Zoology, Bio and Pharma Research

Content Available at www.saapjournals.org

(An International Online Peer-Reviewed Journal) ISSN (O): 3139-3233

Review Article

OPEN ACCESS

A REVIEWON: THE CHEMISTRY AND MULTIFACETED APPLICATIONS OF LEMON FRUIT

BADRI SIREESHA*[1], R.BADRI NARAYANA [2], D.HARI KRISHNA[2], K.ANIL KUMAR[2], N.SHIVA NARAYANA[2]

[1]Department of Pharmaceutical Analysis , Dr. Samuel George Institute of Pharmaceutical Sciences, Tarlupadu Road, Markapur, Markapur Dt, Pincode: 523316

[2]B.Pharmacy. Dr. Samuel George Institute of Pharmaceutical Sciences Tarlupadu Road, Markapur, Prakasam dt. Pin code 523316

Article History: Received: 14 Feb 2026, Revised: 26 Feb 2026, Accepted: 15 Mar 2026

***Corresponding Author**

Badri Sireesha

Abstract

Lemon is a flowering plant of the Rutaceae family. It is notable that the existing procedures make use of the juice alone, and discard the remaining 70% of the lemon's mass. The juice is administered as a 1:1 mixture with ethanol, to improve the solubility and the taste. As a catalyst, lemon juice has also been demonstrated to facilitate the oxidation of sulfides and boronic acids.Lemon flowers contain acids like citric acid, ascorbic acid, and caffeic acid. Lemon juice is used to treat plague and to make *acridine citri*, a syrup that helps reduce thirst. It can also cause irritation. Metabolism refers to how our bodies use digested food for energy and development. Food is turned into blood sugar, which is primarily made up of bodies is glucose. In the absence of insulin, glucose is unable to enter our cells.

Keywords: *Lemon, Metabolism , Extraction, Green Chemistry***.**

INTRODUCTION

The organic chemistry of *Citrus limon* is characterized by a wide variety of naturally occurring compounds that are responsible for its unique taste, fragrance, and biological properties. These substances mainly include organic acids, flavonoids, terpenes, carbohydrates, and several secondary metabolites. The structural variation among these compounds plays an important role in defining the physicochemical behavior and pharmacological activities of lemon. The word "lemon" is believed to have originated from the Old French term "limon." Similar terms such as "limone" in Italian, "lamun" or "lmun" in Arabic, and "lmun" in Persian are also used in different regions. The general term "lime" for citrus fruits is related to the Sanskrit word "nimbu." Lemon belongs to the Rutaceae family of flowering plants. The citrus genus consists of approximately 140 genera and around 1300 species. Although there is already extensive knowledge regarding the uses of lemons, research continues to explore new possibilities. Earlier methods mainly focused on using lemon juice while discarding nearly 70% of the fruit, which leads to significant wastage and does not align with the principles of green chemistry. Therefore, a more comprehensive approach has been adopted to utilize the whole lemon in laboratory applications [1]. Citrus belongs to the Rutaceae family and is widely distributed, with about 140 genera and 1300 species. Common citrus fruits include sweet orange (*Citrus sinensis*), lemon (*Citrus limon*), grapefruit (*Citrus paradisi*), citron (*Citrus medica*), lime (*Citrus aurantifolia*), shaddock (*Citrus grandis*), mandarin (*Citrus reticulata*), and sour orange (*Citrus aurantium*), which are known for their nutritional and medicinal uses.

A small evergreen tree native to Asia is known as *Citrus limon* (lemon). It produces yellow, oval-shaped fruits and includes several varieties. Among citrus fruits, lemon is considered one of the most important species after oranges and mandarins. The citric acid present in lemon juice is widely used in organic chemistry for breaking protective groups such as silanes and acetals. Lemon juice is often mixed with ethanol in a 1:1 ratio to enhance solubility and improve taste. Additionally, lemon juice acts as an effective catalyst in various reactions, including the oxidation of sulfides and boronic acids. Even a small quantity, such as a few drops of lemon juice, is sufficient to catalyze aldol condensation reactions.

Green chemistry has become a highly significant concept in modern chemical science. It focuses on developing environmentally friendly and sustainable chemical processes [2]. This approach emphasizes reducing waste, minimizing the use of hazardous substances, and improving efficiency. Earlier chemical

practices often did not consider environmental impact, but modern chemistry prioritizes safer and more sustainable methodologies. The key principles highlight that chemical reactions should be efficient and practical, while also ensuring that the reagents and solvents used are as safe as possible [3].

HISTORY

The The origin of lemon is not clearly established, but it is generally believed that its earliest cultivation took place in regions such as Assam in north-eastern India, northern Burma, or China. Genetic studies have indicated that lemon is a hybrid formed from bitter orange (sour orange). In the early centuries AD, lemons were introduced into European regions, particularly near southern Italy during the period of Ancient Rome. Later, around 700 AD, lemons spread to Persia, followed by their introduction into Iraq and Egypt. Citrus fruits were first documented in early Islamic literature, especially in an Arabic agricultural text from the 10th century. Between 1000 and 1150 AD, lemons became widely distributed throughout the Arab world and the Mediterranean region [4]. By the mid-15th century, organized and significant cultivation of lemons in Europe began in Genoa.

In 1493, during his voyages, Christopher Columbus carried lemon seeds to Hispaniola, which led to their introduction into the Americas. Spanish expeditions further contributed to the spread of lemon seeds across the New World. Initially, lemons were mainly used for ornamental and medicinal purposes. During the 19th century, lemon cultivation expanded considerably in areas such as Florida and California. In 1747, James Lind conducted studies on scurvy, demonstrating the importance of including citrus juices in the diet, although the role of vitamin C was not known at that time.

The earliest citron remains in Roman times were found in the Roman Forum and date from the late 1st century BC to the early 1st century AD. Citron seeds and pollen were also found in the gardens of wealthy Romans, especially near Mount Vesuvius. Lemon (*Citrus limon*) took about 400 years to reach the Mediterranean and was likely introduced to southern Italy around 200 AD. During the Roman period, citron and lemon were not widely grown or used in cooking. However, rich Romans valued these plants for their beauty, fragrance, medicinal uses, and rarity [5].

CHEMISTRY OF LEMON

General Chemical Profile *Citrus limon* has a rich chemical composition that gives it nutritional and medicinal value. It contains sugars and organic acids, as well as compounds like flavonoids, limonoids, and volatile substances.

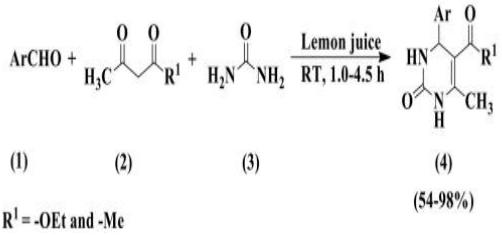
Organic Acids Organic acids form the main component of lemon juice, with citric acid being the chief constituent that gives it its characteristic sour taste. The level of citric acid not only determines the flavor but also provides preservative properties by preventing microbial growth. Apart from citric acid, small amounts of malic acid and tartaric acid are also present, which together increase the acidity and improve the stability of the juice [6].

Ascorbic Acid (Vitamin C) Among the different nutrients found in lemon, ascorbic acid is particularly important because of its strong antioxidant activity. It takes part in redox reactions and helps protect cellular components from damage caused by oxidation.

Flavonoids and Phenolic Compounds

Lemon is an abundant source of flavonoids, which are polyphenolic compounds recognized for their biological activities. The major flavonoids present in *Citrus limon* include hesperidin, eriocarpin, diosmin, and naringin. These compounds possess powerful antioxidant and anti-inflammatory properties, helping in the prevention of various chronic diseases.Essential Oils and Volatile Constituents [7].

The outer peel of lemon is rich in essential oils, mainly consisting of monoterpenes such as limonene, which is the major component. Other volatile substances like β-pinene, γ-terpinene, and citral also play an important role in giving lemon its distinctive aroma and flavours. Carbohydrates and Dietary FiberLemon contains small quantities of carbohydrates, mainly as simple sugars like glucose and fructose. Although it is not a significant source of energy, these sugars help to balance the acidity of the fruit and enhance its taste.



Minerals and Trace Elements

Lemon provides important minerals like potassium, calcium, and magnesium, which help the body function properly. Potassium is especially important for maintaining electrolyte balance and keeping the heart healthy [8]. Organic lemons were used to obtain lemon juice, which was standardized based on its citric acid content. A continuous-wave diode laser system was applied for irradiation, and distilled water was used as the solvent.

The sample was analyzed using instruments like a UV–Vis spectrophotometer, TEM, DLS, FTIR, and a zeta potential analyzer. A 0.01 M silver nitrate ($AgNO_3$) solution was mixed with lemon juice extract in different ratios (1:1, 1:2, and 1:3) to study the effect of concentration. The mixture was then exposed to laser light under controlled conditions, with power from 10 mW to 100 mW and exposure time from 1 to 30 minutes. The process was monitored using UV–Vis spectroscopy to observe the formation and growth of nanoparticles [9].

GENERAL USES OF LEMON

Lemons are also widely used for cleaning purposes. The citric acid present in lemon juice helps eliminate bacteria and other harmful microorganisms. The exact origin of lemons is uncertain, but their usefulness has been documented for nearly 2,000 years. Lemon trees grow in tropical and subtropical regions and can reach a height of about 10–20 feet. They are mainly cultivated in Mediterranean countries, as well as in China, India, Mexico, Argentina, and Brazil. In the United States, they are grown in California, Arizona, Texas, and Florida. Fresh lemons are available throughout the year in markets. Lemon juice has a wide range of uses, from culinary to medicinal purposes. Lemons are used in desserts, drinks, sauces, dips, and to decorate meat and fish dishes. Lemon juice is also used as a natural cleaner and stain remover. Lemon oil is used for fragrance in perfumes, soaps, and skincare products. The essential oils of lemon contribute to health benefits and provide a pleasant and refreshing aroma [10]. They are highly versatile and can be used internally in diluted form, applied topically, or inhaled for various therapeutic purposes.

MORPHOLOGICAL ANALYSIS

Field Emission Scanning Electron Microscopy (FE-SEM) was used to examine the shape and size of silver nanoparticles (Ag NPs). The images showed that the nanoparticles were uniformly distributed and had a semi-spherical shape, with sizes ranging from 20–40 nm. This uniform size and shape are important for improving their performance in different applications.

In photothermal therapy, the size and shape of nanoparticles affect how well they convert light into heat. Uniform nanoparticles can absorb and scatter light evenly, which helps in the targeted destruction of cancer cells without damaging nearby healthy tissues. This makes the treatment more accurate and effective.

In environmental remediation, uniform nanoparticles show better interaction with pollutants. Their consistent size allows them to spread evenly and come into contact with contaminants more efficiently, which improves the removal of harmful substances from water and soil. The semi-spherical shape also increases the surface area, which enhances their reactivity [11].

CHEMICAL COMPOSITIONS

The essential oils from lemon (*Citrus limon*) leaves and peel contain different components. In both oils, limonene is the main compound. Leaf oil contains β-pinene, myrcene, neral, geranial, neryl acetate, geranyl compounds, and β-caryophyllene. Peel oil contains μ-terpinene, β-pinene, and myrcene. Lemon also contains flavonoids such as hesperidoside and limocitrine, especially in the peel. The flower contains acids like citric acid, ascorbic acid, and caffeic acid. Small amounts of caffeine are also present in the flowers and leaves.

Lemons are important for health because they contain many useful chemicals, especially vitamin C (ascorbic acid). About 100 mL of lemon juice contains around 50 mg of vitamin C and about 5 g of citric acid, which is about 55% of the daily recommended value. However, vitamin C decreases quickly after squeezing, with about 20% loss after 8 hours at room temperature or 24 hours in a refrigerator [12].

Lemon also contains important minerals such as sodium (Na), potassium (K), calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), zinc (Zn), and phosphorus (P). Among these, potassium is present in the highest amount and is essential for body functions and growth. Calcium helps in bone formation and supports many cellular processes. Phosphorus is also important for nutrition, while magnesium helps in nerve function and activates enzymes. Iron, copper, and zinc are essential for health and are widely used in nutrition and environmental studies.

PHYTOCHEMISTRY

Lemons contain many phytochemicals such as polyphenols and terpenes. Like other citrus fruits, they are rich in citric acid (about 47 g/L of juice). They also contain compounds like flavonoids, vitamin C, carotenoids, mucilage, calcium oxalate, pectin, sugars, citric acid, malic acid, and other bioactive substances [13].

The peel (rind), which makes up about 45% of the lemon, is an important source of essential oil. Lemon peel contains more than 200 volatile and non-volatile compounds. The main component of lemon oil is limonene (about 70%), along with around 20% monoterpenes. It also contains small amounts of aldehydes, alcohols, and esters such as citral and linalool, and less than 1% coumarins.

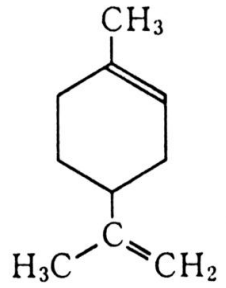


Fig 01: Chemical structure of Limonene

TAXONOMYAND BREEDING OF CITRUS

The genus *Citrus* belongs to the order Geraniales, family Rutaceae, and subfamily Aurantioideae. The Rutaceae family includes about 160 genera and 1,650 species of trees and shrubs. Citrus plants are diploid, with a genome size of about 367 Mb and 18 chromosomes (2n = 18).Scientific studies show that citrus species originated in tropical and subtropical regions of Southeast Asia. These areas include north-eastern India near the Himalayan foothills, south western China (Yunnan), Myanmar, the Indochinese region, and the Malaysian archipelago [14]. From these regions, citrus plants spread to other parts of the world. Australian citrus species and the Japanese Tachibana mandarin separated from mainland citrus

during the early Pliocene and Pleistocene periods. Citrus domestication likely began when people selected and propagated useful plants, often hybrids, rather than breeding them like annual crops. The genus *Citrus* has developed through a long and complex process. Its classification is difficult because citrus species can easily crossbreed, and mutations occur frequently. Most of the citrus varieties we know today were developed later through human selection.

A major step in citrus classification was made by Carl Linnaeus in 1737 in *Genera Plantarum*. He identified the genus *Citrus* and named three main species: *Citrus medica* (including citron and lemon), *Citrus aurantium* (including sweet orange, bitter orange, and pummelo), and *Citrus trifoliata* (Poncirus).

Fig 02: Taxonomy of Citrus trees

Citrus trees have an open growth pattern with relatively few large branches. The lateral (side) branches grow in a flattened manner, spreading outward. Growth activity is higher in the smaller branches, which results in uneven or eccentric growth rings. New shoots mainly develop from the leaf axils, especially during the spring and summer seasons [15,16].

The citrus fruit is made up of two main parts: the pericarp and the endocarp. The pericarp is the outer edible part of the fruit, commonly known as the rind or peel, while the endocarp forms the inner pulp. The peel itself is divided into two layers. The outer colored layer is called the flavedo (epicarp), and the inner white layer is known as the albedo (mesocarp).

The flavedo acts as a protective layer and contains a cuticle-covered epidermis along with closely packed parenchyma cells. It is also responsible for the color and aroma of the fruit. The albedo is softer and spongy in nature and lies beneath the flavedo, contributing to the overall structure of the peel.Lemon trees are more sensitive to cold compared to orange trees because they grow continuously and do not tolerate low temperatures well. They also have a lower ability to recover from cold damage. When the temperature drops to about 22–24°F (−5.5 to −4.4°C), the tree begins to lose its leaves (defoliation).If the temperature falls further to around 20°F (−6.7°C), it can cause serious damage to the wood of the tree, especially if the cold conditions occur suddenly without gradual cooling. The flowers and young fruits are very sensitive and can be damaged or killed at about 29°F (−1.7°C). Nearly mature fruits are also affected and can be severely damaged when the temperature goes below 28°F (−2.2°C) [17].

APPLICATIONS

1. Photothermal therapy

- Silver nanoparticles (Ag NPs) made using lemon juice extract and low laser irradiation show high stability and strong plasmon resonance. Because of these properties, they are useful in photothermal therapy. In this treatment, Ag NPs convert light into heat, which helps in destroying cancer cells.
- The nanoparticles have a uniform size and spherical shape, which improves their ability to absorb light and convert it into heat efficiently. This is important for effective tumor treatment. During photothermal therapy, the Ag NPs are placed at the tumor site. When exposed to near-infrared light, they absorb the light and produce heat in that specific area.
- This heat raises the temperature of cancer cells and leads to their destruction, while causing minimal damage to nearby healthy tissues. The controlled size and shape of the nanoparticles ensure consistent performance, making them suitable for medical applications [18].

2. Environmental remediation

- Silver nanoparticles produced by this green method can be used in environmental applications, especially for water purification. Their strong antimicrobial properties help in removing pollutants and killing harmful microorganisms present in contaminated water.
- The nanoparticles prepared using lemon juice and laser irradiation is stable and well-dispersed, which allows them to remain effective for a longer time. This improves their usefulness in practical environmental applications.
- They work by damaging microbial cell walls and producing reactive oxygen species, which help in killing microbes. In addition, their uniform size ensures consistent performance and makes it easier to use them in existing water treatment systems [19].

3. Medicinal Properties of Lemon

- Lemon leaf blades are oval in form. The leaf morphology is determined by the tree's vitality. When the laminae develop, they turn green, while newly produced leaves remain purple. Most Citrus species, including the lemon, are tap-rooted.
- The root emerges at germination and soon expands into a well-defined taproot. Fibrous roots grow in little bunches 20-30 cm long on the taproots of young seedlings and pioneer roots of older plants.
- The blooms in ripe citrus are 1.5-3 cm long and have a pedicel. The cup with five sepals is

comparable to a calyx. Interlocking marginalpapillae form the petals, which are thick andhave 20-40 partially joined filaments, each with a yellow, four-lumped anther. Others encircle the pistil at the stigma. The Flor side disk produces the stomach from liquid nectar.

- The ovary is sub globous, as opposed to a tight form like orange or sub cylindric, with a fusion in the fashion of citrus. The pistil consists of 8-14 carpet ovaries.
- The fruit measures 2 to 3 inches. Waiting for the right size and not worrying too much about hue is preferable to expecting them to be completely yellow. Citrus fruit that is ready to pluck is also moderately brilliant. Citrus like to make decisions early rather than late. Lemons that are yellow-green in colour will most likely ripen off the tree.

Uses in medicine: Lemon juice has traditionally been used for treating ailments such as plague and for preparing medicinal syrups like acridine citri, which helps relieve thirst. When combined with honey, it acts as a digestive aid and is also applied externally to reduce pimples and dark spots on the skin. Citrus fruits, including lemon, are rich in phytonutrients, making them both nutritious and therapeutic. They are a primary source of vitamin C for primates. Ascorbic acid enhances iron absorption in the small intestine and plays a vital role in connective tissue metabolism, including the formation of scar tissue, teeth, and bones. It also helps relieve stress, protects against colds, and acts as an antioxidant by neutralizing free radicals caused by UV radiation.

Anti-diabetic properties: Diabetes is a metabolic disorder that affects how the body utilizes digested food for energy and growth. Food is converted into glucose, which serves as the main energy source, but without insulin, glucose cannot enter the cells. Lemons, especially their peel, contain polyphenols, which are organic compounds known to reduce fat accumulation, blood glucose levels, insulin resistance, hyperlipidaemia, and weight gain associated with obesity. Citrus peel also contains essential oils that exhibit strong antibacterial activity, helping to inhibit the growth of harmful microorganisms. Health benefits and Nutritional Information

Lemon is an excellent source of vitamin C and dietary fibre and contains several beneficial plant compounds, minerals, and essential oils. It is low in fat and protein, consisting mainly of carbohydrates (about 10%) and water (88–89%). The carbohydrates are primarily simple sugars such as glucose, fructose, and sucrose, along with fibre, especially pectin. Soluble fibre like pectin helps regulate blood sugar levels by slowing down the digestion of sugars and starch. Dietary fibre is essential for maintaining good health and is associated with numerous health benefits [20].

Lemon is also rich in important vitamins and minerals:
Vitamin C – essential for immune function and skin health.
Potassium – helps lower blood pressure and supports heart health
Vitamin B6 – plays a role in converting food into energytheplant compounds present in lemons and other citrus fruits may have beneficial effects against cancer, cardiovascular diseases, and inflammation.

Main plant compounds in lemons

Citric acid –the major organic acid that helps prevent kidney stone formation
Hesperidin – strengthens blood vessels and helps prevent atherosclerosis
Diosmin – improves circulation and reduces inflammation in blood vessels
Eriocitrin – a powerful antioxidant found in lemon peel and juice
D-limonene – the main component of lemon essential oil, responsible for its aroma and useful in relieving heartburn and reflux.

MATERIALS AND METHODS

In this study, the effect of rootstock and substrate on lemon fruit characteristics (Citrus limon (L.) Burm var. 'Verna') was evaluated using nine different treatment combinations. These treatments varied based on two factors: rootstock (three types) and culture media (three types). The rootstocks included Citrus macrophylla, Citrus aurantium, and a combination of Citrus aurantium and Citrus sinensis (commonly known as sweet orange intermediate wood). The growing media consisted of mixtures of peat and phytoremediated marine sediment in ratios of 25:75, 50:50, and 75:25. The sediment used was obtained from Livorno port (Italy) and had undergone phytoremediation for three years. All plants were pruned and maintained at a uniform height of 0.75 cm to standardize growth conditions, similar to commercial practices in southeastern Spain, a major lemon-producing region with high sunlight exposure (about 3000 hours annually) [21].

Extraction Methods for Lemon

Solvent Extraction:

This is a commonly used method for extracting phenolic compounds, flavonoids, and vitamin C using solvents such as ethanol, methanol, or water. It involves soaking the plant material, followed by filtration and concentration. Although simple and economical, it requires more time and larger solvent volumes.

Soxhlet Extraction A continuous extraction method that repeatedly washes plant material with fresh solvent, ensuring efficient extraction. However, prolonged heating may degrade heat-sensitive compounds like vitamin C.

Steam Distillation: Used mainly for extracting essential oils from lemon peel. Steam passes through the material, carrying volatile compounds, which are then condensed. While widely used industrially, some heat-sensitive compounds may be lost.

Cold Pressing: A mechanical method that extracts essential oils without heat by rupturing oil glands in the peel. It preserves the natural aroma and quality but may yield less oil compared to other methods [21].

CONCLUSION

Lemon (*Citrus limon*) is a highly valuable fruit with a wide range of chemical constituents and applications. Its rich content of vitamin C, flavonoids, citric acid, and essential oils contributes to its antioxidant, antimicrobial, and therapeutic properties. These characteristics support its use in traditional medicine as well as in modern pharmaceutical, cosmetic, and nutraceutical industries. Beyond health benefits, lemon is widely used in food preservation, flavouring, cleaning, and industrial applications. Its natural origin, safety, and eco-friendly nature make it a suitable alternative to synthetic substances. Ongoing research into its phytochemistry and biological properties continues to expand its importance in scientific and industrial fields.

ACKNOWLEDGEMENT

Not declared

FUNDING

No

CONFLICT OF INTEREST

No

REFERENCES

1. Phytoconstituents of Citrus limon as potential inhibitors against SARS-CoV-2. ChemistryOpen, 13(10).
2. S.A. Jatoi, A. Kikuchi, S.A. Gilani, K.N. Watanabe. (2007). Phytochemical, pharmacological and ethnobotanical studies in mango ginger (Curcuma amadaRoxb.; Zingiberaceae). Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives. 21(6): 507-516.
3. Sujitha, M.V., Kannan, S. (2013). Green synthesis of gold nanoparticles using Citrus fruits (Citrus limon, Citrus reticulata and Citrus sinensis) aqueous extract and its characterization. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 102: 15-23.
4. Ankamwar, B., Damle, C., Ahmad, A., Sastry, M. (2005). Biosynthesis of gold and silver nanoparticles using Emblica Officinalis fruit extract, their phase transfer and transmetallation in an organic solution. Journal of nanoscience and nanotechnology, 5(10): 1665-1671.
5. Akama,Y.; Tong,A., Spectroscopic Studies of the Keto and Enol Tautomers of 1-Phenyl-3-Methyl-4-Benzoyl-5- Pyrazolone.*Microchem. J.*1996, 53, 34-41.
6. Mironowicz, A.,Biotransformation's of racemic acetates by potato and topinamburtubers.*Phytochemistry*, 1998, 47, 1531-1534.
7. Sanofer, A.A. (2014). Role of citrus fruits in health. *Journal of Pharmaceutical Sciences and Research*, *6*(2), 121.
8. A. Rauf, G. Uddin, J. Ali. (2014). Phytochemical analysis and radical scavenging profile of juices of Citrus sinensis, Citrus anrantifolia, and Citrus limonum. Organic and medicinal chemistry letters. 4(1): 5.
9. Sachdeva,H.; Saroj,R.; Khaturia,S.; Dwivedi,D., Environ-Economic Synthesis and Characterization of Some New 1,2,4-Triazole Derivatives as Organic Fluorescent Materials and Potent Fungicidal Agents.*Org. Chem. Int.* 2013, ID 659107, 1-19.
10. "*A green deprotection strategy: Removing acid-labile protecting groups using lemon juice/ethanol as the solvent*" W. Wang, Y.Chen, X. Li, Q. Zhang, *Tet. Green. Chem.*, 2023, **2**, 100026.
11. Deshmukh,M. B.; Patil,S. S.; Jadhav,S. D.; Pawar,P. B., Green Approach for Knoevenagel Condensation of Aromatic Aldehydes with Active Methylene Group.*Synth.Commun.*2012, 42, 1177-1183.
12. A. Rauf, G. Uddin, J. Ali. (2014). Phytochemical analysis and radical scavenging profile of juices of Citrus sinensis, Citrus anrantifolia, and Citrus limonum. Organic and medicinal chemistry letters. 4(1): 5.
13. Huang, X., El-Sayed, I.H., Qian, W., El-Sayed, M.A. (2006). Cancer cell imaging and photothermal therapy in the near-infrared region by using gold nanorods. Journal of the American Chemical Society, 128(6): 2115-2120.
14. Pal, R.; Khasnobis,S.; Sarkar,T., First Application of Fruit Juice of Citrus limon for Facile and Green Synthesis of Bis- and Tris(indolyl)methanes in Water.*Chem. Jour.*2013, 3, 7-12.
15. Yerou, K.O., Ibri, K., Bouhadi, D., Hariri, A., Meddah, B. and Touil, A.T. (2017). The use of orange (Citrus sinensis) peel as antimicrobial and anti-oxidant agents. *Journal of Fundamental and Applied Sciences*, *9*(3), 1351-1357.
16. Ertl, P.;Rohde,B.; Selzer,P.,Fast calculation of molecular polar surface area as a sum of fragment based contributions and its application to the prediction of drug transport properties.*J. Med. Chem.*2000, 43, 3714-3717.
17. M.A. Hanif, H.N. Bhatti, M.S. Jamil, R.S. Anjum, A. Jamil, M.M. Khan. (2010). Antibacterial and antifungal activities of essential oils extracted from medicinal plants using CO2 supercritical fluid extraction technology. Asian Journal of Chemistry. 22(10): 7787.
18. G.O. Onawunmi. (1989). Evaluation of the antifungal activity of lemon grass oil. International Journal of Crude Drug Research. 27(2): 121-126.

19. Sanofer, A.A. (2014). Role of citrus fruits in health. *Journal of Pharmaceutical Sciences and Research*, 6(2), 121.
20. Altammar, K.A. (2023). A review on nanoparticles: Characteristics, synthesis, applications, and challenges. Frontiers in Microbiology, 14: 1155622.
21. Vekiari SA, Protopadakis EE, Papadopoulou P, Papanicolau D, Panou C, Vamvakias M. 2002. Composition and seasonal variation of the essential oil from leaves and peel of a cretan lemon variety. J Agric Food Chem, 50(1): 147–153.