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## Biological Activities of Lemon

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### Abstract

Lemon is an important plant, which on the bases of its biological activities, used for medicine belongs to Rutaceae family and also known as a medicinal plant. Essential oils and other compounds present in lemon juice are at the main interest of biologists because of their various functionals. Lemon juice is the product of natural origin can be use as an alternative to synthesis products and play a vital role because of its biological activities. The results obtained from many studies reveal that the biological potentials of essential oil and other compounds of C. limon are probably due to the particular chemical composition of lemon juice mainly the high amounts of vitamin C. Therefore, this essential components could be used for various purposes based on their biological activities. The aim of this review article is to explore the vital importance of vitamin C and constituents of lemon juice and to evaluate its biological activities.

### Introduction

Lemon belongs to the family Rutaceae and having a spherical shape. It is native to South Asia and India. [1]. Citrus is mostly used in the industries for drinks garnishing of drinks salad dressing and also use at the home level in cooking meat and vegetables by squeezing it juice. It is also used for making cosmetics, perfumes and also for aesthetic purposes. The lemon composition includes mostly acid which is about 5% with pH 2 to 3. Acid gives a sour taste to the lemon. And lemon juice is known for its fresh tart and tangy flavor. Lemon is a prominent source of natural health for the human being because of the antimicrobial property and use of plant extract and phytochemicals can be widely used for remedial treatments. It's different crude extract portion such as stem leaves to root and flowers have anti-cancer and anti-bacterial potential [2].

The study of vitamin C present in lemon juice is associated with a history of an unrelenting search for the cause of the haemorrhagic disease. The vitamin C present in lemon plays an important role in formation of bone, healing of wounds and the maintenance of the health gums.

Vitamin C plays a vital role in a lot of metabolic functions, for example, the activation of the vitamin B, the conversion of cholesterol, folic acid and the conversion of the amino acid and tryptophan. Vitamin C is an antioxidant that prevents body from the damage of free radical. It is widely used as therapeutic agent in a lot disorders and diseases.

Vitamin C decreases the severity of allergic reactions, protects immune system and also helpful in fight off infections. However the importance and significance effects of vitamin C in regards to human disease such as cancer, neurodegenerative disease, atherosclerosis diabetes, and metal toxicity remains equivocal. Thus further continuous experimental efforts will also open new field of benefits of vitamin C present in lemon to understand its significance in management of diseases in Human being.

### Chemical Composition

Lemon peels contain protein, phosphorous, calcium, copper, manganese, iron, zinc, sodium, potassium, and some chemical parameters [3].

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The percentage of these parameters is following [4];

1. Protein (9.42%)
2. Fat (4.98%)
3. Ash (6.26%)
4. Fiber (15.18)
5. Sodium (755.5mg/100g)
6. Potassium (8600mg/100g)
7. Calcium (8452.5mg/100g)
8. Copper (4.94mg/100g)
9. Zinc (13.94mg/100g)
10. Phosphorous (6656mg/100g)

### Plant Biotechnological Studies On Lemon

Plant biotechnology is providing great opportunities for the use of plants in vitro culture, especially in the pharmaceutical and food industries. In vitro cultures is a good option to grow plants rather than in vivo. Plant biotechnology helps to conduct the experiments in vitro cultures and also helps to optimize the cultures for the conduction of these experiments. It also helps to optimize the culture medium which includes plant growth, regulators of development, and genetic transformation. The micropropagation process can also be handled by in vitro cultures [5]. In vitro culture, the highly concerned subject of research is *C. limon* cultures along with the development of micropropagation protocols. In vitro culture plant biotechnologists focused on selecting those regulators that promote the growth of plants especially root and shoot.

Goswami performed the biotechnological research for the micropropagation of *C. limon* [6]. He used a Murashige and Skoog medium to propagate and shoot culture taken from the plant roots [7]. The medium contains PGRs of different types and concentrations. At a low level of 6-benzylamine (BA) 0.1mg/L, the maximum number of shoots and regeneration of shoot was obtained. Shoot proliferation decreased when he increased the concentration of BA in MS medium. The proliferated shoot also showed the induction of shoot on the medium which contains 1.0mg/L of indol-3-butyric acid.

The Department of Citriculture in Murcia also performed a biotechnological study on *C. limon* [8]. The researcher made a histological characterization of mature

nodal explants of two important cultivars of *C. limon* which are Verna 51 and Fino 49. They also studied organogenesis. They used two medium MS medium and Woody plant medium and they obtained a large number of buds per regenerated explants on MS medium. For the development of adventitious buds, there is a need for the presence of BA and gibberellic acid on the medium. When BA is used without GA on the medium the organogenesis was observed at the lowest extent [9].

Lemon (*Citrus limon*) possesses phytochemical compounds such as alkaloids, flavonoids, steroids, tannic acid, and phenolic compounds. Phytochemicals are found in plants and they are non-nutritive but they have certain disease-preventing properties [10]. They give protection against pathogens. Phytochemicals work in different ways like antioxidants which prevent cell damage. These have a property to stimulate certain enzymes and they can reduce the effect of many ailments. Phytochemical compounds also act as antimicrobial and hormonal stimulants. Lemon contains phenolic compounds, flavonoids, vitamins, and essential oils. These compounds are responsible for protection against diseases related to anti-oxidative, antitumor, antimicrobial activities, and chronic diseases [11]. Phytochemicals prevent the substances from becoming carcinogenic in the human body. They reduce inflammation in the body. Prevent oxidative damage to the DNA of the cell and the ability of cells to repair themselves. Phytochemicals also help to regulate hormones.

### Biological Activities

Biological activity of vitamin C present in lemon juice of *C. limon* fruit confirmed by scientific research for the treatments of diseases and disorder in human being can be given as follow:

#### Anticancer Activity

Lemon peel oil have several cancer-fighting properties. For example, flavonoid intake is directly associated with a reduction of risk of several types of cancer, and vitamin C can also boost up the growth of white blood cells, which help to eliminate mutated cancer cells. Vitamin C present in lemon juice play a vital role in inhibition of the proliferation of cancer cells, Activation of apoptotic cell death which may become cancerous cells, Inhibition of tumour growth in chronic myelogenous leukaemia (CML), Antioxidant action and induction of apoptosis in MCF-7 cells also results in prevention of formation of cancerous tumor [12].

#### Antibacterial Activity

The bioactive compounds present in lemon juice also have an antibacterial. Lemon (*Citrus aurantifolia*) juice other

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than being used as an antibacterial, it is also important as an antioxidant. The main content of lemon (*Citrus limon*) juice is vitamin C and citric acid. That's why vitamin C plays a vital role in inhibition of NF- $\kappa$ B factor, nitric oxide synthase, induced cyclooxygenase (COX-2) (hesperidin, hesperitin) and Down-regulation of TLR-signaling pathway (limonin) [13]. Thus, vitamin C have a great ability to control the bacterial diseases.

### Effects on the Nervous System

Lemon juice has vitamin C as a main component which keeps the immune system strong and helps minimize the stress. So when you feel stressed or tired, by having a glass of lemon water you will feel refreshed. Lemons are full of potassium, which is beneficial for the brain and nerve functions. The inhibitory effect of vitamin C on pain receptors similar to that of the indomethacin and hyoscine (D-limonene). It also have sedative and anxiolytic effect by activating dopamine and serotonin receptors [14].

### Lipolytic and Cholesterol-Lowering Activity

Vitamin C has been shown to be an important therapeutic for reducing total serum cholesterol, but the epidemiologic studies have evolved that low-density lipoprotein cholesterol and high-density lipoprotein cholesterol are the better predictive measurements for coronary heart disease risk. It can also reducing the level of triglycerides and increase the level of high-density lipoprotein cholesterol in the blood. Thus, Lowering cholesterol and arachidonic acid levels by stimulating liver enzymes and cytochromes and also have Lipolytic activity ( $\gamma$ -terpinene and p-cymene) [15].

### Effect on the Digestive System

The vitamin C can cause relief from heartburn, as lemon juice becomes alkaline, reducing acidity in digestion. It can cause increase in gastric motility and decrease the chances of nausea (D-limonene). It can also neutralize the stomach acids (D-limonene) thus relief of gastric reflux (D-limonene) and increased bile flow [16].

### Anti-Obesity Activity

The vitamin C present in lemon juice can reduce cholesterol and thus prevent from fat deposition (D-limonene). It also equalizes blood sugar (D-limonene). Thus it can prevent from obesity. It is also helpful in regeneration of pathological variations in the liver and pancreas [17].

### Diabetes Prevention

A small study in 2007 found that by the intake 1,000 milligrams of vitamin C for six weeks can be help in reduction of the risk of type 2 diabetes complications by reducing the

blood sugar and lipid levels. In 2014 studies it was found that the need for vitamin C supplementation may be greater in people with diabetes. The vitamin C present in lemon juice can decreased glycolized haemoglobin (D-limonene), gluconeogenesis enzymes, glucose-6-phosphatase and fructose-1,6-biphosphatase (D-limonene). It can also reduce blood glucose. In this way, it can prevent from diabetes (D-limonene) [18].

### Effects on the Cardiovascular System

Vitamin C can reduce the risk of cardiovascular disease and stroke. It can also lower blood pressure. While lemons don't top the list of citrus fruits high in vitamin C, but they are still a good source. The vitamin C has an ability in limiting myocardial damage (naringenin) by decreasing blood fibrinogen and lowering blood pressure in people with hypertension [19].

### Effects on the Skeletal System

It is known to everyone that vitamin C present in lemon juice is a water-soluble vitamin that is a vital role for our body to form collagen in bones, muscle, cartilage, blood vessels and supports the absorption of iron. In this way, it has an ability to increase the bone density, decrease osteoclast activity. It can also decrease TRAP-positive multinucleated cell numbers (nomilin) resulting in decreasing the bone resorption activity (nomilin) and down regulation osteoclast-specific genes (NFATc1 and TRAP mRNA levels) (nomilin) [20]. In this way it can prevent from many of bone diseases.

### Effects on the Respiratory System

The vitamin C present in lemon juice have an ability to treat the chronic pneumonia (naringenin).

### Antiviral Activity

The proven antibacterial and antiviral properties of vitamin C present in lemons can accelerate the healing process in the case of cankers. Mix the juice of freshly squeezed lemon into a glass of lukewarm water and rinse your mouth with this solution. By doing it this three times a day will result in inhibition of replication of Herpes simplex [21].

### Antifungal Activity

In 2008, studies were made to explain the antifungal effect of vitamin C present in lemon, orange and grapefruit on a number of fungi, for example, *Aspergillus niger*, and the results showed that the vitamin C present in these citrus fruits also have antifungal activities. It also has the inhibiting properties against *Candida glabrata* strains [22].

### Hepatoregenerative Activity

The vitamin C present in lemon juice helps in the

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normalization of alanine aminotransferase (ALAT), alkaline phosphatase (ALP) and bilirubin. That's why it has ability to reduce malonic dialdehyde (MDA), lipid peroxidation, superoxide dismutase (SOD) and catalase that may have dangerous effects on accumulation.

#### Antiparasitic Effect

The effect of vitamin C present in *C. limon* on *Sarcoptes scabiei* var. *cuniculi* has been evaluated in vitro and in vivo. On experimental bases, the infected parts of rabbits were treated topically once a week for four successive weeks. In vitro application results showed that vitamin C in limon (10% and 20%, diluted in water) caused mortality in 100% of mites after 24 h post-application. In vivo application of 20% vitamin C on naturally infected rabbits showed complete recovery from clinical signs and absence of mites in microscopic examination from the second week of treatment [23].

#### Anticaries Activity

The citric acid present in lemon is helpful in inhibiting growth of *Streptococcus mutans* and its adhesion to enamel and it inhibit glucosyltransferase transcription and also the enzymatic activity. It also tend to inhibit the formation of caries and prevent tooth decay anticaries effects. It can be an anticaries toothpaste additive.

#### Lemon Peel as a Cholesterol-Reducing Agent

Studies have shown that lemon peel had the highest TPC (Total Polyphenol Content) followed by the grapefruit and mandarin. So it possesses the strongest antioxidant activity. Furthermore, the lemon peels and the waste stream of the lemon peels are very effective in lowering the plasma and liver cholesterol in hamsters as the pectin extracted from the peels and that also compounds other than pectin are probably responsible for the cholesterol-lowering effect of the citrus peels [24]. The cholesterol-lowering effect of the peels could be completely accounted for by the pectin in the peels. D-limonene is a major constituent in a citrus essential oil that is used in various foods as a flavoring agent.

Recently, d-limonene has been reported to alleviate fatty liver induced by a high-fat diet. In the treatment, it was observed that d-limonene reduced serum TG, low-density lipoprotein cholesterol (LDL-c), and fasting blood glucose levels and glucose tolerance. It also increased serum high-density lipoprotein cholesterol (HDL-c) in obese mice. The data suggested that the intake of d-limonene may benefit patients with dyslipidemia and hyperglycemia and is a potential dietary supplement for preventing and ameliorating metabolic disorders [17]. So, citrus peels have a cholesterol-lowering effect comparable to that of pectin

extracted from other peels [25].

#### Diuretic Effect of C.Limon

About 2 billion people are considered obese or overweight worldwide [26]. There are so many approaches that are available to lose weight by the surgical and drug-based means or by different diet programs. The surgical treatment involves gastric bypass or gastrectomy which results in a massive weight loss in the patients. However, patients need to be focused on their diet and regular exercise. Obesity comes with risks of internal bleeding, pulmonary embolism, and ultimately death [27]. On the other hand, weight loss drugs work on the principle of suppressing appetite and increasing metabolism. But these drugs are associated with the side effects of myocardial infarction and stroke [28]. The most common treatment of obesity is dietary plans such as Keto-Diet, Mediterranean Diet, etc.

Lemon dieting is a VLCD diet (very-low-calorie diets) that is using since the 1940s and provides 800 to 1000 kcal per day [29]. This diet often consists of Neera syrup (a blend of maple and palm tree syrups) and lemon juice. The syrup has high contents of minerals and also the trace elements and the lemon detox provides high minerals and vitamins ratio than the other VLCDs [30]. The active weight loss ingredient in this diet is lemon juice which is a known diuretic and the mechanism may involve angiotensin-renin system (RAS). Further studies showed the effect of dietary lemon peel polyphenols on high-fat diet-induced obesity in mice and examined that the regulation of lemon polyphenols on the expression of the gene is involved in the lipid metabolism to elucidate the mechanism. After the experimentations, body weight gain induced by the high-fat diet was significantly reduced by feeding with the diet containing lemon polyphenols. Thus, feeding with lemon polyphenols suppressed body weight gain and body fat accumulation.

#### Other Uses of Lemon

##### A. Cosmetological application

Lemon becomes an objective of scientific studies because of lemon extract, essential oil, and active compounds obtained from the raw material. Lemon has a positive impact on acne. Products derived from lemon have a good effect on the skin because of its positive effect it is traditionally used in many parts of the world. People in Tanzania use the juice of a lemon for skin and mostly mixed the juice of the lemon with the albumin of egg and honey and apply it on the skin especially at night to make the skin smoother and to cure acne problems [31]. In Palestine,



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freshly extracted juice of the lemon is used to treat hair along with olive oil and scalp disorder [32]

The essential oil of *C. limon* is also used in the formation of shampoos, disinfectants, and toothpaste because of its flavoring and antibiotic properties [33]. Fruit extract of *C. limon* has a significant antioxidant effect that's why it is highly recommended for anti-aging cosmetics. In the process of *C. limon* extract different types of carriers are used especially hyalurosomes and glycosomes in the production technology of cosmetics as they inhibit oxidative stress for example fibroblast in the skin [34]. The ingredients present in the essential oil of *C. limon* are citral, beta-pinene, and D-limonine. The inhibiting activity of tyrosinase and L-dihydroxyphenylalanine has a depigmentation effect [35]. The essential oil supports the water-soluble vitamins, it is also used to promote the penetration of active substances through the skin. They are also used as natural preservatives [36]. *C. limon* can be used in 23 forms according to the cosmetic ingredient database. It keeps the skin in good condition and improves the odor of cosmetics and it is known as the most common activity according to the cosmetic database [36]. Use of *C. limon* essential oil is strictly forbidden in high concentrations if the skin is exposed to sunlight as the UV rays present in the sunlight can damage the skin.

#### B. *C. limon* in Food Industry

Raw material and fruit-derived from *C. limon* have a huge amount of chemical composition, they have a special role in food processing and the food industry. Lemon is processed to make jellies, jams, and juices [37]. Lemon fruit can be kept for several months their level of carbohydrates and vitamins can be maintained during storage. But during industrial processing or storage, the vitamin C content in lemon decreased. Oxygen, light, storage temperature, as well as the duration of storage, became a reason for lowering these content. To maintain the level of ascorbic acid and antioxidant properties lemon fruit/juice should be stored at 0-5 °C and water loss can be protected by packing it properly [38]. A high amount of pectin is present in the peel of *C. limon* and it is highly used in the food industry that is a jelling agent, jam, jellies, and as emulsifiers, thickener, and as stabilizer in many products especially dairy. Pectin also plays a vital role in the formation of dental and pharmaceutical products because of its jellifying properties [39].

Juice is also present in beverages as an ingredient (lemonade and soft drinks). Its juice is also used in the manufacturing of different sauces. Juice of lemon is also used to add acidic taste in foods or drinks. It lowers the

pH of foods and acts as a natural preservative. *C. limon* is free from pesticides; raw material of *C. limon* is used to enhance the flavor of liqueurs that is limoncello which is traditional liquor. It is made by soaking the peel of lemon in sugar, water, and ethanol [40]. Essential oils prepared from lemon are used as a natural preservative because of their antimicrobial and antifungal properties [41]. Sometimes they are also used in seafood products to extend the short shelf life. They reduce the production of microorganisms that's why they are used in some cheese [42].

#### Impacts of Temperature on Physiological Properties of Lemon

Many changes occur when lemon is stored for 4, 8, and 12 weeks at 24 °C. Fresh weight solid content, soluble solids, acidity, and ascorbic acid change in lemon during storage [43]. The storage also changes the peel color in lemon. Color changes at different temperatures. When the temperature is between 5°C to 20°C the peel color changes from green to yellow. When the temperature is at 5 c peel retained their green. Low storage promoted peel degreening in lemon [44]. Low temperature is also associated to the promotion of lemon ripening [45]. Lemon fruit is sensitive to chilling injury this makes it hard to store in commercial cold stores due to sensitivity for chilling and limited storage life lemon is mostly stored in the form of concentrated juice. This process increases the shelf life and also preserves fruit for off-season [46].

The chemical properties of lemon were affected by different storage temperatures and storage period. And in lemon juice tannins and browning are highly affected by storage temperature. Lemon juice is stored for 90 days at refrigeration temperature. For the storage of lemon juice, refrigeration temperature is better than room temperature. Assam lemon is one of the most important fruits of Assam. They have different storage time and temperature. Assam lemon fruit is stored at ambient temperature 30°C to 32°C. The beneficial for this variety because it extends the shelf life of this fruit without and detritions in the quality of fruit. It saves save freshness of fruit up to 1 month without any decay [47].

For safe preservation of lemon two techniques are used. Applications of low temperature and chitosan with essential oils. These methods are mostly utilized because they maintain quality. Low temperature is the main technique that extends the shelf life. It also reduces the thermal decomposition and respiration process [48]. Chitosan is a nontoxic high molecular polymer. It is an ideal compound to maintain the freshness of the product [49]. Lemon is cut

into 5- 8 mm round slices with a sharp knife. These fresh-cut slices are dipped in composite chitosan coating. After dipping, freshwater was drained out and these slices are packed. It is stored for 0 °C-0.5°C.

Vitamin c present in lemon is a highly unstable molecule present in lemon. Vitamin c is dissolved in boiling water. When juice is preserved or packed vitamin c is lost. The temperature effect is more fresh lemon. By storage, vitamin C content is a decrease in lemon juice [50]. The loss of ascorbic acid at each temperature followed a first-order kinetic model. During cold storage, fruits evolve the antioxidant mechanism for defense. It produces heat shock proteins it reduces the chilling injury. The lemon is treated with MJ and SA waxed and stored for 4.5 c. MJ and SA Convey chilling tolerance to lemon fruit [51,52].

## Conclusion

Citrus fruit juices provide an enough and important source of vitamin C for human nutrition, although only the one-fourth of the vitamin C content of lemon fruit is found in the juice. For lemon, the concentration of vitamin C in the proximity of the peel is higher than in the center of the fruit. But it is proved that the vitamin C present in C. limon has a very beneficial and significant role in the biological activities occurring in human body to maintain human health. The vitamin C of C. limon fruit is a main component that can be used in different forms in a lot biological activities and phenomenons. The physiological properties and biological activities in lemon can vary according to the variations in external environment.

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