

# Extraction and Characterization of Pectin from *Citrus Sinensis* for its Application in Biodegradable Materials

Sophia J. Algarín Montañez, Naomi Kery García, Geliz M. Sánchez Guzmán

Mentor: Miguel A. Florián Algarín, Ph.D.

Polytechnic University of Puerto Rico - Undergraduate Research Program for Honor and Outstanding Students (URP-HOS)

2024 - 2025

## ABSTRACT

Considering the escalating environmental concern over plastic, which accounts for 73% of global waste, and the increasing contamination from food biomass, there is an urgent need for sustainable solutions. A clear example of this problem can be seen in Puerto Rico, where organic waste represents more than 35% of municipal solid waste. Therefore, the development of sustainable alternatives and an effective food waste management strategy is necessary. This study researches the use of orange peels, an organic solid waste, as a potential source for the extraction of pectin, a biopolymer known for its gel-forming capabilities and biodegradability. The objective was to extract and characterize citric pectin to determine its potential development of sustainable materials to reduce environmental impact. Pectin was extracted using two hydrolysis methods: acid hydrolysis with acetic acid ( $\text{CH}_3\text{COOH}$ ) and basic hydrolysis with sodium hydroxide ( $\text{NaOH}$ ), and compared with commercial pectin through FTIR and characterization tests. Thus, the basic extraction produced the highest methoxylated pectin (% DE: 99.09 % , % DM: 27.04 %), while the acid extraction provided a pectin with a gelling capacity of 67.14%, implicating further assessment of gelation potential under specific conditions and its corresponding properties. However, the commercial pectin sample was superior in purity and quality, due to it having a humidity of 0.77% and ash content of 1.40%. Therefore, this research aimed to demonstrate the viability of transforming food waste into biomaterials that could ultimately replace non-renewable sources and reduce plastic production.

## INTRODUCTION

The current state of pollution is critical, as global plastic production has risen dramatically from 2.3 million tons in 1950 to 162 million tons in 1993, and reaching 448 million tons by 2015 (Mendoza et al. , 2020). As the need for sustainable solutions becomes increasingly urgent, researchers have begun shifting their attention toward organic waste as an environmentally friendly alternative to conventional plastics. In Puerto Rico, approximately 1.8 million tons of municipal solid waste are generated each year, with an estimated 630,000 tons consisting of organic plant waste. Among these, orange peels are recognized as environmentally impactful; their anaerobic decomposition releases  $\text{CO}_2$ , nitrates, sulfates, and phosphates, contributing to eutrophication and other environmental impacts (Sayah et al., 2014). In light of these challenges, this study aims to evaluate the pectin extracted from plant waste—specifically orange peels—using both acid and base extraction methods. The research will compare the techniques to determine which yields the highest quantity of pectin, and gelling properties for potential biomaterial development.

## OBJECTIVES

- Compare the yield of pectin obtained using acid and basic extraction methods to determine which method produces a higher quantity and quality.
- Characterize the extracted pectin in terms of its physical, chemical, and gelling properties to assess its performance for various applications.
- Evaluate the feasibility of using the extracted pectin in the manufacture of bioplastics and other sustainable materials.
- Analyze the potential of pectin as an eco-friendly alternative to petroleum-derived plastics in industries such as pharmaceutical, food, cosmetics, and textile.
- Propose a strategic plan for the valorization of plant-based waste to promote the sustainable management of organic residues in Puerto Rico

## METHODOLOGY

The following diagrams show the procedure that was carried out to extract pectin from orange peels using the acid hydrolysis method and the basic hydrolysis method.

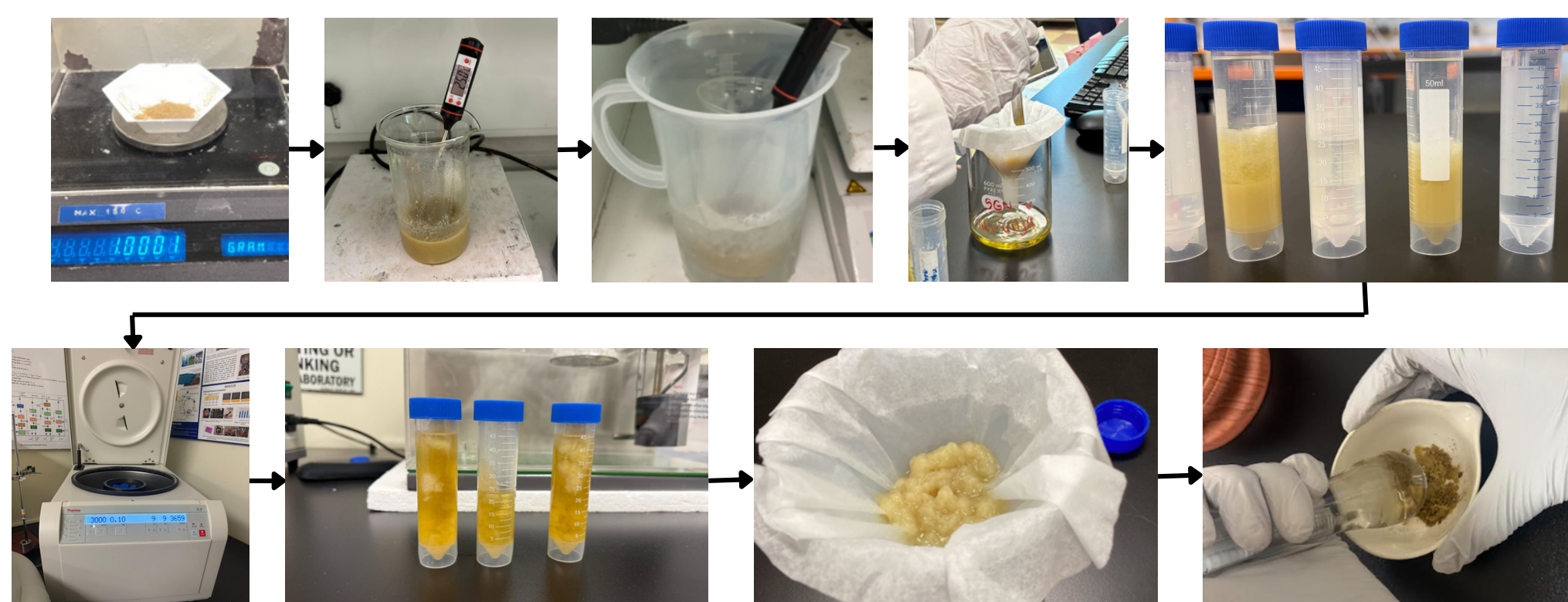


Figure 1. Procedure for extracting pectin by the acid hydrolysis method (Algarín, Kery & Sánchez, 2025).

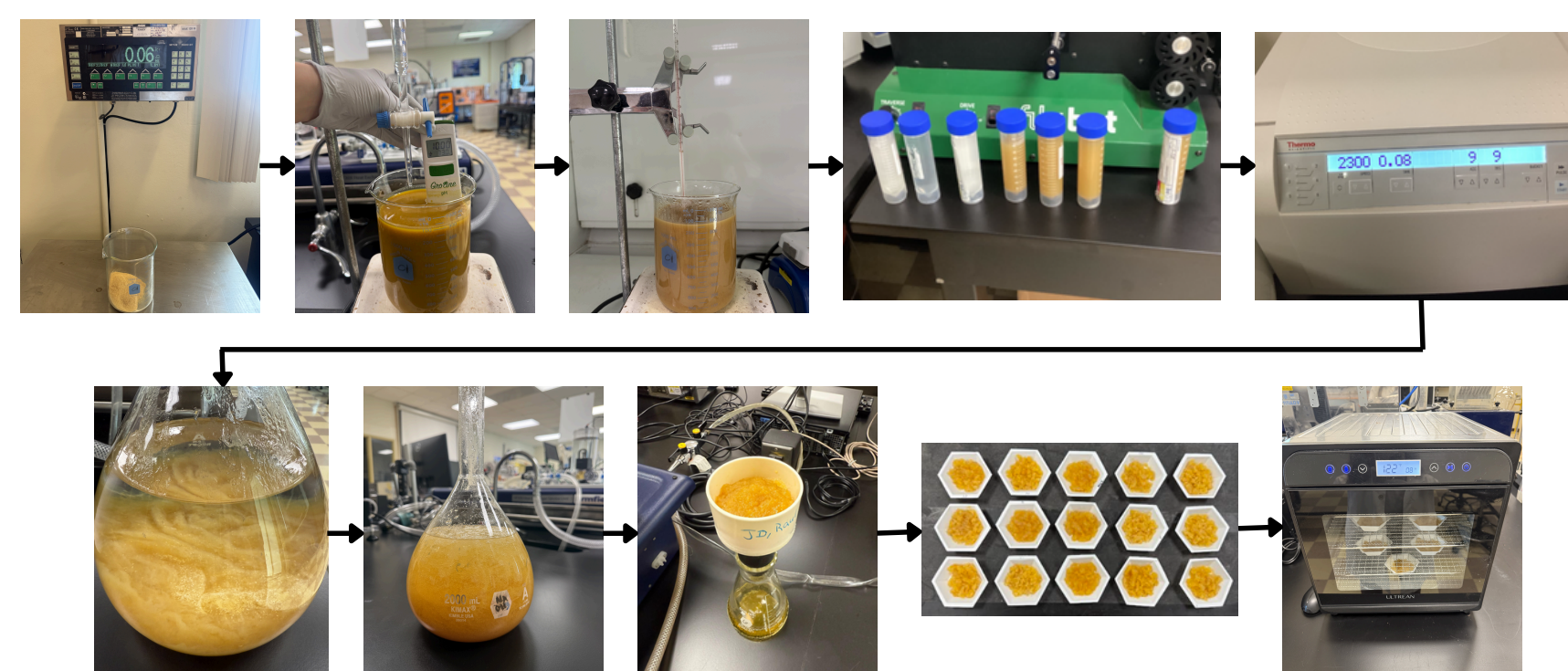


Figure 2. Procedure for extracting pectin by the basic hydrolysis method (Algarín, Kery & Sánchez, 2025).

## DATA

Table 1 includes data gathered from characterization tests of pectin extracted via acid hydrolysis (PA), basic extraction (PB), and commercial pectin as reference (PC).

Table 1. Characterization results of extracted and commercial pectin

TESTS	PA	PB	PC
Degree of Esterification (%)	61.22	99.09	96.76
Methoxyl Content (%)	5.59	27.04	16.5
Gelling Capacity (%)	67.14	25.58	47.41
Humidity (%)	7.34	9.91	0.77
Ash Content (%)	2.50	4.60	1.40
Water Retention Capacity (g $\text{H}_2\text{O}$ / g pectin)	1.76	1.66	34.58

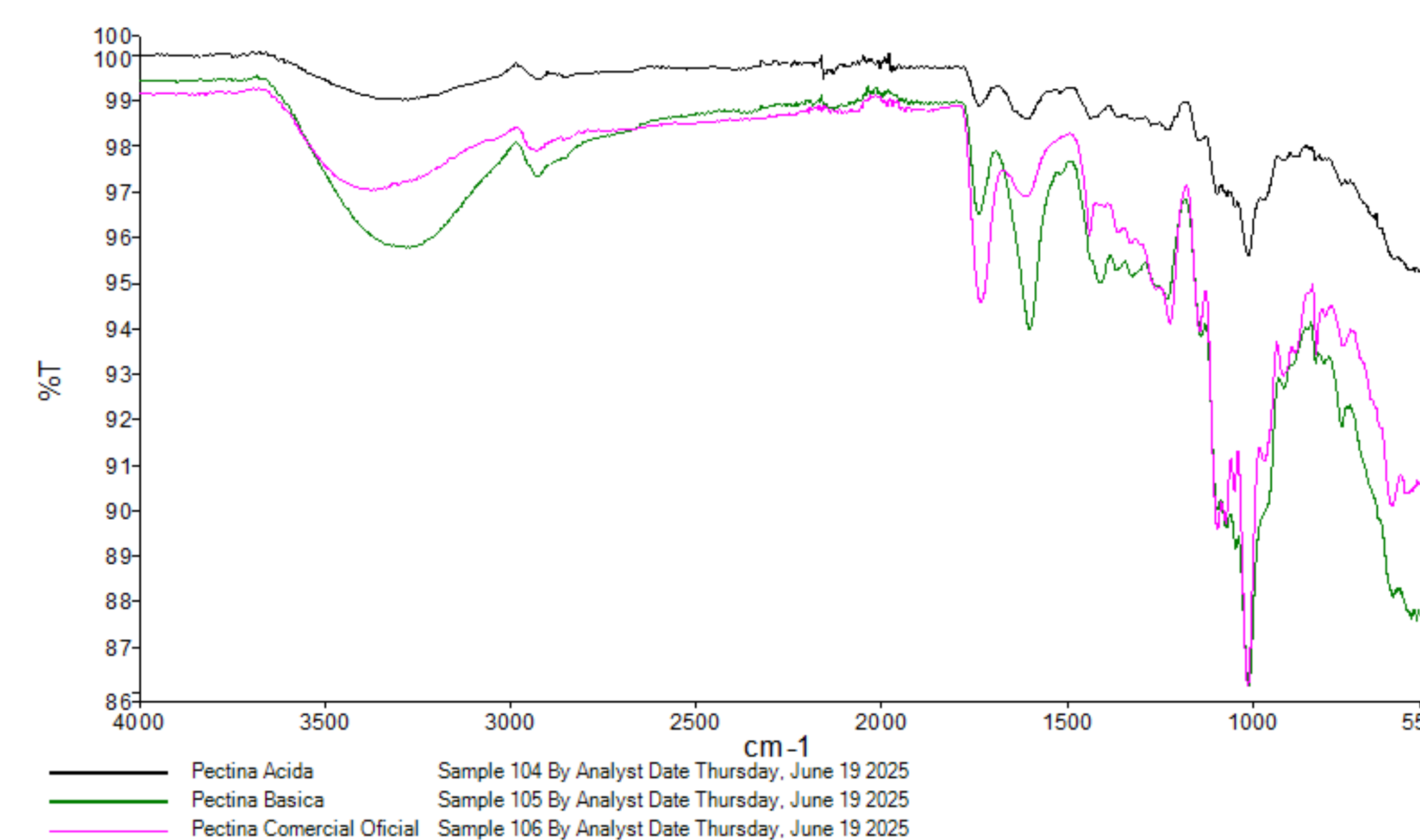


Figure 3. Infrared spectrum generated for extracted pectins and commercial pectin (Algarín, Kery & Sánchez, 2025).

## ANALYSIS AND RESULTS

The extracted pectins showed low humidity and ash content, ensuring purity and suitability for possible use in diverse industries. The acid hydrolysis method yielded pectin with a high gelling capacity, potentially ideal for applications needing a firmer gel. Nonetheless, the basic extraction produced the highest % DM, but the lowest gelling capacity, implying further analysis for gelling under certain conditions. Therefore, the pectin derived from orange peels demonstrated some properties comparable to those of commercial pectin, supporting their potential.

## CONCLUSIONS AND RECOMMENDATIONS

This study successfully extracted pectin from orange peels using acid and basic methods, comparing both to commercial pectin through FTIR and characterization tests. The basic extraction method yielded a great amount of pectin, as well as the highest degree of esterification (%DE) and methoxyl content (%DM), classifying it as a highly methoxylated pectin. However, the pectin extracted from acid hydrolysis showed the highest gelling capacity. While all samples had acceptable humidity and ash content, commercial pectin had the lowest values, indicating superior purity and the highest water retention capacity.

Based on these findings, it is crucial to further investigate the use of basic-extracted pectin for applications where its properties offer specific advantages, while acid-extracted pectin may be more suitable for products prioritizing gelling strength. The next phase of this research will involve developing biofilms from the extracted pectin to determine the most suitable type for biomaterial applications.

## FUTURE WORK

- Evaluate different raw materials for extracting pectin, such as mango peels.
- Explore extraction methods assisted by enzymes.
- Design and simulate a sustainable and cost-effective extraction process.
- Determine average molecular weight of extracted pectin.
- Develop a pectin-based biodegradable material for various applications.

## ACKNOWLEDGEMENTS

This research was supported by the *Undergraduate Research Program for Honor and Outstanding Students* (URP-HOS) through the HSI-STEM Grant at the Polytechnic University of Puerto Rico. We thank our advisor, Ph.D. Miguel A. Florián, for his invaluable mentorship, as well as to the lab technicians, Ángel López and Natalia Rivera, and student Ivaniel Rivas for their assistance. We extend a special thanks to *La Placita de Dios* for their generous donation of the raw materials used in this study.

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