

Citrus Fruit Processing By-Products

Technologies and Basic Protocols

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Preface to the Series

The Methods and Protocols in Food Science series is devoted to the publication of research protocols and methodologies in all fields of food science. The series is unique as it includes protocols developed, validated, and used by food and related scientists as well as provides theoretical basis for each protocol. Aspects related to improvements in the protocols and adaptations and further developments in the protocols may also be approached.

The Methods and Protocols in Food Science series aims to bring the most recent developments in research protocols in the field as well as very well-established methods. As such the series targets undergraduates, graduates, and researchers in the field of food science and correlated areas. The protocols documented in the series will be highly useful for scientific inquiries in the field of food sciences and presented in such a way that the readers will be able to reproduce the experiments in a step-by-step style.

Each protocol will be characterized by a brief introductory section, followed by a short aims section, in which the precise purpose of the protocol is clarified. Then, an in-depth list of materials and reagents required for employing the protocol is presented, followed by comprehensive and step-by-step procedures on how to perform that experiment. The next section brings the dos and don'ts when carrying out the protocol, followed by the main pitfalls faced and how to troubleshoot them. Finally, template results will be presented and their meaning/conclusions addressed.

The Methods and Protocols in Food Science series will fill an important gap, addressing a common complain of food scientists, regarding the difficulties in repeating experiments detailed in scientific papers. With this, the series has a potential to become a reference material in food science laboratories of research centers and universities throughout the world.

Campinas, Brazil

Anderson S. Sant'Ana

Preface

Citrus fruit by-products, namely, peels (flavedo and albedo), seeds, and pomace, are regarded as valuable bio-resource materials with multifaceted applications. These by-products are abundant in bioactive compounds that offer significant health benefits and are ideal for developing specialized food products. Given the significant proportion of these by-products and their rich nutrient profiles, comprehensive knowledge of the analytical methods for assessing citrus peels, seeds, and pomace is crucial for food science professionals. Hence, this handbook aims to furnish researchers with advanced methodologies and procedures pertinent to the analysis of citrus by-products. Each chapter offers comprehensive insights into the techniques and protocols for the extraction of bioactive compounds, as well as the determination of phenols, flavonoids, carotenoids, dietary fiber, pectin, organic acids, and essential oils present in citrus by-products. The handbook extensively covers reagent and sample preparation, analytical instruments employed in conducting research, and safety considerations. Its primary objective is to facilitate the strategic utilization of citrus by-products obtained from the citrus fruit-processing sector. The main goal is to create a pathway for improved utilization of citrus by-products in alignment with the United Nations Sustainable Development Goal No. 12: Responsible production and consumption.

Chapter 1 provides an overview of citrus by-products, discussing their market potential and applications. It emphasizes the effective use of these by-products to reduce waste and promote sustainable practices, which is important for food security. Chapter 2 focuses on methods to extract bioactive compounds from citrus by-products. It covers both traditional and new green extraction methods, along with their advantages and disadvantages. Chapter 3 explains procedures to determine total phenols in citrus by-products. It describes standard methodology for estimating total polyphenol content, including its benefits and limitations. Chapter 4 discusses methods to determine total flavonoids in citrus by-products. It includes various extraction techniques, like solvent extraction, followed by quantification using colorimetric, HPLC, or spectrophotometric methods. Chapter 5 explores the methods for estimating antioxidants in citrus by-products. It presents various *in vitro* assays, including DPPH, FRAP, ABTS, TEAC, and ORAC. Chapter 6 discusses procedures to estimate dietary fibers in citrus by-products, focusing on an enzymatic-gravimetric method to measure total dietary fiber. Chapter 7 deals with methods to quantify carotenoids in citrus by-products. Chapter 8 covers approaches for measuring pectin content in citrus peels. It discusses advanced techniques like FTIR and HPLC that provide valuable knowledge of the pectin's structure and function. Chapter 9 explores methods for separating and identifying organic acids in citrus by-products. It discusses reliable techniques such as high-performance liquid chromatography with photo-diode array detection, gas chromatography with mass spectrometry, and ion chromatography. Chapter 10 describes a protocol for extracting, separating, and quantifying naringin in citrus by-products using HPLC. This chapter presents a quick and simple method for reverse phase separation and measurement of naringin using HPLC-UV, assisted by ultrasonic extraction. Chapter 11 explores the procedures to analyze functional groups in citrus by-products using Fourier transform infrared spectroscopy. Chapter 12 discusses methods for identifying essential oils in citrus seeds. It highlights extraction methods, including solvent-based techniques, and advanced

analysis tools like gas chromatography, gas chromatography-mass spectrometry, high-performance liquid chromatography, and enzyme-linked immunosorbent assay.

This book serves as a valuable resource for food scientists, researchers, academicians, principal investigators, horticulturists, agriculturists, pharmacologists, laboratory scientists, and graduate students. The editors have made a deliberate effort to select contributors with recognized expertise in citrus fruit processing. We extend our sincere gratitude to all the authors for their valuable contributions. Special thanks are also due to our readers and the editorial staff at Springer Nature for their support and insightful suggestions.

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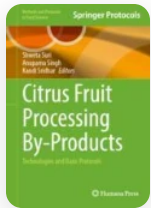
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Pectin Quantification in Citrus Peels

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Citrus Fruit Processing By-Products

Priyanka Dubey, Rahul Singh, Alvina Farooqui & Owais Yousuf

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Abstract

Citrus peel waste, a major by-product of citrus fruit processing, is an abundant source of pectin, a polysaccharide with significant industrial value due to its gelling, stabilizing, and emulsifying properties. This chapter explores methodologies for extracting, quantifying, and characterizing pectin, focusing on sustainability and maximizing economic efficiency. Various approaches are discussed in detail, including gravimetric, titrimetric, colorimetric, and spectrophotometric methods. Advanced techniques like FTIR and HPLC provide precise insights into pectin's structural and functional attributes. Protocols such as alcohol precipitation, calcium pectate precipitation, and carbazole assays are evaluated for their accuracy, efficiency, and reproducibility. By comparing the strengths and limitations of different methods, this chapter provides a valuable resource for researchers and industry

professionals to estimate pectin in a constructive and precise manner. It emphasizes the potential of citrus peel waste as a sustainable, high-value ingredient, contributing to environmental conservation and economic sustainability.

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