EXPLORING THE POTENTIAL OF CITRUS PEELS: A COMPARATIVE STUDY OF AGROINDUSTRIAL WASTE

ABSTRACT

Valorization strategies have been used for various waste streams, including agro-industrial by-products and olive mill wastewater. The focus is on extracting antioxidants and producing enzymes. The valuation of knowledge in the valorization process presents challenges due to its subjective nature. Financial valuation methods, particularly the income approach, are commonly used but may require difficult-to-validate assumptions. Despite these challenges, waste valorization remains a promising approach for sustainable waste management and resource recovery.Quantitative studies and antimicrobial activities were carried out using peels of C. aurantifolia (Key Lime), C. maxima (Pomelo), C. sinensis (orange), Citrus limetta (Sweet Lemon), and C. reticulata. Citrus aurantiifolia is believed to be a hybrid of Citrus medica, Citrus grandis, and a Micro-citrus species, with significant antibacterial activity. Citrus reticulata, found mainly in eastern India, has the highest amount of vitamin C among citrus species and exhibits high antimicrobial activity. Citrus limetta Mosambi is gaining popularity due to its delicious taste and high vitamin C content. Citrus sinensis is small, spherical fruit rich in vitamin C and vitamin A. Pummelo, or Citrus maxima, is known for its large, sweet fruits with abortifacient and menstrual stimulant properties. Peels of C. maxima exhibit the highest amount of antioxidant activity equivalent to ascorbic acid and display significant antimicrobial activity against Klebsiella species.Citrus peels can be used to make value-added goods, including animal feed, dietary supplements, and essential oils. The article applies valuation in the context of citrus fruit waste to convey the financial and environmental advantages of employing these tactics.

Keywords: **Valorization, citrus fruits, Vitamin C, antibacterial, agro-industrial waste, neutraceutical**

Introduction

Citrus fruits play a common role in our daily lives, and their peels, pulps, and seeds offer various benefits. Since childhood, we've known that citrus fruits are rich in vitamins and are good for human health. The peels of fruits make up a significant portion of their weight and are often discarded as waste. While the pharmaceutical industry and synthetic medications are widely relied upon in the modern world, many people are unaware of the beneficial qualities of numerous herbs and vegetables. One of the main antioxidants in circulation, vitamin C, has immune-stimulating and anti-inflammatory properties and is necessary for optimal health at every stage of life. Scientific pathology may recommend synthetic pharmaceuticals to treat a variety of ailments, but it's important to focus on our natural healing process, which is something that Mother Nature always does her best to support [1]. However, it's worth noting that these fruit remnants can still be utilized in several ways rather than simply being thrown away. Citrus fruits are known for being a rich source of phytochemicals and biologically active compounds that contribute to their health-promoting properties. It's recommended to incorporate a variety of fruits and vegetables into your diet to ensure a well-rounded intake of nutrients and bioactive compounds. Valorization is a concept aimed at sustainably managing industrial residues by recovering valuable components or producing useful products from waste materials [2]. It encompasses various approaches, including physical, chemical, and biological methods, to transform waste into economically valuable and environmentally friendly products [3]. The concept aligns with industrial ecology principles, promoting loop-closing and resource efficiency [4]. Valorization strategies have been applied to diverse waste streams, such as agro-industrial by-products and olive mill wastewaters, focusing on extracting antioxidants and producing enzymes (Federici et al., 2009). However, the valuation of knowledge in the valorization process presents challenges due to its subjective nature. Financial valuation methods, particularly the income approach, are commonly used but require assumptions that may be difficult to validate [5]. Despite these challenges, waste valorization remains a promising approach for sustainable waste management and resource recovery.

When citrus peel is used as a substrate in anaerobic digestion processes, it can inhibit the process. This is because the high content of certain compounds in citrus peel, such as d-limonene, can interfere with the activity of methanogenic bacteria responsible for methane production. As a result, this interference can lead to reduced biogas production and longer lag phases before methane production begins [6].

Citrus fruit peels contain high levels of flavonoids, polyphenols, and dietary fiber. These components have antioxidant, anti-inflammatory, and potential anti-cancer properties. Extracts from citrus peels have been studied for their cholesterol-lowering effects, skin health benefits, and as potential natural remedies for various health conditions. Fruit residues, often considered waste, have the potential to be valuable nutraceutical resources. Citrus peels, pulp, and seeds contain various beneficial compounds that offer health-promoting properties. By effectively utilizing these residues, we can reduce waste and harness their nutraceutical potential [7]. The value of citrus fruit residues as nutraceuticals can be recognized by finding innovative ways to use them, thus reducing waste and benefiting from their health-promoting properties. Proper processing and quality control are essential to maximize their safety and effectiveness as nutraceutical resources. The use of citrus peel waste in the medicine industry involves extraction techniques to isolate and concentrate the bioactive compounds. Ongoing research and development aim to explore their therapeutic potential, optimize extraction methods, and develop innovative drug delivery systems. While citrus peel and its bioactive compounds show promise in medicine, it is crucial to ensure appropriate quality control, standardization, and safety evaluation when using them for medicinal purposes [8].

Citrus peels were once considered waste, but they are now valued for their medicinal properties and are used in various applications, including food products. Citrus peels are rich in vitamins, fibers, and bioactive compounds, which contribute to their potential health benefits. Their antioxidant properties help to eliminate harmful free radicals in the body, providing protection against degenerative conditions. They also have antimicrobial properties that can inhibit the growth of certain bacteria and fungi. Additionally, researchers have taken note of their anti-inflammatory and anticancer properties. Whether in the form of powder or essential oils, citrus peels have been successfully incorporated into food products to enhance their nutritional value without compromising taste and sensory attributes when used in appropriate amounts. The journey of citrus peels, from being discarded as waste to being utilized in the laboratory and eventually making their way to the dining table, is a testament to their versatility and potential for both health and economic benefits[9].

The utilization of waste materials generated from citrus fruit processing, such as peels and pulp, for the extraction of cellulose and nanocellulose, is a fascinating area of research. Cellulose is a natural polymer found in plant cell walls and has various applications due to its unique properties. In the present study, the waste materials from citrus were treated with an alkaline solution to extract cellulose. The cellulose was then subjected to acid hydrolysis, resulting in the reduction of fiber size and the formation of nanocellulose. X-ray diffraction analysis revealed that the cellulose had an amorphous structure, indicating the breakdown of the crystalline regions during the extraction process. At high magnification, break points in the cellulose fibers were observed, resembling carbon nanotubes in appearance. This indicates that the acid treatment caused structural modifications to the cellulose fibers. Overall, this study highlights the potential of citrus peel waste as a valuable source of cellulose and nanocellulose. By extracting and modifying cellulose from citrus waste, researchers have discovered a novel application for this abundant agricultural byproduct. The utilization of citrus peel waste for cellulose extraction offers both environmental and economic benefits, as it reduces waste generation and provides a sustainable alternative to traditional cellulose sources. [10].Citrus fruits generate significant waste during processing, including peels, seeds, and pomace. Proper management and utilization of this waste can minimize environmental impacts and optimize resource utilization for a more sustainable approach to citrus fruit processing.

Materials and methods

Samples taken

Peels of the citrus species thatwere taken for the experiments were ***Citrus aurantifolia*, *Citrus limetta*, *Citrus reticulata* (Aroma King lemon/ gandhoraj), *Citrus sinensis*, and *Citrus maxima***

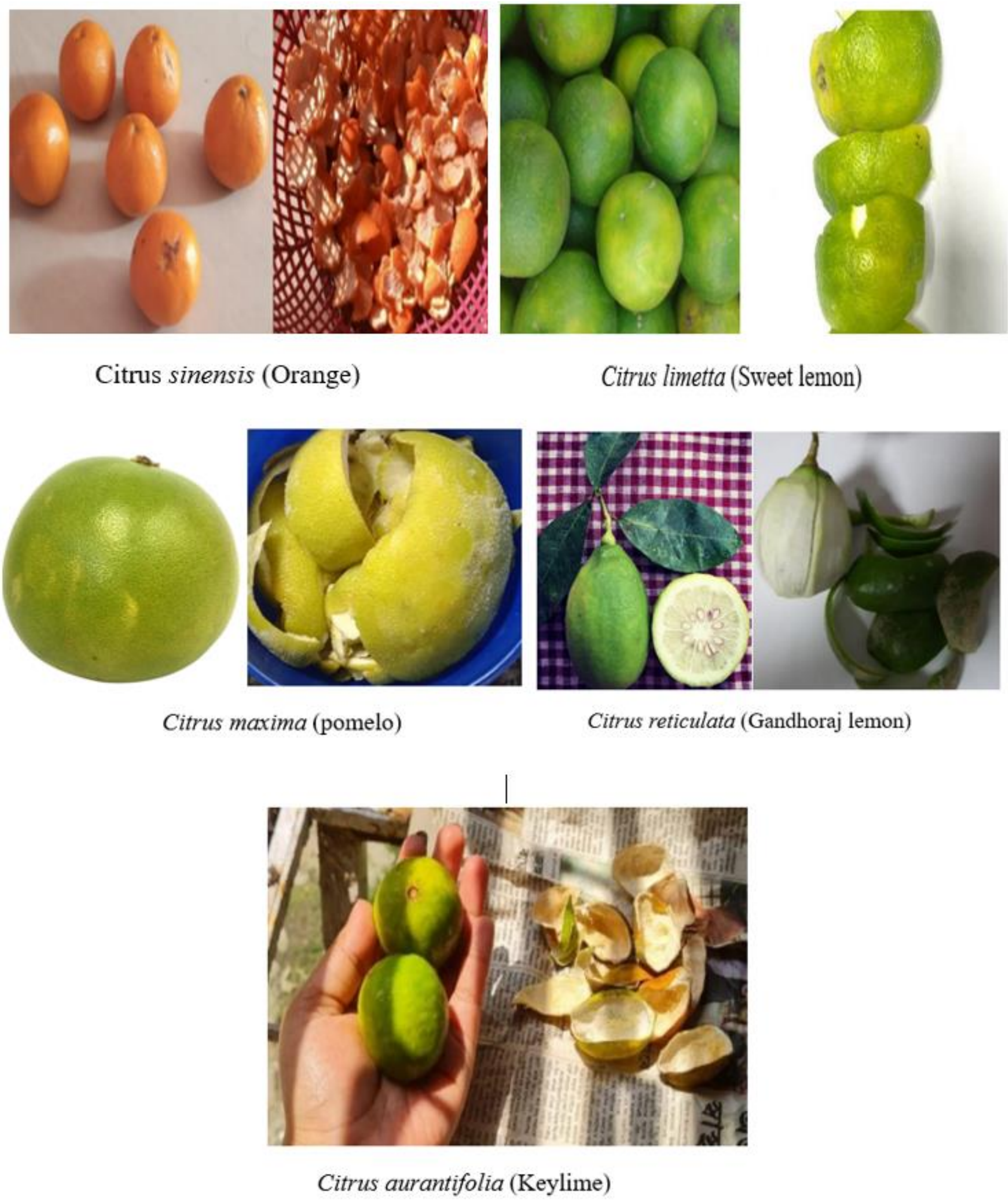

Fig 1: These samples were taken.

Peels of every citrus species have been attached for a clear view. [fig 1]

Quantitative nutritional analysis

Total vitamin C and protein estimation by UV spectrophotometric method, followed by vitamin C quantification assay using the potassium iodate and potassium iodine titration method [11]. Bradford assay, and Lowry assay [12]. Carbohydrate estimation was done through the Anthrone method [13].

3.2.1 In vitro antioxidant assay using DPPH

The stability of the extracts' DPPH (2, 2-diphenyl-2-picrylhydrazyl) free radical scavenging activity was assessed using the usual method [14].

3.3 In vitro antimicrobial assay

The antibacterial assay was performed using the disc diffusion method against Gram-negative ***Klebsiella sp.&Enterobacter sp***.and Gram-positive bacteria ***Staphylococcus epidermis***, ***Bacillus sp.*** The bacteria strains were maintained in 100 mL of nutrient broth at 37°C and incubated overnight.

Results

Quantitative nutritional analysis of peels of the samples

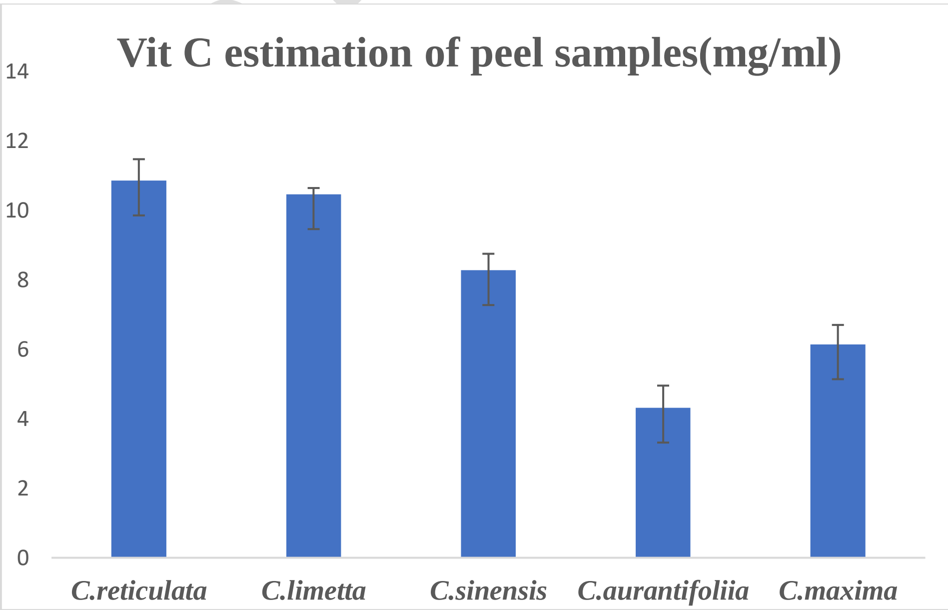

Fig. 2: Vitamin C amount in the peel samples

Out of five samples, *C.reticulata*(10.85±2.49 mg/ml) *C. limettta*(10.46±2 mg/ml), *and C sinensis*(8.96±1.6 mg/ml), have a good amount of vitamin C than other samples. Sd measured (n=3) for each of the samples.

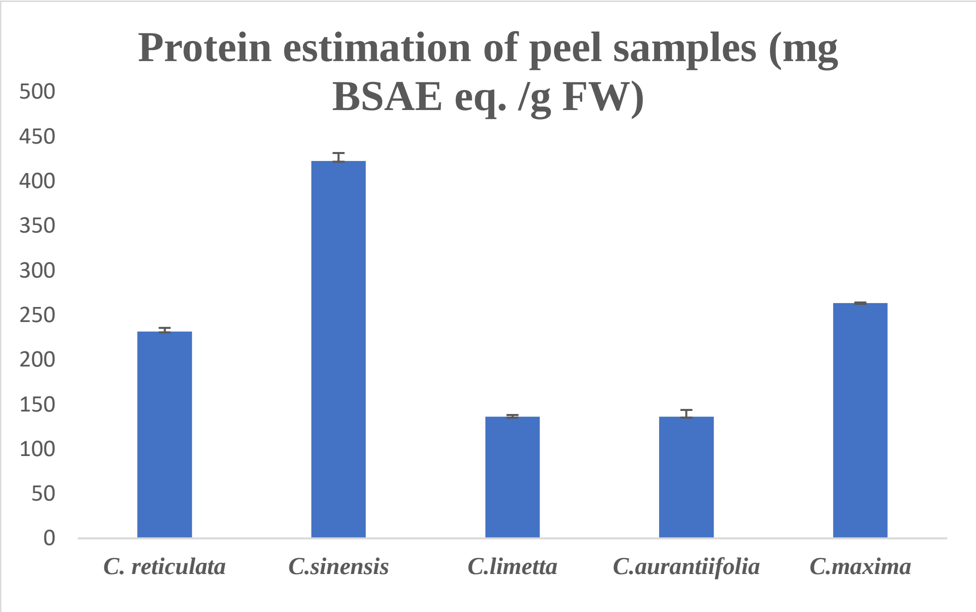

Fig. 3: Protein amount in the peel of the samples

Peels of the citrus fruits have enough protein, out of these C. sinensis has a significantly higher amount of protein than others Sd measured (n=3) for each of the samples **[fig3]**

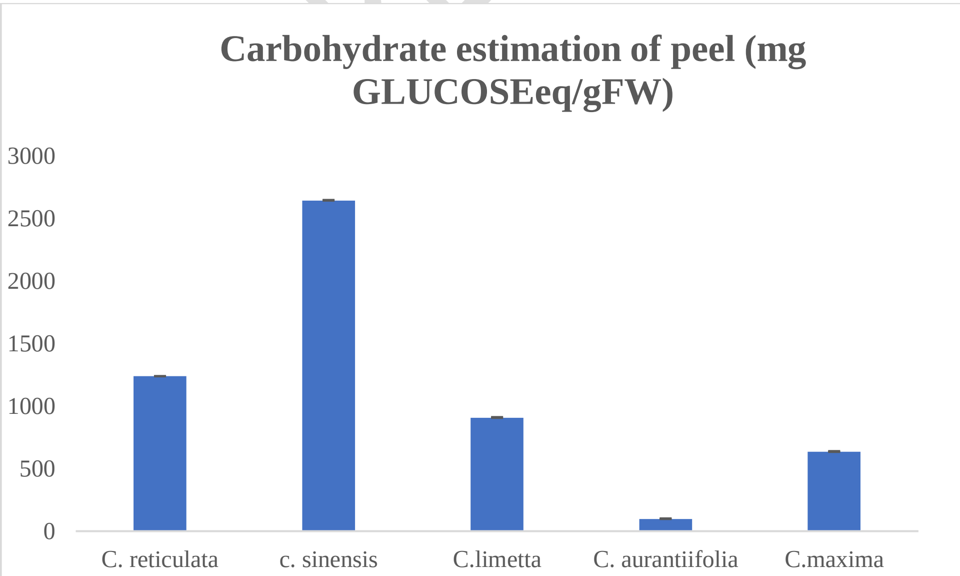

Fig. 4:Carbohydrate amount in the peel samples

The result clearly shows *C. sinensis* has a significantly higher amount of carbohydrate equivalent to glucose, than the other samples. Sd measured (n=3) for each of the samples **[fig**

4]

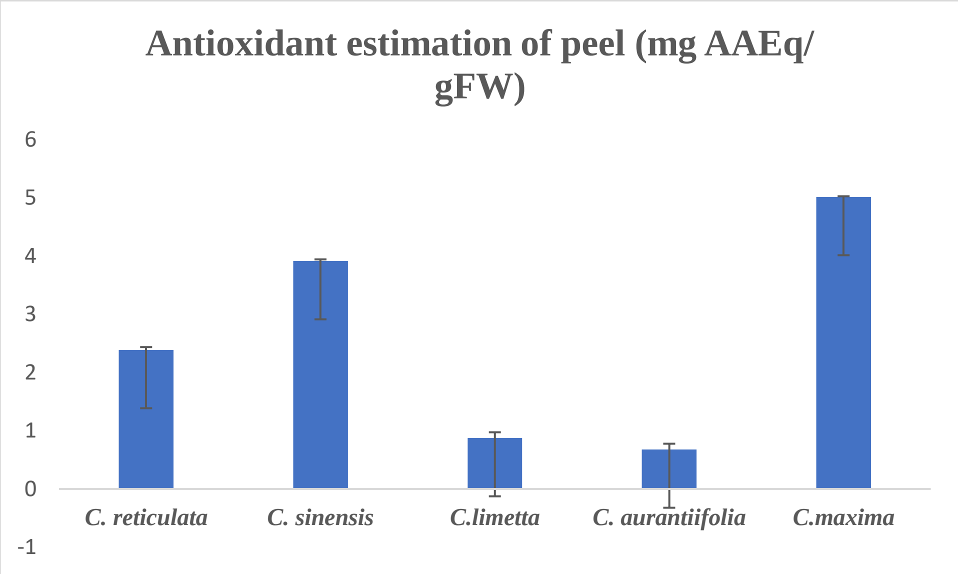

Fig. 5: Antioxidant activity of the peel samples

C. maxima and C. sinensis have significantly higher amounts of antioxidant activity equivalent to ascorbic acid than others. Sd measured (n=3) for each of the samples [fig 5]

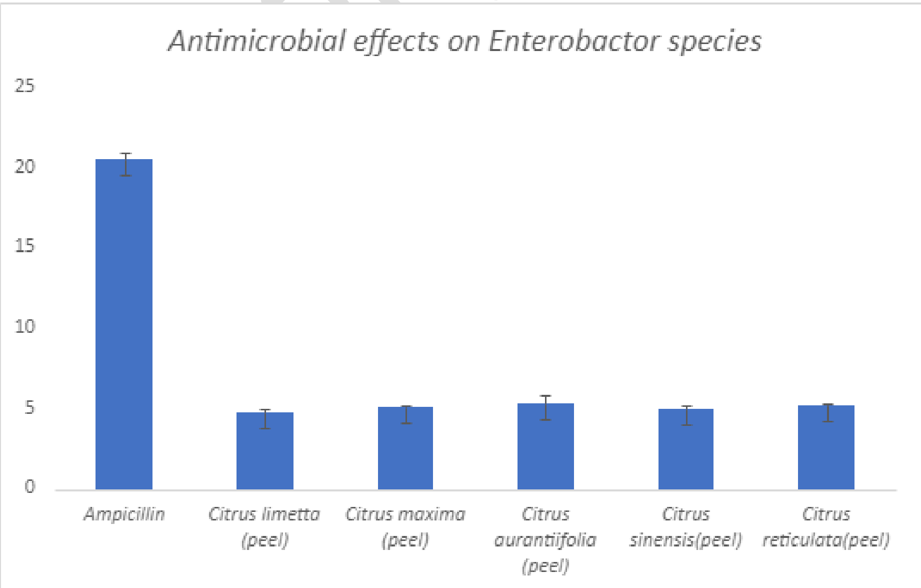

Fig 6a: The diagrammatic representation of the antimicrobial activity of the samples on Enterobacter species.

Fig 6b: The measurement area is the disc diffusion results using the gram (-) bacteria Enterobacter sp. inhibitory zones (mm scale).

The result clearly shows that all of the samples have a similar amount of antimicrobial activity among other samples. ampicillin was the control, and Sd was measured (n=3) for each sample. [fig 6a]

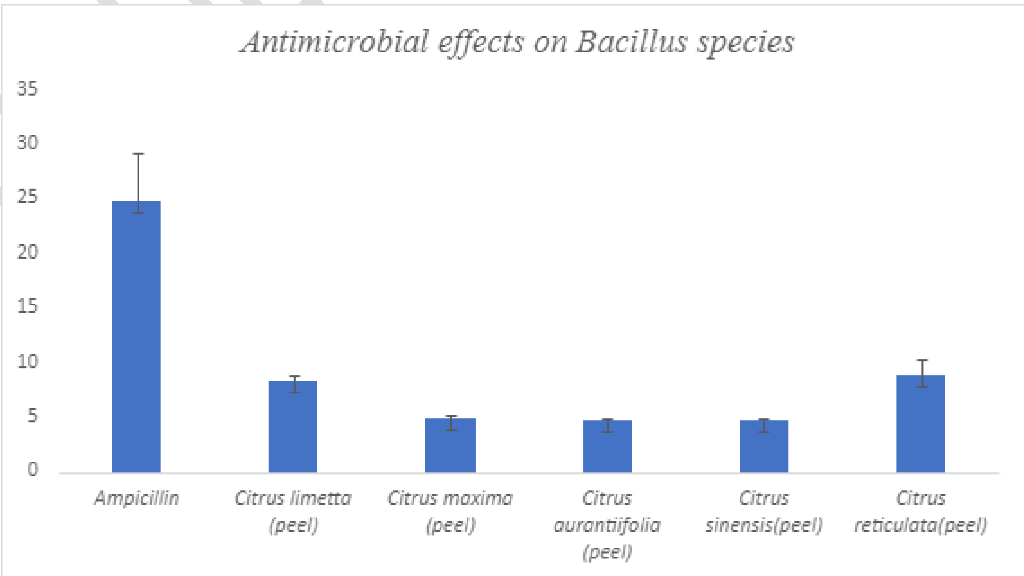

Fig 7a: The diagrammatic representation of the antimicrobial activity of the seed samples on Bacillus species. bacteria.

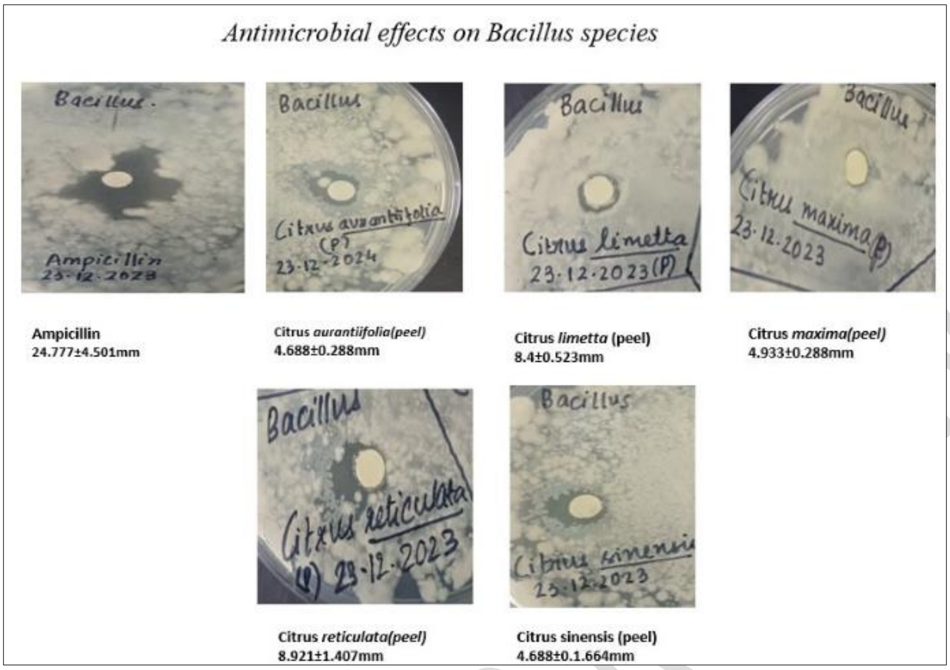

Fig 7b: shows the disc diffusion results using the gram (+) bacteria *Bacillus sp.* inhibitory zones (mm scale) are the area of measurement.

The results indicate that C. limetta and C. reticulata exhibit similar levels of antimicrobial activity compared to other samples. Ampicillin was used as the control, and each sample's standard deviation (SD) was measured (n=3). [Fig. 7a-7b]

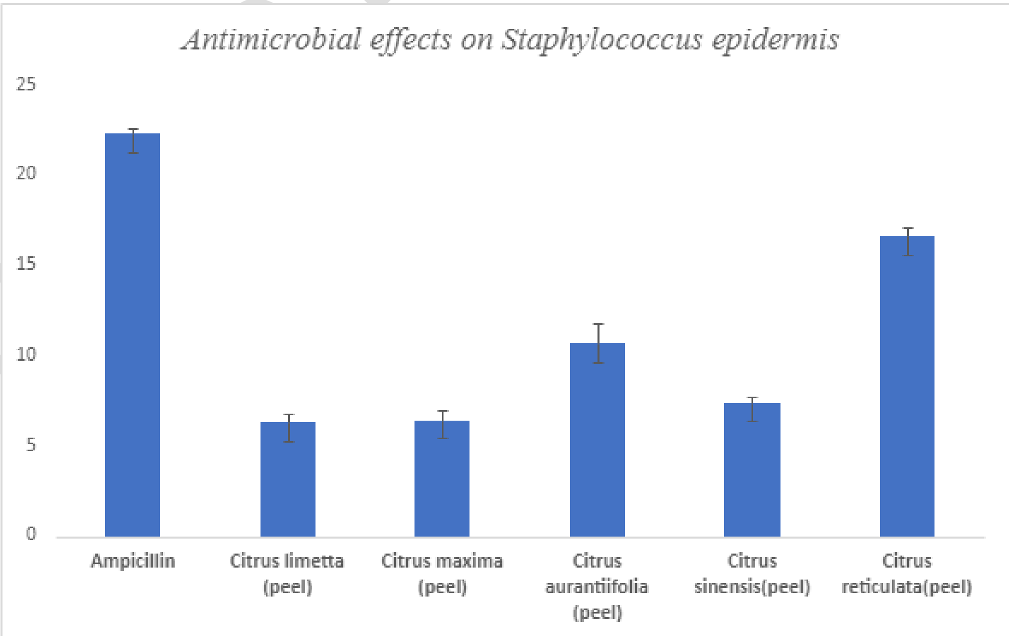

Fig 8a: The diagrammatic representation of the antimicrobial activity of the seed samples on Staphylococcus epidermis bacteria.

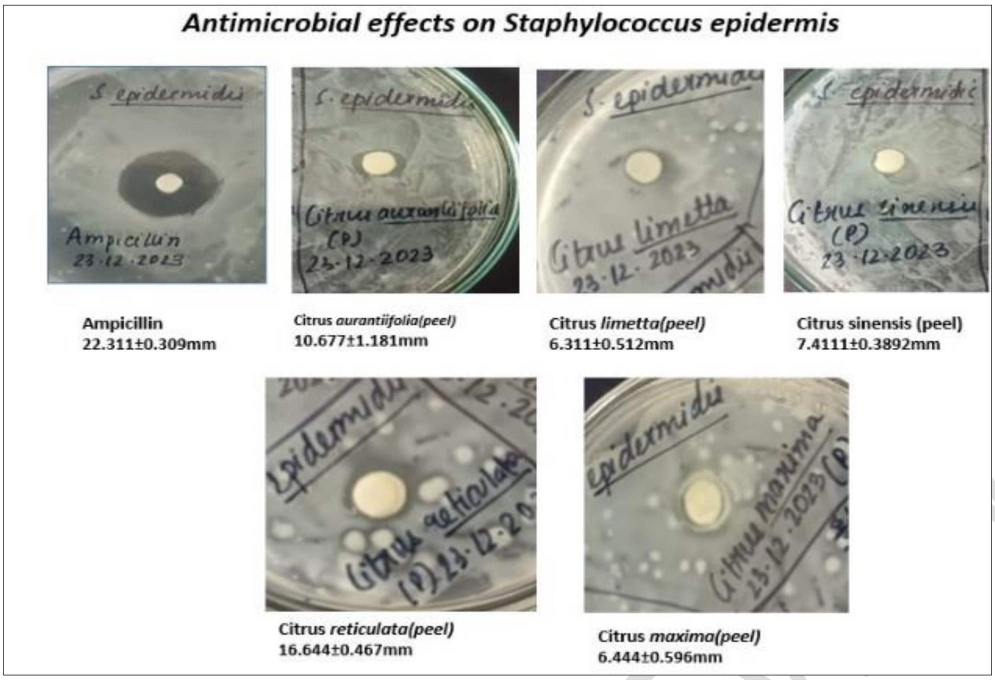

Fig 8b: shows the disc diffusion results using the gram (+) bacteria *Staphylococcus epidermis* inhibitory zones (mm scale) are the area of measurement.

The result clearly shows among all the samples C. reticulata, C. aurantiifolia, and C. sinensis showed antimicrobial activity among other samples., ampicillin was the control, Sd measured (n=3) for each of the samples [Fig 8a-8b]

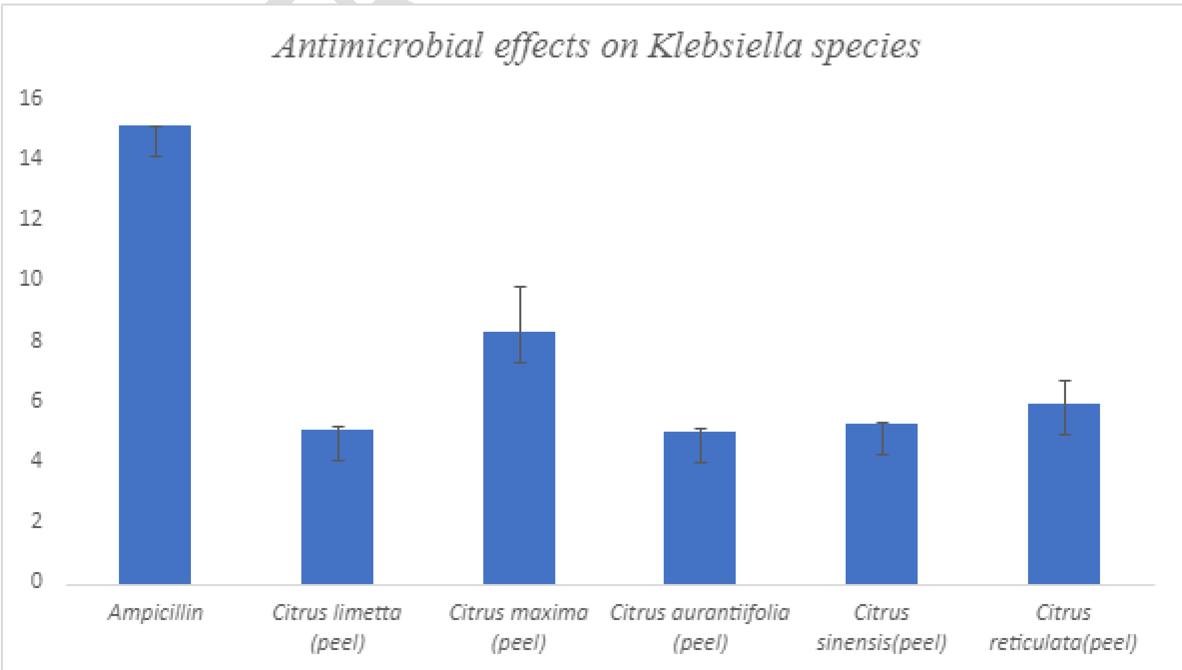

***Fig 9a: shows the diagrammatic representation of the antimicrobial activity* of the seed samples on *Klebsiella* bacteria.**

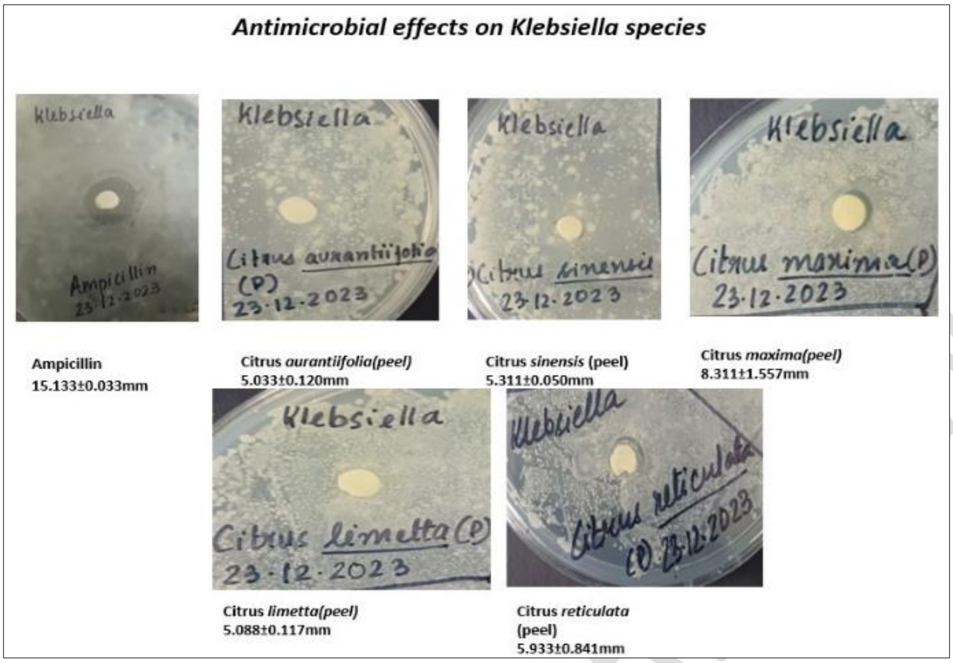

Fig 9b: shows the disc diffusion results using the gram (-) bacteria *Klebsiella* inhibitory zones (mm scale) are the area of measurement.

The result clearly shows among all the samples *C. limetta and C. maxima* showed significant antimicrobial activity among other samples., ampicillin was the control, and Sd measured (n=3) for each of the samples [fig 9a-9b]

DISCUSSION

In recent years, research has demonstrated connections between oral microbiota and systemic illnesses, including head and neck cancer [15]. Ampicillin is a commonly used antibiotic that is effective against infections caused by various susceptible organisms, such as intestinal bacilli, salmonella, shigella, enterococci, listeria, and some forms of hemophilic bacilli. Citrus fruits are popular worldwide and offer various nutritional and medicinal benefits. For example, Citrus aurantiifolia is believed to be a hybrid of Citrus medica, Citrus grandis, and a Micro-citrus species. The spherical fruit, with a diameter of 25–50 mm, is typically harvested when green and turns yellow when ripened. Citrus aurantiifolia exhibits significant antibacterial activity. Citrus aurantiifolia and C. maxima show the highest antimicrobial activity. Citrus reticulata, also known as the Aroma King Lemon or Gandhoraj, combines the flavors of mandarin orange and lime. This species is found mainly in eastern India. The peel of Citrus reticulata has the highest amount of vitamin C among the five citrus species and exhibits high antimicrobial activity against Staphylococcus epidermis and Bacillus species. Citrus limetta Mosambi, a popular lime variety, is gaining worldwide popularity due to its delicious taste and high vitamin C content. Citrus sinensis, resembling a typical lime, is a small, spherical fruit rich in vitamin C and some vitamin A, making it highly nutritious. The peel and pulp of Citrus sinensis have the highest amount of protein among all species, while the seeds and peel are good sources of carbohydrates.

Pummelo, or Citrus maxima, is a citrus tree producing large, sweet fruits with a history of use in herbal and traditional medicine due to its abortifacient and menstrual stimulant properties. Excessive use of these drugs can lead to severe liver damage, vomiting, and bleeding, which can be fatal. Contact with rue can also cause severe phytophotodermatitis and burn-like blisters after sun exposure. Peels of C. maxima exhibit the highest amount of antioxidant activity equivalent to ascorbic acid and display significant antimicrobial activity against Klebsiella species.

Conclusion

Valuation techniques can have a significant impact on resource efficiency and waste reduction. For example, citrus peels can be repurposed to create valuable products such as animal feed, dietary supplements, and essential oils. The article effectively demonstrates how applying valuation methods to citrus fruit waste can highlight the financial and environmental benefits of implementing these strategies. Furthermore, it discusses the potential for scaling up these valuation methods and their support for environmentally friendly waste management techniques. This deeper investigation could enhance the overall impact of valuation and consider the potential for producing nutraceuticals from citrus peels.

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