Chapter

Citrus Fruits: Nutritive Value and Value-Added Products

Abu Saeid and Maruf Ahmed

Abstract

Citrus fruits are essential sources of food and energy and play a critical role in supplementing healthy diets. Citrus fruits contain mostly carbohydrates such as sucrose, glucose, and fructose and are good dietary fiber sources, which help prevent gastrointestinal disease and promote high circulating cholesterol. Besides, citrus fruits are also significant sources of vitamin C and various bioactive compounds. It is suggested that these components are of vital importance in improving human health due to their antioxidant properties and being converted to vitamin A. However, citrus fruit is still being used for different purposes like juice, jam, jelly, squash, pies, cake, candies, marmalades, etc. Most citrus waste materials are currently used as animal feed. Innovations are occurring in the conversion of citrus by-products into valuable commodities with the development of innovative technologies. This chapter has put up primary and secondary research findings of citrus fruits, especially lemon and pomelo, their chemical properties, composition, and their use in health and cosmetic needs.

Keywords: citrus, lemon, pomelo, nutritional properties, value-added products

1. Introduction

Citrus is an evergreen shrub that belongs to the Rutaceae family from South Asia, China, India and the Malay Archipelago, which is native to the subtropical and tropical regions of Asian regions [1]. The genus of citrus includes sweet orange (*C. sinensis*: 61.1 % of world citrus production), tangerine (*C. reticulata*: 19.9 %), limon and lime *(C. limon* and *C. aurantifolia*: 12.1 %) and grapefruit (*C. paradisi*: 5%). Minor types of citrus, which constitute much of the remaining 2.0%, include sour orange (*C. quarantium*), shaddocks (*C. grandis*), citrus (*C. medica*), which seem to be promising sources for many beneficial human nuts [2]. Citrus fruit is divided into two sections like peel and flesh (**Figure 1**). Peel is made from epicarp or flavedo (colored peripheral surface) and mesocarp or albedo (white soft middle layer). The peel (60–65%), internal tissues (30–35%), and seeds (0–10%) comprise citrus fruits [3]. Citrus fruits provide carbohydrates, such as sucrose, glucose, and fructose mostly. Fresh citrus fruits are also an immeasurable source of dietary fiber associated with gastrointestinal disease prevention and lowered circulating cholesterol. Citrus fruits also have a distinct aroma and delicious taste along with low protein and fat content.

Citrus fruits also provide the most potent source of vitamins C and B (thiamines, pyridoxines, niacins, riboflavin, pantothenic acids, and folate). The fruit also leads to the use of phytochemicals, such as carotenoids, flavonoids, and limonoids [1].

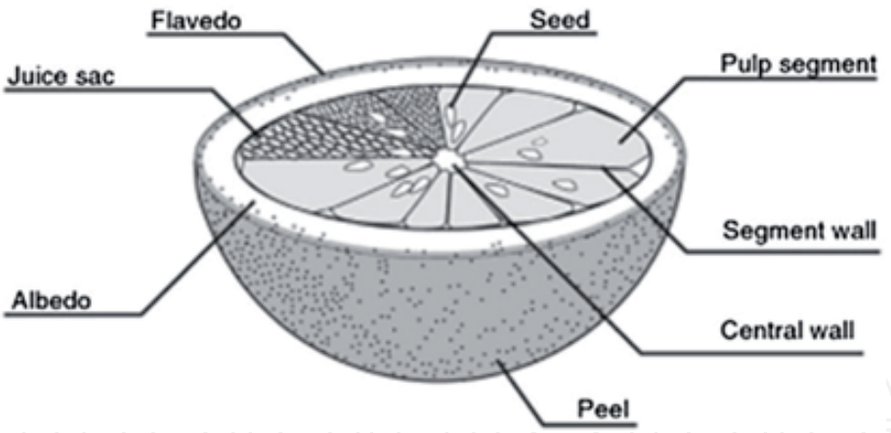

Figure 1.
Structure of the citrus fruit [2].

Citrus phytochemicals contain antibacterial, antiviral, antifungal, anti-carcinogenic, anti-thrombotic, or anti-inflammatory agents [4]. Several studies have proposed citrus fruit evaluation as a healthy and delicious diet [5]. Prior research suggested that citrus and citrus products are rich sources of vitamins, minerals, and dietary fibers [6]. However, the bioactive and non-nutrient compounds in citrus are appreciated to reduce the risk of various chronic diseases [7].

Citrus fruits are eaten as fresh goods and juice throughout the world. Peel is discarded as waste containing many secondary components with significant antioxidant activity related to other fruit portions [8]. In recent years, flavonoids such as polymethoxy flavones (PMFs), which are present in citrus fruits, have been attracted growing attention by their antioxidants [9] and anti-cancer properties [10]. Various bioactive compounds in citrus peel extract and powder may reduce overall cholesterol, triglycerides, LDL, and glucose levels [11]. Citrus by-products produce a range of value-added products, including essential oils, pectin, enzymes, single-cell collagen, natural antioxidants, ethanol, organic acids, and prebiotics. Orange, lemon, mandarin, and grapefruit contained essential oils show antifungal activity upon the fungi *A. niger*, *A. flavus, P. chrysogenum,* and *P. verrucosum*. The essential oil may be regarded as acceptable for the food industry as alternatives to chemicals [12]. Pectin extracted from *Citrus* peel is used in various industrial food processes as gelling agents, including jam, jellies, and as thickener, texturizer, emulsifier, and stabilizer in dairy products. Pectin is also used to jellify properties in the pharmaceutical, dental, and cosmetic industries [13]. Therefore, this chapter highlighted the nutritional values of major essential nutrients such as Vitamin C, carotenoids and vitamin A, Folate, Dietary fiber, flavonoids, and limonoids, as well as value-added products such as food ingredients, pectin, essential oil, enzymes, a natural antioxidant, and packaging film retrieved from citrus especially lemon and pomelo fruit.

2. Characteristics of citrus fruits (lemon and pomelo) and their chemical compositions

2.1 Lemon

Lemon (*Citrus limon L.* from Rutaceae*)* is one of the most common globally and ranks third among the Citrus species globally by 4,200,000 metric tons after orange and mandarin [14]. Lemon fruits typically consist of three parts: pulp, skins (albedo and flavedo), and seeds. It offers an extensive supply of natural compound

products such as citric acid, ascorbic acid, minerals, flavonoids and essential oils [15]. Lemon bioactive compounds like flavonoids, vitamins, minerals, dietary fiber (**Table 1**), and essential oils are used in the food, cosmetic, and pharmaceutical industries. Most by-products of the lemon juice industry can provide functional foods with nutritional substances such as non-digestible carbohydrates, dietary fiber and bioactive (flavonoids and ascorbic acid). Lemon fruits can function against photo-oxidamage because carotenoids exist. Lemon fruit, rich in flavonoids, has a significant role in the healthy diet, particularly in preventing diseases such as obesity, diabetes, lowering blood lipids, cardiovascular disease, and some forms of cancer [18]. The citrus fruits used for direct consumption or converted into juices, jam, jelly, molasses, lemoncello beverage and more in addition to the lemon skin are added value products such as pectins, essential oil and functional ingredients [12, 18].

2.2 Pomelo

Pomelo is one of the most commonly grown and eaten citrus fruits and orange, mandarin, lemon, and grapefruit [19]. Pomelo (**Table 1**) is a promising source of carbohydrates, proteins, fiber, vitamins and minerals originating in warm tropical climates in south-eastern Asia [20]. The presence of bioactive (carotenoids, lycopene,

Component	**Lemon** ***(Citrus limon)***	**Pomelo** ***(Citrus maxima)***
Moisture (g/100g)	84.2	87.0
Fiber (g/100g)	1.6	1.60
Carbohydrate (g/100g)	10.8	11.5
Protein (g/100g)	0.9	0.6
Fat (g/100g)	0.8	0.20
Vitamin (mg/100g)		
β-carotene	50.0	120
Thiamine	0.02	0.03
Riboflavin	0.01	0.03
Vitamin C	37	20.0
Mineral (mg/100g)		
Ca	70.0	10.0
Mg	12.0	21.6
Na	1.50	2.70
P	10.0	20
K	148	106
Fe	0.23	0.40
Zinc	0.12	0.15
Cu	0.20	0.19
Total phenol (mg GAE/g)	204.40	70.56
Total flavonoids (mg QUE/g)	27.50	13.06
Carotenoid (mg/100 mL)	0.31-0.35	0.72-0.73

Table 1.
Chemical composition of Citrus fruits as [15–17].

polyphenols, flavonoids, limonoids, fiber and vitamin C) contributes to their protection against oxidative stress, hyperglycemia, and high blood pressure. Due to its essential health promotion properties, pomelo segments in food products are growing in importance in producing functional foods [21]. Pomelo is eaten fresh or made into juice [19], or pomelo fortified noodles help the diabetic population [21]. On the other hand, researchers have investigated alternative ways of restoring pomelo peels to the advantage of value-added products such as pectin, essential oils, polysaccharides, phytochemicals [19]. Production of juice and consumption of fresh fruit create large quantities of agricultural waste. The main components of wet Pomelo Peel waste, like other citrus fruits, include water, cellulose and hemicellulose, soluble sugars, lipids (mainly D-limonene), and bioactive compounds (i.e., polyphenols, mostly flavonoids).

3. Nutritional values of citrus fruits

Citrus has many natural plant compounds such as vitamin C, carotenoids (some can convert to vitamin A), folic acid, flavonoids, and fiber. **Table 2** shows the amount of vitamin and mineral consumption in lemon and pomelo fruits.

3.1 Vitamin C (ascorbic acid)

Citrus is a valuable source of vitamin C. By consuming a moderate amount of citrus fruits each day, an individual can achieve 100 percent Vitamin C level. Vitamin C is an essential water-soluble vitamin essential for the body's defense [22]. It is transmitted through muscle fibers, carnitine biosynthesis, neurotransmitters, collagen, and bones because these particles connect the fibers. The immune system

	Vitamin C	Vitamin A	Folate	Fiber
Oranges	**53-88 mg**	**17 μg**	**30 μg**	**2.4 g**
Children under 9 y (%)	213-589	3-6	15-20	10-13
Persons 9+ y	59-195	2-4	8-10	6-11
Pregnant/Lactating women	44-110	2-3	5-6	8-9
Grapes	**31-61 mg**	**58 μg**	**13 μg**	**1.6 g**
Children under 9 y	125-244	12-15	7-9	6-8
Persons 9+	35-135	6-10	3-4	4-8
Pregnant/lactating women	26-76	4-8	2-3	6
Tangerines	**27-72 mg**	**46-144 μg**	**16 μg**	**1.8 g**
Children under 9	107-480	9-36	8-11	7-9
Persons 9+	30-160	5-24	4-5	5-9
Pregnant/lactating women	21-90	4-19	3-4	6
Lemons/limes	**29-61 mg**	**2-22 μg**	**11-16 μg**	**1.8-2.8 g**
Children under 9	116-407	0.4-6	4-7	11-15
Persons 9+	32-135	0.2-4	2-4	9-13
Pregnant/lactating women	24-76	0.2-3	1-2	10

Table 2.
The number of nutrients and the percent of the recommended daily allowance or adequate intake met from the consumption of 100 g of selected citrus fruit [22].

can be effectively stimulated by consuming vitamin C, which boosts white blood cells [23]. When Vitamin C is taken for pregnancy, it can decrease pre-eclampsia risk [24]. Some studies indicate that vitamin C supplementation can reduce the severity of colds symptoms or duration [23]. Anti-oxidants such as Vitamin C could reduce the risk of artery stiffening and cardiovascular diseases [25]. Above 200 mg of vitamin C daily is a healthy intake, and citrus fruits are a huge source of this vitamin. Lemon provides 37 mg of ascorbic acid per 100 g of fruit [16]. Pomelos have 52.3 mg of ascorbic acid in 100 g of the flesh [26].

3.2 Carotenoids and Vitamin A

There are many types of carotenoids, including terpenes responsible for pigments commonly found in plants, and there are about 600 carotenoids in foods and 50 in human bodies [27, 28]. The highest carotenoid levels, such as lutein, zeaxanthin, lycopene, and vitamin A, are found in fruits and vegetables, including orange and carotene. Benefits of carotenoids in foods include improving immune function, promoting bone formation, promoting eye health, and maintaining visual quality [22]. There is a large amount of data supporting that carotenoids reduce the risk of cancer, macular degeneration, cataracts, skin damage to the sun, and cardiovascular diseases [29]. Higher consumption of β-carotene is linked to a lower breast cancer risk [30]. Beta carotene, lycopene, or lutein may decrease the rate of UV-induced lipid peroxidation in human skin fibroblast cells [30]. Lutein is inversely related to colorectal cancer in both men and women [31]. The levels of lutein, zeaxanthin, β-cryptoxanthin, and β-carotene in the lemon and pomelo, were around 2.95, 0.81, 0.81 and 10.3 (μg/g, db), respectively [32]. The content of carotenoids in pummelos' peel was 0.012-0.015 mg/gdb [33].

3.3 Folate (folic acid)

Folic acid, which is a water-soluble vitamin, and its derivatives are collectively called folate or folacin. The most notable folate compounds in Citrus are the reduced 5-methyl tetrahydrofolate (monoglutamate) and polyglutamate compounds [34]. Folate plays a vital role in DNA, which is involved in homocysteine regulation and protein production primarily through the methylation transfer reactions [22]. Because there is a high DNA production during pregnancy, a folate deficiency is significantly linked to birth defects such as neural tube defects [35]. Lack of folic acid caused higher levels of homocysteine, raising heart disease and atherosclerosis [22]. Previous studies show that citrus fruits' daily consumption can help improve folate levels, which will subsequently decrease blood homocysteine (tHcy), thus reducing cardiovascular disorder and neural tube defects [36]. Citrus is a parallel source of dietary folate that can help to cover up to 10% to 20% of the recommended daily allowance of adults, children, and infants with a consumption of 100 g of citrus fruits. The consumption of citrus fruit is an easy way to obtain vitamin C and dietary folate, which is vital for absorption in the body. Lemon, a citrus fruits representative, has eleven to sixteen micrograms of Folate in 100 grams [22]. According to El-Otmani and Ait-Oubahou [37] Citrus limon contained 11mg of folic acid per 100 g of citrus.

3.4 Dietary fibre

The fiber is found in vegetables and fruits cannot be digested and absorb in the small intestine. There are two kinds of dietary fiber; soluble and insoluble fiber. Insoluble fibers are highly fermentable and connected with carbohydrate and lipid

metabolism, while soluble fibers contribute to fecal bulk and reduce transit time [34]. Although pectin, cellulose, and hemicellulose comprise the most abundant dietary fiber on the plants, they also contain only trace amounts of lignin. Pectin is citrus' primary fiber, which occurs primarily in citrus peels and rinds. Consumption of citrus fruit can contribute significant quantities of pectin in a diet. Dietary incorporation of pectin appears to affect several metabolic and digestive processes; principal interest affects glucose absorption and cholesterol level [38, 39]. There is a significant benefit in consuming citrus fruit because of its pectin content. Dietary incorporation of pectin appears to have many implications for metabolic, digestive, and health affairs. One way fiber can reduce colon cancer is by diluting and trapping the harmful chemicals in the colon from bile-absorption and bile-excretion [34]. Scientific studies have proven that fiber can help promote laxation and satiety, the uptake and reabsorption of glucose, fat, cholesterol, and bile acids, thereby lessening heart disease risk and possibly enhancing healthy intestinal microbial fermentation [40, 41]. Citrus fruits significantly reduce cholesterol levels depending on the esterification degree of fiber consumption, viscosity, and molecular mass [22]. A fiber-rich diet has a low risk of deadly chronic diseases such as diabetes, heart disease, weight, and cancer and lowers cholesterol levels and blood sugar [42]. Several epidemiological studies reported that citrus peel support reducing plasma liver cholesterol, total serum cholesterol, serum triglyceride levels, and total liver lipids [43].

3.5 Flavonoids and limonoids

Citrus pulp, peel are rich sources of flavonoids. Toh et al. [44] found that pomelo peeled (356.95 mg/QE) had higher total flavonoid content than pomelo pulp (13.06 mg/QE). Makni et al. [15] found the amount of quercetin in lemon flesh (56.16 mg Eq Quercetin/g dry weight) was higher than in peel (27.50 mg Eq Quercetin/g dry weight). Citrus fruits are also rich in flavonoids such as hesperidin, hesperetin, naringin, naringenin, diosmin, quercetin, rutin, nobiletin, tangeretin, and others [45]. Citrus flavonoids have both antioxidant and anti-inflammatory properties, and because of that, it can increase the antioxidant capacity and effect reducing cholesterol and triglycerides levels and provide more excellent bone health [22]. Preclinical studies and clinical trials demonstrated that flavonoids' effects in the forms of hesperidin and its aglycone hesperetin prevent various types of diseases, including neurological, psychiatric, and cardiovascular disorders [46]. Over the years, naringin and hesperidin are gaining attention for their great antioxidant capacity, contributing sweet flavor to foods and beverages [47]. Some known naturally occurring flavonoids have potency in defending against certain types of RNA and DNA viruses [48].

Limonoids are also known as flavonoids, which are compounds found in citrus fruits. In citrus fruits, there are two groups of limonoids: aglycones and their corresponding glucosides. Bitter taste in citrus results from limonoids present. Limoninin's most important constituents are glycosides called limonin and nomilin [22]. In animal and human cell lines, limonoids slow down the development of aggressive cancers like the pancreas, colon, stomach, and breasts. On the other hand, limonoids are also reported to reduce skin cancer in animal models. Limonoids are known for their medicinal or health beneficial effects like anti-cancer, anti-microbial and antimalarial activities [49]. Limonoids have antibacterial and antiviral effects. Some limonoids are known to stimulate the in vivo production of the detoxifying enzyme glutathione S-transferase in the liver and inhibit the formation of chemically induced tumor cells in the oral cavity, forestomach, small intestine, colon, lung, and skin of

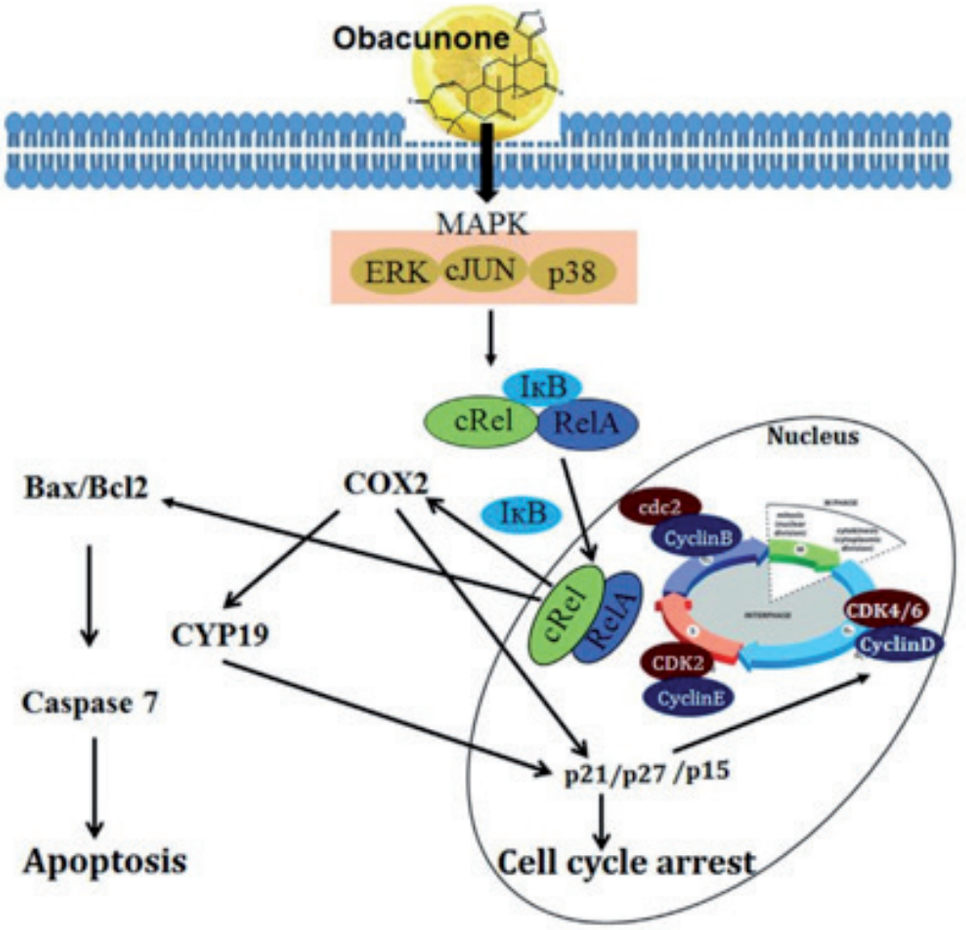

Figure 2.
Proposed model for signaling pathways leading to growth inhibition by obacunone in estrogen-responsive breast cancer (MCF-7) cells [53].

animals [50, 51]. Limonoids found in citrus fruits decreased the spread of cancer cells in animal studies [52]. Studies showed that lemon-lime oil in the form of obacunone appeared to prevent breast cancer by inhibiting aromatase enzyme and anti-inflammatory pathways [53] (**Figure 2**). Several studies have revealed that limonin and nomilin are found in fruits, pulp, and seeds. Pummelo juice contained 18 ppm of limonin and 29 ppm of total limonoid glucosides [54]. Wattanasiritham et al. [55] reported limonin content of 18 ppm in the juice of pomelo cultivars. Limonin levels in extracted juice from seven pummelo cultivars from Florida ranged from 10.07 to 29.62 ppm. As shown by analysis, mature lemon seeds contain 1300 μg/g of different limonoid glucosides on a fresh weight basis [56]. The mature seeds contain much higher amounts of glucosides than commercialized juice, therefore. Fong et al. [57] documented that the commercial lemon juice had only 82 μg/g of glucosides.

4. Value-added products

Citrus fruits are known for being highly fragrant, with a tart taste and higher vitamin C content. The world has a wider variety of citrus fruit because of the continued type changes, such as sour oranges, oranges, pummelos, lemons, and limes, among others [22]. Nowadays, citrus pulp/pomace, seed, and peel are used for various commercially valuable products such as food ingredients, pectin, essential oils, enzyme production, a natural antioxidant, and packaging film formation.

4.1 Food ingredient or food products

The nutritional supplement of pomelo fruit segments has been added to products to be developed like noodles prepared with 30% new segments and 5% dry. These noodles can satisfy those with regular diabetes and the general public [21]. A high dietary fiber food was created by reducing the dietary fiber-rich pomelo peel to a powder that contained nearly 50% of dietary fiber. Lemon fruit is usually eaten fresh, but it is also processed to make juices, jams, jellies, molasses, candies and much more [18]. Lemon juice has been used as a coagulant during the manufacture of wara cheese [58]. Another innovation implemented in the beef burger is to use lemons for "enhancing the cooking properties of the burger" [59]. Lario et al. [60] had reported that the high-fiber lemon powder extract from lemon peel debris by-products is an ideal additive for food products (as meat, dairy, and bakery products).

4.2 Pectin

Pectin is an agent of gelling, emulsifying, stabilizing, texturizing, which appears as a white to light brown powder broadly accepted as a functional ingredient [61]. Fruit peels are a highly desirable pectin source because they cover up to 20% of the fruit's total Pectin [62]. Pomelo is a highly valued source of natural Pectin. About 20.75% pectin is derived from lemon peel for jams. In the study, the high extraction (36.71%) of Pectin from lemon peel has something to contribute to this industry [63]. Moneim et al. [64] recommended utilizing 20.75% of the lemon peels' total weight in making pumpkin jam. The researchers were added 16.740% of Pectin from pomelo peel to the pressed carrots before storage [65]. Studies by Methacanon et al. [66] have shown that pectin yield was 23.19% for pomelo peel. On the other hand, Roy et al. [65] were found that pomelo peels are a good source of Pectin, and then carrot jam made by extracting Pectin from pomelo peel.

4.3 Essential oil

Essential oils (Eos) are volatile, complex, natural mixture of aromatic oils obtained from plants [67]. Citrus essential oil is commonly known to produce a good fragrance and has been officially approved for healthy public consumption. All over the world, EOs are used in cosmetics, perfumery, toiletries, flavoring, beverage, pharmaceuticals and other personal hygiene products [68–70]. Lemon oil is often used on the skin because of its antimicrobial and antifungal properties. Pomelo peel (PP) has approximately 299 recognized volatile compounds. A significant number of these volatile compounds is considered as terpenoids (189 volatiles, 63.2%). Various kinds of chemicals released are monoterpenoids, monocyclic monoterpenoids, bicyclic monoterpenoids, diterpenoids, acyclic sesquiterpenoids, monocyclic sesquiterpenoids, bicyclic sesquiterpenoids, and tricyclic sesquiterpenoids. Another major volatile present in PP EO is nonterpenoid alcohols (4.7%), nonterpenoid aldehydes (6.0%), nonterpenoid hydrocarbons (5.7%), and esters (8.7%). The unknown volatiles covered 11.7% (35 volatiles) of total volatile compounds. The structures of widely known terpenoids in Polypropylene EO has shown in **Figure 3a,b**. The most critical monoterpenoids (1 to 16) and sesquiterpenoids (17 to 29) are present in PP EO [19]. According to studies conducted, lemon essential oils retain aroma in foods because of their natural preservative and flavoring properties [71]. The effect of lemon essential oils on the cheesemaking process dramatically reduces microorganisms' population, especially those of the Enterobacteriaceae family [58]. In the food and pharmaceutical industries, citrus

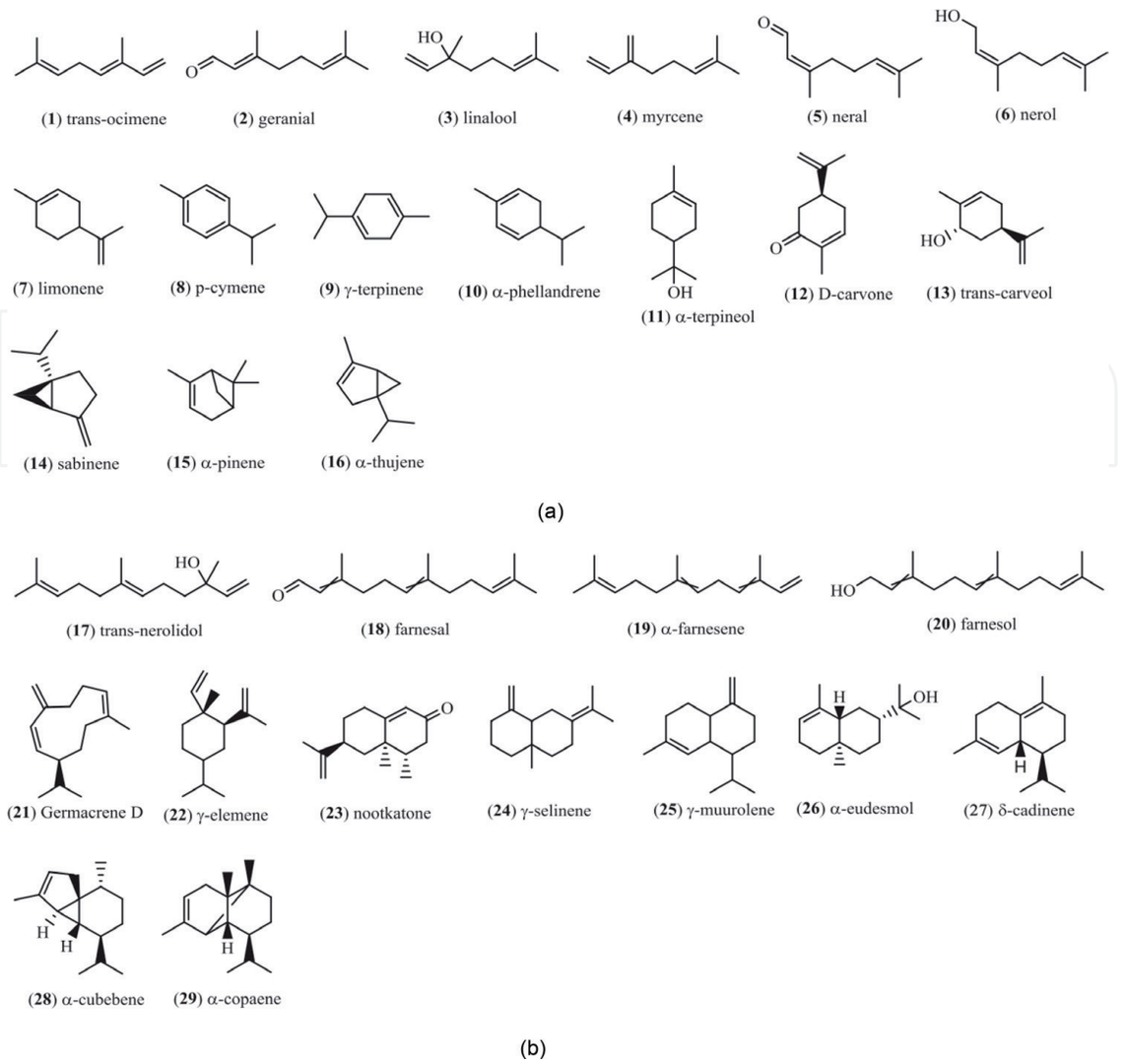

Figure 3.
*(a) Major monoterpenoids in pomelo peel essential oils (**1-16**); (b) Major sesquiterpenoids in pomelo peel essential oils (**17-29**).*

EOs can be employed to inhibit mold and fungal growth. Lemon EO (Citrus limon) was used as a possible fungicide to manage the pathogenic fungi attacking grapevines, namely Eutypa sp., Botryospaeria dothidea, and Fomitiporia mediterranea. The antifungal activity was observed for EO against all the three fungi with the highest action against strain Eutypa sp. (82% inhibition) and the lowest tolerance (33.1%) towards F. Mediterranean [72]. These essential oils repress the growth of mold and yeast. The raspberries coated with alginate and lemon EO (0.2 percent) or orange EO (0.1 percent) halted bacteria, yeast, and mold and also reduced the quality deterioration right after harvest [73]. The lemon EOs mixed in the chitosan films can be used to control L. Multicellular pathogens in refrigerated foods Researchers Rahmawati et al. [74] observed that an edible coating applied with lemon essential oil only delayed aging of tofu and fresh strawberry.

4.4 Enzymes

The most basic usage of citrus peels is to produce the pectinolytic enzyme for beneficial purposes. Larios et al. [75] studied endo-polygalacturonase production by Aspergillus sp. CH-Y-1043 using untreated lemon peel and citrus pectin as carbon sources. Lemon peel being employed as a substrate in submerged cultures to obtain high pectinase titers by A. flavipes FP-500 and A. terreus FP-370 [76].

A. niger produces approximately 2,181.23 U/L pectinases from lemon, peel pomace in a solid-state reactor [77]. Seyis and Aksoz [78] have shown that lemon pomace and peel are suitable substrates for heterotrophic xylanases enzyme production using fungus Trichoderma harzianum. Aspergillus niger LFP-1 was studied in solid-state fermentation (SSF) using pomelo (Citrus grandis) peels as a substrate [79]. Maller, et al. [80] determined that lemon peels are extremely capable of triggering the production of Polygalacturonase in the aspergillus niveus. Pectin lyase yield increased through fungal strain Aspergillus oryzae process derived from lemons peel and used in solid-state fermentations [81]. Studies said that Polemo pericarp powder utilized as a substrate for Aspergillus oryzae JMU316 has Naringinase enzyme [82]. Pectinase enzyme produced from pomelo peels by By Aspergillus niger through Solid State Fermentation [83]. Lemon peels could be a good source of naringin, which could be used as a carbon source in submerged fermentation for naringinase production using Aspergillus niger [84]. Naringinase is essential for the production of sweetener precursors, preparation of prunin, aroma enhancement in winemaking, biotransformation of antibiotics, and rhamnose manufacturing [82].

4.5 Natural antioxidant

Antioxidants are chemical substances that can reduce or prevent the damage caused by free radicals in the body, thus reducing the risks of cardiovascular disease and cancer [85]. Results of studies showed that lemon peel contained almost 75.9% of antioxidant content. The unique ability of Paneer was derived from compounds found in the Peel of orange, lemon and pomegranate [85]. Peel taken from Tambun White pomelo type contains higher levels of antioxidants and is also a rich source of natural antioxidants [44]. Lemon peel and flesh had the highest antioxidant capacity, and they had a significant impact on the prevention of cardiovascular diseases and other diseases [86].

4.6 Packaging film formation

More sustainable, biodegradable plastic has gained popularity among environmental scientists. The researcher created plastic films from citrus peels. By applying the peels of citrus, biodegradable packaging material could be made [87]. Wu et al. [88] prepared fruit peel as the edible packaging film with high content biopolymer to form film for packaging. The film was designed to incorporate tea polyphenols, which causes interacting molecules to become more closely crowded. Soy protein with essential oil of lemon peel was used to create a degradable film and create cheese curdorants for preservation [89]. Dias et al. [90] reported that the use of citrus essential oil and its aroma significantly improved consumers' health and significantly increased the acceptance of biscuits' packaging. Das et al. [91] demonstrated that chicken feather keratin combined with pomelo peel pectin to form biodegradable composite film and wrapping of fried fish fillets resulted in less weight loss, hardness value, and reduction in the surface microbial count.

5. Conclusion

Citrus has positive effects on human health, and it could be an essential raw material to the biotechnological industry. Citrus is a mighty source of vitamins, minerals, and dietary fibers. Bioactive and non-nutrient compounds in citrus are valuable for controlling chronic diseases such as diabetes, cholesterol, obesity, cardiovascular disease, and some forms of cancer. Besides citrus, vitamin C also

has other benefits, including fighting diseases such as cardiovascular disease, boosting white blood cells, immune function, and symptoms or duration of colds. Peel, flesh/pomace, and seed from the citrus fruit are employed in making different novel foods like noodles, extract pectin, enzyme extracts, and essential oil. Therefore this information might be necessary for the readers because it gives facts about the popular citrus fruit. Also, choosing the best citrus for an edible ingredient can be beneficial for citrus processors.

Author details

Abu Saeid[1] and Maruf Ahmed[2*]

1 Department of Food Engineering, NPI University of Bangladesh, Manikganj, Bangladesh

2 Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

*Address all correspondence to: maruf@hstu.ac.bd; maruffpp@gmail.com

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