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REVIEW Article

A BRIEF REVIEW ON RECENT ADVANCES OF CITRUS MAXIMA (CHAKOTA)

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ABSTRACT

A great number of epidemiological studies have shown that Citrus fruit consumption is protective in a variety of human cancers and many more diseases and Citrus maxima being the largest citrus fruit also has these medicinal properties. The present review is aimed to evaluate the cytoprotective action of *Citrus maxima* for various diseases especially cancer and it has been reported to have a broad range of therapeutic effects, including antibacterial, antiviral, antifungal, antitumor, antihelmin, analgesic, hypotensive, anti-inflammatory, and immune enhancing effects. This article summarizes external morphology of the plant including leaves, fruit and seeds. Also captured is the chemical analysis in which various chemical constituents present in the different parts of the plants. Also captured are the medicinal properties which have been used from centuries and the recent developments.

INTRODUCTION

India is well known for its Ayurvedic medicines from centuries. Ayurveda has given many herbal medicines which are very useful against Cancer, Heart diseases and many more but there are number of plants, which are not studied totally. From such plants, one of these is *Citrus maxima*. As citrus is important part of our diet including oranges, lemons, limes and grapefruits and are a principal source of important nutrients, which are suggested to be responsible for the prevention of degenerative disease. These include vitamins C, folic acid, carotenoids, dietary fibres, potassium, selenium and a wide range of phytochemicals. A great number of epidemiological studies have shown that Citrus fruit consumption is protective in a variety of human cancers and many more diseases. It is native to Asia and cultivated for utilization of its medicinal properties in many countries like Japan, Vietnam, Malaysia, Indonesia and Thailand. The fruits are a rich source of vitamin C, B1, B2, B12, protein and calcium. Decoctions of the leaves, flowers, fruits and seeds are used to treat convulsive cough, fever and gastric disorders and are also given for their sedative effects in cases of epilepsy. Citrus peels exhibit prominent antioxidant and anti-inflammatory effects. Leaves and peels contain numerous bioactive compounds such as phenolic acids, flavonoids and limonoids. Some of the compounds like limonene, citral, aldehydes, geraniol, cadinene and linalool are skin irritants which may cause dermatitis on excessive contact. [1]

Citrus maxima, the pomelo (also called pummelo or shaddock) in the Rutaceae (citrus family). Its scientific name is *Citrus maxima* because it is the largest citrus fruit. The closest in size to this king of citrus fruits is a grapefruit. *C. maxima* is considered as an easily recognized species due to a number of notable morphological characteristics, such as huge leaves borne on broadly winged petioles, very large and fragrance flowers and big fruits with a single embryo, while most of other Citrus species are polyembryonic (Uzun and Yesiloglu, 2012) [2]. Pomelos are primarily found in Southeast Asia, which is their native region, and primarily found there. It has not become widely popular in other parts of the world, because it typically takes 8 years before the seeds can begin to flower and bear fruit. Also, much of the weight and volume of pomelos is tough and inedible, while only the inner flesh is palatable. It is a medium sized tree but the largest of all Citrus species, with large leaves, flowers, and fruits. The species is native to southern China and Malaysia (and possibly other parts of Southeast Asia), and is now cultivated in many tropical and semitropical countries for its large fruits. This species was a progenitor of the grapefruit (C. X paradisi) and the tangelo (C. reticulata), among other modern citrus hybrids. Pomelos are often confused with grapefruits, from which they can generally be distinguished by their larger size, thicker rinds, milder-even sweet-flavor, and tough bitter membranes that are often considered inedible. *Citrus maxima* was originally called "shaddock" in English, after the captain of an East India Company ship who introduced it to Jamaica in 1696. Recently

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the word "pomelo" has become the more common name, although "pomelo" has historically been used for grapefruit.

Like other citrus fruits, pomelos are high in vitamin C. They are generally eaten as a fresh fruit, and they store well. They have long been popular in Asia, especially China, Indonesia, and Thailand, but are increasingly found in specialty markets in the U.S. as well. The juice is also used in various beverages (both alcoholic and non alcoholic) and the peel may be candied. Traditional medicinal uses of the fruit include treatment of coughs, fevers, and gastrointestinal disorders. The aromatic flowers are picked and processed into perfume in Vietnam, and the wood, which is heavy and hard grained, used for making tool handles.

Several recent studies have demonstrated that the cytoprotective action of citrus fruits is enhanced by the presence of antioxidants including vitamin C, phenolics, carotenoids and flavonoid. Additionally, epidemiological studies reveal a strong correlation between high levels of citrus fruit consumption and CVD risk reduction, but the mechanisms of action, particularly on endothelial cells and cardiac cells, have not been fully explored. [2]

About *Citrus maxima* plant:

Local Names [4]

Pomelo, Pommelo, Pummelo, Pompelmous, Shaddock

Common Names [4]

Burmese - Shouk-ton-oh, Kywegaw
Dutch - Pompelmoes
English - Shaddock, Pummelo, Pumelo, Chinese grapefruit, Pompelmous
Sanskrit - Madhukarkati
Hindi - Mahanimbu
Marathi - Panis, Papanas
Bengali - Betabi lebu
Assamese Robab teng
Manipuri Nobbab
Malayalam Kambili narnga
French Pamplemousse
German - Pampelmus, Pompelmus
Indonesian - Jeruk besar, Jeruk Bali
Khmer - Krôoch thlông
Lao - Sino-Tibetan
Malay - Bali lemon, Pomelo
Thai - Som-o,ma-o
Vietnamese - Bu'o'i
Transcribed Chinese - You, zhu luan
Portuguese - Jamboa

Classification [5]

Citrus maxima (Burm. f.) Merr.
Kingdom: Plantae-Plants
Subkingdom: Tracheobionta - Vascular plants
Superdivision: Spermatophyta - Seed plants
Division: Magnoliophyta - Flowering plants
Class: Magnoliopsida - Dicotyledons
Subclass: Rosidae
Order: Sapindales
Family: Rutaceae Rue family
Genus: Citrus L.Citrus
Species: *Citrus maxima* (Burm. f.) Merr.Shaddock

Biology

Pummelos may flower 2-4 times a year. In the prime-growing region in southern Thailand, fruiting is heaviest in May-October and scant in January-March and November-December. In Nepal, pummelo trees starts fruiting from September-February. In Florida, the fruits ripen from November to February and there may be a small crop in the spring. Pummelo is largely self-incompatible, and unlike other Citrus species, does not produce nucellar seedlings. Cross pollination and fertilization occur between pummelo and other species of the genus, giving it a greater range of genetic variability relative to other Citrus species. In most cases, the quality and quantity of production of pummelo is very low in farmers' fields due to inferior trees grown from seeds. The citrus species are famous for the source of essential oils. *Citrus maxima* is same as other citrus species that contain essential oil glands in their fruit peel and flower petals. [6]

Geographic Distribution

The Pomelo is native to south eastern Asia and all of Malaysia and grows wild on river banks in the Fiji and Friendly Islands. It may have been introduced into China around 100 B.C. It is much cultivated in southern China (Kwangtung, Kwangsi and Fukien Provinces) and especially in southern Thailand on the banks to the Tha Chine River. In Taiwan and southernmost Japan, southern India, Malaya, Indonesia, New Guinea and Tahiti, Pomelos are like unexpected guests that appear, say a quick hello, and then run off. In India these fruits grow from November through December, during which they come and go from the markets. Because these fruits do not grow on a large-scale commercially, those who live more than 30 miles from the nearest pummelo grove are out of luck. On occasion, pomelos are imported from overseas and thus appear in specialty grocery stores. Their appearance shouldn't be credited to local demand, but rather the growing number of Asian expats living in India. [5], [7]

Distribution: 2

The Pummelo is tropical or near-tropical and flourishes naturally at low altitudes close to the sea. On the salty mud flats, farmers dig ditches and create elevated beds of soil for planting the trees. The salt content of the water varies throughout the year but may be as high as 2.11 % at times. In Malaysia, the tree grows well on the tailings of tin mines.

Documented Species Distribution

The map below shows countries where the species has been planted. It does neither suggest that the species can be planted in every ecological zone within that country, nor that the species cannot be planted in other countries than those depicted. Since some tree species are invasive, you need to follow biosafety procedures that apply to your planting site.

Exotic range-Not found
Native range-Bangladesh, Cambodia, Chile, India, Indonesia, Japan, Laos, Malaysia, Philippines, Thailand, Vietnam. [6]

Life history and behavior

Altitude - 01300
Habit - Tree
Fruit Details - Fruit Is Modified berry known as hesperidium
Habitat - Saline mud flats and mostly cultivated
Flowering Period - April June
Fruiting Period - Oct Dec
Fruit Type - Berry
Bark Type - Rugged
Bark Details - Bark grayish brown and lenticellate
Leaf Type - Compound
Leaf Arrangement - Alternate (leaves born singly along stem)
Mean annual temperature - 25 30ºC
Mean annual rainfall - 1,500 1,800 mm
Flower Colour - White
Drought Tolerance - Low
Salinity Tolerance - Medium
Sun Tolerance - High
Wind Tolerance - High
Water-Log Tolerance - Low
pH Level - Basic
Pest Tolerance - Medium
Disease Tolerance - High
Growth Rate - Medium
Fragrance - Yes
Growth Habit - Upright/Spreading
Soil type - From its coastal habitat, it prefers the rich silt and sand overlying the organically enriched clay loam of the flood plain and highly tolerant to brackish water pushed inland by high tides. Although it tolerates a wide range of soils from coarse sand to heavy clay, pummelo prefers deep, medium-textured fertile soils free from salt. In southern Florida and the Bahamas, the trees grow and fruit modestly on oolitic limestone. [8]

Plant Description

The Pomelo tree may be 16 to 50 ft (515 m) tall, with a somewhat crooked trunk 4 to 12 in (1030 cm) thick, and low, irregular branches. The young branchlets are angular and often densely hairy, and there are usually spines on the branchlets, old limbs and the trunk. The leaves are alternate, ovate, ovate oblong, or elliptic, 2 to 8 in (520 cm) long, 3/4 to 43/4 in (212 cm) wide, leathery, dull green, glossy above, dull and minutely hairy beneath. The flowers are fragrant, borne singly or in clusters of 2 to 10 in the leaf axils, or sometimes 10 to 15 in terminal racemes 4 to 12 in (1030 cm) long with 4 to 5 petals, yellowish white, 3/5 to 1 1/3 in (1.53.5 cm) long, somewhat hairy on the outside and dotted with yellow green glands. Stamens are white, prominent, in bundles of 4 to 5, anthers orange. The fruit ranges from nearly round to oblate or ear shaped, 4 to 12 in (1030 cm) wide. The peel, clinging or more or less easily removed, may be greenish yellow or pale yellow, minutely hairy, dotted with tiny green glands, 1/2 to 3/4 in (1.252 cm). The pulp varies from greenish yellow or pale yellow to pink or red and it is divided into 11 to 18 segments, very juicy to fairly dry. The segments are easily skinned and the sacs may adhere to each other or be loosely joined.

Fig 1 Tree of *Citrus maxima*.

The flavor of the pulp varies from mildly sweet and bland to subacid or rather acid, sometimes with a faint touch of bitterness. Generally, there are only a few, large, yellowish white seeds, white inside, though some fruits may be quite seedy.

A Pomelo cross pollinated by another pummelo is apt to have numerous seeds. If it is cross-pollinated by sweet orange or mandarin orange, the progeny will not be seedy. [5]

The citrus species are famous for the source of essential oils. The *Citrus maxima* is the same as other species of citrus that contains essential oil glands in their fruit peels and flower petals. The citrus oil have strong aroma with refreshing effect. They have been used as flavouring in food, beverages and pharmaceutical products. They also have been used as fragrance in perfumes, cosmetics and aromatherapy. The citrus flower oil have relaxing and hormone balancing effect which has been used in Aromatherapy and perfumery.

In Thailand, after peeling the citrus fruit for juice and fruit pulp, the metric ton of peeled part is used for its oil as a by-product. Nowadays, there are no *Citrus maxima* essential oil available. Because the extraction of flower essential oil needs modern methodology for reducing solvent residue, impurities

and chemical transformation and increasing yield. This factors only influences on the oil quality. Therefore supercritical carbon dioxide extraction is considerable advantage over the other extraction method.

It is true that gardeners or cultivators grow *Citrus maxima* trees for their fruits and not for flowers. However after the fertilization of *Citrus maxima* flower, their petals fall down and they are allowed to wither with and no use. Then the development of *Citrus maxima* flower oil extraction is profitable for the gardener. Because the *Citrus maxima* is unique in Southeast Asia and its flower oil could generally substitute neroli that import from western countries.

Soil and Climatic Adaptation

The pummelo thrives in the lowland tropics. For commercial production, elevation not exceeding 400 masl is preferred with optimum temperature of 2530 C. It can tolerate a wide range of soils from coarse sand to heavy clay. However, it prefers deep, medium textured, fertile soils free from injurious salts; Optimum pH from 5.5 to 6.5; Annual rainfall requirement 15001800 mm. In the 3 major pummelo provinces of Thailand, the best orchards are situated on the banks of current and former river courses.

Cultural Practices

Plant Propagation

Pummelo can be propagated sexually by seed or asexually by air layering (marcotting), budding, grafting and stem cuttings. In Southeast Asia, the most common propagation method is air layering. However, when there are certified disease free mother plants, grafting and budding are recommended. In the Philippines, shield budding is the standard budding method using calamandarin rootstocks. Calamandarin is believed to be a hybrid of the calamondin (x*Citrofortunella microcarpa*) and mandarin (*Citrus reticulata*).

Land Preparation and Planting

In sloping lands and in staggered planting, the farm can be prepared by slashing of the vegetation and clearing of the immediate peripheries of the hills. Otherwise, the land should be prepared thoroughly by ploughing and harrowing. If the soil is too acidic, lime should be applied. Holes or pits are then dug about 0.5 m deep and wide.

The plant to plant spacing is 810 m x 68 m, depending on the terrain and soil fertility. This is equivalent to a population density ranging from about 125 to 208 plants per hectare. To ensure supply of nutrients, compost is applied at the bottom of the hole or mixed at about 1/3 proportion with the topsoil which will be used to refill the hole after planting. In general, planting is delayed for at least 15 days if raw manure will be used. Planting is better done during the onset of the rainy season. But it can be done anytime if rainfall is well distributed throughout the year or where there is irrigation. In Thailand, pummelos are grown on raised beds with ditches in between beds.

Watering

Watering should be done immediately after planting to ensure contact of the soil and roots and to prevent wilting. The regular supply of water is especially important before flowering and until after harvest. To force early flowering, irrigation is delayed during the dry season until the trees show signs of wilting. The wilting trees are then irrigated. To sustain new shoot growth and the development of flowers and fruits, regular supply of water is needed. A mature pummelo tree may need 100 to 200 litres water daily during dry periods.

Intercropping

Planting of intercrops like banana and areca palm on the strips between the rows of pummelo has been practiced to maximize utilization of vacant farm spaces, provide shade and protection from wind, and serve as cash crops during the juvenile stage of the main crop. Annual intercrops will also serve as cover crop.

Weeding

Just like other crops, pummelo needs regular weeding to eliminate competition for soil moisture and nutrients. The uprooted weeds can be piled around the base of the trees to serve as mulch.

Pruning

At 46 months after planting, the trees are pruned to induce branching. This is done by top pruning about 30-40 cm from the ground. 3 branches which are evenly distributed in separate horizontal directions are retained and allowed to develop.

Genetics and improvement

There has been practically no genetic improvement of pomelos. All existing cultivars were obtained from selection of chance seedlings and somatic mutations.

Fertilizing

Proper fertilization is a standard cultural practice in fruit production, especially in association with floral induction. A practice in Nakhon Prathom, Thailand is to apply 5 kg complete fertilizer per tree per year split into 6 applications or every two months. Foliar fertilizer is also applied every new flushes. In the last application before harvest, NPK combination of 131321 is used to improve fruit taste. In other parts of the country, 2 split applications are recommended, the first before flowering and the second 46 months later.

Pests and Diseases Control*:* All pests of citrus also attack the pummelo plant. These include the common leafminers (*Phyllocnistis citrella*), leaf eating caterpillars, fruit boring caterpillar (*Citripestis* sp.), scales, red mites, fruit flies, nematodes and rats. The major disease of pummelo is the bacterial canker caused by *Xanthomonas citri*. Symptoms are characterized by oily spots on the leaves and fruits which later turn brown and corky.

Control methods: include defoliation and, in severely infected plants, burning to prevent spread. Other diseases are the root rot, gummosis on the trunk and brown rot of the fruit, all of which are caused by the Phytophthora fungi. Both fruits and leaves are also infected by scab caused by *Elsinoe fawcetti*. To control fungal diseases, repeated spray of chemical fungicides is recommended. The leaves, fruits and sometimes the branches are likewise prone to sooty mold which is caused by *Capnodium citri* or *Miliola citricola*. Sooty mold can be prevented by proper insect pest control. A recent innovation to

prevent serious damage due to insect pests and diseases is the bagging of fruits.

Harvesting

The pummelos are picked at maturity which occurs about 140 to 160 days from fruit set. The dull skin of the fruit brightens upon ripening as the oil glands become more prominent and shiny. This change starts near the tip of the fruit and progresses towards the stalk.

Postharvest operations

At maturity, the color of the rind changes as the oil glands become more prominent and shiny. The fruit should be harvested immediately in order to obtain the highest quality and longest shelf life, which may be as long as several months. Having a rather thick rind, little postharvest treatment is considered necessary.

Fruiting season

The fruiting season of *Citrus maxima* is different in different regions of the world. If we talk about Vietnam, in the South, September to February (peak season November to January). In the North, August to November (peak season in October). There is some difference in cultivars with respect to fruit maturation, for example Phuc Trach (a popular cultivar of Ha Tinh province in the North), matures in August to September. And in India, These fruits grow from November through December and sometimes mid in the year.

Yield

Pomelos are potentially heavy bearers because they do not have a severe problem with pests and diseases. Normally about 70 to 100 fruits per year are expected from a five year old or older tree. This is equivalent to about 20 t/ha. [9]

Review

Leaves of Citrus maxima

Leaves, compound, appearing simple, having one leaflet, alternate, glandular, dotted, ovate to elliptical, 5-20 cm long, 2-12 cm wide and leathery. Petiole broadly winged to occasionally nearly wingless, up to 7 cm wide. [6]

Fig 2 *Citrus maxima* Leaves

Macroscopic Study of Citrus maxima Leaf: 10 to 12 matured leaves were taken for macroscopic study. Size measured is mean of ten readings (Figure 2). Leaves were evenly distributed on branches of tree.

Leaf- 15-16cm long and 5.5-6.5cm width.

1. Petiole 4-4.5 cm long (Winged) and 2.5-2.8cm width.
2. 2. Shape: Ovoid.
3. Apex: Acute.
4. Base: Asymmetrical.
5. Margin: Entire.
6. Color: Greenish.
7. Surface: Glarus.
8. Midrib: Prominent on both surfaces of leaf.
9. Odour: Characteristic.
10. Taste: Acrid

Leaf preparation for microscopy [10]: Fresh leaves were taken & boiled with chloral hydrate solution for clearing the section. Transverse section of leaf through midrib was taken & then photographs of section were taken (**Figure 3 & 4)** Following are some of the microscopic characters observed in sections;

Lamina: Leaf showed dorsiventral characteristics.

Epidermis: Lower and upper epidermis showed abundant Anisocytic stomata and uniserate, multicellular, thin walled, covering trichomes on lower epidermis. It showed single layer of palisade cells on upper epidermis.

Mesophyll: It is middle part between lower & upper epidermis of leaf. It shows the sclerenchymatous cells covering to vascular bundle. Parenchymatous cells contain calcium oxalate crystals. Collechyma cells were present in mesophyll under the vascular bundle & lower epidermis.

Starch grain and yellow colored oil globules were present.

Midrib: Vascular bundle: Vascular bundle present & showing xylem and phloem arrangement at middle of midrib.

In their research Ratna Susandarini and coworkers from Indonesia for assessment of Taxonomic Affinity for Indonesian Pummelo on the basis of Morphological characters, a total of 60 accessions were collected, including 17 accessions representing 11 commercial cultivars and 43 accessions representing landraces.

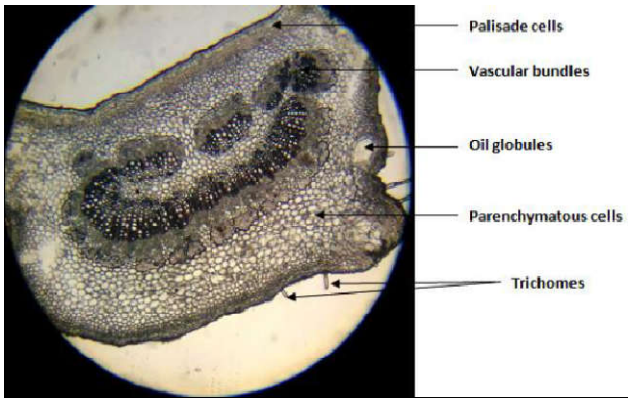

Fig 3 T. S. of *Citrus maxima* leaf without stain.

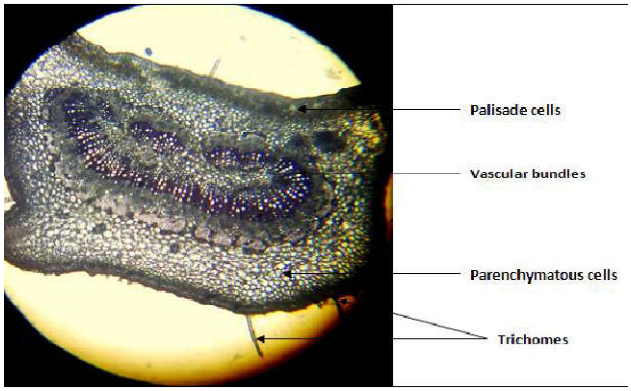

Fig 4 T.S. of *Citrus maxima* leaf with Phloroglucinol staining.

Observation on leaves morphology revealed a number of variability among accessions, including shape of leaf blade, leaf base, leaf apex, leaf margin, length of petiole, shape of petiole wing, ratio of leaf blade to petiole wing and the nature of connection between leaf blade and petiole wing. Flowers morphology varied only on their size and relative position of stamens to pistil. Fruits showed variability in their shape, apex, base, peel texture, appearance of oil glands on the peel, mesocarp color, number and arrangement of fruit segments, fruit flesh color and texture and number of seeds. Since flowers were not always available in all samples, thus the data used for subsequent analysis was consisted of morphological characters from leaves and fruits. The dendrogram constructed using UPGMA method showed that two main clusters commonly known as "Sour and Bitter Pummelo", whereas the second cluster (group B) was comprised of accessions known as "Sweet Pummelo".

Table 1 Morphological characteristics of two pummelo groups

Morphological character	Group A: Sour and Bitter Pummelo	Group B: Sweet Pummelo
Shape of petiole wing	Obcordate or obdeltate	Obovate or linear
Leaf length to petiole wing length ratio	Big (wide petiole wing)	Small (narrow petiole wing)
The nature of connection between leaf blade and petiole wing	Imbricate or valvate	Separate
Leaf margin	Crenate	Entire
Rind texture	Medium rough or rough	Smooth or medium rough
Number of seeds in fruit	Numerous	Few or medium

Each group could be recognized by combination of characters with consistently clustered accessions belonging to the corresponding group and thus combination of these characters was regarded as distinguishing characters for the group were formed. The first cluster (labeled as group A) consisted of Pummelo accessions.

The grouping of accessions resulted from cluster analysis which represented considerable degree of phenotypic variability did not show any correlation pattern to geographical origin of the samples. Members of a particular cluster were consisted of accessions from various sampling areas and thus indicated that phenotypic variability was not influenced by their habitat or other environmental factors. It was reasonable to affirm that this phenotypic variability had a genetic basis. Results of this study also suggested that leaves and fruit morphological characters provided a practical approach in distinguishing cultivar groups within pummelo and thus applicable for common people and breeders in selecting favourable cultivars. [11]

Table 2 Phytochemical screening of leaves of chakota [12]

Phytoconstituent	Test	Result
Alkaloids	Dragendorff's test	+ve
	Hager's test	+ve
	Wagner's test	+ve
Flavonoids	Shinoda test	-ve
	Lead acetate test	-ve
Phenolics	Ferric chloride test	-ve
	Folin ciocalteu test	-ve
Sterols and triterpenoids	Salkowski test	-ve
	Libermann-Buchardt test	-ve
Cardiac glycosides	Legal test	-ve
	Baljet test	-ve
Saponin glycosides	Foam test	+ve
	Lead acetate test	+ve
Anthraquinone glycosides	Borntrager test	-ve
	Modified Borntrager test	-ve
Carbohydrates	Fehling's test	+ve
	Molisch test	+ve

Phytochemical analysis showed the presence of important classes of phytoconstituents like alkaloids, saponins and carbohydrates. This indicates that this plant can be useful for treating different diseases because the therapeutic activity of a plant is due to the presence of particular class of compounds. Development of such a monograph would help in isolation of phytoconstituents, therapeutic investigations and standardization of formulations containing its leaf material. [12]

Flower Description

Flowers fragrant, borne singly or in clusters of 2-10 in the leaf axils, or sometimes 10-15 in terminal racemes, 10-30 cm long; rachis and calyx hairy; 4-5 petals, yellowish-white, 1.5-3.5 cm long, somewhat hairy on the outside and dotted with yellow-green glands. Stamens 20 25, white, prominent, in bundles of 4-5, anthers orange. Flowers are highly aromatic and used for making perfumes in Vietnam.

Fig 3 Flowers of *Citrus maxima*.

Fruit Description

This fruit is biggest among citrus family. Fruit ranges from nearly round to oblate or pear-shaped; 10-30 cm wide; the peel, clinging or more or less easily removed, may be greenish-yellow or pale-yellow, minutely hairy, dotted with tiny green glands; 1.25-2 cm thick, the albedo soft, white or pink; pulp varies from greenish-yellow or pale-yellow to pink or red; is divided into 11-18 segments, very juicy to fairly dry; the segments are easily skinned and the sacs may adhere to each other or be loosely joined; the flavour varies from mildly sweet and bland to sub-acid or rather acid, sometimes with a faint touch of bitterness. Seeds few, large, yellowish-white and white inside; though some fruits may be quite seedy. [6]

Fig 4 Unripen fruit.

Fig 5 Ripen Fruit

Its flesh is juicy, soft in texture and rich in nutrients. However, the pomelo cannot be picked immature for after-ripening because it contains little starch and is non-limacteric. The rind of the pomelo consists of the flavedo, which is green with oil glands spotted all over the fruit peel, and the albedo, which is white and has a spongy texture (Fig. 6). There are eight to nine segments containing juice sacs (flesh) which are covered with a tough skin called the lamella. At the center of each lamella, there is a core which is hollow when the fruit is ripe. Close to the core in the juice sac segments are the seeds. These parts of the fruit change texturally and physicochemically during maturation. The ripening occurs in the final phase of fruit development, and involves deep metabolic changes in the biochemistry, physiology and gene expression of the fruit in the form of chlorophyll degradation and pigment (carotenoids and anthocyanins) biosynthesis, conversion of starch to simple sugars, accumulation of flavor and cell wall softening, ethylene receptor degradation, simple sugar and organic acid accumulation, volatile oil production and flesh softening. Many of the changes have been primarily characterized in climacteric fruits, but are poorly understood in non-climacteric fruits.

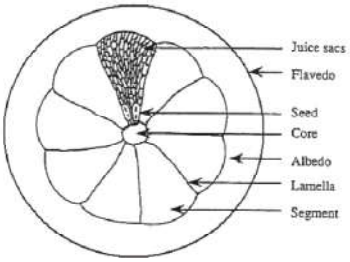

Fig 6 Schematic diagram of pomelo fruit [13]

Semi-quantitative analyses of thin sections of pummelo peel revealed a gradual transition in density between exocarp and mesocarp. Thus, structurally, the dense exocarp cannot be separated clearly from the spongy mesocarp. We hypothesize that due to this lack of an abrupt change in tissue composition and therefore in structural and mechanical properties the risk of delamination of the tissues during impact is reduced. The impact force acting on the pummelo depends on the velocity of the fruit before impact and its weight, but also on the consistency of the ground. Under natural conditions, part of the total energy is dissipated by the relatively pliable ground, as typically existing in the regions where pummelos grow naturally. In the tests presented, mechanical loads acting on the fruits were increased by dropping the fruits onto a hard ground. Thus all kinetic energy must have been dissipated by the fruits themselves. The mesocarp with its air filled intercellular spaces represents a compressible foam. As the Young's modulus of this spongy part of the peel is rather low, we conclude that its ability to dissipate large amounts of energy must result from the structural composition of the peel. [14]

Checking for Ripeness in Pomelo

Many delicious pummelos have green skin while others have a burnt yellow appearance. The range of the fruit's colorful exteriors means that the skin color should not be used as a

baseline. Pick pummelos that feel heavy for their size, are firm, smooth and shiny. Avoid fruit with marks, coarse or wrinkly skin, and soft spots. The thinner rind fruits often contain the most flesh, especially those practically emitting citrus oil while in the hand. A good chakota is also aromatic near the stem.

Pomelos have the taste of grapefruit without the bitterness and acidity, coupled with gorgeous floral overtones and a clean taste. The texture is fleshy and has more membrane than many other types of citrus; A bad pummelo is marked by dry, desiccated flesh with little juice.

There are actually three types of the pomelo;

White Pomelo: Belonging to the Citrus Grand family; the Israeli variety of the Pomelo is actually an exclusively huge fruit, described as huge juice saccules, extremely thicker peel, sweet pulp as well as exclusive odour. White pomelo is usually offered as treat which will help in the digestion of food. The Pomelo is collected in between mid-October as well as mid-May

Fig 7 White Pomelo

Red Pomelo: Red pomelo has got softer as well as thinner-skinned variety.

Fig 8 Red Pomelo.

The Red Pomelo is good, tangy, as well as sour, compact along with pink pulp with a little more compacted design. This massive citrus fruit, abundant with vitamin C as well as potassium, is really an indigenous of Malaysia and is also thought to be the ancestor of the grape fruit. The Israeli-grown Red Pomelo ripens in between September as well as January.

Pink Pomelo: Pink pomelo consists of numerous seeds and is also sweet as well as juicy. The pink pomelo can also be regarded as the remedy for stomach or even the intestinal worms.

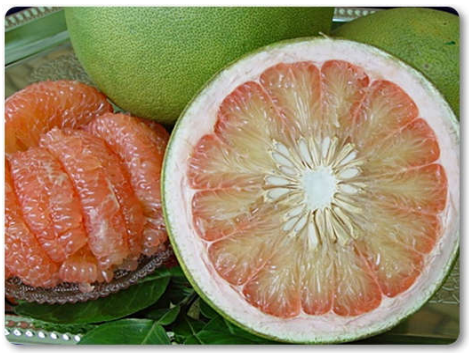

Fig 9 Pink Pomelo.

Nutritional values of C.maxima

Malnutrition problem is a matter of great concern in developing countries. Health profile of a community is greatly influenced by its nutritional status and life style. India is one of the developing countries of the world, where aforesaid problem is very common, especially in villages. Nutritionist have raised concern on the nutritive value of cooking food because density of the most nutrients like protein, carbohydrates, vitamins and mineral are very poor. Fruits have been included in the human diet since prehistoric time and now in the western and developing countries, there is a habit to take fresh fruits after meal. Fruits are major source of above mentioned food supplements. *Citrus* is primarily valued for the fruits, which is either eaten alone as fresh fruit, processed into juice, or added to dishes and beverages. All species have traditional medicinal value.

The *Citrus* is rich source of Vitamin C. Its juice also contains carbohydrates, proteins, amino acids, phenolic compounds and minerals etc. Sometimes, after starvation of serious diseases, doctors suggest to take some *Citrus* fruits for vitamins, minerals and other necessary food supplements, which recover weak health condition by improving appetite quickly. Fruits and vegetables are rich source of secondary metabolites such as phenolics which are now identified as natural antioxidant agents. Phenolic compounds have been shown to possess an antioxidant activity based on their (hydroxyl group) donation to free radicals.

Table 3 Various nutritional constituents present in fruit juice of *Citrus maxima* [15]

S. No.	Constituent	***Citrus maxima*** (mg/100 ml)
1.	Total Soluble Sugar	4.87 ± 0.09
2.	Total RNA & Pentose Sugar	59.60 ± 6.33
3.	Total Free Amino Acids	5.30 ± 0.07
4.	Total Soluble Proteins	60.51 ± 3.42
5.	Total Phenolic compounds	16.08 ± 0.65
6.	Total Vitamin C	55.25 ± 4.71

Table 4 Nutritional value of fruit juice of *Citrus maxima* [16]

Nutritional value per 100 g (3.5 oz)		
Energy	159 kJ (38 kcal)	
Carbohydrates	9.62 g	
Dietary fiber	1 g	
Fat	0.04 g	
Protein	0.76 g	
Vitamins		
Thiamine (B1)	0.034 mg	(3%)
Riboflavin (B2)	0.027 mg	(2%)
Niacin (B3)	0.22 mg	(1%)
Vitamin B6	0.036 mg	(3%)
Vitamin C	61 mg	(73%)
Trace metals		
Iron	0.11 mg	(1%)
Magnesium	6 mg	(2%)
Manganese	0.017 mg	(1%)
Phosphorus	17 mg	(2%)
Potassium	216 mg	(5%)
Sodium	1 mg	0.00
Zinc	0.08 mg	(1%)

Peel of *Citrus maxima*

Peels were separated from fruits and dried in tray drier. Peel powder was stored in air tight container at room temperature. 25 g of powdered peel was extracted with methanol using soxhlet extractor till complete exhaustion. Extract was concentrated using rotary vacuum evaporator at 40 °C and stored in the vacuum desiccator.

Fig 10 Peel of Pomelo

Pharmacognostic studies

In their study, Aruna Jadhav and her coworkers from Navi Mumbai of Microscopical, Physicochemical and Phytochemical screening of *Citrus maxima* peel made detailed analysis of *C.maxima* fruit peel. [17]

Macroscopic and Microscopic characteristics *Citrus maxima* fruit is mature hesperidium fleshy indehiscent approximately 7.9 cm in diameter, spherical in shape. Outer surface of fresh peel is greenish yellow in color and turns to brownish yellow when dried. Inner surface of fresh peel is white and turns to brownish when dried. Fresh peel has strong aromatic odour while dried peel is less aromatic. Taste is sour and bitter. T.S. of peel shows layer of small epidermis with characteristic stomata (Figure 11 and 12). Next is a zone of parenchyma, composed of loosely packed thin-walled cells. These cells contain prismatic crystals of calcium oxalate (Figure 13). Scattered in parenchyma are large oil glands and xylem vessels with spiral thickening (Figure 14 and 15)

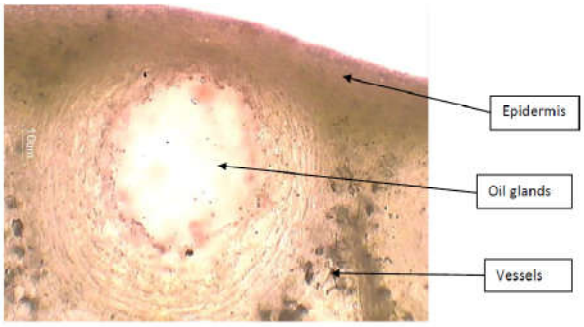

Fig 11 T.S. of *Citrus maxima* peel stained with solution of sudan red.

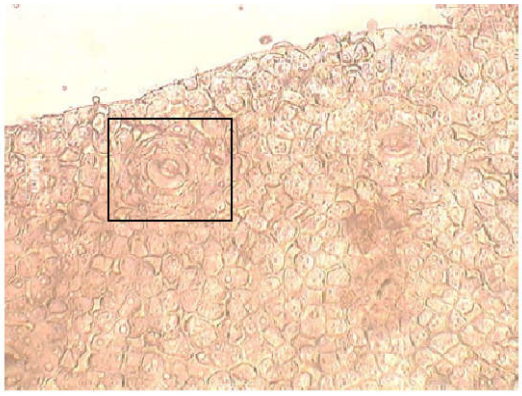

Fig 12 Stomata

Fig 13 Calcium Oxalate Crystal

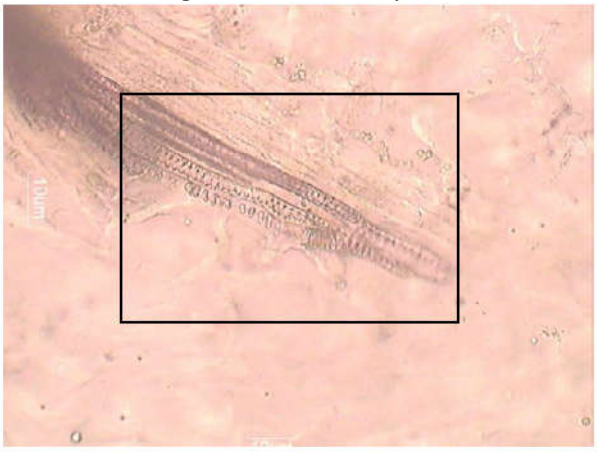

Fig 14 Spiral Vessels

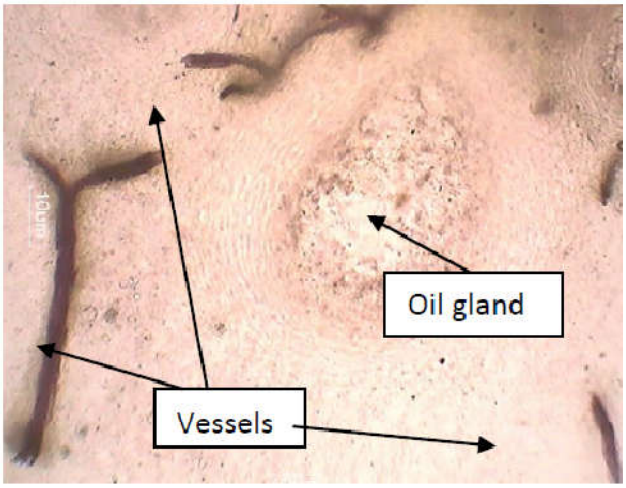

Fig 15 T.S. of *Citrus maxima* peel.

Powdered peel shows presence of epidermis with stomata, xylem vessels and calcium oxalate prisms.

Physicochemical analysis The physical constant evaluation of the drugs is an important parameter in detecting adulteration or improper handling of drugs. Physicochemical characterization of peel powder of *Citrus maxima* is shown in Table 5

Table 5 Physicochemical parameters of *Citrus maxima* peels [17]

Parameters	Values
Total ash	3.17 % w/w
Acid insoluble ash	0.83 % w/w
Water soluble ash	0.67 % w/w
Alcohol soluble extractive	29.24 % w/w
Water soluble extractive	10.25 % w/w

Preliminary Phytochemical analysis The results of qualitative phytochemical analysis of the methanolic extract of pomelo peel are shown in Table 6. Peel had maximum flavonoids and steroids while saponins and tannis were in less amount.

Table 6 Qualitative phytochemical analysis of *Citrus maxima* peel [17]

Phytochemical	Methanolic extract
Flavonoids	+ ve
Alkaloids	+ ve
Steroids	+ ve
Tannins and Phenolic compounds	+ ve
Saponins	+ ve
Anthraquinones glycosides	+ ve
Cardiac glycosides	+ ve
Coumarin and Coumarin glycosides	+ ve
Proteins	- ve
Amino acids	- ve
Carbohydrates	+ ve
Fats and Oils	+ ve

The preliminary phytochemical screening of *Citrus maxima* peels indicated that the plant possesses medicinally important phytochemicals hence can be employed as herbal medicine for primary health care needs as the conventional chemical drugs have many side effects. This study could be useful to establish the authenticity of this medicinally useful plant.

Chemical Constitution of Citrus maxima [18]

There are plenty of reports about the constituents in the different parts of C. maxima including alkaloids, amino acids, benzenoids, carbohydrates, carotenoids, coumairns, flavonoids, mooterpenes, sesquiterpenes and steroids.

Fig 16 Products of Pomelo.

Class	Compound	Plant part
Alkaloids		
	5-hydroxyacronycine	root bark, stem bark
	acriginine A	root
	atalafoline	stem bark
	baiyumine A	root bark
	baiyumine B	root bark
	Buntanbismine	stem bark
	Buntanine	root bark, stem bark
	Buntanmine	stem bark
	citbismine A	root
	citbismine B	root
	citbismine C	root
	citbismine E	root
	citpressine I	root bark, stem bark
	citracridone I	root bark, stem bark
	citracridone II	root bark
	citropone A	root bark
	citropone B	root bark
	citrusinine	root bark
	Geibalansine	stem bark
	glycocitrine I	root bark
	grandisine I	root bark
	grandisine II	root bark
	grandisine III	root
	Grandisinine	root bark, stem bark
	Honyumine	root bark, stem bark
	natsucitrine II	root bark
	Prenylcitpressine	root bark
	Preskimmianine	root bark
	Pumiline	root bark
	Caffeine	flower
Amino acids		
	Alanine	leaf
	Asparagine	leaf
	aspartic acid	leaf
	Coline	leaf
	glutamic acid	leaf
	Glycine	leaf
	Proline	leaf
Benzenoids		
	Crenulatin	root bark, stem bark
	Diphenylamine	fruit juice, flavedo
	n-methylanthranilate	leaf
	p-hydroquinone	root bark
Carbohydrates		
	phytol	leaf
	synephrine	peel
	methyl antranilate	flower (essential oil)
	fructose	leaf
	glucose	leaf, fruit peel
	pectin	peel
Carotenoids		
	carotene	peel
	roseoside	peel
Coumarins		
	5-geranoxy-7-methoxy-coumarin	peel
	5-methoxy seselin	root bark, stem bark
	5-methyltoddanol	stem bark
	6-hydroxy-methylherniarin	stem bark
	aurapten	peel
	auraptene	peel
	bergamottin	peel
	bergapten	peel
	buntansin A	stem bark
	buntansin B	stem bark
	buntansin C	stem bark
	cedrelopsin	root bark
	(Z)-isokhellactone	stem bark
	citrubuntin	root bark, stem bark
	clausarin	root bark
	honyudisin	root bark
	isoimperatorin	peel

Class	Compound	Plant part
	isomeranzin	peel
	meranzin	flavedo
	meranzin hydrate	flavedo
	nordentatin	root bark
	osthole	root bark
	pranferin	peel
	scopoletin	root bark, stem bark
	suberenone	stem bark
	suberosin	root bark
	thamnosin	root bark
	thamnosmonin	stem bark
	umbelliferone	root and stem bark, peel
	xanthotoxol	peel
	xanthoxyletin	root bark, stem bark
	xanthyletin	root bark, stem bark
Class	Compound	Plant part
Flavonoids		
	4'-5-7-8-tetramehoxy flavone	peel
	acacetin	leaf
	apigenin trimethyl ether	peel
	cosmosiin	leaf
	diosmetin	flavedo
	diosmin	flavedo, fruit juice
	eriocitrin	albedo
	hespeidin	peel, fruit juice
	honyucitrin	root bark
	isosinensetin	peel
	luteolin	fruit juice, peel, leaf
	naringenin	peel, leaf
	naringin	fruit juice, peel, leaf
	naringin glucoside	flavedo, albedo
	narirutin	fruit juice, peel, leaf
	neodiosmin	fruit juice, peel
	neoeriocitrin	fruit juice, peel, leaf
	neohesperidin	fruit juice, peel, leaf
	neoponcirin	fruit juice, peel
	nobiletin	peel
	poncirin	albedo, leaf
	quercetin	fruit juice
	rhoifolin	fruit juice, peel, leaf
	rutin	peel, leaf
	sinensetin	fruit juice, peel
	tangeretin	peel
Monoterpenes		
	α-pinene	peel, flower, leaf
	α-terpineol	peel
	anethole	peel
	β-pinene	peel, leaf
	camphene	peel, flower
	camphor	flower
	citral	peel, flower, leaf
	citronellal	leaf
	citronellol	peel
	farnesol	peel, flower
	geraniol	peel
	geraniol acetate	peel, leaf
	limonene	peel, flower, leaf
	linalool	peel, flower, leaf
	linalyl acetate	leaf
	myrcene	leaf
	neral	peel, flower, leaf
	perilla aldehyde	peel
	terpinene	peel
Class	Compound	Plant part
Sesquiterpenes		
	α-bisabolol	peel
	α-cadinene	peel
	α-copaene	peel
	α-cubebene	peel
	β-caryophyllene	peel, flower, leaf
	β-copaene	peel
	β-cubenene	peel
	β-elemene	peel
	δ-cadinene	peel

	elemol	peel
	α-humelene	peel
	nerolidol	peel, flower
	nootkatone	peel
	valencene	peel
Triterpenes		
	deacetynomilin	seed
	deoxylimonin	seed, fruit pulp
	limonin	peel, leaf, seed, fruit pulp and juice
	nomilin	peel, leaf, seed, fruit pulp
	nomilin glucoside	peel
	nomilinic acid	seed
	obacunone	leaf, seed, fruit pulp
	obacunone glucoside	seed
Steroids		
	β-sitosterol	peel, root
	campesterol	peel
	daucosterol	peel
	stigmasterol	root
Miscellaneous		
	α -tocopheral	peel
	ascorbic acid	fruit juice
	chlorophylls	peel
	decan-1-al	peel
	decyl acetate	peel
	dodecyl acetate	peel
	fumaric acid	leaf
	malonic acid	leaf
	nonan-1-al	peel
	nonyl acetate	peel
	octan-1-al	peel
	octyl acetate	peel
	oxalic acid	leaf
	succinic acid	leaf
	tartaric acid	leaf
	2-dodecenal	peel
	citric acid	fruit juice, peel
	decanoic acid	peel
	heptyl acetate	peel

Biological activities of C. maxima

As they are the secondary metabolites, essential oils have been known as the protective compound of plants. They have lots of bioactivities, especially antioxidant and antimicrobial activites. Thus, they are used in skin care products for perfuming and aromatherapy purposes. There have been a plenty of researches on biological activities, since the anti-microbial has been the common activity found in essential oils from plants.

Aimee Sheree A. Barrion and her coworkers from Philippines had tested the antioxidant and antibacterial activities of the phytochemical constituents of the pericarp, mesocarp and segment membrane. Crude ethanolic extracts of Pummelo (*Citrus maxima* (*Burm.*)) fruit were tested against *Escherichia coli* and *Salmonella typhimurium*. Preliminary phytochemical test revealed the presence of phenols, tannins, saponins expressed as catechine equivalent (CE)/100ml and flavonoid expressed as gallic acid equivalent (GAE)/100ml. The order of which was as follows pericarp > segment membrane > mesocarp. The strongest antioxidant activity was obtained by the pericarp extract (29.64 expressed as % lipid peroxidation). The differences in the measured amount of phytochemicals and antioxidant activity among the three sample extracts were found to be significant. In terms of antimicrobial activity, the pericarp, mesocarp and segment membrane extracts generated zone of inhibitions measuring 17.10, 18.00 and 17.03 mm for *S. typhimurium*, respectively at 100% concentration. *E. coli* was noted to be inactive in all three sample extracts at 100% concentration. The capacity of *E. coli* to counteract the inhibitory effect of the phytochemicals contained in the pummelo extracts may be attributed to its rough corrugated cell

Table 8 Biological activities of C. maxima [18]

Acitvity	Part	Sample	Methods	Concentration	Result
Antibacterial	Peel	Essential Oil *Staphylococcus aureus* *Pseudomonas aeruginosa*	Agar plates	20.0 µl/agar disc	Active
	Peel	Essential Oil *Esherichia coli* *Shigella dysenteriae* *Vibrio cholera*	Agar plates	20.0 µl/agar disc	Inactive
	Peel	EtOH extract *Esherichia coli* *Pseudomonas aeruginosa* *Staphylococcus aureus*	Agar plates	20.0 µl/agar disc	Inactive
Antifungal	Peel	Essential Oil *Trichophyton mentagrophytes* *Microsporum audounil*	Agar plates	MIC 500.0 ppm	Active
	Peel	Essential Oil *Alternaria solan* *Curvularia luna* *Fusarium equiseti* *Macrophomina phaseolina*	Agar plates	N/S	Inactive
Antiyeast	Peel	EtOH extract Candida albicans	Agar plates	30.0 µl/agar disc	Inactive
Antioxidant	Peel	Essential Oil	DPPH	N/S	Active
	Peel	70% EtOH extract	Inhibition of lipid peroxidase	N/S	Active
Larvicidal	Peel	Essential Oil mosquito larvae. Culex quinquefasciatus Culex tritaeniorhynchus Aedes aegypti	Against	0.02 ml/L	Active
Smooth muscle relaxation	Peel	50% EtOH extract	Cell culture of intestine	250.0 µg/ml	Active
Uterine relaxation	Peel	50% EtOH extract	Cell culture of uterus (non-pregnant)	250.0 µg/ml	Active
Capillary Permeability	Peel	50% EtOH extract	Cell culture	5.0 µg/ml	Increase
Inotropic effect	Peel	50% EtOH extract	Cell culture of uterus (non-pregnant)	1.0 µg/ml	Active
Platelet aggregation inhibition	Peel	50% EtOH extract	Cell culture	5.0 µg/ml	Increase

N/S : Not Stated
EtOH : ethanol
MIC : minimum inhibitory concentration
DPPH : 2,2-diphenyl-1-picrylhydrazyl

wall and thick periplasmic space as opposed to the smooth curved and barely seen periplasmic space of *S. typhimurium*. [19]

Table 9 Phytochemical composition and antioxidant activity of Citrus maxima (Burm.) Merr. fruit portion extracts.[19]

Extract Sample	Total Phenol mg CE/100ml	Tannins mg CE/100ml	Flavonoids mg GAE/100ml	Saponins mg CE/100ml	Anti-oxidant activity % LP	Alka-Loids	Terpe-Noids
Pericarp	25.71[a]	40.47[a]	31.48[a]	345.39[a]	29.64[c]	Positive	Positive
Mesocarp	13.94[c]	7.94[c]	11.65[c]	79.03[c]	75.95[a]	Negative	Positive
Segment Membrane	18.46[b]	21.02[b]	20.17[b]	147.93[b]	71.54[b]	Positive	Positive

Table 10 Zone of inhibition (diameter in mm) of Citrus maxima (Burm.) Merr. fruit portion extracts against E. coli and S. typhimurium.[19]

Conc. (%)	E. coli					S. typhimurium				
	Different Pummelo Extracts			Control		Different Pummelo Extracts			Control	
	Pericarp	Mesocarp	Segment Membrane	+*	−**	Pericarp	Mesocarp	Segment Membrane	+*	−**
10	0	0	0	26.70	0	8.10ac	8.13b	8.10c	28.06	0
30	0	0	0			8.17a	8.16ab	7.95b		
50	0	0	0			8.23a	8.23ab	8.17c		
100	0	0	0			17.10ac	18.00b	17.03c		

Essential oil from Citrus spp

Natural flavors and fragrances are the odoriferous principles found in various parts of the plant including the seeds, roots, wood, bark, leaves, flower, fruits, balsam and resin. They are called essential oils because they represent the characteristics essence of the origin. The responsible chemical for the flavour or aroma are organoleptic compounds, which affect the sense organs. They are present in their sources at various concentration levels ranging from part per billion to part per hundred. These compounds have molecular weights normally below 300 amu and are relatively volatile.

Essential oils or aroma chemicals differ in their chemical constitutions, but they have some common characteristic physical properties, such as refractive index, optical activity, immiscibility with water, and sufficient solubility to impart aroma to water. They are soluble in ether, alcohol, organic solvents, as well as supercritical carbon dioxide.

Essential oils are volatile oils that differ from nonvolatile fixed oils, i.e., glycerides of fatty acids. These essential oils can be classified into:

1. Acyclic monoterpene hydrocarbons such as myrcene and ocimene.
2. Cyclic monoterpene hydrocarbons such as p-cymene, pinene and sabinene.
3. Acyclic oxygenated monoterpenes such as farnesol, linalool and neral.
4. Cyclic oxygenated monoterpenes such as terpineol and geraniol.
5. Acyclic sesquiterpene hydrocarbons such as farnesene
6. Cyclic sesquiterpene hydrocarbons such as copaene and humulene.
7. Acyclic oxygenated sesquiterpenes such as nerolidol.
8. Cyclic oxygenated sesquiterpenes such as nootkatone and spathulenol.
9. Aromatic compounds such as indole.
10. Long chain hydrocarbons such as tetradecanal and dodecanal.

Terpene hydrocarbons (monoterpenes and sesquiterpenes) are the hydrocarbons derived from isoprene unit (2-methyl butadiene) having molecular formular of $(C_5H_8)_n$ (monoterpene hydrocarbons contain n = 2 and sesquiterpene hydrocarbon contain n=3). They are the unsaturated compounds that can decompose by hydrolysis or photolysis and change to the other compounds. The odour and taste of essential oils are mainly determined by these oxygenated constituents, which to some extent are soluble in water, and most of them are soluble in alcohol.

The essential oils from *Citrus* spp. (fruit peel, leaf and flower) are well known as the perfumery and flavouring agent from natural source and have been produced in metric tons per year. The quality of Citrus essential oils obviously depends on a large extent of factors deriving from the nature itself (provenance, type of soil, climate, Citrus variety), but the processing of raw material also has a significant effect. Since the fragrance of an essential oil is directly related to the content of aldehydes and esters, then extraction technique is very important. In order to produce Citrus oil with a high aldehyde content, the amount of water used in the procedures should be reduced to the minimum as necessary. The chemical transformations of Citrus oil which may occur during the distillation method, by subject to high temperatures (95-105 °C) for long periods of time (6-12 hours) in a very acidic environment (pH 2.2-2.4) can modify the Citrus oil in its composition:

aldehyde content (neral, geranial) and sabinene almost disappear, otherwise, 1,4- and 1,8-cineole, terpinolene, α-terpineol and *p*-cymene are formed.

Physical and chemical characteristics

Physical values and Infrared spectra (IR spectra) of SCP, CP, VP, SC-f and neroli were shown in Table. The density and refractive index of *C. maxima* peel and flower oils and neroli were close to each other. Their density was around 0.8433-0.9445 g/ml and their refractive index was about 1.4622-1.4685. Their optical rotation vary from +6.975 to +9.369. From the values of density, optical rotation and refractive index and the IR spectrums of all kind of oils that were very close to each other meant that the chemical components in the oils might be nearly the same, but different in proportion.

Table 11 Physical properties of essential oils from C. maxima peel and flower, and neroli [18]

Properties	SCP	CP	VP	SC-f	Neroli
Density (gm/ml)	0.8803	0.8881	0.8433	0.85	0.9445
Optical rotation [α]D	6.975	7.821	9.369	6.975	0.875
Refractive index [n]D	1.4667	1.4622	1.4685	1.4632	1.4647
Appearance	clear solution	clear solution	clear solution	clear solution	clear solution
Color	dark-green	dark-green	no color	yellow	Yellow

Table 12 Classification of the chemical compositions of C. maxima peel and flower essential oils and neroli [18]

Compounds group	Compounds name
Acyclic monoterpene hydrocarbons	(Z)-β-ocimene
	(E)-β-ocimene myrcene
Cyclic monoterpene hydrocarbons	p-cymene
	α -(-)-pinene
	β-(+)-pinene
	α -phellandrene
	Terpinolene
	α –thujene
	Camphene
	γ-terpinene
	R-(+)-limonene sabinene
Acyclic oxygenated monoterpenes	(E,E)-farnesol
	(E,Z)-farnesol
	(Z, E)-farnesol
	(Z,Z)-farnesol
	citronellol
	Linalool
	Nerol
	Citronellal
	Geranial
	Neral
	dihydrolinalyl acetate
	neryl acetate
	geranyl acetate
	geranyl formate
	linalyl acetate
Cyclic oxygenated monoterpenes	α -terpineol
	(Z)-(+)-carveol
	(E)-(+)-carveol
	γ -terpineol
	Geraniol
	terpinen-4-ol
	perilla aldehyde
	α -terpinyl acetate
	(Z)-limonene oxide
	(E)-limonene oxide
	(Z)-(-)-linalool oxide
	(E)-(+)-linalool oxide
	(E)-sabinene hydrate
Acyclic sesquiterpene hydrocarbons	(E,E)- α –farnesene
Cyclic sesquiterpene hydrocarbons	α -copaene
	β-copaene
	α -(-)-cubebene
	β-(-)-cubebene
	α -humulene
	α -(-)-selinene
	β-(+)-selinene
	δ-(+)-cadinene
	β-(-)-elemene
	δ-elemene
	γ -(+)-elemene
	bicyclogermacrene
	germacrene B
	germacrene D
	β-caryophyllene
Acyclic oxygenated sesquiterpenes	(E)-nerolidol
Cyclic oxygenated sesquiterpenes	germacrene D-4-ol
	(+)-spathulenol
	(+)-nootkatone
	caryophyllene oxide
Aromatic compounds	phenyl ethyl alcohol
	methyl anthanilate
	methyl benzoate
	2-(formylamino)-bezoate
	Indole
Long chain hydrocarbons	3,7-dimethyl-1,5-octadien-3,7-diol
	3,7-dimethyl-2,6-octadien-1-ol
	dodecanal
	n-decanal
	tetradecanal
Miscellaneous	unknowns

Hybrids of Citrus

This is a summary picture of the current hypotheses of the relationships of the most common species and hybrids of *Citrus*:

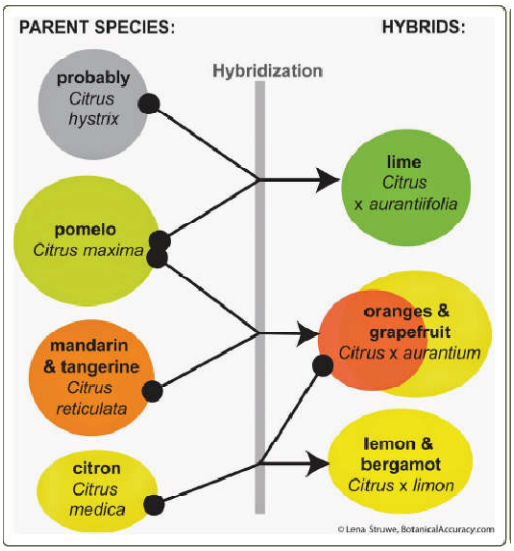

Fig 17 Origins and scientific names for the most commonly cultivated citrus fruits [20]

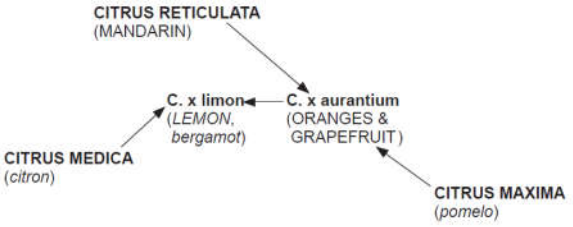

Fig 18 The origins of oranges, grapefruit, lemons and bergamot [20]

Medicinal Properties of Citrus maxima

Medicine: Medicinally, decoctions of the leaves, flowers, fruits and seeds have properties, which can treat coughs, fevers and gastric disorders in the Philippines and Southeast Asia. Fruit has alkalizing effect on blood, is a purgative, antibacterial and cleansing agent.

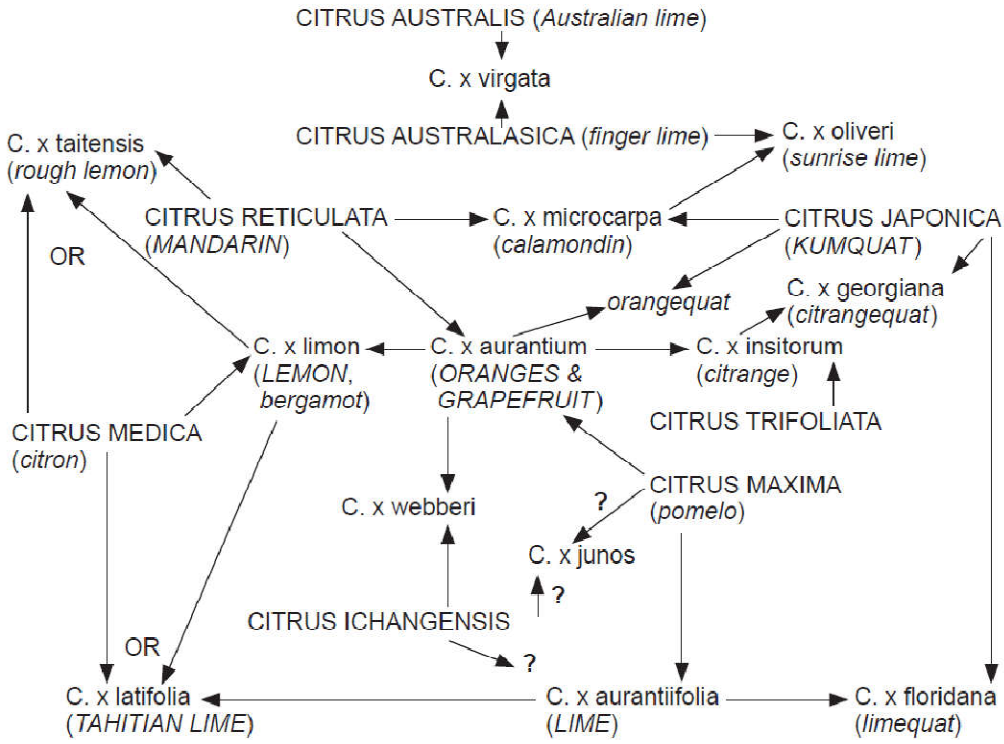

Fig 19 The relationship of commercially significant fruits and their wild allies as revealed through hybridisation and molecular analysis. Name of the parental, apparently, truly wild species in roman block capitals, those of significant crop plants in italic block capitals. [21]

The leaves are used for medicinal infusions. Decoctions of leaves, flowers and rind are given for their sedative effects in cases of epilepsy, chorea and convulsive coughing. The hot leaf decoction is administered on swellings and ulcers and fruit juice as febrifuge. The seeds are used against coughs, dyspepsia and lumbago while gum exudes remedies for cough in Brazil. The rind has pectin used in ointments/paste for burns. [6]

Prevent Cancer

The rind of pomelo is rich in bioflavonoid. Studies have shown that bioflavonoid in the fruit eliminates extra estrogen in the body and halts breast cancer cells from spreading. Pomelo rind is commonly used in Chinese cooking to add flavor to dishes. And the anticancer property of plant extracts were analysed using HeLa cell line. The results of leaf and fruit peel extracts of *C.maxima* may be helpful to develop nutraceutical product for cancer prevention. [22]

Fight Cold and Flu

Pummelo is an excellent source of vitamin C, supplying 193% of RDA. This potent antioxidant vitamin helps improve the body's immune system to protect it from common cold and influenza.

Assist in Weight Loss

Pommelo contains loads of dietary fibre. Foods high in dietary fibre make you feel full longer and require more chewing time, thereby able to reduce the intake of food. The fat burning enzyme in the fruit also promotes food absorption and lowers the starch and sugar in the body.

Reduce Blood Pressure Levels

Like banana, avocado and guava, pomelo has a good amount of potassium. This essential mineral plays an important role to regulate blood pressure levels and therefore beneficial to people with hypertension.

Get Rid of Arterial Deposits

Abundant with pectin, pummel juice is capable of clearing the arterial deposits accumulated in the body, thereby reducing the impurities.

Constipation Aids

Pommelo is full of dietary fibre, a vital compound that is useful to promote regular bowel movements, effectively protect you against hemorrhoids and lower the risk of colon cancer.

Alkalize the Body

Research has shown that an alkaline body is less prone to getting various common diseases. Like lemon, pomelo juice has an alkaline effect after digested, thereby having therapeutic value to your body.

Anitumor Activity

Citrus maxima leaves possesses potent anticancer activity which can be attributed to the flavonoids present in it which can therefore serve as a stepping stone for the discovery of a new anticancer agent. [23]

Antidepressant like activity

The aqueous extract of leaves of this plant showed that it has antidepressant activity. Extract was found to be safe as no mortality was observed following treatment with doses as high as 2000 mg/kg. [24]

Analgesic and Anti-Inflammatory Activities

The extracted compounds from *C.maxima* exhibited analgesic activity against chemical and thermal noxious stimuli on both early and late phases of pain by the *Citrus maxima* extracts (300 mg/kg). And it possesses anti-inflammatory activity in formalin induced paw edema models in comparison to control. [25]

Antibacterial Activity

The plant extract of *Citrus maxima* (Burm.) Merr showed significant antibacterial activity against Escherichia coli and Pseudomonas aeruginosa. [26]

Antihyperglycemic effect

The methanol extract of *C. maxima* leaves exert a marked antihyperglycemic effect in STZ induced diabetic Wistar rats as well as hypoglycemic activity in normoglycemic rats. [27]

Antioxidant effect

The consumption of *Citrus maxima* juice can be linked to improved antioxidant status and reduction in the risk of oxidative stress. [28]

Anti-diabetic, cholinesterase and tyrosinase inhibitory potential

C.maxima not only possesses antioxidant and radical scavenging activities but also exhibits excellent inhibitory potential against α-amylase, α-glucosidase, acetylcholinesterase, tyrosinase and β- glucuronidase in vitro. [29]

Effect of C.maxima fruit juice on Human Endothelial Cells: Enhancing Cell Migration and Delaying Cellular Aging

The pummelo (*Citrus maxima* Merr. var. Tubtim Siam, CM) fruit extract on human umbilical vein endothelial cell (HUVECs) migration and aging shows positive effect in vitro. [30]

Treatment of anxiety disorders

The potentiality of *C. maxima* will be an alternative source for psychiatric and neurological disorders which are proven on depressant, anxiolytic, convulsant, hypnotic and muscle relaxant experimental animals. [31]

CONCLUSIONS

Citrus maxima being the largest citrus fruit offers significantly greater medicinal benefits as compared to the other fruits. Apart from its various medicinal properties, bio flavonoids play an important role in prevention of cancer. Also the traditional usage of various parts of *Citrus maxima* have shown a broad spectrum of cures in treatment of various diseases. *Citrus maxima* thus is a multi-faceted plant which has larger use in human life as large its fruit is in size. As reviewed in this paper, extracts of leaves, fruit, peel and stem have been studied for secondary metabolites and their properties, however these secondary metabolites are yet to be isolated, identified and evaluated for their medicinal properties.

Author's Contribution

Trupti Sawant was involved in preparing manuscript. Dr. Deepa Panhekar participated in discussions of views represented in the paper. Both authors have read and approved the final manuscript.

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