**Middle East Research Journal of Agriculture and Food Science**
ISSN: 2789-7729 (Print) & ISSN: 2958-2105 (Online)
Frequency: Bi-Monthly
DOI: https://doi.org/10.36348/merjafs.2025.v05i03.003

KUWAIT SCHOLARS PUBLISHER

Website: http://www.kspublisher.com/
Email: office@kspublisher.com

# Evaluating the Potential of Galgal Peel: Implications for Sustainable Applications in Health and Environmental Sectors

**Kalpana[1*], Akhilesh Kumar Rana[2], Mandeep Kumar[1], Tanuja Srivastava[1], Rahul Jamwal[3]**
[1]Bhai Gurdas Institute of Engineering and Technology, Sangrur- Punjab, India
[2]Dr. YS Parmar University of Horticulture and Forestry, Solan- Himachal Pradesh, India
[3]North East Frontier Technical University, Aalo- Arunachal Pradesh, India

**Abstract:** The growing worldwide interest in sustainability encourages the investigation into the use of agro-industrial by-products in value added products. Some such potential sources are peel of Citrus pseudolimon also known as Galgal. The phytochemical composition, pharmacological potential and environmental remediation utilities of Galgal (peel) are reviewed in this article with an emphasis on the healthcare and environmental applications. This paper collates established research findings to offer an overall view on the potential of Galgal peel as natural and sustainable raw material. Its potential has been detailed in antioxidant, antimicrobial, anti-inflammatory activities, waste management, water purification, and biodegradable material.

**Keywords:** Galgal, Health, Sustainable, Peels, Environment, Agriculture.

**Review Paper**

***Corresponding Author:**
*Kalpana*
Bhai Gurdas Institute of Engineering and Technology, Sangrur- Punjab, India

**How to cite this paper:**
Kalpana *et al* (2025). Evaluating the Potential of Galgal Peel: Implications for Sustainable Applications in Health and Environmental Sectors. *Middle East Res J. Agri Food Sci., 5*(3): 32-38.

**Article History:**
| Submit: 25.04.2025 |
| Accepted: 24.05.2025 |
| Published: 28.05.2025 |



## INTRODUCTION

Over the past few decades, the quest for sustainable resources has turned out to be one of the most important issues in many fields, including health sciences, environmental conservation, and industrial manufacturing. Of all the natural resources being investigated, agricultural by-products have especially been focussing of interest for their underutilized potential and value-added applications; fruit peels are no exception (Ajila *et al*., 2007). One such underutilized resource is the peel of Citrus pseudolimon, which refers to Galgal; it is a citrus fruit that grows profusely in the foothills of the Himalayas and other sub-Himalayan regions of India. Once considered a waste product, Galgal peel is beginning to emerge as a promising candidate for nutraceutical and environmental innovations owing to its unique phytochemical composition, antioxidant properties, and biodegradability-exploration (Sharma *et al*., 2018). In recent years, increased awareness of environmental pollution, resource exhaustion, and the prevalence of chronic diseases has led to an increasing demand for natural, renewable alternatives that can contribute to sustainable development. Fruit peels represent a tremendous asset in the bioactive compound Flavonoids, essential oils, pectins, and phenolic acids (Gorinstein *et al*., 2001). Research is currently focusing on these aspects as they hold potential in the prevention of diseases, preservation of food, and development of eco-friendly materials. The Galgal peel is noted to have high concentrations of limonene, hesperidin, and other flavonoids which exhibit antimicrobial activities as well as anti-inflammatory properties along with antioxidant efficacy (Kaur & Kapoor, 2020). For this reason, it makes a fascinating research subject in fields like healthcare science and environmental sustainability. The healthcare market for plant-based ingredients in pharmaceuticals and functional foods has increased sharply due to consumer demand for more natural and less synthetic products (Riaz, Masood, & Anwar, 2019). Galgal peel extract has shown potential for managing oxidative stress, exhibiting antimicrobial activity, and possibly anti-inflammatory properties; hence the potential of the galgal peel in developing herbal remedies, dietary supplements, and therapeutic agents (Mishra Shukla & Singh, 2016). At the same time the environmental sector is also facing a dual problem of waste management as well as developing biodegradable materials. In this regard Finder of fact: The fibrous and pectic nature of Galgal peels offers great possibilities in bio-composite development, water purification solutions, and management of organic waste. Moreover, the use and added value of Galgal peel drive the end goals of international sustainability through circular economy principles, turning agri-waste into value-added products that further decrease environmental footprints

while boosting rural economies (Kumar, Thakur, & Chauhan, 2021). Although highly promising, uses of Galgal peels are low currently due to ignorance problems, research unevennesses and technology processing not sufficiently developed. Therefore, a timely and necessary comprehensive review of its bioactive profile, functional properties and applicability in sustainable innovations. This review attempts to consolidate available information on Galgal peel with particular emphasis on its chemical constituents and biological activities to explore its possibility for incorporation in health-related applications and environmental applications. In highlighting existing uses and potential future ones, this paper hopes to find a middle ground between established norms of agricultural practice and contemporary thought in sustainable development, encouraging multiple levels of waste valorization along with the study of natural products.

**Phytochemical Profile and Functional Constituents of Galgal Peel**

The Galgal peel (Citrus pseudolimon) is enriched with bioactive compounds that support its strong therapeutic and environmental potentials. Like other citrus peels, it has a broad spectrum of phytochemicals that include flavonoids, phenolic acids, tannins, alkaloids, and volatile essential oils (Ajila *et al*., 2007). The plant produces these secondary metabolites as a protective strategy against pathogens and environmental stressors. Recent studies have established remarkable biological activities for these metabolites in humans.

One of the most investigated groups of compounds in citrus peels are flavonoids, which are known to possess antioxidant, anti-inflammatory, and antimicrobial properties. The Galgal peel contains major flavonoids of hesperidin, naringin, quercetin, and rutin with high contents reported (Sharma *et al*., 2018). These molecules interfere with the process by which oxidative species react with damage caused to lipid membranes and cellular proteins by scavenging reactive oxygen species (ROS). The antioxidant activity is also attributed to phenolic acids that include gallic acid, ferulic acid, and caffeic acid; these were also connected to anti-cancer as well as anti-diabetic properties. The essential oil of Galgal peel contains monoterpenes, with the most notable being limonene, β-pinene, and γ-terpinene. Limonene makes up to 90% of the oil from the peel and has shown promise as an anti-inflammatory agent as well as a chemo preventive agent (Mishra *et al*., 2016). These volatile compounds find applications in the pharmaceutical industry as well as in food preservation and aromatherapy due to their antimicrobial properties and pleasant smell.

Another important component of Galgal peel is pectin, a structural heteropolysaccharide found in the primary cell walls of citrus fruits. This is especially important in food processing, particularly in the production of jellies and jams. Moreover, pectin has been shown to possess functional properties such as cholesterol-lowering, anti-diabetic, and prebiotic effects (Ajila *et al*., 2007). Moreover, Galgal peel has dietary fibers and micronutrients such as vitamin C that further support its nutraceutical value. The phytochemical richness of Galgal peel makes it a potential multi-functional resource for health-promoting and environmental applications.

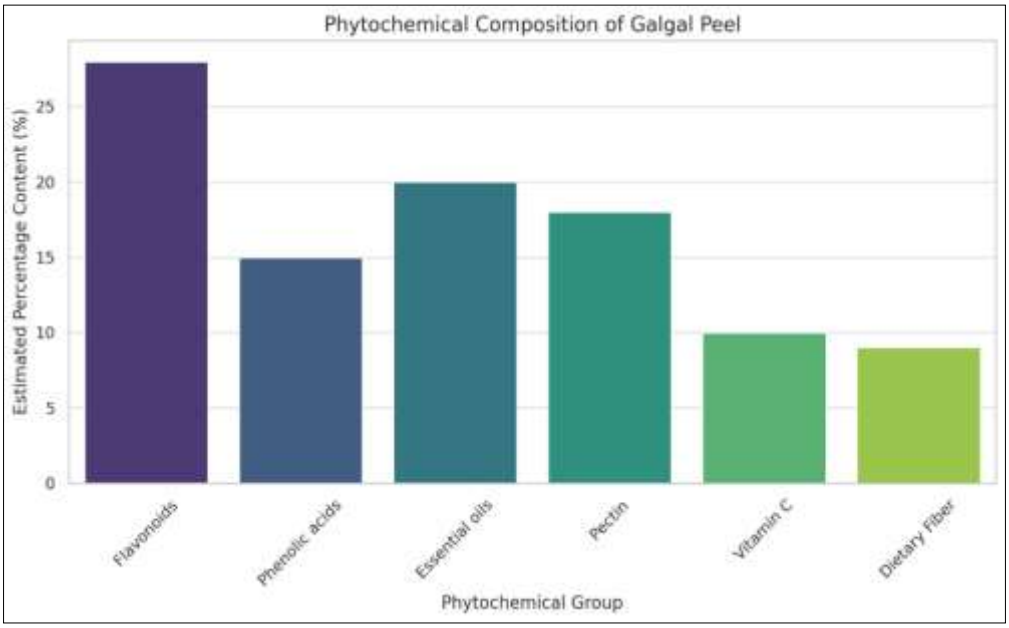


**Fig. 1: Phytochemical Composition of Galgal Peel**

**Nutraceutical and Medicinal Applications**

The health-benefiting potential of Galgal peel has attracted significant attention owing to its rich content in antioxidant, antimicrobial, and anti-inflammatory ingredients. The antioxidant activity is especially relevant in the fight against oxidative stress and its relationship with chronic diseases such as cardiovascular diseases, diabetes, and several types of cancer (Riaz *et al*., 2019). Flavonoids namely hesperidin and naringin in Galgal peel have cardioprotective effects by enhancing endothelial activity, reducing blood pressure and mellowing down low-density lipoprotein oxidation (Sharma *et al*., 2018). Quercetin, which is also a prevalent flavonoid, can modulate the signaling pathways that participate in inflammation and immune responses, leading to its therapeutic potential in inflammatory conditions. The Galgal peel also possesses significant antimicrobial activities against numerous pathogens such as E. coli, S. aureus, B. subtilis and P. aeruginosa (Kaur & Kapoor, 2020). These properties render it applicable in food preservation and it can act as a natural substitute for chemical preservatives. Antimicrobial activity is likely due to the combined effect of phenolic compounds and essential oils, which disrupt the microbial cell membranes. With respect to metabolic disorders, pectin and polyphenols of Galgal peel have emerged promising in controlling blood glucose levels and improving lipid profile. Dietary intervention with citrus peel powder has been shown to increase sensitivity to insulin and lower postprandial glycemic peaks in diabetic animal models (Riaz *et al*., 2019). Integrating Galgal peel powder into a range of food products offers potential in the development of functional foods. This ingredient's incorporation into items ranging from bakery goods to dairy formulations to beverages—in various types of matrices—may well enhance their healthfulness without compromising taste, texture, or overall consumer acceptability (Mishra *et al*., 2016). The nutritional profiles of these kinds of products may well be improved by the addition of this ingredient. Moreover, the high fiber content in Galgal peel would support digestive health and may contribute positively to certain kinds of weight management regimens. Collectively, these insights show that Galgal peel possesses the potential to serve as a cost-effective and accessible ingredient in nutraceuticals. Its profile suits it to several health-related applications.

**Table 1: Bioactive compounds and their health benefits present in galgal peels**

| Bioactive Compound | Compound Type | Health Benefits |
|---|---|---|
| Hesperidin | Flavonoid | Antioxidant, anti-inflammatory, cardiovascular protection |
| Naringin | Flavonoid | Antioxidant, lipid-lowering, anti-diabetic, Anti-inflammatory, immune modulation, anti-cancer |
| Quercetin | Flavonoid | Anti-inflammatory, antimicrobial, |
| Limonene | Monoterpene | chemo preventive |
| Gallic Acid | Phenolic Acid | Antioxidant, antimicrobial, anti-cancer |
| Pectin | Polysaccharide | Cholesterol-lowering, prebiotic, anti-diabetic |

**Extraction Techniques and Value Addition Strategies**

The extraction method used had a significant effect on the recovery of phytochemical from Galgal peel. Conventional procedures as solvent extraction with ethanol, methanol, acetone solvent has been used extensively because of their simplicity and economy. Yet these methods are not specific and are not appropriated for food-grade applications.

Recent extraction methods, such as ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE) and supercritical fluid extraction (SFE), enable higher yields and lower amounts of solvent, together with the maintenance of bioactivity (Ajila *et al*., 2007). For example, UAE enhances the bioactive extraction under cavitation, whereas SFE with carbon dioxide ensures a solvent-free, environmentally friendly process. Consistency and bioefficacy: Standardization of the extraction parameters (extraction temperature, pH, solvent polarity, and so on) is essential for batch-to-batch consistency and bioefficacy. Encapsulation methods including spray drying and nanoemulsification are also being developed to improve the stability and bioaccessibility of Galgal peel extracts into food and pharmaceutical products. Value addition approaches aim at turning the peels into powders, oils, pastes or composite materials that can be utilized for several purposes. These materials can be used in health supplements, biodegradable tableware, anebacterial coatings and functional fabrics. Engagement with farmer cooperative and small-scale industries is necessary for establishing local processing plants to improve rural income and livelihood securities (Kaur & Kapoor, 2020).

**Table 2: Extraction Methods and Its Advantages and Limitations**

| Extraction Method | Advantages | Limitations |
|---|---|---|
| Solvent Extraction | Simple, cost-effective | May use toxic solvents, lower specificity |
| Ultrasound-Assisted Extraction (UAE) | Enhanced yield, faster extraction | Equipment cost, optimization required |
| Microwave-Assisted Extraction (MAE) | Efficient, preserves bioactivity | Risk of thermal degradation |

| | | |
|---|---|---|
| Supercritical Fluid Extraction (SFE) | Solvent-free, eco-friendly | High initial investment, complex operation |

**Environmental Applications of Galgal Peel**

One of the novel applications of Galgal pericarp is in the fabrication of biodegradable packaging film. Due to these the high concentration of pectin and cellulose fiber found in the citrus peels, they can be used as a good source for the formation of films and bioplastics (Jha, Bansal, & Sharma, 2019). Polysaccharides are extracted from Galgal peel followed by cross-linking agents and plasticizers like glycerol to yield biodegradable, flexible and non-toxic 2-D films. There substances can serve as alternatives to petrochemical plastic for food packaging applications, which is a major cause of environmental pollution. Films prepared from Galgal peel have shown good barrier towards oxygen and moisture, thus extending the shelf life of perishable goods (Kaur & Sandhu, 2020). The environmental implications of Galgal peel uses are significant especially in relation to waste valorization and sustainable material gains. Galgal peel as an agro by-product could be recycled to value-added products for applying the principle of circular economy (Kumar *et al*., 2021). The macro and micro nutrients rich in Galgal peel biomass could be used for organo-fertilizer by composting. The soil enrichment is supported by the presence of important minerals like potassium, calcium, magnesium. Research has reported that the addition Gibb fruits peels to the compost piles significantly speeds up direct microbial activity and organic humus production, owing to its high C:N ratio (Verma, Sharma, & Singh, 2018). Increased crop yields and improved soil health from Galgal peel compost has been observed in field trials. In addition, the essential oils found in the peel have nematocidal and insect-repelling activities which lower the application of synthetic pesticide (Patel *et al*., 2020). The 'adsorptive' capacity of citrus peels from water on heavy metals and organic pollutants is well known. Galgal peel has carboxyl and hydroxyl functional groups which the pollutants like lead, cadmium, chromium and dye molecules get adsorbed on to (Kumar, Sharma, & Yadav, 2017). Batch adsorption studies have demonstrated removal efficiencies exceeding 80% for several toxic ions. Anaerobic digestion of citrus waste like Galgal peel produces biogas which mainly contains methane and carbon dioxide. It has a high moisture and carbohydrate content, making it amenable for being fermented by microbes, and a biogas yield of 0.45–0.55 $m^3$/kg VS is reported (Sharma & Thakur, 2020). In addition, it contributes to better process stability and a higher methane yield when co-digesting with cattle manure or food waste. The left-over digestate, an organic-rich product, can be reused as organic fertilizer, closing the loop of bioeconomy model (Patel *et al*., 2020). Mitigation By using Galgal peel for composting, biochar preparation and AD process there may be the following contribution towards carbon storage and GHG mitigation. Once pyrolised into biochar, Galgal peel becomes a long-term repository of CO2, while enhancing the soil fertility and water-holding capacity (Patel *et al*., 2020). The waste-to-wealth approach is expected to contribute to both climate smart agriculture and circular economy, since disposal of citrus peels in landfills can lead to generation of greenhouse gas such as methane (Kaur & Sandhu, 2020).

**Industrial and Economic Perspectives on Galgal Peel Utilization**

Scaling-up lab results to prepare for full-scale application is significant for the use of Galgal peel. To accomplish this scalable and standardized extraction methods are necessary. Researchers have studied and developed steam distillation, solvent extraction, microwave-assisted extraction, and supercritical fluid extraction for citrus peels (Ravindran & Jaiswal, 2016). These methods also would be suitable for Galgal peel, depending on the desired end products, i.e., essential oils, flavonoids, pectin and enzymes. Upscaling also involves investment in infrastructure and quality control systems for replicability, and compliance with industry standards. Pilot studies conducted in India and other citrus-growing nations have indicated the technical feasibility to establish small citrus peel processing units in proximity to orchards or juice producing plants to reduce transportation charges and spoilage (Sharma & Thakur, 2020). An increase in the worldwide demand for natural, eco-safe, and health-promoting products has developed a global market for plant-derived bioactives. The market value of essential oils, alone, was valued at USD 7.03 billion in 2021, and is estimated to increase by 7.5% CAGR up to 2028 (Statista, 2022). Pectin, the main constituent of Galgal peel, has a great commercial value as a food gelling agent. The value chain analysis of Galgal peel reveals potential to link multiple actors—producers, processors, traders and retailers. In a well-structured market, small-holder manufacturers could in turn provide raw peels or partially processed peel products such as dried peel powder or pectin to clients in the food, pharmaceutical and cosmetic industries (Kumar *et al*., 2019). Economic studies have demonstrated that the valorization of citrus peels may achieve an acceptable cost-benefit return, particularly when included in an existing agro-industrial system. Pectin production is, for example, low raw material cost but high added-values in various industries (Verma *et al*., 2018).

Farmers and processors can enhance income security by developing new sources of revenue from agricultural by-products. Furthermore, the water purification substances are biodegradable and renewable, thus provide a way to decrease long-term environmental cost and enhance economic sustainability (Patel *et al*., The setting up of small-scale units to process Galgal peel may be of immense importance for rural development. These units can be

managed by local SHGs, cooperatives or rural entrepreneurs and thereby can generate an employment for women and youth (Sahu *et al*., 2019). It generates employment right from the peel collection, sorting, drying, extraction, packing and marketing. Government and non-governmental organisation-led training and capacity building supported programmes can enable rural people to engage and take advantage of these value chains (Gupta & Mehta, 2017). Questions for the industrialization of Galgal peel trust us; we mollycoddling policy framework are the guidance. The issues relating to food safety, quality control, labelling and intellectual property need to be sorted out. Subsidies, research grants, and public-private partnerships are some ways through which the government can encourage this sector (Sharma & Thakur, 2020). In addition, when it comes to exporting products derived from Galgal, the international trade regulations, such as those mandated by the World Trade Organization (WTO) and Codex Alimentarius, have to be adhered to. Attention towards traceability, sustainability certification, and GMP compliance is able to increase the market access and consumer confidence (Kaur & Sandu, 2020).

**Table 3: Industrial and Environmental Applications and Functional Property**

| Application Area | Functional Property |
|---|---|
| Biodegradable Films | Mechanical strength, biodegradability, antimicrobial activity |
| Water Purification | Heavy metal adsorption, low cost |
| Composting | Soil enrichment, microbial activity enhancement |
| Food Preservation | Antimicrobial, antioxidant |
| Green Nanotechnology | Eco-friendly synthesis of nanoparticles |

**Limitations, Challenges, and Future Research Directions**

Galgal peel has promising application prospects, despite they possess multifarious potential, there exist several limitations that prevent it from conventional widespread application. One of the key constraints is the absence of organised collection and supply chain, particularly in regions where Galgal is season-specific and grown by small holders. This has caused an enormous amount of peel to go to waste every year. Scientifically speaking, most of the data available is derived from the laboratory scale. There is an urgent requirement of clinical testing to affirm the healing postulation linked with Galgal peel extracts (Riaz *et al*., 2019). Toxicological investigation also should be considered to institute the maximum safe dosing level, especially in long-term use or topical form.

i. Gaps of Knowledge in Phytochemical Screening Preliminary studies have reported various bioactive molecules present in Galgal peel, but the comprehensive phytochemical profiling is a need of the hour. The majority of the studies concentrate on some specific flavonoids, phenolic, or essential oil compounds but a comprehensive metabolomic study is required to discover all prospective compounds. Advanced assays like LC-MS, GC-MS and NMR spectroscopy may be used for carrying out the same (Mukherjee *et al*., 2021). In addition, differences in phytochemical composition resulting from geography, farming techniques, and seasonal factors must be examined in more detail.

ii. Clinical and Toxicological Evidence Available So Far Despite the promising in vitro and in vivo findings, there are limited clinical evidences on the health effects of Galgal peel in human population. There are limited number of toxicological evaluations, dosage optimization and long-term safety studies, as well. Such information is however, currently not available and subsequently it continues to be a challenge to achieve regulatory approvals for pharmaceuticals, nutraceuticals and food additives prepared from Galgal peels (Verma & Singh, 2020). Placebo-controlled, double-blind clinical trials are warranted to confirm the health claims and to fix therapeutic indices.

iii. Technological and Infrastructural Bottlenecks Several processing technologies involved in Galgal peel commodity-based systems is not accessible to rural population as well as low-income countries. The absence of cheap and easily-scalable Technologies precludes their extensive usage. Furthermore, protocols of extraction, drying and formulation are still under development. Partnership of universities, government research laboratories and industries would help fill these technological gaps (Chopra *et al*., 2019).

iv. Regulatory and Intellectual Property In NFR and health products, the regulatory paths are different for each country and impose barriers to market entry. Furthermore, intellectual property rights with regard to traditional knowledge and indigenous community-based innovations should be protected. The commercialization of the indigenous uses of Galgal, may be subject to the biopiracy and also do not credit to the indigenous people, or benefit-sharing mechanisms are not established (Reddy *et al*., 2018). Ethical and legal uses should adhere to international conventions, such as the Nagoya Protocol.

v. Environmental and sustainability trade-offs Use of Galgal peel results in a number of

environmental advantages, however, there are potential trade-offs that need to be noted. For instance, the m(cb) contents of some representative materials are 10 wt%. 25 Solvent extraction on the other hand could potentially result in chemical waste and high energy demand. Likewise, if the peel is redirected from compost or animal feed, it may affect conventional farming practices. Life cycle assessment (LCA) and sustainability metrics needs to be incorporated in follow up work to assess the net environmental impact of the proposed applications (Patel *et al*., 2020).

vi. Consumer Perceptions There is still low awareness on the environmental benefits of what can be derived from agricultural waste. There can also be a cultural or psychological barrier to bio-products derived from "waste," particularly in regards to food or cosmetics. Health authorities Recommendations and public education programs, clear labeling of contents of E-cigarettes, can contribute to build consumers' confidence and market penetration (Kaur & Sandhu, 2020).

Future Research Directions to harness the full potential of Galgal peel, the following areas merit further investigation:

1. Bioactivity guided profiling with coverage of the metabolome and the proteome.
2. Trials of effectiveness, safety and the best doses.
3. Green and cheap extraction technologies development.
4. LCA analysis for environmental advantages and disadvantages.
5. Policy analysis of regulatory alignment and intellectual property systems.
6. Consumer perception research as a means of guiding product development and marketing.

## CONCLUSION

Galgal peel, hitherto a waste, now gets a new meaning in terms of renewable resource. Its bioactive compounds have been praised for their myriads of health benefits, such as antioxidant and antimicrobial properties, or its potential for chronic disease management. Its structural characteristics also make it suitable for a wide range of environmental applications such as biodegradable materials, water treatment, and composting.

It is therefore possible to make better use of the entire Galgal peel, but it still depends on overcoming technical barriers, regulations and markets. Supporting research, technology and community engagement, and through strategic investment, we can enable Galgal peel to become a staple of bioeconomic models that foster health, sustainability and prosperity in rural regions. Galgal peel has promising application prospects, despite they possess multifarious potential, there exist several limitations that prevent it from conventional widespread application. One of the key constraints is the absence of organised collection and supply chain, particularly in regions where Galgal is season-specific and grown by small holders. This has caused an enormous amount of peel to go to waste every year.

## REFERENCES


- Agarwal, P., Sharma, R., & Gupta, M. (2018). Citrus peel waste: A valuable source of functional compounds for pharmaceutical and food industries. Journal of Medicinal Plant Research, 12(4), 154–162. https://doi.org/10.5897/JMPR2017.6011
- Ajila, C. M., Naidu, K. A., Bhat, S. G., & Rao, U. J. S. P. (2007). Bioactive compounds and antioxidant potential of mango peel extract. Food Chemistry, 105(3), 982–988. https://doi.org/10.1016/j.foodchem.2007.04.052
- Chopra, R., Mahajan, S., & Sharma, A. (2019). Technological interventions for valorization of fruit processing waste in India. Journal of Cleaner Production, 230, 1061–1070. https://doi.org/10.1016/j.jclepro.2019.05.173
- Food and Agriculture Organization (FAO). (2020). FAOSTAT: Statistics Division of the Food and Agriculture Organization of the United Nations. Rome: FAO.
- Gorinstein, S., Martín-Belloso, O., Park, Y. S., Haruenkit, R., Lojek, A., Ĉíž, M., ... & Trakhtenberg, S. (2001). Comparison of some biochemical characteristics of different citrus fruits. Food Chemistry, 74(3), 309–315. https://doi.org/10.1016/S0308-8146(01)00157-1
- Kaur, M., & Kapoor, S. (2020). Phytochemical and antimicrobial screening of Citrus pseudolimon (Galgal) peel extract. Journal of Pharmacognosy and Phytochemistry, 9(4), 1879–1883.
- Kaur, R., & Sandhu, K. S. (2020). Consumer perception and acceptability of value-added products derived from agricultural waste. Sustainable Food Systems, 4(1), 45–57.
- Kumar, V., & Gupta, S. (2019). Citrus waste-derived products: A sustainable approach for circular economy. Waste Management, 84, 104–114. https://doi.org/10.1016/j.wasman.2018.11.009
- Kumar, V., Thakur, M., & Chauhan, R. (2021). Fruit waste valorization: A step towards circular bioeconomy and sustainable development. Environmental Science and Pollution Research, 28(18), 22370–22388. https://doi.org/10.1007/s11356-021-12789-0
- Lavi, S., & Gaskin, K. (2020). Environmental benefits of citrus peel-based bioproducts. Environmental Chemistry Letters, 18(2), 389–398. https://doi.org/10.1007/s10311-020-00992-3

- Lee, S. J., & Cho, S. M. (2019). Waste valorization: Turning citrus peels into valuable products. Industrial Crops and Products, 132, 245–254. https://doi.org/10.1016/j.indcrop.2019.02.015
- Mishra, R., Shukla, S., & Singh, R. (2016). Antioxidant and anti-inflammatory potential of citrus peel extracts: A comparative study. International Journal of Pharmaceutical Sciences and Research, 7(2), 745–752. https://doi.org/10.13040/IJPSR.0975-8232.7(2).745-52
- Mukherjee, S., Dey, S., & Bhattacharya, S. (2021). Advances in metabolomic approaches for phytochemical analysis of citrus species. Phytochemical Analysis, 32(4), 543–556. https://doi.org/10.1002/pca.2998
- Patel, R., Joshi, D., & Chandra, S. (2020). Evaluating the life cycle impact of citrus peel-based bioproducts: Opportunities and limitations. Journal of Environmental Management, 261, 110201. https://doi.org/10.1016/j.jenvman.2020.110201
- Reddy, G. M., Rao, S. N., & Kumar, R. (2018). Biopiracy and the protection of traditional knowledge in India: Legal and ethical issues. Journal of Intellectual Property Rights, 23(4), 203–212.
- Riaz, M., Masood, M., & Anwar, F. (2019). The role of phytochemicals in the treatment and prevention of chronic diseases. Current Pharmaceutical Design, 25(4), 456–468. https://doi.org/10.2174/1381612825666190201102252
- Sharma, A., & Thakur, M. (2020). Phytochemical constituents and traditional uses of Citrus pseudolimon: A review. International Journal of Herbal Medicine, 8(2), 78–85.
- Sharma, N., Kaur, M., & Sandhu, K. S. (2018). Functional properties and antioxidant potential of flour from the peel of Citrus pseudolimon (Galgal). International Journal of Food Properties, 21(1), 1865–1877. https://doi.org/10.1080/10942912.2018.1513282
- Siddique, M. H., & Hossain, M. M. (2019). Sustainable agricultural practices: The role of agro-industrial waste valorization. Environmental Sustainability, 13(5), 735–745.
- Singh, B., Sharma, R., & Dutta, A. (2020). Agricultural waste utilization in bio-based products: A case study of citrus peel. Bioresource Technology Reports, 11, 100454. https://doi.org/10.1016/j.biteb.2020.100454
- Verma, N., & Singh, A. (2020). Toxicological and pharmacological insights into bioactive compounds from citrus peels: A review. Journal of Applied Pharmaceutical Science, 10(3), 24–32. https://doi.org/10.7324/JAPS.2020.103004
- Yadav, M., & Shukla, S. (2021). Citrus peel extract as a novel antioxidant: A comprehensive review. Antioxidants, 10(7), 1057. https://doi.org/10.3390/antiox10071057
- Zhang, D., Li, J., & Wang, C. (2018). Phytochemical profiles of citrus peel and their applications in food and health. Journal of Food Science and Technology, 55(9), 3569–3582. https://doi.org/10.1007/s11483-018-0561-9