



DESCRIPTION OF THE BIOLOGICAL CHARACTERISTICS OF LEMON (*Citrus lemon* L.)

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Abstract: Lemon (*Citrus limon* L.) is a valuable fruit known for its rich phytochemical composition and wide range of biological activities. Its fruit, peel, and seeds contain diverse bioactive compounds, including flavonoids (hesperidin, diosmin, eriocitrin), phenolic acids (ferulic, caffeic, sinapic), essential oils (D-limonene, β -pinene, γ -terpinene), vitamin C, carotenoids, and pectins. These constituents contribute to the fruit's potent antioxidant, antimicrobial, anti-inflammatory, and anticancer properties. Lemon extracts exhibit strong inhibitory effects against pathogenic microorganisms such as *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*, acting as a natural antimicrobial agent. The antioxidant potential of lemon is attributed to its high flavonoid and phenolic content, which neutralizes free radicals and mitigates oxidative stress. Moreover, compounds like D-limonene and limonoids demonstrate anticancer potential by suppressing tumor growth and promoting apoptosis in malignant cells. Due to these multifaceted properties, lemon and its derivatives are extensively applied in the food industry as natural preservatives and in cosmetology as antioxidant, anti-inflammatory, and skin-brightening agents. An evaluation based on international descriptors further supports the significance of lemon as a functional fruit with considerable nutritional, medicinal, and industrial value.

Keywords: Lemon, biological characteristics, phytochemical composition, antioxidant, antimicrobial, pharmacological effect, food industry, cosmetology, hybrid lemons.

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Introduction:

The taxonomy and phylogeny of citrus are highly complex, controversial, and confusing. This is mainly due to the sexual compatibility between *Citrus* and related genera, the high frequency of bud mutations, and the long history of cultivation and wide distribution (Nicolosi et al., 2000). In addition, the level of variation among citrus species and their precise species status have not yet been fully determined. In the past, citrus taxonomy was primarily based on morphological and geographical characteristics, and numerous classification systems were developed. Among these, the systems proposed by Swingle &

Reece (1967) and Tanaka (1977) are the most widely accepted.

Lemon (*Citrus limon*) is a plant species belonging to the Rutaceae family, naturally distributed in India, China, and South Asia. It has been used since ancient times for both medicinal purposes and as a food product. (Fig1.). Research on the origin of lemons suggests that they resulted from the hybridization of *Citrus medica* (citron) and *Citrus aurantium* (bitter orange). This unique genetic combination has endowed lemons with a rich phytochemical composition (Klimek-Szczykutowicz, M., Szopa, A., & Ekiert, H., 2020).

Fig.1. Lemon (*Citrus limon*)

The main components of lemons include vitamin C, flavonoids, phenolic compounds, pectin, and essential oils. These components provide various pharmacological properties. Studies show that the phytochemicals found in lemons exhibit strong antioxidant and anti-inflammatory effects, potentially preventing cardiovascular diseases, cancer, and certain metabolic disorders (Magalhães, D., Vilas-Boas, et al M., 2023). Additionally, the antibacterial and antifungal properties of lemons enable their use both as a natural preservative and as a food industry conservant. The bioactive compounds present in lemon peel and juice play a significant role in disease prevention and treatment.

Lemons are not only important in food and medicine but also play a crucial role in agriculture and environmental protection. Bioactive compounds derived from lemon waste are used in the production of environmentally friendly fertilizers and natural pesticides. Moreover, lemon oil serves as a natural antiseptic and is included in various cleaning products. Different lemon varieties vary in fruit size, color, acidity, and seed count (Salem Abdelmoaty, Mohammad Moneruzzaman Khandaker, et al., 2021).

This article provides a detailed analysis of the key biologically active compounds in lemons, their effects on the human body, and their industrial applications. It also explores the primary lemon varieties and their

characteristics. The objective is to highlight the significance of lemons in health, industry, and environmental sectors while assessing their potential benefits more comprehensively (Rafiq, S., Kaul, R., Sofi, S. A. et al., 2018).

1. Phytochemical Composition of Lemon

Lemon (*Citrus limon* L.) is a rich source of biologically active phytochemicals that contribute to its nutritional, medicinal, and industrial importance. The fruit, peel, and seeds contain a wide spectrum of secondary metabolites, each playing a distinct physiological and pharmacological role. These compounds can be categorized into several main groups:

Flavonoid compounds (hesperidin, diosmin, eriocitrin): Flavonoids represent one of the most abundant classes of phytochemicals in lemon (Fig.2). They possess strong antioxidant and anti-inflammatory activities by scavenging reactive oxygen species (ROS) and reducing lipid peroxidation. These compounds also play a crucial role in vascular protection, improving capillary resistance and circulation. Moreover, hesperidin and eriocitrin are reported to modulate enzyme activity involved in detoxification and enhance the body's defense mechanisms against oxidative stress (Klimek-Szczykutowicz, M., Szopa, A., & Ekiert, H., 2020).

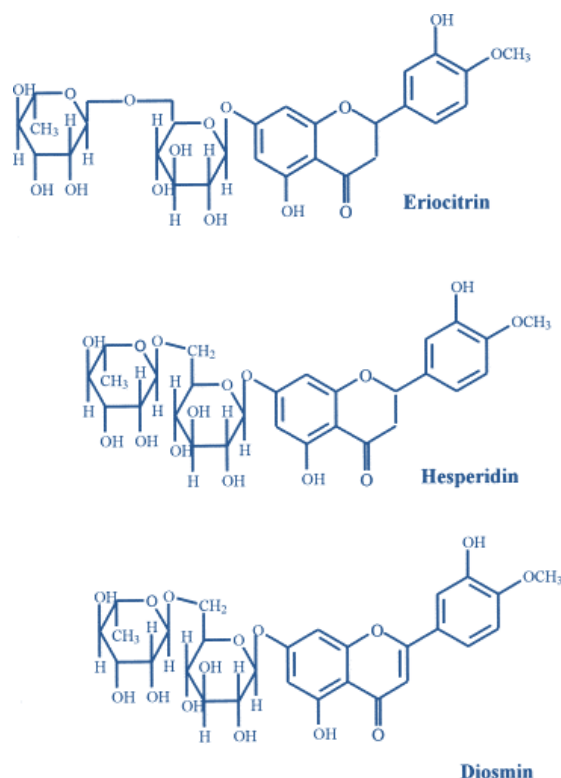


Figure. 2. Flavonoidd

Phenolic acids (ferulic, caffeic, sinapic):

Phenolic acids are responsible for many of lemon's antioxidant and antimicrobial effects. They prevent oxidative damage to cellular lipids, proteins, and DNA, contributing to the reduction of inflammation and the risk of chronic diseases. Additionally, studies have shown that phenolic acids may inhibit cancer cell proliferation and induce apoptosis in tumor tissues. Their antimicrobial potential further enhances lemon's role as a natural preservative in food and pharmaceutical products (Magalhães, D., Vilas-Boas, et al M., 2023).

Essential oils (D-limonene, β -pinene, γ -terpinene): Lemon essential oils are complex mixtures of volatile compounds with broad-spectrum antimicrobial, antifungal, and antiviral properties. D-limonene, the major constituent, has been extensively studied for its antioxidant, anti-inflammatory, and chemopreventive effects. These oils can disrupt microbial cell membranes, leading to leakage of cellular contents and cell death. Additionally, their pleasant aroma makes them widely used in the food, perfume, and cosmetic industries (Hassan, S. M., Farman, M., Mughal, S. S. et al., 2020).

Vitamin C (ascorbic acid):

Lemon is one of the best natural sources of vitamin C, a potent antioxidant that supports the immune system, enhances collagen synthesis, and maintains skin elasticity. It plays a protective role against cardiovascular diseases by promoting vasodilation and preventing oxidative modification of low-density lipoproteins (LDL). Furthermore, ascorbic acid improves the absorption of non-heme iron from plant-based foods, contributing to nutritional balance (Rafiq, S., Kaul, R., Sofi, S. A. et al., 2018).

Carotenoids and pectins:

Carotenoids, including β -carotene and lutein, act as natural pigments and antioxidants that protect cells from oxidative damage. They also contribute to eye health and immune system regulation. Pectins, which are complex polysaccharides found in the lemon peel, exhibit prebiotic properties, supporting the growth of beneficial gut microbiota. They also help regulate blood glucose and cholesterol levels, improve digestion, and enhance detoxification processes by binding toxins in the gastrointestinal tract (IPGRI, 1999).

In summary, the diverse phytochemical composition of lemon contributes to its multifunctional health-promoting effects, including antioxidant, antimicrobial, anti-inflammatory, and anticancer activities. These bioactive components make lemon an important natural source for pharmaceutical, nutraceutical, and food industry applications.

2. Antimicrobial Effect

Lemon extracts have been proven effective against pathogenic microorganisms such as *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. Essential oils degrade bacterial cell membranes, halting their activity. As a result, lemon acts as a natural antibiotic and helps prevent bacterial infections (Abbate, L., Mercati, F., et al, 2019).

3. Antioxidant Effect

The flavonoids and phenolic compounds in lemons reduce the formation of free radicals in the body, preventing oxidative stress. This effect decreases cell damage and slows down the aging process (Mabberley, D. J., 2004).

4. Anticancer Effect

D-limonene and flavonoid-containing compounds restrict the spread of tumor cells, activate apoptotic mechanisms, and help inhibit certain carcinogenic enzymes. Research suggests that limonoids found in lemon peel may prevent the development of some malignant tumor types (Rafiq, S., Kaul, R., Sofi, S. A. et al.,2018).

5. Applications in the Food Industry and Cosmetology

Lemon's natural preservative properties make it widely used in the food industry. Lemon extracts and essential oils function as preservatives by preventing the growth of bacteria and fungi. In cosmetics, lemon is utilized as a skin-brightening, antioxidant, and anti-inflammatory component (Hassan, S. M., Farman, M., Mughal, S. S. et al., 2020).

6. Evaluation of Lemon Based on International Descriptors

The following table presents the evaluation of lemon according to international descriptors (IPGRI 1999).

Table 1: Evaluation of Lemon Based on 12 Descriptors

Category	Descriptor	Characteristics
Botanical Characteristics	Type Weight Color Fruit form	Citrus lemon 80-200 gr Light yellow to dark yellow Round or elongated
Chemical Composition	Vitamin C amount Flavonoid content Essential oils	40-60mg/100mg Hesperidin, diosmin, eriocitrin D-limonen, γ -terpinen
Nutritional Value	Calories Pectin	29kcal/100mg 1-2%
Industrial Applications	Food Industry Cosmetology Pharmaceuticals	Natural preservative, aromatic additives Skincare and whitening agents Antiseptic, immune booster

7. Lemon Variety

Citrus fruits (including lemons) are mainly grown in the southern subtropical region of Azerbaijan — especially in the Lankaran District and Astara District. According to one

source, lemons in Azerbaijan are cultivated from both introduced and local varieties.

Lemons are divided into two main groups: True lemons and hybrid lemons. Within both groups, there are various species with some



significant characteristics as follows:

1. True Lemons

Eureka: This is one of the most popular lemon varieties and belongs to the non-hybrid lemon group. It is sensitive to cold climates. Known for its yellow rind and greenish-yellow pulp. (Fig.3)



Figure 3. Eureka

Lisbon: Compared to the Eureka variety, it is produced less but is more resistant to cold. It has yellow, rough-textured fruit, with light green-yellow pulp and very few seeds. (Fig 4.)



Figure 4. Lisbon

2. Hybrid Lemons

Meyer: This variety is a hybrid of lemon and mandarin orange. The fruit is orange-colored, and its acidity level is moderate. It is resistant to cold climates. (Fig. 5.)



Figure. 5. Meyer Lemon

Key Lime (*Citrus aurantifolia*): Widely grown in Malaysia, this lemon variety has small, green or lightyellow fruits. It is sensitive to cold climates, and its rind has antibacterial properties. (**Fig. 6.**)



Figure. 6. Lime (*Citrus aurantifolia*)

Calamansi Lime (*Citrus microcarpa*): Originating from China, this variety is widely spread in Malaysia. It has small, green fruits and mainly differs in its level of acidity. (**Fig. 7.**)



Figure. 7. Calamansi Lime (*Citrus microcarpa*)

Summary:

Lemon (*Citrus limon*) is a widely cultivated citrus fruit known for its rich phytochemical composition and extensive applications in the food, pharmaceutical, and cosmetic industries. It contains essential bioactive compounds such as flavonoids, phenolic acids, essential oils, vitamin C, and

pectin, which contribute to its antioxidant, anti-inflammatory, antimicrobial, and anticancer properties (Abbate, L., Mercati, F., et al, 2019). Flavonoids and phenolic compounds in lemon play a crucial role in reducing oxidative stress and protecting cells from damage (Hassan, S. M., Farman, M., Mughal, S.S. et al., 2020). Its essential oils exhibit strong antibacterial and



antiviral properties, making them valuable in both food preservation and skincare formulations (IPGRI 1999). Additionally, lemon is recognized for its pharmacological benefits, including cardiovascular protection, immune system enhancement, and digestive health support (Klimek-Szczykutowicz, M., Szopa, A., & Ekiert, H., 2020). In the food industry, lemon is utilized as a natural preservative due to its antimicrobial properties, which help extend shelf life and prevent spoilage (Mabberley, D. J., 2004). In cosmetics, lemon extracts contribute to skin brightening, elasticity improvement, and anti-aging effects (Magalhães, D., Vilas-Boas, et al M., 2023). Recent studies have also highlighted lemon's neuroprotective potential and its role in combating metabolic disorders (Rafiq, S., Kaul, R., Sofi, S. A. et al., 2018). This review comprehensively examines the biological properties of lemon, emphasizing its health benefits and industrial applications. Future research should focus on further exploring its bioactive compounds and their therapeutic potential through clinical studies.

Conclusion:

Lemon, being rich in biologically active compounds, makes a significant contribution to health and various industries. The flavonoids, phenolic acids, essential oils, and vitamins it contains stand out for their antioxidant, anti-inflammatory, antimicrobial, and anti-cancer properties. In the food industry, lemon extracts and essential oils are used as natural preservatives, which extend the shelf life of products (Magalhães, D., Vilas-Boas, et al M., 2023). In cosmetology, lemon is widely used for maintaining skin health, as well as for its whitening and anti-aging effects (Mabberley, D. J., 2004). Additionally, lemon's pharmacological effects help maintain cardiovascular health, strengthen the immune system, and alleviate digestive problems (Rafiq, S., Kaul, R., Sofi, S. A. et al., 2018). Modern scientific research shows that the bioactive compounds in lemon may also positively impact the prevention of neurological diseases and metabolic syndromes (IPGRI 1999).

Future research should further explore the pharmacological effects of lemon's bioactive components and identify new applications for them. Specifically, more clinical studies are needed to assess the effectiveness of lemon-based preparations against various diseases and their use in medical practice.

In conclusion, lemon is an indispensable component in the food, pharmaceutical, and cosmetics industries and holds vast potential in preserving human health and serving as a natural remedy (Abbate, L., Mercati, F., et al, 2019).

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