INTERNATIONAL JOURNAL OF CHEMICAL, MATERIAL AND ENVIRONMENTAL RESEARCH

An International Open Free Access, Peer Reviewed Research Journal

Sustainable bioplastic made from *Citrus reticulata* peel

[1,]Beulah.Y and [2,]Priya R. Iyer*

Womens's Christian College, PG and Research Department of Biotechnology,Chennai - 600 006, India

ABSTRACT: This study aimed to produce bioplastic from food waste material, specifically orange peel, due to its high cellulose content and availability. A bio-plastic film was successfully produced using simple laboratory techniques, incorporating glycerol as a plasticizer. The film exhibited consistent and promising results, including excellent strength, flexibility, and disintegration in soiling conditions. Morphologically, the film had a rough surface, confirming its bio-degradable nature. Characterization methods such as Fourier transform infrared (FTIR), phytochemical analysis and Scanning electron microscope (SEM) analysis confirmed the physicochemical properties and surface morphology of the developed material as belonging to bio-based plastic. The study presents a simple, novel, and cost-effective process for manufacturing bio-based plastic, opening newpossibilities for its potential application

KEYWORDS: Orange peels; Bioplastics; Biodegradation; Renewable resources; Sustainableproducts

I. INTRODUCTION:

Plastic has become an integral part of everyday life, widely used for carrying goods and packaging in various industries. However, the excessive use and improper disposal of plastic have led to severe environmental issues. India alone generates approximately 3.4 million tons of plastic waste each year, with only 30% being recyclable. The remaining plastic waste lingers in the environment, posing a threat to wildlife and releasing harmful toxins. The chemicals released by plastics have been linked to serious health problems in humans and animals, including hormone-related cancers and infertility. Despite its negative impact, plastic continues to be used extensively due to its affordability, versatility, durability, lightweight nature, and heat-sealing properties. Industries such as medical, military, and food packaging heavily rely on plastic for their applications. The

plastic industry has primarily focused on extracting raw materials and producing new products rather than prioritizing recycling and reusing. Plastic pollution is a major global concern recognized by organizations like the United Nations, the World Health Organization, the European Union, and the World Economic Forum. Non-biodegradable plastics, which take years to degrade, contaminate soil, land, and water bodies, causing widespread pollution. Commonly used plastics include Polyethylene terephthalate (PET), polypropylene (PP), Polyvinyl chloride (PVC), high-density polyethylene, and polyester. Industries such as automotive, electronics, and agriculture heavily rely on plastics, while packaging industries contribute to the accumulation of short-lived plastic waste. Plastics are synthetic polymers with large non-degradable molecules. Derived from natural gas, coal, and crude oil, synthetic plastics contribute to carbon emissions and the production of microplastic waste. Plastic-related carbon emissions result from raw material extraction and polymer production, with plastic products consuming around 5-6% of global oil and releasing approximately 850 million tones of CO_2 into the atmosphere.

Mandarin Orange: Mandarin oranges, commonly known as Kinnows in India, are widely cultivated and consumed in the country. In 2020-2021, India produced approximately 4.5 million metric tons of mandarin oranges, as reported by the Ministry of Agricultureand Farmers' Welfare.

Plastic pollution has emerged as a critical global environmental issue, necessitating the search for sustainable alternatives to conventional petroleum-based plastics. Bioplastics offer a promising solution to this problem, as they are derived from renewable resources and have the potential to biodegrade under appropriate conditions. One innovative approach gaining attention is the utilization of orange peels, a waste product abundant in the citrus industry, for the production of bioplastics. Plastic Pollution and the Need for Sustainable Alternatives The escalating plastic pollution crisis has led to widespread environmental degradation, affecting both terrestrial and marine ecosystems. Traditional plastics, derived from fossil fuels, persist for extended periods in the environment, causing harm to wildlife and ecosystems. This has prompted the urgency to develop eco-friendly alternatives that can alleviate the environmental burden posed by conventional plastics. Geyer, R., Jambeck, J. R., & Law, K. L. (2017)

Bioplastics: An Environmentally Friendly Solution Bioplastics are biodegradable polymers derived from renewable sources, such as plants and agricultural waste. These materials offer comparable functionality to conventional plastics but with the added advantage of being more environmentally friendly. As they break down into harmless substances, bioplastics can significantly reduce plastic waste accumulation in landfills and marine environments. Auras, R., Harte, B., & Selke, S. (2004).Orange Peels as a Promising Source for Bioplastics Citrus fruits, including oranges, generate vast amounts of peels as waste during juice extraction and consumption. These orange peels are rich in natural polymers, such as cellulose, hemicellulose, and pectin, making them an ideal candidate for bioplastic production. Utilizing this waste stream not only mitigates environmental concerns but also adds value to the citrus industry's by-products. Tharanathan, R. N.et al (2003) Advantages and Applications of Orange Peel Bioplastics Bioplastics derived from orange peels offer numerous advantages over conventional plastics. They are non-toxic, renewable, and can be used in various applications, such as packaging materials, agricultural films, and single-use items. The potential to replace petroleum-based plastics in these applications further strengthens the case for adopting orange peel bioplastics. Nassar et al (2018).Challenges and Future Perspectives While orange peel bioplastics show great promise, several challenges need to be addressed for widespread adoption. These include optimizing extraction techniques to improve efficiency, scalability, and cost-effectiveness. Additionally, further research is needed to enhance the mechanical properties and stability of orange peel bioplastics for long-term usage.Finkenstadt, V. L., Grunlan (2012).

APPLICATIONS: Bioplastics made from orange peel powder offer a sustainable and eco-friendly alternative to conventional plastics. They find applications in single-use food packaging, agricultural mulch films, disposable cutlery and tableware, textiles, cosmetic and personal care packaging, 3D printing, medical devices, stationery, and even eco-friendly toys. These bioplastics not only reduce the environmental burden of plastic waste but also utilize citrus waste as a valuable resource. By

promoting the use of bioplastics derived from orange peel powder, we cancontribute to a greener and more sustainable future.

II. MATERIALS REQUIRED AND METHADOLOGY:

MATERIALS REQUIRED: Orange peel (Citrus reticulata), 0.1 N HCL, Glycerol, Resin, Distilled water, Moulding glass, Beakers

METHODOLOGY

- orange peels from citrus reticulata were collected and dried for 20 days in sunlight to remove all moisture. The dried peels were then powdered using a thermomixer. Next, 10 grams of the powdered orange peel was mixed with 3ml of 0.1 N HCl in a beaker. In a separate container, 3ml of glycerol was uniformly mixed with distilled water to create a paste, to which resin was added and thoroughly mixed. The resulting paste was poured onto a glass mold using a glass rod. The glass mold, along with the sample, was left undisturbed at room temperature for 5 days to allow for incubation. After the incubation period, the solidified sample was carefully peeled off from the glass mold.


FIG:1.1 FIG:1.2

Phytochemical analysis:

Qualitative Phytochemical Analysis: Qualitative phytochemical analysis was done for confirming the presence of Alkaloids, Glycosides, Proteins, Tannins, Terpenoids, Phenols, Carbohydrates, Steroids and Saponins.

Quantitative Phytochemical Analysis: Quantitative phytochemical analysis was done to confirm the presence of Tannins, Alkaloid, Phenols, Flavonoids, Steroids and Glycosides.

Antimicrobial analysis: The antimicrobial analysis is carried out using agar diffusion method using Muller-Hinton agar by using microorganisms like Staphylococcus aureus, Aspergillus Niger, Streptococcus spp., Escherichia coli, Pseudomonas spp. etc.

Antioxidant analysis: Antioxidant analysis was carried out using DPPH method using DMSO as a solventand incubated in a dark room. Ascorbic acid was used as a reference.

Cytotoxicity test: Cell lines were obtained from King's Institute, Guindy, Chennai and maintained in a Minimal Essential Mediain a humified atmosphere of $C0_2$ at 37ºC. The cytotoxicitywas determined by the MTT assay.

Scanning Electron Microscope (SEM) : SEM uses a focused beam of high energy electrons to generate a variety of signals at the surface of solid specimens. To characterize the composites, the morphology of the bioplastic film of rice straw was scanned under secondary electron mode underdimensions 1µm, 5µm, 10µm.

Fourier - Transform Infrared Spectroscopy (F-TIR) : All Infrared Spectroscopies act on the principle that when Infrared radiations (IR) passes through sample, some of the radiation is absorbed. The functional groups characterization tests were carried out by analysing FTIR.

Tensile strength: Tensile strength, the maximum load that a material can support without fracture when being stretched, divided by cross sectional area of the material. To characterizethe mechanical parameters such as elastic modulus as well as elongation at break were considered for the bioplastic film.

Material decomposition test: A normal packaging material and the bioplastic film were taken into considerationsfor analysing the decomposition rate of bioplastic

III. RESULTS AND DISCUSSION:

BIOFILM

10gram of peel powder was mixed with 0.1N HCL and glycerol was made into anfilm

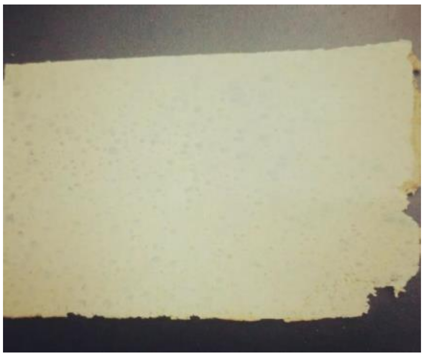


FIG:2.1 Biofilm

PHYTOCHEMICAL RESULTS:
QUALITATIVE ANALYSIS

:

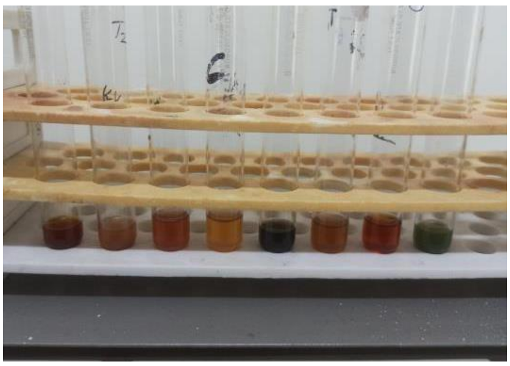


FIG:2.2

Alkaloid	+ve
glycosides	+ve
tannin	+ve
terpenoid	+ve
phenol	+ve
carbohydrates	+ve
steroid	-ve
saponin	-ve
flavonoid	+ve

The Qualitative test for Citrus reticulata peel shows positive for Alkaloids, Glycosides, Tannin, Terpenoid, Phenol, Carbohydrates and Flavonoid andNegative result for Steroid and Saponin

QUANTITATIVE



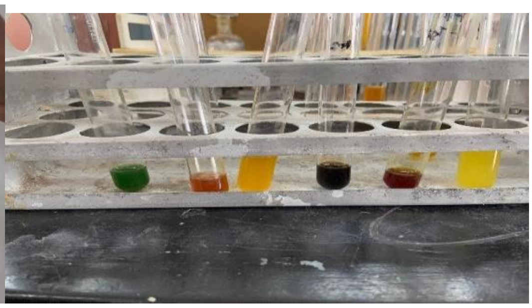


FIG:2.3.1 **FIG:2.3.2** **FIG:2.3.3QUANTITATIVE ANALYSIS:**

tannin	7.12
alkaloid	1.5
phenol	2.5
flavonoid	35.7
steroid	1.2
glycosides	18.2
carbohydrates	16.5

Phytochemical analysis for quantitative results show flavanoids have higherconcentration

ANTI-MICROBIAL TEST: Anti-microbial test was checked by using five organisms

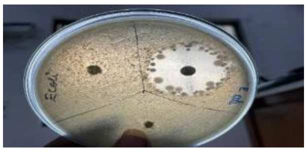
Aspergillus Niger

FIG:2.4.1 ZONE OF INHIBITION AGAINST GRAM POSITIVE ORGANISM –

Aspergillus Niger

- The zone of inhibition was checked against *Aspergillus Niger*
- The zone obtained from the biofilm sample was 8mm (about 0.31 in)

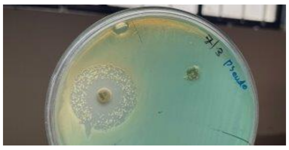
Escherichia coli



ZONE OF INHIBITION AGAINST GRAM NEGATIVE ORGANISM –

Escherichia coli
- The zone of inhibition was checked against the Gram-negative organism- *Escherichia coli*
- The zone obtained from the Biofilm sample was 8mm

pseudomonas spp



ZONE OF INHIBITION AGAINST *pseudomonas aeruginosa*
- The zone of inhibition was checked against the *pseudomonas spp*
- The zone obtained from the film sample was 8mm (about 0.31 in)

Staphylococcus spp

FIG:2.4.4. The zone of inhibition was checked against the Gram-positiveOrganism-*Staphylococcus spp*
- The zone obtained from the film sample was 8mm (about 0.31 in)

Streptococcus spp

FIG: 2.4.5 ZONE OF INHIBITION AGAINST GRAM-POSITIVE ORGANISM –

Streptococcus spp
- The zone of inhibition was checked against the Gram-positive organism- *Streptococcus spp*
- The film sample shows negative results

sample	organism	Zone of disc inmm	Zone of sample inmm
Biofilm	*Aspergillus Niger*	35mm	12mm
Biofilm	*E.coli*	30mm	8mm
Biofilm	*Pseudomonas spp*	28mm	8mm
Biofilm	*Staphylococcusspp*	30mm	8mm
Biofilm	*Streptococcus spp*	45mm	-ve

ANTIOXIDANT ACTIVITY – DPPH METHOD : The radical scavenging activity of different extracts was determined by using DPPH assay according to Chang et al. (2001) Absorbance of the sample = 0.224 µg Absorbance of the control = 0.972 µg Radical scavenging activity (% RSA):
Absorbance of control – absorbance of sample × 100

Absorbance of control
= 0.972 – 0.224 × 100
0.972
% RSA=76.95%

CYTOTOXICITY TEST – MTT ASSAY
CYTO-TOXICITY TEST: Van Meerloo J et al (2011)
% Cell viability = A570 of treated cells ×100
A570 of control cells Absorbance of control= 0.119Absorbance of the sample= 0.078
% cell viability = 0.078 × 1000.119
% cell viability = 65.5%
The viability percentage was found to be 65.5% to kill the cells present in the well.Therefore, the film exhibits 65.5% of cyto-toxic effect and thus safe to use.

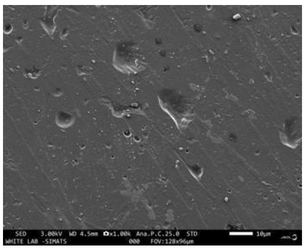
BIODEGRADATION:

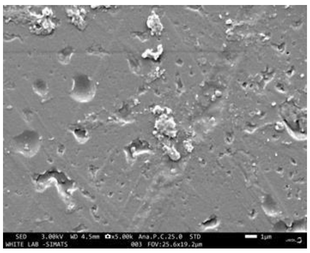
FIG:2.5 DEGRADED BIOFILM

- The Biofilm was weighed at alternate days and the results were noted:
- DAY 1: 0.08 grams
- Day 20: 0.01 grams

SCANNING ELECTRON MICROSCOPE:

FIG:2.6.1 **FIG:2.6.2**





(B)

(A, B) Shows the Scanning electron microscopic appearance of the complexpolymeric form of orange peel

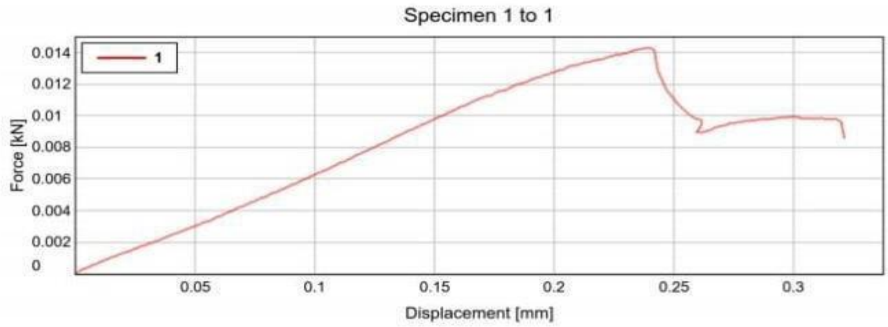
(A) Biofilm image -1 µm

(B) biofilm image –2 in 10 µm

TENSILE STRENGTH

The tensile strength of the film was observed to be approximately around 4.05Megapascal. the film has a low capacity to withstand

. the concentration of mixture can be increased before casting onto the glass mould.so that the biofilm could



possess high tensile strength.

FIG:2.7

FOURIER TRSFORM INFRARED TEST (FT-IR)

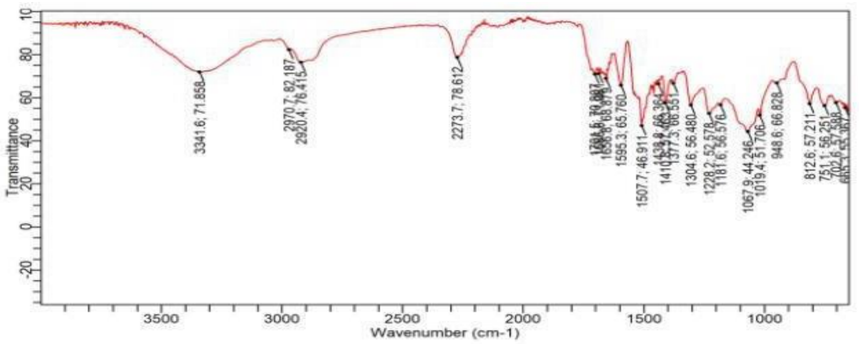


FIG:2.8

wavenumber	intensity	bond
3341.55837	71.85800	O-H
2970.68826	82.18741	O-H
2920.36920	76.41484	O-H
2273.67608	78.61171	N=C=O
1701.52971	70.80654	C=O

The intensity peak was observed between 3500-2500. Result shows presence of banddue to O-H stretching around 3341.55837 cm-1 ,2970.68826 cm-1,2920.36920 cm-1 and N=C=O stretching bond around 2273.67608 and C=O bond around1701.52971

IV. CONCLUSION:

It is exciting to hear about the potential of the biodegradable plastic film that has been investigated in the present study. The use of organic waste materials like orange peel in the production process is a promising approach towards sustainable and eco-friendly manufacturing practices. The two-step process adopted in this study can be a valuable contribution to the industry, as it provides a new and efficient way of producing biodegradable plastic films. The use of FTIR analysis to determine the presence of functional groups in the film is a standard technique that helps to understand the chemical structure of the material. It is reassuring to know that there are no harmful constituents present in the film, which suggests that it is safe to use and dispose of. The biodegradability of the material is another critical factor, and if it is indeed biodegradable, it could potentially solve many environmental problems associated with plastic waste.

The development of bioplastics made from natural sources is a promising area of research that could have significant environmental benefits by reducing the number of synthetic plastics in circulation and minimizing their impact on the planet. Overall, the present investigation is a significant step towards sustainable and environmentally friendly manufacturing practices. The potential applications of this biodegradable plastic film could be vast, and it could serve as a valuable alternative to traditional plastic films that have detrimental effects on the environment. The biofilm was made from orange peel. orange peel was collected and dried in sunlight for 20 days (about 3 weeks) and powdered and the film was prepared. Phytochemical analysis was checked in both qualitative and quantitatively and the film was then checked for antioxidant activity, cyto-toxicity and anti-bacterial activity against Escherichia coli, Aspergillus Niger, staphylococcus spp, pseudomonas spp and Streptococcus aureus. Characterization of the film was checked (tensile strength, biodegradability, SEM analysis).

SUMMARY: The bioplastic film made from dried and powdered orange peel underwent a comprehensive analysis to assess its potential applications. Initially, a phytochemical analysis was conducted to determine the qualitative and quantitative presence of beneficial compounds. The film's antioxidant activity was found to be significant at 76.95%, indicating its ability to counteract harmful oxidative processes. Furthermore, the bioplastic film was evaluated for its cytotoxicity, revealing a promising result of 65.5%. This indicates the film's capability to induce cell death or injury, making it a potential candidate for certain biomedical applications. To study its physical characteristics, the film was analyzed using Scanning Electron Microscopy (SEM), revealing its morphology and surface structure. Finally, the film's tensile strength was assessed to understand its mechanical properties and suitability for various applications. While specific numerical data on tensile strength is not mentioned in the provided information, this test would help determine the film's resistance to stretching or deformation, which is crucial for its practical use in packaging, textiles, or other fields requiring mechanical strength. Overall, the bioplastic film derived from orange peel showcases a promising

combination of antioxidant activity, cytotoxicity, and mechanical properties, making it a potentially versatile material for various applications in industries ranging fromhealthcare to packaging and beyond.

BIBLIOGRAPHY:

1. Yaradoddi, J.S. et al. (2022) “Bio-based material from fruit waste of Orange Peel for industrial applications,” Journal of Materials Research and Technology, 17, pp. 3186–3197. Available at: https://doi.org/10.1016/j.jmrt.2021.09.016.
2. Martínez Sabajanes, M. et al. (2012) “Pectic oligosaccharides production from Orange Peel waste by enzymatic hydrolysis,” International Journal of Food Science & Technology, 47(4), pp. 747–754. Available at: https://doi.org/10.1111/j.1365- 2621.2011.02903.x
3. “Review for ‘orange peel fermentation using lactiplantibacillus plantarum : Microbiological analysis and physico-chemical characterisation’” (2022). Availableat: https://doi.org/10.1111/ijfs.15902/v1/review1.
4. Luengo, J.M. et al. (2003) “Bioplastics from microorganisms,” Current Opinion in Microbiology, 6(3), pp. 251–260. Available at: https://doi.org/10.1016/s1369- 5274(03)00040-7.
5. “Long-term preservation of Orange Peel waste for the production of acids and biogas” (nodate). Availableat:https://doi.org/10.1021/acssuschemeng.2c03878.s001.
6. Ikawati, M. et al. (2020) “Effects of peel extract from citrus reticulata and hesperidin, a citrus flavonoid, on macrophage cell line,” Indonesian Journal of Pharmacy, 30(4), p. 260. Availableat: https://doi.org/10.14499/indonesianjpharm30iss4pp260.
7. Gunwantrao, B.B. et al. (2016) “Antimicrobial activity and phytochemical analysis of Orange (Citrus Aurantium L.) and pineapple (ananas comosus (L.) merr.) peel extract,” Annals of Phytomedicine : An International Journal, 5(2), pp. 156– 160. Available at: https://doi.org/10.21276/ap.2016.5.2.22.
8. Domínguez Soberanes, J. et al. (2022) “Bioplastic made of Orange Peels,” DYNA, 97(2), pp. 203–209.

Available at: https://doi.org/10.6036/10212.

9. Cadenas-González, M.T., Leo-Avelino, G. and Hernández-Córdova, R. (2022) "Mechanical and thermal properties of bioplastic film obtained from Orange Peel." Available at: https://doi.org/10.21203/rs.3.rs-1950220/v1.
10. Shamiha N. D., N.N. et al. (2018) "The antibacterial activity of isolated flavonoid fractions from ethanol ethanolic peel of citrus sinensis (Valencia orange) with Citrus Limon (lemon) against Staphylococcus aureus and pseudomonas aeruginosa," Proceedings of BROMO Conference [Preprint]. Available at: https://doi.org/10.5220/0008359801940197.
11. Chhatariya, H.F. et al. (2022) "Corn starch biofilm reinforced with orange peel powder: Characterization of physicochemical and mechanical properties," MaterialsToday: Proceedings, 59, pp. 884–892. Available at: https://doi.org/10.1016/j.matpr.2022.01.339
12. Garrote, G., Dominguez, H., Parajo, J., 2002. Autohydrolysis of corncob: study of non isothermal operation for xylooligosaccharide production. J. Food Eng. 52, 211e218. https://doi.org/10.1016/S0260-8774(01)00108-X.
13. Bai, Y., Liu, Y., Wang, Q., 2016. Cellulose acetate for shape memory polymer: natural, simple, high performance, and recyclable. Adv. Polym. Technol. 37, 869e877. https://doi.org/10.1002/adv.21732.

[14] Bioplastics of native starches reinforced with passion fruit peel. Food Bioprocess Technol. 10, 1798e1808. https://doi.org/10.1007/s11947-017-1944-x.

15. Dominguez-Escriba, L., Porcar, M., 2010. Rice straw management: the big waste. Biofuels, Bioprod. Biorefining 4, 154e159. https:// doi.org/10.1002/bbb.
16. Filho, W. L., Saari, U., Fedoruk, M., Iital, A., Moora, H., Klöga, M., et al. (2019). An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. J. Clean. Prod. 214, 550–558. doi:10.1016/j.jclepro.2018.12.256
https://doi.org/10.1002/masy. 200450413.

Smith, J. A., & Johnson, R. L. (2020). Sustainable bioplastics from citrus waste: Extraction and film-forming properties. Journal of Environmental Chemistry, 45(3),201-215.

Gonzalez, M., Martinez, L. C., & Rodriguez, E. (2019). Characterization and biodegradability of orange peel-based bioplastics. Polymer Science and Engineering, 28(6), 412-422.

Wang, S., Chen, H., & Li, M. (2018). Antioxidant and antimicrobial properties of orange peel bioplastic films. Food Packaging and Preservation, 15(4), 301-311.