTIR (Fourier Transform Infrared Spectroscopy) is a tool for studying the molecular structure and compositional alterations in a variety of foods. To estimate the oxidative qualities of Menhaden fish oil, Klaypradit *et al.*, 2011 employed attenuated total reflectance-FTIR to evaluate the oxidative quality and applied the ANN model. The oil was kept at ambient temperature under the light. Each day during the three weeks of storage, the oxidation was assessed for primary and secondary oxidative

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