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Citrus Waste: A Sustainable Pathway to Value-Added Products – A Review

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Abstract: The production of citrus fruits generates over 15 million tons of waste byproducts globally each year, mostly in the form of peels, pulp and seeds which is highly bioactive compounds and Vitamin C (ascorbic acid). With the focus of extraction, purification, and subsequent use of citrus waste into value-added products. This paper provides a comprehensive review on using citrus trash as a potential source of Vitamin C and other value-added products. Efficiency and environmental impact of various extraction processes such as mechanical, solvent extraction and enzymatic procedures are examined. A comprehensive analysis is conducted to show how Vitamin C and other bioactive compounds derived from citrus waste can be used in pharmaceuticals, cosmetics, functionals foods, cleansing agents and other purposes. Its role in improving product quality and market value is highlighted. The study also addresses the economical and environmental benefits of converting citrus waste into high-value products, which is in favor of the circular economy. The evaluation also covers how reducing industrial waste and advancing circular economy and the environment by turning citrus waste into high-value products. Furthermore, the review emphasizes current technological advancements and future research directions needed to optimize extraction efficiency and scalability. By integrating sustainable waste management strategies with innovative bioprocessing techniques, the valorization of citrus waste can play a significant role in supporting green industries and achieving long-term environmental goals.

1. Introduction

One of the crops that is grown worldwide most frequently is the Citrus fruit. Oranges were the most produced citrus fruit in 2020, with a global production of 158,490,986 tons, up 7.5% from 2017 2017 (*FAOSTAT*, 2022). In 2024, citrus fruit production is expected to go beyond 38 million tons. Since people all over the world enjoy them in such large quantities, they create both opportunities and challenges (Venkataraman *et al.* 2024). The environmental burden is increased by the growing consumption and interest in citrus fruits, but also by the relatively rising waste output. Throwing them without proper treatment poses a risk to the environment (Mahawar *et al.* 2020). The process of making citrus juice wastes about half of the fresh fruit's mass. Wastewater, pomace, peels (which account for 50-55 % of the total fruit mass), and seeds (20-40% of the total fruit mass) make up this waste. Peels, pulp, seeds, and bits of ruined fruit are all covered by citrus wastewater (Suri *et al.* 2022). Food processing industries, vegetable markets, and restaurants generate large amounts of biodegradable waste like fruits, vegetables, and peels (Saramanda & Kaparapu 2017).

It is reported that the fraction of waste material discarded from the food processing industries is very high (pomegranate 40–50%, mango 30–50%, Banana 20%, and Citrus 30–50% (Chavan *et al.* 2018). Traditionally, citrus trash is either fed to animals or composted. This suggests that the management of agricultural residues is limited and does not completely utilize their potential value (Nancy Medina-Herrera 2024). Sweet orange, sweet blood orange, tangerine, grapefruit, lemon, lime, and Seville orange are examples of citrus-based dishes. Citrus fruits are processed industrially to create a variety of final goods, including juice concentrates, jams, jellies, candies, marmalades, and ice creams. This process also generates heaps of garbage and peels (Duhan *et al.* 2023). Citrus waste can be converted into goods with added value by extracting valuable substances like vitamin C, pectin, flavonoids, and essential oils (Othman & Fadzil 2021).

Due to their high nutritional content, delicious flavor, and pleasant aroma, citrus fruits are consumed in large quantities. The byproducts of citrus processing mainly consist of food-grade (jellies, jams, candies, flavoring agents, etc.) and aromatic/cosmetic (essential oils) items (Šafranko *et al.* 2023). Numerous writers have documented the antioxidant and radical-scavenging characteristics of essential oils (Guimarães *et al.* 2010). Approximately 15 million tons of garbage and byproducts are produced annually worldwide by the citrus industry. Since they're packed with natural beneficial compounds, different methods can be used to extract them and create beneficial ingredients for food products (Andrade *et al.* 2023).

Fruit and vegetable peels are not used to make antimicrobial agents; instead, they are thrown away as agricultural waste. Several studies on peels have revealed that they contain essential ingredients with pharmacological or medical uses (Haddou *et al.*, 2024; Saleem & Saeed, 2020). It is mainly grown for its alkaloids, which have antibacterial and anticancer properties in crude extract in different parts of the plant, including the leaves, stem, root, and flower (Dhanavade *et al.* 2011). Through biotransformation, the citrus waste can be further used to create ethanol, biogas, fuels, and biosorbents once bioactive compounds like limonene have been extracted. The latter comprises physico-chemical processes and/or microbial fermentation (Mahato *et al.* 2021). Parashar *et al.* 2014 shows that Citrus peel oils exhibit strong antibacterial properties, with a minimum inhibitory concentration of 1 :20 for *Pseudomonas aeruginosa*, 1 :20 for *Salmonella typhimurium*, and 1 :20 for *Micrococcus aureus* when using various solvents. Studies reveal lemon peel (LP) contains higher phenolic compounds and dietary Fibers than flesh. It consists of an outer flavedo layer and an inner albedo layer, rich in flavonoids (Magalhães *et al.* 2023). Essential oils are well-known for their antibacterial qualities as well as their potential to influence economically damaging bug species. Essential oils are new techniques for managing insect populations in grains that are stored in storage facilities. Numerous essential oils work well against insect pests like Sitophilus species, Callosobruchus species, Tribolium species, and others through their multi-organ toxic insults (Visakh *et al.* 2022).

The present review gives an overview of different value-added products obtained from Citrus waste.

Chemical Composition

Since the middle of the 1980s, citrus fruit production and consumption have grown significantly worldwide. Research has demonstrated that citrus residues are rich in polyphenols, including phenolic acids and flavonoids, which mainly consist of polymethoxy flavones, flavanones, and glycosylated flavanones (Singh *et al.* 2019). China is the top citrus-producing nation, generating 44.63 million MT of citrus fruit in 2020, or 28.16% of the world's total citrus fruit production. According to **Figure 1**

other significant producers of citrus fruits include Brazil, India, and Mexico, which collectively account for over 5% of the world's citrus fruit production (Suri *et al.* 2022). Flavonoids possess antibacterial, antimicrobial, antioxidant, and anti-inflammatory properties. They have also been shown to scavenge free radicals, stimulate certain hormones and neurotransmitters, and inhibit certain enzymes (Henderson *et al.* 2018).

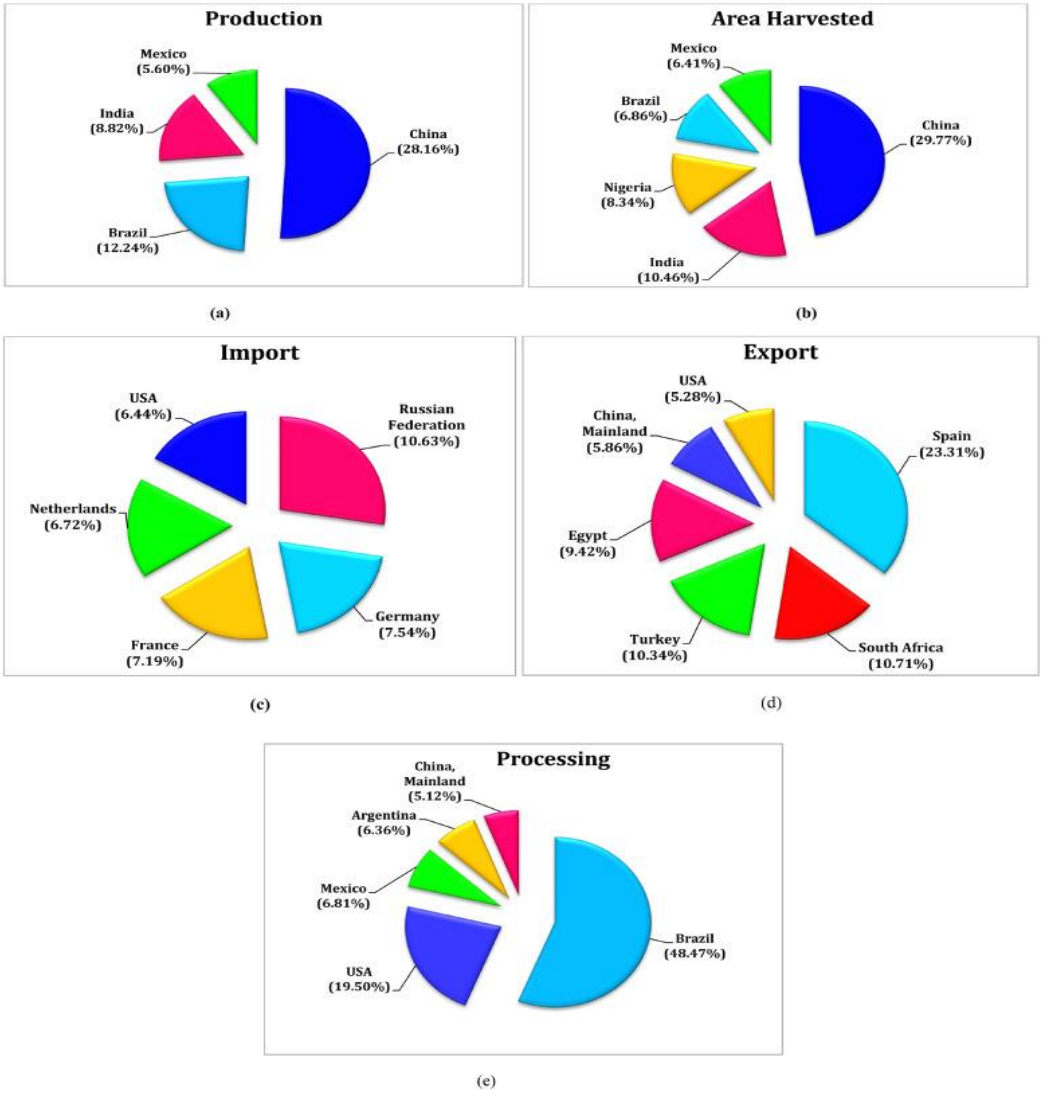

Figure 1: Countries that harvest, produce, import, export, and process at least 5% of the Total Global Citrus Area (Suri *et al.* 2022).

Table 1: Total phenolic, total flavonoid contents and antioxidant activity of citrus peels (Zaki & Naeem 2021).

Sample	Content of Total Phenolic Compounds (mg GAE / 100g)	Total Flavonoid Content (mg quercetin/100g)	Antioxidant Activity
Orange peel	1108±2.8	518±2.6	45.99±2.1
Lemon peel	930±2.4	420±1.1	36.10±4.6
Mandarin peel	581±3.6	860±2.2	43.60±3.2

Citrus fruits also contain bioactive substances like vitamin C, citric acid, phenolic compounds, dietary fiber, and essential oil, providing antimicrobial, anti-inflammatory, and antioxidant benefits for health (Tinh *et al.* 2021). Lemons are among the citrus fruits whose peels are well known for containing flavonoids, which are potent antioxidants, essential oils, and other valuable substances (Juhari *et al.* 2021). Alkaloids, saponins, sterols, steroids, terpenoids, proteins and amino acids. Tanins and carbohydrates were found in the phytochemical analysis performed using methanolic extracts of the dried fruit of the Citrus limon plant (Ali *et al.* 2017).

Fruit peel waste, rich in vitamins, chemical components, and other nutrients, is suitable for processing due to its high nutritional content (Martgrita *et al.* 2023). The lemon peel (LP) has two layers: flavedo and albedo, rich in fibers and polyphenolic chemicals like hesperidin, which has anti-inflammatory, antioxidant, and cancer-fighting properties (Tinh *et al.* 2021). Citrus fruit peels are useful for their physiological and ecological roles because they are rich in polymethoxylated flavones, which are vital for the food and pharmaceutical industries. They also have strong antibacterial capabilities (Saramanda & Kaparapu, 2017). Citrus peel is a powerful source of phytochemicals and is used in food, beverages, pharmaceuticals, and cosmetic industries (Suri *et al.* 2022).

Essential oils, extracted from plants, have various applications in medicine, cosmetics, textiles, and food (Diass *et al.*, 2023; Haddou *et al.*, 2023). Techniques for encapsulating biomolecules, active chemicals, nanocrystals, and oils have been developed in academic publications (Asbahani *et al.*, 2015). Cedro oil is another name for the essential oil that is extracted from Citrus Limon. The oil is low viscosity, has a pleasant pale yellowish green tint, and a strong scent (Hernawan *et al.*, 2015). Citrus fruit EOs can be extracted using a variety of techniques. Soxhlet extraction, solid-liquid extraction, liquid-liquid extraction, maceration, steam distillation, infusion, and other traditional extraction techniques are among them (Grover *et al.*, 2024). A large portion of the active chemical compounds are organic acids. These acids are abundant in Citrus fruits, and some of them even have antioxidant qualities. Citric and malic acids are the primary organic acids found in citrus fruits; citric acid is the more significant of the two and helps to maximize the effects of Vitamin C (Nieto *et al.*, 2021). Citrus peels contain valuable compounds like flavones and catechins, which are powerful antioxidants. As polyphenols, they help protect the body by neutralizing harmful free radicals and preventing damaging redox reactions (Singh *et al.*, 2019).

Potential value-added products from Citrus waste

By-products from the citrus fruit processing industries, such as peels, seeds, pomace, and wastewater, make up 55-60% of the weight of the raw fruit. These by-products contain bioactive substances, useful in various industries (Panwar, Saini *et al.*, 2021). Citrus waste are used in the food and industrial sectors to produce high value goods like ethanol, enzymes, organic acids, pectin, bio-oil, fertilizers, and adsorbent materials (Yousof *et al.*, 2022). Citrus by-products can be utilize in many sectors as shown in **Figure 2** (Suri *et al.*, 2022). The process of recovering the citrus waste's value-added product involves several stages, including extraction, isolation, purification, identification, and characterization. Pith, albedo, seed, and flavedo are among the primary compounds found in citrus waste byproducts, and they are used in a variety of sectors (Mahato *et al.*, 2018).

Human Health: Citrus peels include natural substances such as sugars, flavonoids, carotenoids, folic acid, vitamin C, pectin, and volatile oils that are especially advantageous to human health and food industry (Zaki & Naeem 2021). Among the citrus by-products, polyphenols, carotenoids, and essential oils are thought to be the most biologically active compounds (BAC). The numerous health advantages

of polyphenols and carotenoids are primarily ascribed to their antioxidant activity (Mahato *et al.* 2018). Citrus fruits' active ingredients, including flavonoids, vitamins, carotenoids, and minerals, have therapeutic properties, including antitumor, antioxidant, and anticancer actions, potentially reducing chronic illnesses (Khan *et al.* 2021). A sufficient amount of vitamin C, folic acid, potassium, and pectin are also provided. It has been determined how citrus species can prevent serious illnesses (El-Sawi & Ibrahim 2017).

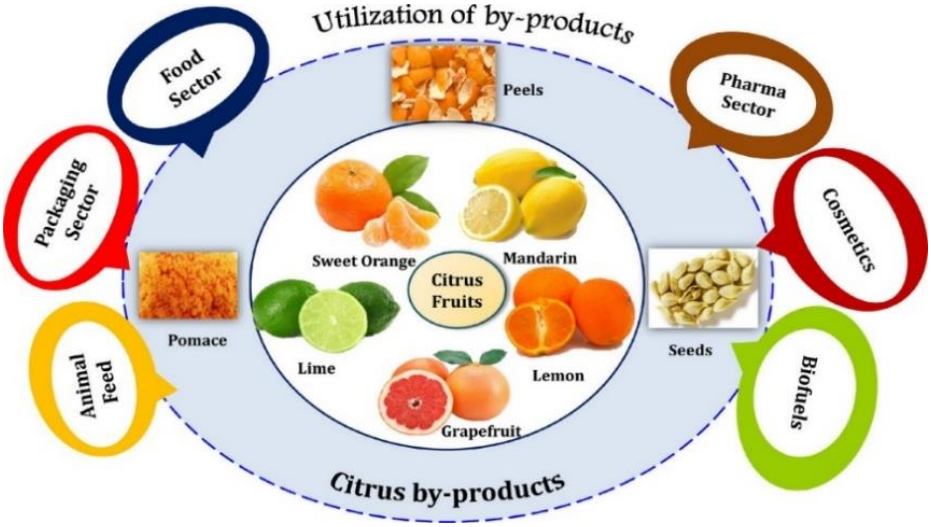

Figure 2: Citrus by-products (Suri et *al.* 2022).

Citrus peel flavonoids are said to offer numerous antioxidants, anti-inflammatory and anti-cancer effects in addition to other positive health effects (Peng *et al.* 2024). One of the most well-known conventional antioxidants, vitamin C has a long history of beneficial health effects that have been amply documented. It is particularly effective in treating and preventing infectious infections (Tokuşoğlu 2018). Khan *et al.* 2021 demonstrates that vitamin C and B derivatives are abundant in the citrus genus. Vitamin C has antioxidants properties, aids in connective tissue remodelling, and improves iron adsorption. Consuming foods high in vitamin C strengthens the body's defenses against viral germs (Kaur & Singh 2021). Citrus bioactive compounds, particularly flavonoids, carotenoids, terpenes, and limonoids, have antioxidant properties that can reduce oxidative stress-related illnesses. As a result, they may be used to treat cancer, obesity, inflammatory diseases, atherosclerosis, and neurodegenerative diseases (Saini *et al.* 2022).

Cleansing Agent: Conventional cleaning products, including clothes washing, household cleaning, and industrial cleaning, often contain petrochemicals, which can be harmful to human health and the environment due to hazardous compounds and slow degradation (Lazim *et al.* 2021). Fruit solutions are an example of a natural cleaning product (Gurusiddappa *et al.* 2023). Peels from a variety of citrus fruits are commonly used to clean and get rid of odors from kitchenware, as well as to rinse, cook, and preserve fish, meat, and fish-and-meat-based curries (Kora 2024)**.** Lemon, a crucial crop fruit, is used in beverages, ice creams, desserts, and cleansing agents due to its tart flavor and bioactive compounds, providing health benefits (Tinh *et al.* 2021). A natural, environmentally friendly cleansing and disinfection, eco-enzyme is derived from fruits and other organic components. It is frequently used as a substitute for abrasive cleaners that contain chemicals. We can use ripe fruits to make eco-enzyme from fruit sources. Enzymes that are isolated from fruit waste can be utilized to disassemble substances

into smaller units (Benny *et al.* 2023). Rivers contaminated by waste can be treated with wastewater using eco-enzymes derived from various citrus peels. Applying Ecoenzyme can lessen pollution and enhance the water's unpleasant odor (Janarthanan *et al.* 2020). Additionally, saponins found in the peels and pericarps of *Citrus* sp. fruits and Indian gooseberry (*Phyllanthus emblica*) fruits are used as dishwashing detergents (Narayana Saibaba 2023). Citrus waste-based active carbon biochar is a cost-effective and efficient bio-sorbent material that can be modified through physicochemical processes to remove harmful heavy metals and dyes wastewater (Yousof *et al.* 2022).

Bioactive Compounds: Citrus peels are rich in nutrients and bioactive substances, including pigments, dietary fibers, essentials oils, polyphenolic compounds, and flavonoids (polymethoxylated flavones, hesperidin, naringin, nobiletin, and tangerine). With a broad range of health advantages and superior antioxidant capabilities, flavonoids are the most abundant type of polyphenols found in citrus fruits (Panwar, Panesar *et al.* 2021). Polar solvents like ethanol, methanol, and water are used to extract phenolic-rich fractions from oil extraction materials, particularly from citrus wastes, by improving solvent penetration and phenolic component extraction (Medina-Herrera *et al.* 2024). Citrus cell walls and middle lamella contain pectin, a high molecular weight gelatinous polymer. Pectins are thickening, emulsifying, texturizing, stabilizing, and fat-substituting agents used in food manufacturing. Pectins can be processed to make biodegradable films, pastry fillings, jams, jellies, and confections (Kesbiç *et al.* 2022). Comparing oranges and grapefruits to lemon peels and peeled fruits (Gorinstein *et al.* 2001) discovered that lemon peels and peeled fruits have the highest antioxidant activity. Citrus fruits contain secondary metabolites like phenolic acids, flavonoids, limonoids, carotenoids, essential oils, and alkaloids, which have anti-inflammatory, anti-oxidative, neuroprotective, anti-cancer, and cardiovascular-protective effects on human health **(Figure 3).**

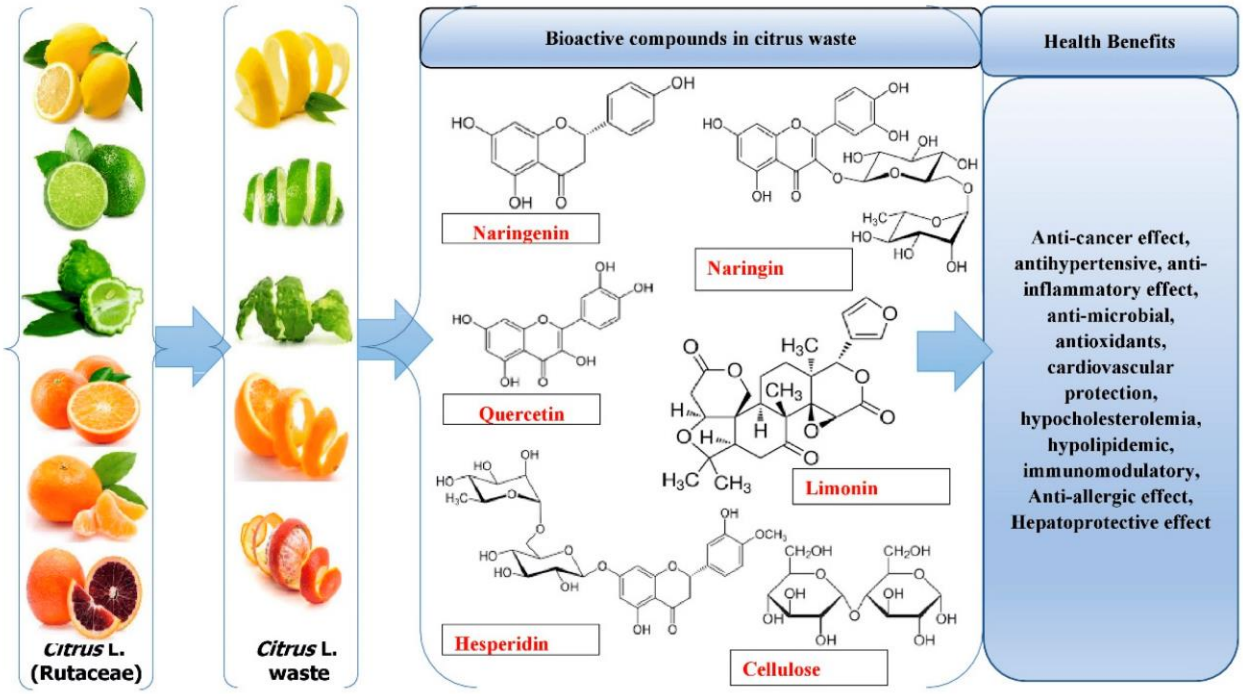

Figure 3: Bioactive compounds in citrus waste and their health benefit (Maqbool *et al.* 2023).

Various compositions found in citrus limon essential oil, such as limonene, βpinene, and ɣ-terpinene, acting as anti-fungi, are beneficial for protecting the body (Hernawan *et al.* 2015). Because of its

aromatic flavor, citrus essential oil (EO) is frequently used in alcoholic beverages, confections, soft drinks, perfumes, soaps, cosmetics, and home items (Omre *et al.* 2018). Seasonal and regional variations, the extraction process, and the length of time peels are stored all affect the components of essential oils (El-Sawi & Ibrahim 2017).

Limonoids, such as limonin and nomilin aglycones and limonoid glucosides (such as limonin glucoside and nomilic acid glucoside), are found in citrus wastes (Kesbiç *et al.* 2022). Limonoids possess antibacterial, antioxidant, anticancer, and cholesterol-lowering qualities. When limonoids are taken into consideration, citrus molasses has the highest concentration of any citrus waste (Breksa III *et al.* 2011). Various techniques have been used to extract essential oils from citrus trash. The most widely utilized techniques are steam-distillation, hydro distillation, and cold pressing; the extraction process with the least adverse environmental effects is cold pressing (Medina-Herrera *et al.* 2024).

Antimicrobial Agents: There has been an increasing number of reports about the antibacterial qualities of natural compounds and plant extracts. They have undergone testing in the areas of microbe eradication and water conditioning for human use (Douhri *et al.* 2017). Each fruit has unique antibacterial or antimicrobial substances that work to prevent the growth of bacteria or other microorganisms. The limonoids found in citrus wastes, such citrus limon, have the power to stop bacterial activity (Juhari *et al.* 2021). Saramanda & Kaparapu, 2017 investigated the antibacterial potential of waste enzymes using agar well diffusion techniques. Findings revealed that the waste enzyme solution had zones of inhibition for *S. aureus*, *Pseudomonas aeruginosa*, and *E. Coli*, as well as a larger zone of inhibition for bacteria and fungus than the positive control standards. Citrus limon fruit peel methanolic extracts have shown antibacterial efficacy against most test organisms. The plant phytoconstituents, including alkaloids, saponins, sterols, and terpenoids, provide a combination of properties for modern treatments against various microbes (Ali et *al.* 2017). Prakash *et al.* 2018 found that the antimicrobial activity of citrus peel increased with increasing altitude against most bacteria. This was demonstrated by the in-vitro antimicrobial activity of extracts from four different citrus species against five bacterial strains, as measured by the zone of inhibition, which varied according to samples and bacterial strains with different altitudes. As the concentration was increased to 1000 ppm, the results showed that the antimicrobial activity was most effective against *E. coli* and *Bacillus subtilis* when compared to other bacteria, and the inhibition of bacterial growth was dose-dependent. Microbial strain was inhibited using the disc diffusion assay, which is expressed as Zone against pathogenic bacteria in different extracts. **Table 2** presents the findings with inhibitory zone widths of 26 mm and 24 mm, respectively, the ethanol extract from orange peel had the strongest antibacterial effectiveness against *Pseudomonas aeruginosa* and *Bacillus cereus* (Zaki & Naeem 2021). Orange peel effectively prevents the scaling of drinking water, increases its value, and protects the environment from food industry waste, which rejects 60% of citrus fruits (Bendaoud-Boulahlib & Ghizellaoui 2016).

Antioxidants: Antioxidants are compounds that possess the ability to scavenge free radicals. Two examples of naturally occurring antioxidants are vitamins C and E (Grover *et al.* 2024). Essential oils work as antioxidants by scavenging free radicals, reducing agents, inhibiting the formation of chains, stopping peroxides, preventing further hydrogen abstraction, quenching the formation of singlet oxygen, and binding transition metal ion catalysts, among other mechanisms (Tongnuanchan & Benjakul 2014). Citrus peels are an excellent source of phenolic chemicals, which can be isolated and used to create functional foods or as natural antioxidants to prevent certain foods from oxidizing (Zaki & Naeem 2021). According to **Table 1,** the antioxidant activity of powdered orange peel, mandarin

peel, and lemon peel was 45.99, 36.10, and 43.60%, in that order. Compared to mandarin and lemon peels, the dried orange peel extract had a greater DPPH% activity. According to Parashar *et al.* 2014 research on the antioxidant/radical scavenging capacity, reducing power ability, total phenolic content, total flavonoid content, and antioxidant activities (% DDPH scavenging activity) of several orange peel extracts, the results revealed that the ethanolic extract displayed the highest value for yield. Naringin has significant bioactive effects on human health as a source of antioxidants, system modulators, and radical scavengers with anti-inflammatory qualities (Kaur & Singh 2021).

Table 2: Analyse the 200 µL ethanol and water extracts of citrus peels (orange, mandarin, and lemon) for their antibacterial activity against a few pathogenic microbial strains (Zaki & Naeem 2021).

Pathogens	***Pseduomones aeruginosa***	***Salmonella typhimurium***	***Staphylooccus aureus***	***Bacillus cereus***	***Eschrichia coli***	***Candida albicans***	***Aspergillus niger***
Extract	**Zone of Inhibition**						
Ethanol extract of orange peel	26	20	21	24	21	22	17
Water Extract of orange peel	14	12	12	13	ND	13	ND
Ethanol extract of mandarin peel	24	17	19	21	16	12	13
Water extract of mandarin peel	10	10	9	13	ND	ND	ND
Ethanol extract of lemon peel	19	12	14	15	13	11	10
Water extract of lemon peel	9	ND	9	9	ND	ND	ND

Biofuels: Waste from citrus peels is also used as a natural resource to produce biofuels including bioethanol, biodiesel, and biogas. Citrus peels are bio converted into biofuel through a variety of natural processes, including fermentation and anaerobic digestion. For example, bioethanol (50-600L/kg) was made from mandarin peel by using microbial fermentation and steam explosion as a pretreatment (Suri *et al.* 2022). Biodiesel can be produced from citrus peel waste by mixing the essential oil with alcohol through a process called transesterification. Lemon peels are a good source of vitamin C, which makes them suitable for essential oil extraction. The process of extracting oil from citrus peels and seeds to make biodiesel is being researched by several authors. They used the seed oil of citrus reticulata, or mandarin oranges, to make biodiesel. Transesterification of the oil with methanol was accelerated by sodium methoxide to form the biodiesel *(Taghizadeh-Alisaraei et al.* 2017). Peels from citrus limetta have recently been utilized as a starting point for the synthesis of bioethanol by undergoing an acid-catalyzed steam pretreatment, which is followed by enzymatic hydrolysis and fermentation. After 48 hours of treatment, the study found that an ethanol yield of 64% was achieved at pH 4 (John *et al.*

2020). The manufacture of bioethanol from citrus trash is constantly being considered. Prior to enzyme/acid based hydrolysis and fermentation, several recent studies used various pretreatment techniques, including steam explosion, auto hydrolysis, diluted acid, and grinding (Suri *et al.* 2021). OPW was utilized in the simultaneous acid-catalyzed steam explosion, independent enzymatic hydrolysis, and Saccharomyces cerevisiae fermentation processes to make bioethanol (Dongre *et al.* 2024).

Bio Adsorbents: Compounds known as "bio-adsorbents" help make the process of removing heavy metals easier. These days, agro-waste is frequently used as an inexpensive bio-adsorbent to remove heavy metals from solutions (Abood *et al.* 2015). Citrus peel has been subject of much research as a green bio-adsorbent source for the removal of hazardous materials or heavy metals (Villen-Guzman *et al.* 2021) investigated the potential of alkali-modified lemon peel as a biosorbent for removing nickel and cadmium, two heavy metals, from industrial effluents. 90% sorption of nickel and cadmium was recorded in the first five minutes of the investigation. Orange peels, often waste, contain essential oils for feeding and pharmaceutical industries, and can be used to remove textile stains and heavy metals. Polysaccharides, proteins, and lipids found in the cellular walls of bio-absorbents have the ability to bind cationic compounds and heavy metals to their surface (Falcó *et al.* 2021). To remove ranitidine from pharmaceutical effluent, citrus limetta peels were carbonized and then activated with an alkali reagent to create an inexpensive, ecologically friendly activated carbon (Suri *et al.* 2022). Silicon sand and orange peel bio absorbent were successfully employed to keep the salt in the saltwater (Dongre *et al.* 2024).

Packaging Film: Citrus processing wastes are regarded as suitable raw materials for food packaging film production. For instance, citrus seed, pomace and peels contain a range of bioactive materials with antioxidant and antibacterial qualities, including polyphenols and essential oil (Yun & Liu 2022). Fruit peels can be used to make edible food coatings, which have shown promise in addressing the problems facing the food preservation sector. These coatings, which are high in polyphenols and antioxidants, prolong the shelf life of perishable food items and provide a sustainable substitute for conventional plastic packaging. Such coatings antioxidants and polyphenols could lessen plastic container deterioration (Joseph *et al.* 2024). Peels from *Citrus limon* and *Citrus aurantifolia* were used to create a tasty covering for fresh strawberries (Suri *et al.* 2022). Citrus waste has drawn interest from scientists to process and use as food product packaging material because it contains a variety of chemicals, including essential oils as bioactive substances and pectin and cellulose as biopolymers (Dubey *et al.* 2023). Up to now, active packaging films have been made using the peel powder of various citrus fruits, such as orange, lemon, lime, and pomelo (Yun & Liu 2022). Extrusion, thermo-compression, calendaring, and molding are a few sophisticated techniques employed in the creation of packaging films but scholars don't often employ them because of their high expense (Dubey *et al.* 2023).

Conclusion

Citrus waste presents a promising and sustainable pathway to the development of value-added products. With its rich composition in bioactive compounds, flavonoids, essential oil, and fibers, citrus waste can be repurposed in various industries, pharmaceuticals, cosmetics, biofuels etc. Various extraction process has been used to extract the phenolics compounds as well as essential oil from citrus peels. This review paper shows the potential utilization of citrus waste into value added products such as an antioxidant, human health, biofuels, pharmaceuticals etc., It has been shown that the amount of

waste generated from juice shop and fruits industry has been drastically increase in the last several decades. The utilization of citrus by-products can help in waste reduction and it can promote circular economy practices and provide an eco-friendly raw material for another purposes. Innovative technologies like extraction and fermentation can unlock the full potential of using citrus waste as a value-added product. This sustainable solution can reduce the environmental impact of not to throw the fruit waste but to use the waste as a raw material in different applications. However, further research is needed for efficient processing of fruit waste and industrial applications. Moreover, citrus waste holds a strong potential to sustainable solution and contributing to a greener future.

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