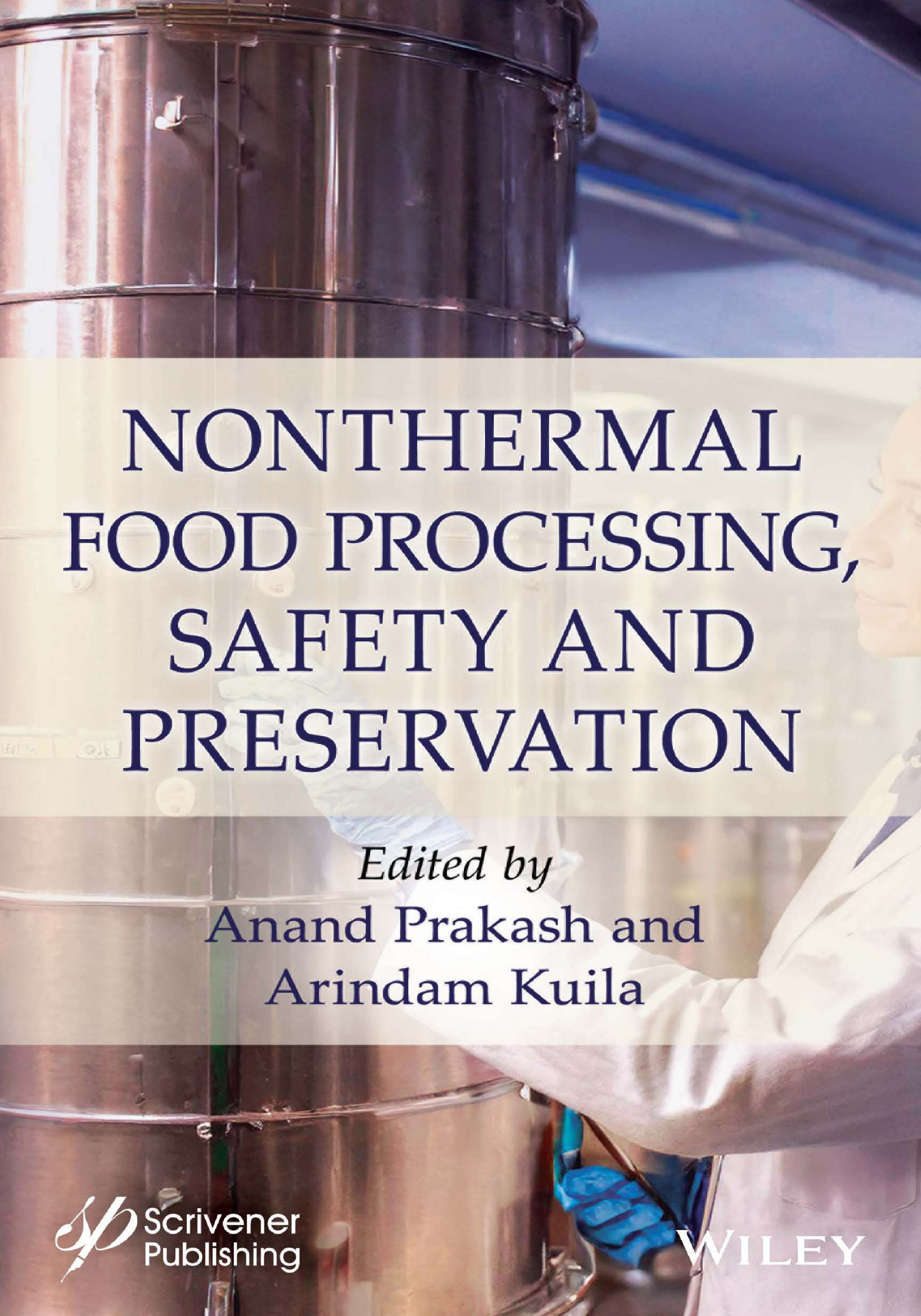

NONTHERMAL FOOD PROCESSING, SAFETY AND PRESERVATION

Edited by

Anand Prakash and Arindam Kuila

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Contents

Preface

Food engineering involves a variety of processes and technologies that deal with the construction, design, operations, and associated engineering principles in order to produce valuable edible goods and by-products. The main goal of integrated food and bioprocess technology is to capture the important aspects of both food science and engineering education, to develop high-quality value-added products from food materials in large quantities, and to provide opportunities to work on pilot-plant studies and manufacturing systems. There is a dearth of published cutting-edge high-quality original studies in the engineering and science of all types of processing technologies, from the beginning of the food supply chain to the consumer & to dinner table. This book seeks to address multidisciplinary experimental and theoretical discoveries that have the potential to improve process efficiency, improve product quality, and extend the shelf-life of fresh and processed food and associated industries.

This book will significantly broaden the scope, capabilities, and application of bioprocess engineering, food processes, biochemical engineering, nanotechnology, biotechnology, and microbiology. This book is for the students and researchers who interested to learn how biological processes are translated into commercial products and services under food biotechnology.

This book has 23 chapters that discuss current technology and future prospect of food and bioprocessing. First three chapters introduces the food in terms of physical properties, food security and mathematical models. Next two chapters describes about the new detection technologies involved in food and beverage industry. Eight chapters has been grouped under food processing technologies, which focuses upon detail discussion about the non-thermal food processing technologies relevant to modern food processing industry. Next three chapters describes the importance of food preservation to enhance the self-life of food products. The group of next four chapters emphasize on assessment of food and valuable product from food waste. The last three chapters describes about the emerging new technologies in modern era food and beverage industry.

The book will be useful for students, researchers in the areas of various branches of food engineering, food technology, biotechnology, bioprocess engineering, chemical engineering, nanotechnology, microbiology etc.

We are grateful to Wiley-Scrivener Publishing Inc.'s Linda Mohr and Phil Carmical for their complete cooperation and assistance in the timely publishing of this book. We would like to express our gratitude to the writers and the publication staff for their efforts for publishing this book.

Dr. Anand Prakash
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1

Selected Physical Properties of Processed Food Products and Biological Materials

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Abstract
Food products are made up of numerous diverse micro and macro components, and they have unique physical, thermal, mechanical, electrical, and optical characteristics. The first and most fundamental characteristics of food products are their physical properties. The physical properties of processed food products are defined as those properties that can be measured by physical means rather than chemical means. It provide relationship between product quality and their effect on the behavior of processed food. Here, a variety of physical properties of processed food materials and their measurement techniques are taken into account. Because customers nowadays seek sustainable and nutritious processed foods in their busy schedules, it is essential to look at their physical properties such as size, shape, texture, color, flavor, and many more, with that many measuring techniques to analyze these properties.

***Keywords*:** Crystal, porosity, texture, rheology, crispness, thermal, frequency, velocity

1.1 Introduction

Food has a diverse hierarchical structure, making it one of the most complicated types of soft matter. Foods are typically formed mostly of some basic macromolecules like proteins, polysaccharides, and lipids, each of which is built of even smaller repeating units. The other component of food is water [1]. Additionally, air and minerals are present in food material, which all help food to acquire sophisticated structural complexity [2]. In terms of processed food's structure, stability, and nutritional content, the original food components are crucial. The majority of foods are capable of being seen as complicated colloidal multiphase systems made up of several aggregation phases, including liquid, solid, crystalline, glassy, and even liquid crystalline. However, due to its multiple advantages, food processing is frequently used. Four broad categories may be used to classify these advantages:

- An increase in food safety by elimination or inactivation of microorganisms, pathogens, toxins, constituents, etc.

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- Intensifying food product quality by releasing flavorable compounds and constructing enhancements of texture, palatability, and taste.
- Enhancing nutritional value via intensifying bioavailability and digestibility and intensifying food product quality by releasing flavorable compounds and constructing enhancements of texture, palatability, and taste.
- The release or synthesis of molecules having bioactive qualities, such as those that are antibacterial or antioxidant, among others.

Processing technology and food formulation are crucial for food preservation and provide millions of people access to healthy, inexpensive, enticing, and sustainable food worldwide.

Consumer demand for foods that are both fresh and little processed, have their nutritional and organoleptic qualities intact and can be kept in the refrigerator for a long time (without compromising safety), and then heated up fast before eating is expanding. Numerous procedures may or cannot entail heating, as they are used to prepare foods to increase their quality and safety.

Because enzymes and bacteria become inactive beyond a certain temperature, thermal procedures have been widely employed in food technology. Additionally, certain heat treatments, such as baking and roasting, may enhance the sensory and textural qualities of food while denaturalizing enzymes or managing microbiological food safety. Through the destruction of cell walls, dissociation of chemical bonds between food components, and disintegration of intricate molecular structures, this process results in the release of natural bioactive substances. For instance, secondary plant metabolites including glucosinolates, carotenoids, polyphenols, and glucosinolates are among the components that are released.

Thermal procedures can generate fresh bioactive molecules through various chemical processes. Among these, the Maillard reaction, the carbonyl-amine reaction caused by reactive carbonyls produced from carbohydrates, is a crucial chemical process occurring during heat food preparation. Another significant source of reactive carbonyls, which are used in carbonyl-amine processes similar to those involving reactive carbonyls produced from carbohydrates, is lipid oxidation. As an alternative to conventional heating methods, microwave heating has been created and has been used, for instance, to deactivate enzymes in fruits and vegetable products. This procedure may also increase the overall antioxidant capacity of meals due to the probable release of natural antioxidants and the chemical reactions.

Nowadays, microwave cooking is often used as a thermal treatment in both household and commercial systems. Smart valves were first introduced as a component of sealing plastic trays or films, which provide a distinctive chance for rapid vapor cooking technologies modify to fresh or barely, ready-to-eat food, catering, which are now more often employed in conjunction with microwave cooking.

Therefore, it has been shown in several studies that the use of microwave radiation may promote carbonyl-amine reactions that include reactive carbonyls generated from either lipids or carbohydrates. In addition to these thermal processes, various nonthermal methods are used to preserve food and may also contribute to the production of antioxidants.

Because of the selectivity of their reactions under pH and temperature, enzymes are often utilized in the food industries. Enzymes have been used to aid in the creation of antioxidant peptides, for example, in the manufacture of antioxidants. Additionally, fermentation is used as a nonthermal process to increase food nutritional content, remove antinutrients, and enhance the sensory qualities of the meal. The structural breakdown of plant cell walls during this process results in the release of several chemicals, including an increase in the quantity of phenolic and flavonoid molecules. Other products are also created, some of which could have antioxidant characteristics.

By eradicating or harming bacteria, irradiation also enhances the sanitary quality of food materials.

Additionally, it affects the antioxidant content of meals as a result of improved enzyme activities and improved ability of natural antioxidants to be extracted from tissues in which they are present. Both ionizing radiation and nonionizing radiation fall under this category. Increases in reactive carbonyls produced from lipids and carbohydrates in carbonyl-amine reactions may potentially contribute to reported increases in antioxidant activity. In food preparation, high pressures are also used as a reverse to nonthermal inactivation of bacteria and pathogens.

Irradiation, high pressure, and microwave procedures are unique in that they allow for the direct treatment of food within the packaging materials, so it is called in-package food technologies, which has the benefit of shielding processed food items from unfavorable posttreatment encounters like oxygen and microorganisms. Since the packaging materials are treated and then sterilized during the food processing techniques without extra handling and sources of contamination. Irradiation treatment or industrial microwave for prepacked food products has low cost with this, the requirement to predisinfect or sterilize containers when food and packaging cannot be prepared simultaneously so producers has time and quality benefits.

Methods that are becoming more popular in food processing include irradiation or hydrogen peroxide, ozone, cold plasma therapy, or UV light.

The packing material is engaged in all of these processes and is subjected to various processing conditions that might change its mechanical, structural, and mass transfer (barrier and migration) capabilities. Three different mass transfer types must be taken into account:

(i) The transfer of vapors or gases (such as water vapor, fragrance compounds, oxygen, etc.) from the external environment into the food products or the headspace via the packing materials.
(ii) Migration of low-molecular weight chemicals (such as monomers, plasticizers, and solvents) from the packaging into the food, which requires regulatory and toxicological studies.
(iii) The removal of low-molecular weight hydrophobic components from the food, such as aromatic compounds, which may have a significant impact on both the mass transfer characteristics of packing materials and the quality of the food.

1.2 Physical Properties

The characteristics of food products that can only be assessed physically rather than chemically have been described by their physical properties as seen in Figure 1.1.

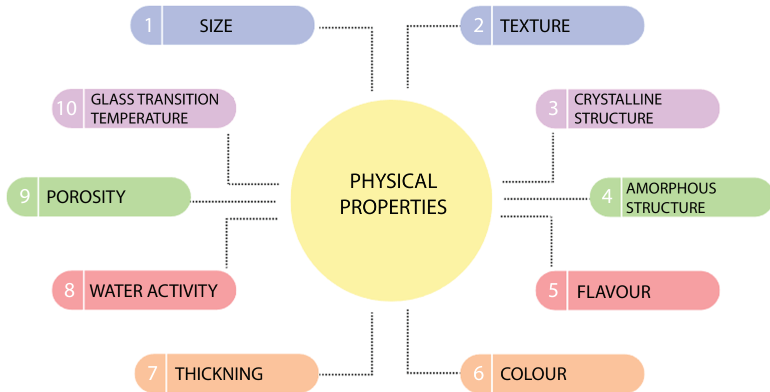

Figure 1.1 Physical properties of processed food.

1.2.1 Shape

As the turgor pressure forms, it retains the cells under an elastic tension and preserves the tissue's shape, hardness, and crispness. The fruit's structure will collapse if the turgor pressure is eliminated. Once the natural turgidity has vanished, it cannot be replaced.

1.2.2 Texture

One of the most crucial factors in determining a food product's quality is its texture. We accept the food products based on their texture and how creamy and spreadable a culinary product is. This has an impact on flavor perception [3]. The primary factors affecting the texture of semisolid food products are proteins or polysaccharides. When a force is applied to food, it deforms, disintegrates, and flows about the texture, which is a sensory and functional expression of the mechanical, structural, and surface qualities of the food that is sensed by the senses of hearing, sight, touch, and kinesthetics.

Furthermore, the notion of texture incorporates crucial ideas like the following:

(a) It is a sensory characteristic that people may sense.
(b) It has many parameters that cover a variety of distinct qualities.
(c) It comes from the food's macroscopic, microscopic, and molecular structures.
(d) It is felt by a variety of senses.

There is evidence in the literature that the protein microstructure network affects how food textures form. It is observed that rheology influences food texture in addition to food structure and its surface characteristics. There are three basic disciplinary perspectives that affect texture perception: sensory, physiology, and food structure. Porosity and density are also used to describe various textural aspects of dried materials in addition to mechanical qualities. The final texture of dried items may be considerably influenced by state variables such as moisture, temperature, and deformation during drying as well as material states such as rubbery and glassy. Finite element modeling has also been used to forecast the textural characteristics of meals based on their microstructure [4].

1.2.3 Crystalline Structure and Amorphous State

The powder particle matrix can have different types of molecular arrangements. This leads to the formation of different structures in food powders. These can be in the form of amorphous structure, crystalline structure, or even mixed. The stability, usability, and application of powders in the manufacturing of food are significantly influenced by their structural makeup. Powders may unnecessarily have an undesired structure during manufacture.

To maintain the product quality throughout storage and future processing, it is crucial to characterize the structure of the powder and quantify the crystalline amorphous proportions present in the powders. Numerous analytical methods with vastly different levels of selectivity and sensitivity have been developed for these reasons.

Food powders are bulk dry solids that comprise extremely small discrete particles ranging in size from nanometers to millimeters. Powdered variants of many commercial food items are available, including starches, flours, sugars, instant coffee, salts, and powdered milk. Food powders can be formed by following different types of processes on either solid ingredients or even from liquid ingredients. Solid ingredients can go through processes like crushing, milling, grinding, granulating, pulverizing, and combining to break the large pieces into small pieces to form a powder-like form. Liquid ingredients like slurry, paste, etc., can also be dehydrated (spray, freeze, and drum and belt dry) to form food powders. The crystallization of supersaturated solutions can also be used as part of the process [5].

The resulting molecular arrangement (amorphous, crystalline, or mixed) in food powders depends on the process used to manufacture them [6]. While crystalline structures are created when the molecules are arranged in a certain sequence, amorphous ones are created when the molecules are haphazardly aligned. Amorphous and crystalline phases may coexist in certain products like icing sugars made by crushing granular sugars, which is referred to as a mixed structure (Figure 1.2a).

The stability and utility of powders in the manufacture of food and subsequent uses are significantly influenced by their structure. In general, certain commercial food powders have a stable crystalline structure (like sugar and salt), with that, the inclusion of an amorphous phase will significantly affect the stability and qualities of the overall powder. Amorphous phases may undergo physically undesired changes during storage, handling, and processing due to their thermodynamically unstable states, provided that the proper preventive measures are taken. By changing the molecular arrangements in food powders

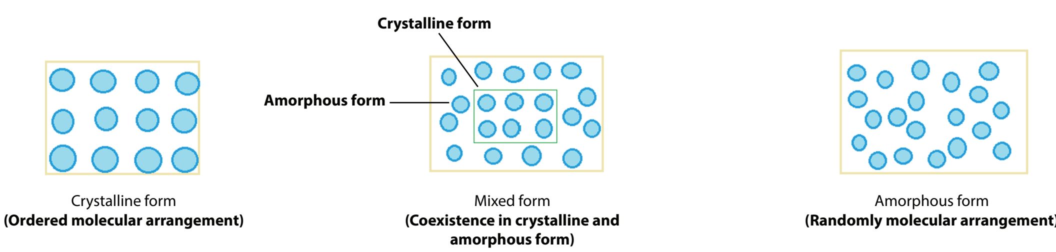

Figure 1.2a Structural characterization of food powders (Modied from Bhandari B, Roos YH) [50].

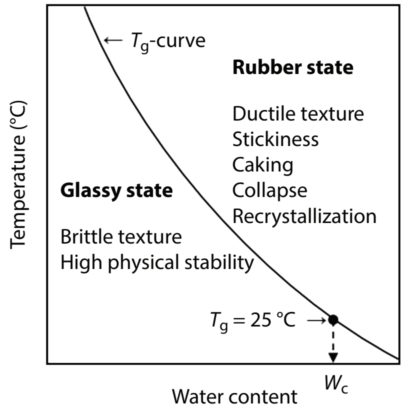

Figure 1.2b Effect of water content on the Tg of dry food materials [51].

from ordered to random or vice versa, several beneficial qualities may be produced [5]. Many food products' appearance, shelf life, texture, and quality depend on their crystalline structure.

Amorphous states are often seen in dry food items. Therefore, during the dehydration-rehydration process, they go through glass to rubber transition (glass transition). Rheological qualities drastically shift as a result of this transition, which entails a physical change between a condition that resembles a solid (glassy) and a state that resembles a liquid (rubbery) Figure 1.2b. The temperature at which the transition of glass happens is known as Tg or the glass transition temperature. Because the Tg of hydrophilic amorphous materials lowers with rising water levels, glass transition may also happen without a change in temperature if the water content varies [7]. The glass transition hypothesis, according to which significant alterations in the apparent porosity (reduction in pore formation) and the collapse of the structure take place at or near Tg, cannot be applied to all dry products [8]. The crucial water content is defined as the water content at which Tg is 25°C (Wc). Using a Tg curve, the glass transition behavior may be explained.

The food product is glassy in the region beneath the Tg curve. Due to their great elasticity, glassy food items have a hard or brittle texture. Additionally, because of their limited molecular mobility, glassy food items should be more physically stable than rubber ones. The food items are in a rubber condition in the area above the Tg curve. The majority of plant-based food products constituent their ingredients in an amorphous condition. It is essential to keep this state to preserve the flavor, taste, and color of the fresh food components.

Glass transition temperature

The critical temperature at which a food's characteristic changes from being glassy to rubbery is known as the glass transition temperature. Water migration causes the matrix of plant-based food products to harden; eventually, it leads to a decrease in the distinctness of the mechanical properties of the matrix and fibers, which may result in the food becoming brittle and glassy.