We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS BOOK CITATION INDEX INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

6

Phytochemical Constituents and Activities of *Morinda citrifolia* L.

Duduku Krishnaiah*, Rajesh Nithyanandam and Rosalam Sarbatly
Universiti Malaysia Sabah, Malaysia

1. Introduction

Both artificial and naturally occurring antioxidants have been reported to play major roles in protecting membranes and tissues from free radical and xenobiotic-induced oxidative damage (Burton, 1989; Carini et al., 1990). Most living organisms harbour both enzymatic and non-enzymatic systems that protect them against excessive reactive oxygen species. However, various external factors (smoke, diet, alcohol and some drugs) and aging decrease the efficiency of these protective systems, thereby disrupting the redox equilibrium that is established under healthy conditions. Thus, antioxidants that scavenge reactive oxygen species may be of great value in preventing the onset and propagation of oxidative diseases (Willet, 1994). Recently, more attention has been paid to the role of natural antioxidants, mainly phenolic compounds, which may have higher antioxidant activity than do conventional antioxidants, such as vitamins C, E and β-carotene (Vinson et al., 1995). The anti-oxidative effects of natural phenolic compounds, in pure form or in extracts from various plant sources (vegetables, fruits and medicinal plants), have been studied *in vitro* using a variety of model systems (Meyer et al., 1998; Pietta et al., 1998; Yen & Hsieh, 1998). Therefore, antioxidants, which can neutralize free radicals, may be of central importance in the prevention of carcinogenicity, cardiovascular disease and neurodegenerative changes associated with aging (Halliwell, 1994; Yu, 1994). Epidemiological studies have shown that the consumption of vegetables and fruits can protect humans against oxidative damage by inhibiting and/or quenching free radicals and reactive oxygen species (Ames et al., 1993).

Oxidative stress occurs commonly in living organisms, and it is involved in the pathology of cancer, arteriosclerosis, malaria, and rheumatoid arthritis. Moreover, it may play a role in neurodegenerative diseases and ageing processes. It has been demonstrated that many vegetables, fruits, medicinal plants and other foods contain compounds with bioactivity against oxidative stress, and this activity has been attributed to vitamin C, vitamin E, α-tocopherol, β-carotene, and polyphenolic compounds (Krishnaiah et al., 2011; Moure et al., 2001). Therefore, research regarding natural antioxidants from foods and plants, particularly from folk medicinal plants, is receiving increasing attention throughout the world.

2. *Morinda citrifolia* L.

The ancestors of the Polynesians are believed to have brought many plants with them, as food and medicine, when they migrated from Southeast Asia 2000 years ago. Of the 12 most

common medicinal plants they brought, *Morinda citrifolia* L. was the second most popular plant used in herbal remedies to treat various common diseases and to maintain overall good health. Other names of *Morinda citrifolia* L. include M. bracteata Roxb.; M. litoralis Blanco; Indian mulberry, Bengkudu, Mengkudu (Malay). It has been reported to have a broad range of health benefits for subjects with cancer, infections, arthritis, diabetes, asthma, hypertension and pain. The Polynesians utilised the whole *Morinda citrifolia* L. plant in their medicinal remedies and as a dye for some traditional clothing. The roots, stems, bark, leaves, flowers, and fruits of the *Morinda citrifolia* L. plant are all involved in various combinations in almost 40 known and recorded herbal remedies. Additionally, the roots were used to produce a yellow or red dye for tapa cloth and fala (mats), and the fruit was eaten for health and nutrition. There are numerous Polynesian stories of heroes and heroines that used *Morinda citrifolia* L. to survive famine. *Morinda citrifolia* has a long history of use as a food in tropical regions throughout the world.

It has also been reported to have broad therapeutic effects, including anti-cancer activity, in both humans and laboratory animal models. However, the mechanisms underlying these effects remain unknown. *M. citrifolia* is unique in view of the large number of medicinal claims that have been made for its efficacy and its rapidly evolving commercial success; nevertheless, little is known about its pharmacological potential compared with other popularly used botanicals.

M. citrifolia L., a shrub originating in tropical Asia or Polynesia, has been extensively used in folk medicine and as a dye in Asian countries. In the tropics, it seems to have been greatly valued medicinally, and the plant is normally cultivated for its roots, leaves and fruits. *M. citrifolia*, which grows prevalently in tropical regions, has recently gained a great deal of interest from scientists and medical professionals due to its pharmaceutical value. Wang et al. (2002) have published a review of *M. citrifolia* L. research that summarises the therapeutic effects of various compounds in this plant.

The *M. citrifolia* L. plant is a small evergreen tree found growing in open coastal regions at sea level and in forest areas up to approximately 1300 feet above sea level. The plant is often found growing along lava flows. Polynesians are reported to have successfully used *M. citrifolia* L. to treat breast cancer and eye problems. *M. citrifolia* has been tested for a number of biological activities in animal and anti-microbial studies and found that the dried fruit has smooth muscle stimulatory activity and histaminergic effects.

The roots of these plants are reported to be good sources of anthraquinones, which are usually present as aglycones and, to lesser extent, in the form of glycosides (Thomson, 1971; Zenk, El-Shagy & Schulte, 1975). Most parts of the tree have been widely used medicinally to relieve rheumatism and other pains and for their healing effects (Perry & Metzger, 1980).

Traditionally, the roots of *M. citrifolia* L. plants were used by Polynesians to produce yellow or red dye, but more importantly, they are now known to contain medicinally active components, such as anthraquinones, which due to their anti-oxidative activity, possess various therapeutic properties. These properties include anti-bacterial, anti-viral, and anti-cancer activities, as well as analgesic effects. These factors make the compounds potentially useful in several medical applications. An increasing number of studies are focusing on finding efficient methods for producing and extracting anthraquinones from these plants. Much of the literature also involves producing the compound in root cultures of *M. citrifolia*.

Nevertheless, extraction of anthraquinones directly from plant roots is still more widely conducted and is conventionally performed by solvent extraction. Other techniques, which include super critical carbon dioxide extraction, subcritical water extraction, ultrasonic-assisted extraction (UAE), and microwave-assisted extraction (MAE) have also become of interest as alternatives to the conventional methods.

2.1 Plant description

The genus Morinda (*Rubiaceae*), which includes the species *M. Citrifolia* L., is made up of around 80 species. *M. Citrifolia* is a bush or small tree, 3-10 m tall, with abundant broad elliptical leaves (5-17 cm length, 10-40 cm width).

Fig. 1. Unripe fruit

The small tubular white flowers are grouped together and inserted on the peduncle. The petioles leave ring-like marks on the stalks and the corolla is greenish-white (Morton, 1992; Elkins, 1998; Dixon et al., 1999; Ross, 2001; Cardon, 2003). The *M. citrifolia* L. fruit (3-10 cm length, 3-6 cm width) is ovular and fleshy with an embossed appearance (Fig. 1). It is slightly wrinkly, semi-translucent, and ranges in colour from green to yellow to almost white at the time of picking. It is covered with small reddish-brown buds containing the seeds. The ripe fruit emits a strong butyric acid-like, rancid smell (Morton, 1992; Dixon et al., 1999). The pulp is juicy and bitter, a light dull yellow or whitish colour, and gelatinous when the fruit is ripe; numerous hard triangular reddish-brown pits are found, each containing four seeds (approximately 3.5 mm) (Dittmar, 1993).

Moreover, *M. citrifolia* L. leaves are well known for their strong antioxidant activity, and they have been shown to be safe in acute, subacute, and subchronic oral toxicity tests on mice (West et al., 2007). Inspired by ancient Polynesian legends, *M. citrifolia* L. leaves have been developed into therapeutic teas. The leaves are also the source for a variety of other health-promoting commercial products. Commercial *M. citrifolia* L. leaf products have been available in Japan and United States for more than seven years, used mainly for making infusions. However, some manufacturers produce capsules containing powdered *M.*

citrifolia L. leaves. The major world-wide source of *M. citrifolia* L. leaves is French Polynesia because leaves from this nation having undergone a safety evaluation (West et al., 2007). Other sources include Panama, Fiji and Hawaii.

Recently, *M. citrifolia* L. fruit juice is in high demand as an alternative medicine due to its potential anti-microbial, anti-cancer, anti-inflammatory, and antioxidant effects (Wang et al., 2002). However, scientific evidence for the benefits of *M. citrifolia* L. fruit juice is still limited. In the past decade, *M. citrifolia* L. fruit juice has emerged on the worldwide market as a safe and popular health product due to its phytochemicals and nutrients. Written documentation of the consumption of this fruit as a food source precedes the twentieth century. Captain James Cook of the British Navy noted in the late 1700s that the fruit was eaten in Tahiti. An 1866 publication in London explained that *M. citrifolia* L. fruit was consumed as a food in the Fiji islands.

Later publications describe the use of this fruit as a food throughout the Pacific islands, Southeast Asia, Australia, and India. In Roratonga, "the fruit was often eaten by the natives". Australian Aborigines were reported to be "very fond" of the fruit. In Samoa, *M. citrifolia* L. fruit was common fare, and in Burma, the fruit was cooked in curries or eaten raw with salt. In 1943, Merrill described *M. citrifolia* L. as an edible plant in a technical manual of edible and poisonous plants of the Pacific islands, in which the leaves and fruits could be used as emergency food. Abbott also reported that *M. citrifolia* L. had been used as a food, drink, medicine, and colourful dye. The medicinal history and accumulated scientific studies have revealed and confirmed the Polynesians' claims regarding the health benefits of *M. citrifolia* L.

M. citrifolia L. has identifiable leaves, white tubular flowers, and a distinctive, ovoid, "grenade-like" yellow fruit. The fruit can grow in size up to 12 cm or more and has a lumpy surface covered by polygonal-shaped sections. The seeds, which are triangular and reddish brown, have an air sac contained at one end, making the seeds buoyant. This could explain, in part, the wide distribution of the plant throughout the Polynesian islands. The mature *M. citrifolia* L .fruit has a foul taste and odour. *M. citrifolia* L. is not considered to be at risk in the wild.

The fruit juice of *M. citrifolia* L. is in high demand in alternative medicine for various illnesses, such as arthritis, diabetes, high blood pressure, muscle aches and pains, menstrual difficulties, headaches, heart disease, Acquired Immune Deficiency Syndrome (AIDS), cancer, gastric ulcers, sprains, mental depression, senility, poor digestion, atherosclerosis, blood vessel problems and drug addiction (Kamiya et al., 2004; Wang et al., 2002). Therefore, one of the challenges in recent years has been to process fruit juice so as to make a more modern drug from a traditional product (Chunhieng et al., 2003). A number of *in vitro* biological activities have been reported, such as angiogenesis inhibition, antioxidant activity, inhibition of cycloxygenases-1 and -2, and tyrosine kinase inhibition. However, most of these have only been tested with crude extracts or fractions of *M. citrifolia* L., and the compound(s) responsible for these biological activities have not been fully determined, except for two compounds, neolignan and americanin A, which were identified in an n-butanol-soluble partition of the methanol extract of *M. citrifolia* L. fruits (Su et al., 2005; Zin et al., 2002).

M. citrifolia L. has recently been the object of many claims concerning its nutraceutical properties. Various publications have shown that *M. citrifolia* L. can be used to relieve multiple diseases, and its registered uses span the Pacific, Asia, and Africa. Two clinical studies have reported that relief from arthritis and diabetes are associated with *M. citrifolia* L. consumption (Elkins, 1998; Solomon, 1999). These beneficial effects may derive from certain compounds, such as scopoletin, nitric oxide, alkaloids and/or sterols, and they also may be due to the antioxidant potential of *M. citrifolia* L. As a result of this reputation, consumption of this fruit is currently high not only in the producing countries but also in the United States, Japan and Europe.

In response to this demand, some countries (such as Costa Rica and Cambodia) have increased their cultivation of *M. citrifolia* L. In these countries, the fruit is often commercialised fresh or as juice in both formal and informal markets, but it is also found as pasteurised juice, either in pure form or in combination with other juices (usually grape or blackberry juice). Commercial interest in *M. citrifolia* L. has increased tremendously in recent years, as indicated by the number of patents registered. In the United States alone, 19 patents have been registered by the US patent and Trademark Office since 1976 (USPTO, 2005). *M. citrifolia* L. juice has been accepted by the European Union as a novel food (European Commission, Scientific Committee for Food, 2002). Nevertheless, despite the real market opportunities, there has been little scientific research addressing the actual nutritional and functional properties of *M. citrifolia* L. products.

Several classes of compounds have been isolated from *M. citrifolia* L., including amino acids, anthraquinones, coumarins, fatty acids, flavonoids, iridoids, lignans and polysaccharides (Chan-Blan-co et al., 2006). Among these, scopoletin, a coumarin derivative, is one of the representative ingredients in *M. citrifolia* L. Its contribution to anti-microbial, anti-inflammatory, and antioxidative activities has been well elucidated (Deng et al., 2007). Samoylenko et al. (2006) recommended scopoletin as a constituent marker for *M. citrifolia* L. quality control. This compound has been ubiquitously found in *M. citrifolia* L. collected from Atlantic and Pacific regions and in all examined squeezed fruit juices. Determination of scopoletin in *M. citrifolia* L. might help to control the quality of *M. citrifolia* L. products. However, no reports have evaluated the antioxidative activity of scopoletin and other coumarin derivatives in *M. citrifolia* L.

Many reports on the antioxidative activity of *M. citrifolia* L. itself have been published. Assays of free-radical-scavenging activity with 1,1-diphenyl-2-picrylhydrazyl (Su et al., 2005; Yang et al., 2007), inhibition of copper-induced low-density lipoprotein oxidation (Kamiya et al., 2004), nitric oxide scavenging activity (Basu & Hazra, 2006) and quenching of H_2O_2 (Chong et al., 2004; Jeffers et al., 2007) have been performed to evaluate the antioxidative effects of *M. citrifolia* L. and its products. Polyphenols, reducing glycosides (Calzuola et al., 2006), lignin derivatives (Su et al., 2005) and anthraquinones (Chong et al., 2004) have been suggested as sources of antioxidative activity in *M. citrifolia* L. However, there is little available information with which to quantitatively evaluate the antioxidative activity of *M. citrifolia* L ingredients. Recently, a correlation between total phenol and free-radical-scavenging activity was reported (r=0.41, Yang et al., 2007).

The chemical components of *M. citrifolia* L. have not been well studied, and several anthraquinones and asperuloside are all that have been previously isolated (Levand &

Larson, 1979; Srivastava & Singh, 1993). For centuries, scientists and medical professionals have been investigating the chemical constituents in all parts of *M. citrifolia* (Noni or Yor), including leaves, fruit, bark and roots. The plants contain several medicinally active components that exhibit various therapeutic effects. These include anti-bacterial, anti-viral and anti-cancer activities as well as analgesic effects. Critical reviews of the therapeutic properties of the plants are given by Chan-Blanco et al. (2006) and Wang et al. (2002). Anthraquinones have been shown to be responsible for the therapeutic properties of *M. citrifolia* L., and among this group of compounds, damnacanthal, which is present mainly in the roots, is of particular interest due to its important anticancer activity (Hiramatsu et al., 1993).

Previous phytochemical studies revealed that *M. citrifolia* L. leaves contain a variety of phytochemical constituents, including terpenoids (Ahmad & Bano, 1980; Saludes et al., 2002; Takashima et al., 2007) phytosterols, fatty acids and their glycosides (Takashima et al., 2007) iridoids and their glycosides (Sang et al., 2001 a,b,c,d; Sang et al., 2003) and flavonol glycosides (Sang et al., 2001a).

Flavonol glycosides appear to predominate in *M. citrifolia* L. leaves; rutin and other flavonol glycosides have previously been identified in raw *M. citrifolia* L. leaves (Sang et al., 2001a). However, the presence of flavonol aglycones in *M. citrifolia* L. leaves has not been previously reported. Flavonoids have been indicated to possess a variety of biological activities (Garcia-Mediavilla et al., 2006; Kampkotter et al., 2007), and they may play an important role in *M. citrifolia* L. leaves. To date, there has been no validated analytical method for determining the flavonol constituents of *M. citrifolia* L. leaves.

2.2 Yield

M. citrifolia L. is a perennial bush, and it is possible to find fruits at different stages of maturity on the same plant at the same time. The species is generally found from sea level to 400 m, although it adapts better to coastal regions (Luberck & Hannes, 2001). Under favourable conditions, the plant bears fruit approximately nine months to one year after planting. At this stage, the fruits can be harvested, but they are generally small, and the yield per tree is low. Some producers choose not to harvest in the first year, and they prune in order to let the bush grow stronger. In Hawaii, *M. citrifolia* L. fruits are harvested throughout the year, although there are seasonal patterns in flowering and fruit bearing (meteorological factors, fumigation, and irrigation) (Nelson, 2001, 2003).

In Hawaii, *M. citrifolia* L. plots are usually harvested two or three times per month, although fruit production is lower during winter. With a density of 638 plants per hectare; good soil fertility, drainage, and irrigation; appropriate pest, disease and weed control; and an appropriate fertilisation plan, it is possible to obtain yields of 7 tonnes/ha/year after the fifth year (Nelson, 2001, 2003). With a juice extraction rate of approximately 50% (w/w), one hectare can thus yield around 35 tons of juice. However, many factors may affect these yields, and most producers do not obtain such good results because of diseases and/or poor agricultural practices (growing wide plants). In Hawaii, an average annual yield of 50 tonnes/ha is generally attained (Nelson, 2001, 2003).

Maturity stage	Colour	Firmness
1	Dark green	Very hard
2	Green-yellow	Very hard
3	Pale yellow	Very hard
4	Pale yellow	Fairly hard
5	Translucent-greyish	Soft

Table 1. Evolution of fruit skin colour and firmness in the course of ripening (adapted from Chan-Blanco et al., 2006)

Depending on the post-harvest technology programme adopted, the fruits may be harvested at different stages of development and continue to mature. The evolution of the colour and firmness of fruits left to ripen naturally on the tree is reported in Table 1. Nonetheless, most processors buy *M. citrifolia* L. harvested at the "hard white" stage for juice production as the fruits become soft too quickly once this stage is reached (Nelson, 2001, 2003). The change from stage 4 to 5 occurs very quickly (within a few hours), and the pulp practically liquefies and turns from green to white, as well as develops the characteristic butyric smell.

The fruits are individually selected on the tree and harvested by hand. At the "hard white" stage, they are well able to withstand being transported in baskets or containers, and exposure of the fruits to light or high temperatures immediately after harvest does not affect their overall quality. Before processing, fruits are ripened at room temperature for one day or more, depending on the end product (such as tea, juice, pulp, dietetic products) (Nelson, 2003).

2.3 Chemical composition of *M. citrifolia* L.

Approximately 160 phytochemical compounds have already been identified in the *M. citrifolia* L. plant, and the major micronutrients are phenolic compounds, organic acids and alkaloids (Wang & Su, 2001). Of the reported phenolic compounds, the most important are anthraquinones (such as damnacanthal, morindone, morindin.) and also aucubin, asperuloside, and scopoletin (Wang & Su, 2001). The main organic acids are caproic and caprylic acids (Dittmar, 1993), whereas the principal reported alkaloid is xeronine (Heinicke, 1985). Chan-Blanco et al. (2006) reviewed the chemical constituents of different parts of the plant (Table 2).

However, chemical composition differs significantly according to the part of the plant. The complete physico-chemical composition of the fruit has not yet been reported, and only partial information is available on *M. citrifolia* L. juice. The fruit contains 90% water, and the main components of the dry matter appear to be soluble solids, dietary fibre and proteins (Chunhieng, 2003). The fruit's protein content is surprisingly high, representing 11.3% of the juice dry matter, and the main amino acids are aspartic acid, glutamic acid and isoleucine (Chunhieng, 2003).

According to a book on Malaysian medicinal plants, the chemical constituents of *M. citrifolia* L. are 5,7-Acacetin-7-O-β-D(+)-glycopyranoside, ajmalicine isomers, alizarin, asperuloside, asperulosidic acid, chrysophanol (1,8-dihydroxy-3-methylanthraquinone), damnacanthol, digoxin, 5,6-dihydroxylucidin, 5,6-dihydroxylucidin-3-β-primeveroside, 5,7-dimethylapigenin-4′-O-β-D(+)-galacto pyranoside, lucidin, lucidin-3-β-primeveroside, 2-methyl-3,5,6-trihydroxy

Source (plant part)	Chemical constituent	References
Flower	2-methyl-4-hydroxy-5,7-dimethoxyanthraquinone 4-O-β-D-glucopyranosyl-(1-4)-α-L-rhamnopyranoside	Sang et al. (2002)
Flower	5,8-dimethyl-apigenin 4′-O-β-D-galacatopyranoside	Sang et al. (2002), Elkins (1998)
Flower	Aracetin 7-O-β-D-glucopyranoside	
Fruit	β-D-glucopyranose pentaacetate	Sang et al. (2002), Elkins (1998)
Fruit	2,6-di-O-(β-D-glucopyranosyl-1-O-octanoyl-β-D-glucopyranose	Dittmar (1993)
Fruit	6-O-(β-D-glucopyranosyl-1-O-octanoyl-β-D-glucopyranose	Wang et al. (1999)
Fruit	Ascorbic acid	Liu et al. (2001)
Fruit	Asperulosidic acid	Morton (1992), Elkins (1998), Wang et al. (2002), McClatchey (2002)
Fruit	Asperuloside tetraacetate	Wang et al. (1999), Liu et al. (2001), Cardon (2003)
Fruit	Caproic acid	Dittmar (1993)
Fruit	Caprylic acid	Sang et al. (2002), Dittmar (1993), Elkins (1998), Wang et al. (2002), Levend and Larson (1979)
Fruit	Ethyl caprylate	Solomon (1999), Dittmar (1993), Cardon (2003), Elkins (1998), Wang et al. (2002), Levand and Larson (1979)
Fruit	Ethyl caproate	Dittmar (1993)
Fruit	Hexanoic acid	Dittmar (1993)
Fruit	Octanoic acid	Farine et al. (1996), Sang et al. (2002)
Fruit	Quercetin 3-O-α-L-rhamnopyranosyl-(1-6)-β-D-glucopyranoside	Farine et al. (1996), Sang et al. (2002), Cardon (2003), Wang & Su (2001)
Heartwood	Physcion 8-O-α-L-arabinopyranosyl-(1-3)-β-D-galactopyranosyl-(1-6)-β-D-galactopyranoside	Wang & Su (2001), Wang et al. (2002)
Leaves	Alanine	Sang et al. (2002), Srivastava & Singh (1993), Cardon (2003)
Leaves	Quercetin 3-O-α-L-rhamnopyranosyl-(1-6)-β-D-glucopyranoside	Sang et al. (2002)
Leaves	Serine	Dittmar (1993), Elkins (1998)
Leaves	Threonine	Dittmar (1993), Elkins (1998)
Leaves	Tryptophan	Dittmar (1993), Elkins (1998)

Source (plant part)	Chemical constituent	References
Leaves	Tyrosine	Dittmar (1993), Elkins (1998)
Leaves	Ursolic acid	Sang et al. (2002), Cardon (2003), Elkins (1998), Wang et al. (2002)
Leaves	Valine	Dittmar (1993), Elkins (1998)
Plant	2-methyl-3,5,6-trihydroxyanthraquinone	Cardon (2003), Inoue et al. (1981)
Plant	2-methyl-3,5,6-trihydroxyanthraquinone 6-O-β-D-xylopyranosyl-(1-6)-β-D-glucopyranoside	Cardon (2003), Inoue et al. (1981)
Plant	3-hydroxymorindone	Cardon (2003), Inoue et al. (1981)
Plant	3-hydroxymorindone 6-O-β-D-xylopyranosyl-(1-6)-β-D-glucopyranoside	Cardon (2003), Inoue et al. (1981)
Plant	5,6-dihydroxylucidin 3-O-β-D-xylopyranosyl-(1-6)-β-D-glucopyranoside	Cardon (2003), Inoue et al. (1981)
Plant	5,6-dihydroxylucidin	Cardon (2003), Inoue et al. (1981)
Plant	Aucubin	Elkins (1998), Wang et al. (2002)
Plant	Linoleic acid	Wang et al. (2002)
Plant	Lucidin	Cardon (2003), Inoue et al. (1981), Ross (2001)
Plant	Lucidin 3-O-β-D-xylopyranosyl-(1-6)-β-D-glucopyranoside	Cardon (2003), Inoue et al. (1981)
Plant	Scopoletin	Farine et al. (1996), Wang et al. (2002)
Leaves	Arginine	Dittmar (1993)
Leaves	Aspartic acid	Dittmar (1993)
Leaves	β-sitosterol	Sang et al. (2002), Chunhieng (2003), Elkins (1998), Wang et al. (2002)
Leaves	Citrifolinoside B	Sang et al. (2002)
Leaves	Cysteine	Dittmar (1993), Elkins (1998)
Leaves	Cystine	Dittmar (1993), Elkins (1998)
Leaves	Glutamic acid	Dittmar (1993)
Leaves	Glycine	Dittmar (1993), Elkins (1998)
Leaves	Histidine	Dittmar (1993), Elkins (1998)
Leaves	Isoleucine	Dittmar (1993), Elkins (1998)
Leaves	Kaempferol 3-O-α-L-rhamnopyranosyl-(1-6)-β-D-glucopyranoside	Sang et al. (2002)

Source (plant part)	Chemical constituent	References
Leaves	Kaempferol 3-O-β-D-glucopyranosyl-(1-2)- α-L-rhamnopyranosyl-(1-6)-β-D-galactopyranoside	Sang et al. (2002)
Leaves	Leucine	Dittmar (1993), Elkins (1998)
Leaves	Methionine	Dittmar (1993), Elkins (1998)
Leaves	Phenylalanine	Dittmar (1993), Elkins (1998)
Leaves	Proline	Dittmar (1993), Elkins (1998)
Leaves	Quercetin 3-O-β-D-glucopyranoside	Sang et al. (2002)
Root, heartwood, root bark	Morindone	Sang et al. (2002), Inoue et al. (1981), Dittmar (1993), Ross (2001), Cardon (2003), Wang et al. (2002)
Root, heartwood, seeds	Damnacanthal	Sang et al. (2002), Cardon (2003)
Leaves	Quercetin 3-O-β-D-glucopyranosyl-(1-2)- α-L-rhamnopyranosyl-(1-6)-β-D-galactopyranoside	Sang et al. (2002)
Root	8-hydroxy-8-methoxy-2-methyl-anthraquinone	Cardon (2003), Solomon (1999)
Root	Rubichloric acid	Elkins (1998), Morton (1992)
Root	1,3-dihydroxy-6-methyl anthraquinone	Morton (1992)
Root	Morenone 1	Solomon (1999)
Root	Morenone 2	Solomon (1999)
Root	Ruberythric acid	Cardon (2003)
Root	Rubiadin	Cardon (2003), Elkins (1998), Inoue et al. (1981), Ross (2001)
Root bark	Chlororubin	Dittmar (1993), Elkins (1998)
Root bark	Hexose	Dittmar (1993)
Root bark	Morindadiol	Dittmar (1993)
Root bark	Morindanidrine	Dittmar (1993)
Root bark	Morindine	Cardon (2003), Dittmar (1993), Elkins (1998), Morton (1992)
Root bark	Pentose	Dittmar (1993)
Root bark	Physcion	Solomon (1999)
Root bark	Rubiadin monomethyl ether	Dittmar (1993)
Root bark	Soranjidiol	Dittmar (1993), Elkins (1998), Ross (2001)
Root bark	Trioxymethylanthraquinone monoethyl ether	Dittmar (1993)
Root, root bark, fruit	Alizarin	Cardon (2003), Dittmar (1993), Elkins (1998), Ross (2001), Wang et al. (2002)
Seeds	Ricinoleic acid	Solomon (1999)

Table 2. Chemical compounds of *M. citrifolia* L. (adapted from Chan-Blanco et al., 2006)

anthraquinone, 3-hydroxymorindone, 3-hydroxymorindone-6-β-primereroside, α-methoxyalizarin, 2-methyl-3,5,6-trihydroxyanthraquinone-6-β-primeveroside, monoethoxyrubiadin, morindadiol, morindin, morindone (1,5,6-trihydroxy-2-methylanthraquinone), morindone-6-β-primeveroside, nordamnacanthal, quinoline, rubiadin, rubiadin 1-methyl ether, saronjidiol, ursolic acid, alkaloids, anthraquinones and their glycosides, caproic acid, caprylic acid, fatty acids and alcohols (C_{5-9}), flavone glycosides, flavonoids, glucose (β-D-glucopyranose), indoles, purines, and β-sitosterol.

Minerals account for 8.4% of the dry matter, and these minerals are mainly potassium, sulphur, calcium and phosphorus; traces of selenium have been reported in the juice (Chunhieng, 2003, Table 3). Vitamins have been reported in the fruit, mainly ascorbic acid (24-158 mg/100 g dry matter) (Morton, 1992; Shovie & Whistler, 2001) and provitamin A (Dixon et al., 1999). Phenolic compounds have been found to be the major group of functional micronutrients in *M. citrifolia* L. juice: damnacanthal, scopoletin, morindone, alizarin, aucubin, nordamnacanthal, rubiadin, rubiadin-1-methyl ether and other anthraquinone glycosides have been identified in *M. citrifolia* L. (Morton, 1992; Dittmar, 1993; Dixon et al., 1999; Wang & Su, 2001). Damnacanthal is an anthraquinone that has been characterised and has some important functional properties (mainly anti-carcinogenic) (Solomon, 1999). Scopoletin is a coumarin that was isolated in 1993 at the University of Hawaii and has been found to have analgesic properties as well as a significant ability to control serotonin levels in the body (Levand & Larson, 1979). Other researchers have shown that scopoletin may also have anti-microbial (Duncan et al., 1998) and anti-hypertensive effects (Solomon, 1999).

Multiple Hawaiian teams (Heinicke, 1985; Solomon, 1999) have reported the presence of a novel component, proxeronine, which is an alkaloid that is claimed to combine with human proteins and improve their functionality. The above authors attribute most of the beneficial effects of *M. citrifolia* L. to xeronine. Nonetheless, neither the chemical characterisation of this alkaloid nor the method used to assess its levels has been published to date.

Characteristic	Chunhieng (2003)[a]	Shovic and Whistler (2001)[a]	European commission (2002)[b]
pH	3.72	-	3.4-3.6
Dry matter	9.8±0.4%	-	10-11%
Total soluble solids (°Brix)	8	-	-
Protein content	2.5%	0.4 g/100 g	0.2-0.5%
Lipids	0.15%	0.3 g/100 g	0.1-0.2%
Glucose	11.9±0.2 g/l	-	3-4 g/100 g
Fructose	8.2±0.2 g/l	-	3-4 g/100 g
Potassium	3900 mg/l	188 mg/100 g	30-150 mg/100 g
Sodium	214 mg/l	21 mg/100 g	15-40 mg/100 g
Magnesium	14 mg/l	14.5 mg/100 g	3-12 mg/100 g
Calcium	28 mg/l	41.7 mg/100 g	20-25 mg/100 g
Vitamin C	-	155 mg/100 g	3-25 mg/100 g

Table 3. Physico-chemical composition of *M. citrifolia* L. juice (adapted from Chan-Blanco et al., 2006)

Approximately 51 volatile compounds have been identified in the ripe fruit (Sang et al., 2001), including organic acids (mainly octanoic and hexanoic acids), alcohols (3-methyl-3-butene-1-ol), esters (methyl octanoate, methyl decanoate), ketones (2-heptanone) and lactones ((E)-6-dodeceno-γ-lactone) (Farine et al., 1996).

Major components

A number of major components have been identified in the *M. citrifolia* L. plant, such as scopoletin, octanoic acid, potassium, vitamin C, terpenoids, alkaloids, anthraquinones (such as nordamnacanthal, morindone, rubiadin, rubiadin-1-methyl ether and anthraquinone glycoside), β-sitosterol, carotene, vitamin A, flavones glycosides, linoleic acid, alizarin, amino acids, acubin, L-asperuloside, caproic acid, caprylic acid, ursolic acid, rutin and a putative proxeronine.

A research group led by Chi-Tang Ho at Rutgers University in the United States (US) is searching for new novel compounds in the *M. citrifolia* L. plant. They have successfully identified several new flavonol glycosides, an iridoid glycoside from *M. citrifolia* L. leaves, a trisaccharide fatty acid ester, rutin, and an asperulosidic acid from the fruit. Two novel glycosides and a new unusual iridoid named citrifolinoside have been shown to have an inhibitory effect on AP-1 transactivation and cell transformation in the mouse epidermal JB6 cell line. James Duke listed 23 different phytochemicals found in *M. citrifolia* L. as well as 5 vitamins and 3 minerals in an authoritative handbook of phytochemicals.

Xeronine system

Retired biochemist Ralph Heinicke states that *M. citrifolia* L. fruit contains a natural precursor of xeronine that he named Proxeronine. Proxeronine is converted to the alkaloid xeronine in the body by an enzyme he named proxeroninase. His hypothesis is that xeronine is able to modify the molecular structure of proteins. Thus, xeronine has a wide range of biological activities. When a protein such as an enzyme, receptor, or signal transducer is not in the appropriate conformation, it will not work properly. Xeronine will interact with the protein and make it fold into its proper conformation. The result is a properly functioning protein. Whenever a problem arises in the cell due to a structural problem with a protein, xeronine's presence would be beneficial. His hypothesis may explain why Tahitian Noni @ juice (TNJ) can help in many health problems in different ways. He has obtained several patents for xeronine. He states that the active ingredient in many of the effective folklore drugs is xeronine. This alkaloid is a critical normal metabolic coregulator. The ailments that he believes are helped by *M. citrifolia* L. include high blood pressure, menstrual cramps, arthritis, gastric ulcers, sprains, injuries, mental depression, senility, poor digestion, drug addiction, and pain. "I have devoted much of my life to the study of this unique substance that I have named 'xeronine'. I am convinced of the tremendous benefits achieved by furnishing the body with a proper supply of this material" (Heinicke, 2001).

2.4 Biological activity of *M. Citrifolia* L.

2.4.1 Anti-microbial effects

The anti-microbial activity of *M. citrifolia* L. may have been its first observed property; indeed, the fruit contains relatively large amounts of sugars that do not ferment even when fruits are stored in closed containers at ambient temperature. This property is used to

transport the fruit by boat from the scattered Pacific islands to processing plants without specific treatment.

It has been reported that *M. citrifolia* L. inhibits the growth of certain bacteria, such as staphylococcus aureus, Pseudomonas aeruginosa, Proteus morgaii, Bacillus subtilis, Escherichia coli, Helicobacter pylori, Salmonella and Shigella (Atkinson, 1956). The same author claims that the anti-microbial effect observed may be due to the presence of phenolic compounds such as acubin, l-asperuloside, alizarin, scopoletin and other anthraquinones. Another study showed that an acetonitrile extract of the dried fruit inhibits the growth of Pseudomonas aeruginosa, Bacillus subtilis, Escherichia coli, and Streptococcus pyrogene (Locher et al., 1995).

It has also been found that ethanol and hexane extracts of *M. citrifolia* L. have an antitubercular effect as they inhibit the growth of Mycobacterium tuberculosis by 89-95% (Saludes et al., 2002). The major components identified in the hexane extract are E-phytol, cycloartenol, stigmasterol, β-sitosterol, campesta-5,7,22-trien-3-β-ol, and the ketosteroids stigmasta-4-en-3-one and stigmasta-4-22-dien-3-one.

Other studies have reported a significant antimicrobial effect on various strains of Salmonella, Shigella, and E. coli (Bushnell et al., 1950; Dittmar, 1993). Furthermore, they showed that the anti-microbial effect is highly dependent on the stage of ripeness and on processing, being greater when the fruit is ripe and undried.

2.4.2 Anti-cancer activity

The immunomodulatory properties (the capacity to enhance the host immune system) of *M. citrifolia* L. juice have been studied by a Japanese research team (Hirazumi et al., 1996; Hirazumi & Furusawa, 1999). The ethanol precipitable fraction (ppt) of *M. citrifolia* L. juice, corresponding to a polysaccharide-rich substance composed of glucuronoic acid, galactose, arabinose and rhamnose, has been found to have immunomodulatory and anti-tumour effects against Lewis lung carcinoma (LLC). In cell models, *M. citrifolia* L.-ppt seems to stimulate the production of T-cells, thymocytes and macrophages that produce cytokines, which are important mediators of tumour cytostasis and cytotoxicity.

M. citrifolia L.-ppt also appears to stimulate murine effector cells to release several mediators such as cytokines. These mediators slow down the cell cycle in tumours, increase the response of cells to other immunised cells that fight tumour growth and have potent macrophage activator activity suspected of playing a role in the death of tumours (Hirazumi et al., 1996; Hirazumi & Furusawa, 1999).

In the same study, mice were inoculated with LLC, and those ingesting a daily dose of 15 mg of *M. citrifolia* L. juice showed a significant increase (119%) in lifespan. Nine out of 22 mice with terminal cancer survived for more than 50 days. In addition, the ingestion of *M. citrifolia* L.-ppt combined with conventional chemotherapy proved to increase the lifespan of mice with cancer, (Hirazumi et al., 1994).

Another Japanese team studied the influence of damnacanthal, an anthraquinone extracted from a chloroform extract of *M. citrifolia* L. fruits. Surprisingly, the researchers found that damnacanthal induces normal morphology in a particular type of cell found in human neoplasias (K-ras-NKR cells) that multiply uncontrollably and are highly malignant (Hiramatsu et al., 1993).

Another study showed that commercial *M. citrifolia* L. juice (Tahitian Noni juice) prevents the formation of chemical carcinogen-DNA-adducts. In the above study, rats with artificially induced cancer in specific organs were fed for one week with 10% *M. citrifolia* L. juice in their drinking water and rat food (rat chow) ad libitum. They showed reduced DNA-adduct formation depending on sex and organ. The reduction rates were: in female rats, heart 30%, liver 42%, lungs 41% and kidneys 80%; in male rats, heart 60%, liver 70%, lungs 50% and kidneys 90% (Wang & Su, 2001).

2.4.3 Anti-oxidant properties

The antioxidant properties of ethanol and ethyl acetate extracts of *M. citrifolia* L. fruit have been assessed using the ferric thiocyanate method (FTC) and thiobarbituric acid test (TBA). The authors found that ethyl acetate extract strong inhibited lipid oxidation, comparably to the same weight of pure α-tocopherol and butylated hydroxyl toluene (BHT) (Mohd et al., 2001).

Radical scavenging activity was also measured *in vitro* by the tetrazolium nitroblue (TNB) assay in commercial juice by assessing the capacity of the juice to protect cells and lipids from oxidative alteration promoted by superoxide anion radicals (SARs). The SAR scavenging activity of *M. citrifolia* L. juice was shown to be 2.8 times higher than that of vitamin C, 1.4 times that of pycnogenol (PYC) and almost the same magnitude as that of grape seed powder (Wang & Su, 2001).

2.4.4 Anti-inflammatory activity

The anti-inflammatory activity of an aqueous extract from *M. citrifolia* L.-juice was observed by inducing a locally acute inflammatory response with the help of a pro-inflammatory agent (bradykinin). It was found that the oral administration of *M. citrifolia* L. juice extract (200 mg) rapidly inhibits the formation of rat paw oedema. This effect may have resulted from interference with the B2 receptor-mediated mechanism by which bradykinin induces rat paw oedema (Mckoy et al., 2002).

Another study showed that commercial *M. citrifolia* L. juice selectively inhibits cyclo-oxygenase enzymes (COX-1 and COX-2) involved in breast, colon and lung cancer and also has anti-inflammatory activity (Su et al., 2001). The ability of noni juice to inhibit these enzymes was compared to that of traditional commercial non-steroidal inflammatory drugs, such as aspirin, Indomethacin and Celebrex. *M. citrifolia* L. juice showed selective inhibition of COX activity *in vitro* and a strong anti-inflammatory effect comparable to that of Celebrex, and presumably, this juice lacks side effects.

2.4.5 Analgesic activity

Recent research has examined the analgesic properties of commercial juice in rats. The results showed that rats fed 10% or 20% *M. citrifolia* L. juice had greater pain tolerance (162% or 212%, respectively) compared with the placebo group (Wang et al., 2002). A French research team has also studied the analgesic and sedative effects of *M. citrifolia* L. on mice through the writhing and hotplate tests. *M. citrifolia* L. root extract (1600 mg/kg) showed significant analgesic activity in the animals, similar to the effect of morphine (75% and 81%

protection using *M. citrifolia* L. extract and morphine, respectively), and it also proved to be non-toxic (Younos et al., 1990).

2.4.6 Cardiovascular activity

Recent research has demonstrated the ability of *M. citrifolia* L. fruit to prevent arteriosclerosis, a disease related to the oxidation of low density lipoproteins (LDLs). Methanol and ethyl acetate extracts showed 88% and 96% inhibition, respectively, of copper-induced LDL oxidation by the thiobarbituric acid relative substance method. This beneficial effect could be due to the presence of lignans, which are phenylpropanoid dimers (Kamiya et al., 2004).

2.5 Biological activities of *M. citrifolia* L. products

2.5.1 Antibacterial activity

Acubin, l-asperuloside, alizarin in *M. citrifolia* L. fruit, and certain other anthraquinone compounds in *M. citrifolia* L. roots, are all proven antibacterial agents. These compounds have been shown to fight infectious bacteria such as Pseudomonas aeruginosa, Proteus morgaii, Staphylococcus aureus, Bacillis subtilis, Escherichia coli, Salmonella, and Shigela. These antibacterial compounds in *M. citrifolia* L. are responsible for the treatment of skin infections, colds, fevers, and other bacteria-caused health problems. Bushnell reported on the antibacterial properties of certain plants found in Hawaii, including *M. citrifolia* L. He further reported that *M. citrifolia* L. was traditionally used to treat broken bones, deep cuts, bruises, sores and wounds. Extracts from the ripe *M. citrifolia* L. fruit exhibit moderate antibacterial properties against Salmonella typhosa. Salmonella montevideo, Salmonella schottmuelleri, Shigella paradys, BH and Shigella paradys, III-Z. Leach demonstrated that acetone extracts obtained from Cycas circinalis, *M. citrifolia*, Bridelia penangiana, Tridax Procumbens, Hibiscus tiliaceus, and Hypericum papuanun show antibacterial activity. The widespread medicinal use of these plants would suggest that they do contain pharmacologically active substances, and alternative methods of extraction and screening should be utilised to find the major bioactive component in the plants for the purpose of new drug development. Locher reported that selected plants including *M. citrifolia* have a history of use in Polynesian traditional medicine for the treatment of infectious diseases. These plants have been investigated for anti-viral, anti-fungal, and anti-bacterial activity *in vitro*. Their study using *in vitro* biological assays confirmed that some of the Hawaiian medicinal plants in ethnobotanical reports have curative properties against infectious diseases.

Duncan demonstrated that scopoletin, a health promoter in *M. citrifolia* L., inhibits the activity of E. coli, which is associated with recent outbreaks resulting in hundreds of serious infections, even death. *M. citrifolia* L. also helps stomach ulcers by inhibiting H. pylori bacteria.

2.5.2 Antiviral activity

Umezawa and coworkers found that a compound isolated from *M. citrifolia* L. roots named 1-methoxy-2-formyl-3-hydroxyanthraquinone suppresses the cytopathic effect of HIV-infected MT-4 cells without inhibiting cell growth.

2.5.3 Anti-tubercular effects

At the International Chemical Congress of the Pacific Basin Societies meeting in Honolulu, Saludes and colleagues from the Philippines reported that *M. citrifolia* L. kills Mycobacterium tuberculosis. A concentration of extracts from *M. citrifolia* L. leaves killed 89% of the bacteria in a test tube, almost as effectively as the leading anti-TB drug Rifampicin, which has an inhibitory rate of 97% at the same concentration. Although there have been anecdotal reports of native use of *M. citrifolia* L. in Polynesia as a medicine against tuberculosis, this is the first report demonstrating the antimycobacterial potential of compounds obtained from *M. citrifolia* L. leaves. "I hope that pharmaceutical companies will pay attention to this research and explore the *M. citrifolia* L. plant as a potential source of drugs", said Saludes in Manila.

2.5.4 Antitumor activity

At the 83rd Annual meeting of the American Association for Cancer Research in 1992, Hirazumi, a researcher at the University of Hawaii, reported that the alcohol-precipitate of *M. citrifolia* L. fruit juice (noni-ppt) has anticancer activity on lung cancer in C57 B1/6 mice. This *M. citrifolia* L.-ppt was shown to significantly prolong (by up to 75%) the life of mice with implanted Lewis lung carcinoma. It was concluded that the *M. citrifolia* L.-ppt seems to suppress tumour growth indirectly by stimulating the immune system. Improved survival time and curative effects occurred when *M. citrifolia* L.-ppt was combined with sub-optimal doses of the standard chemotherapeutic agents, such as adriamycin (Adria), cisplatin (CDDP), 5-fluorouracil (5-FU) and vincristine (VCR), suggesting that *M. citrifolia* L.-ppt has important clinical utility as a supplemental agent in cancer treatment. These results indicate that *M. citrifolia* L.-ppt may enhance the therapeutic effect of anticancer drugs. Therefore, it may be of benefit to cancer patients by enabling them to use lower doses of anti-cancer drugs to achieve the same or even better results.

Dr. Wang and coworkers demonstrated a cytotoxic effect of TNJ on a cultured leukaemia cell line at various concentrations. TNJ showed dose-dependent cytotoxicity on cultured cancer cells by inducing cancer cell necrosis at high doses and apoptosis at lower doses. Synergistic effects of TNJ with known anticancer drugs have been found. At sub-optimal doses, both prednisolone and TNJ can induce apoptosis. When the dose of prednisolone is fixed and the dose of TNJ increases, apoptotic cells significantly increase. Therefore, TNJ is able to enhance the efficacy of anticancer drugs such as prednisolone. When a single dose of Taxol induces a lower percentage of apoptosis in leukaemia cells, TNJ enhances the rate of apoptosis to 100%. These results indicate that TNJ is able to enhance the therapeutic effects of anticancer drugs such as Taxol. These findings regarding the combination of anticancer drugs with TNJ may be significant. This approach may allow lower doses of synthetic anticancer drugs to be used, increase the tolerance of patients to the toxicity of anticancer drugs, and increase immune function, thus creating a new method for treating cancer patients.

In 1993, Hiramatsu and colleagues reported in Cancer Letters the effects of over 500 extracts from tropical plants on K-Ras-NRK cells. Damnacanthal, isolated from *M. citrifolia* L. roots, is an inhibitor of Ras function. The ras oncogene is believed to be associated with signal transduction in several human cancers such as lung, colon, and pancreatic cancer and leukaemia.

Hiwasa and coworkers demonstrated that damnacanthal, an anthraquinone compound isolated from the *M. citrifolia* L. roots, has potent inhibitory activity towards tyrosine kinases such as Lck, Src, Lyn and EGF receptors. In his research, he examined the effects of damnacanthal on ultraviolet ray-induced apoptosis in ultraviolet-resistant human UVr-1 cells. Consequently, the ultraviolet light induced a concurrent increase in both phosphorylated extracellular signal-regulated kinases and stress-activated protein kinases. After pretreatment with damnacanthal, there was a stimulatory effect on ultraviolet-induced apoptosis.

Dong reported that two glycosides extracted from *M. citrifolia* L.-ppt were effective at inhibiting cell transformation induced by TPA or EGF in the mouse epidermal JB6 cell line. This inhibition was found to be associated with the inhibitory effects of these compounds on AP-1 activity. The compounds also blocked the phosphorylation of c-jun, a substrate of JNKs, suggesting that JNKs are a critical target for the compounds in mediating Ap-1 activity and cell transformation.

2.5.5 Antihelmintic activity

An ethanol extract of tender *M. citrifolia* L. leaves was found to induce paralysis and death in the human parasitic nematode Ascaris Lumbricoides within a day. A botanist via Morton reported that *M. citrifolia* L. has been used in the Philippines and Hawaii as an effective insecticide.

2.5.6 Hypotensive activity

Dang Van Ho of Vietnam demonstrated that total extract of *M. citrifolia* L. roots has a hypotensive effect. Moorthy and coworkers found that an ethanol extract of *M. citrifolia* L. roots lowers blood pressure in anesthetised dogs. Youngken's research team determined that a hot water extract of *M. citrifolia* L. roots lowers blood pressure in anesthetised dogs. A Hawaiian physician reported that *M. citrifolia* L. fruit juice has a diuretic effect.

2.5.7 Immunological activity

Asahina found that an alcohol extract of *M. citrifolia* L. fruit at various concentrations inhibits the production of tumour necrosis factor-alpha (TNF-α), which is an endogenous tumour promoter. Therefore, the alcohol extract may inhibit the tumour promoting effect of TNF- α. Hirazumi found that *M. citrifolia* L.-ppt contains a polysaccharide-rich substance that inhibits tumour growth. It does not cause significant cytotoxicity in adopted cultures of lung cancer cells, but it can activate peritoneal exudate cells to impart profound toxicity when co-cultured with tumour cells. This suggests the possibility that *M. citrifolia* L.-ppt may suppress tumour growth through activation of the host immune system. *M. citrifolia* L.-ppt is also capable of stimulating the release of several mediators from murine effector cells, including TNF- α, interleukin-1 beta (IL-1β), IL-10, IL-12, interferon-gamma (IFN- γ) and nitric oxide (NO). Hokama separated ripe *M. citrifolia* L. fruit juice into 50% aqueous alcohol and precipitate fractions, which was found to stimulate BALB/c thymus cells in (^{3}H)thymidine analysis. It has been suggested that inhibition of Lewis lung tumours in mice, in part, may be due to the stimulation of the T-cell immune response.

Wang and coworkers at the University of Illinois college of Medicine observed that the thymus is enlarged in animals treated with TNJ. The wet weight of the thymus was 1.7 times that of control animals on the seventh day after receiving 10% TNJ in drinking water. The thymus is an important immune organ in the body that generates T cells and is involved in the aging process and cellular immune fractions. TNJ may enhance immune function by stimulating thymus growth and thereby exerting anti-aging and anticancer activities and protecting people from other degenerative diseases.

2.5.8 Mental health and improved high frequency hearing

A small human clinical trial of the effects of TNJ on auditory function and quality of life in patients with decreased bone mineral density and auditory function was conducted at the UIC College of Medicine, Rockford, IL. This study showed that TNJ improves both mental health and high frequency hearing. The results suggest that increased amounts or extended duration of TNJ intake may be required to influence this disorder.

2.6 Study of TNJ for cancer prevention

"To take medicine only when you are sick is like digging a well only when you are thirsty – is it not already too late?" (Chi Po, c 2500 B.C.). This proverb suggests that prevention is more important than treatment.

Cancer is the second leading cause of death in the US. According to the American Cancer society, 1500 people per day die from cancer in the United States. Fighting against cancer is a great task for scientists engaged in this field. The aetiology of most cases of human cancer remains unknown. Exposure to environmental carcinogens accounts for more than 90% of human cancers. Cigarette smoke is the number one high-risk environmental factor. Although some cancers are preventable, a means to prevent most cancers is not yet known. Seeking a natural way to prevent human cancer is an urgent task for cancer prevention investigators.

Studies of food, diet, and cancer have indicated that lifestyle changes such as eating more fruits and vegetables and quitting smoking will help prevent cancer. "A new plate" for America (75% vegetables, 25% meat) appeared at the 2001 annual conference of the American Institute for Cancer Research. Although TNJ possesses a broad range of therapeutic effects, its ability to prevent cancer remains unclear. Recently, new hypothesis has been investigated: whether or not TNJ can help prevent cancer during the early stages of chemical carcinogenesis.

This hypothesis was examined using two carcinogenic animal models and one human clinical study of a group of current smokers. The animal models included the following: the DMBA-induced mammary gland tumourigenesis model and an acute liver injury model induced by the liver carcinogen carbon tetrachloride (CCl_4). These are classical extrinsic carcinogenic models. DMBA-induced DNA adduct formation and histological examination by light and electron microscopy were used as sensitive biomarkers to evaluate the preventive effects of TNJ at the initiation stage of multiple-step carcinogenesis. In the mammary breast carcinogenic model, to monitor the mechanisms of carcinogenesis and DMBA DNA-adduct formation in mammary tissue, the focus was on the pathogenic

changes after DMBA administration. In the acute liver injury model, the histopathological changes in liver tissue and levels of both super-oxide anion free radicals (SAR) and lipid hydroperoxide (LPO) after CCl_4 administration were the focus.

DMBA DNA-adduct formation was used as a marker to examine whether TNJ is able to prevent carcinogen-induced DNA damage. Most chemical carcinogens need to be activated by endogenous enzymes to be transformed into a form that readily binds to genetic DNA to form DNA-adducts. Carcinogen-DNA adduct formation is an important DNA damage marker that predicts the possibility of cancer development. Most scientists agree that carcinogen-induced DNA adduct formation is an early critical step in the multiple stages of carcinogenesis. Carcinogen-DNA adducts can be repaired by endogenous enzymes. Unrepaired adducts are fixed after one cell cycle. Unrepaired DNA damage is responsible for mutations and subsequent cancer development. Therefore, preventing carcinogen-DNA adduct formation is a key aspect of preventing the initial steps of carcinogenesis. If TNJ can prevent and/or block the formation of carcinogen-induced DNA adducts, it may prevent cancer at the initiation of multiple-stage carcinogenesis.

In recent years, increasing demand for higher quality and safer foods and medicines, as well as concern for environmental pollution during their commercial production, have triggered stringent regulations on toxin levels in foods and medicines as well as on the discharge of pollutants to the environment. In addition, there has been increasing consumer preference for natural substances. All these factors have provided strong motivation for the development of cost-effective new technologies, such as the eco-friendly extraction of natural substances employing green and safe solvents. In recent years, supercritical fluid extraction (SFE) has emerged as a highly promising environmentally benign technology for the production of natural extracts such as flavours, fragrances, spice oils, and oleoresins; natural anti-oxidants; natural colours; nutraceuticals and biologically active compounds. The state of a substance is called supercritical when both temperature and pressure exceed their critical point values. A supercritical fluid combines two beneficial properties, namely high density (which imparts high solvent power) and high compressibility (which permits high selectivity due to large changes in solvent power in response to small changes in temperature and pressure). In addition, SFE offers very attractive extraction characteristics owing to its favourable diffusivity, viscosity, surface tension, and other thermo-physical properties.

Since the 1980s, several potential applications of SFE have been reported. So far, the most popular SF has been carbon dioxide (CO_2), owing to its easy availability, low cost, nonflammability, nontoxicity, and its possession of a wide spectrum of solvent properties. Its critical temperature is 31.1 ˚C and its critical pressure is 73.8 bar. Dense or supercritical carbon dioxide could very well be the most commonly used solvent in this century due to its wide-ranging applications. Its near-ambient critical temperature makes it ideally suitable for processing thermally labile natural substances. It is generally regarded as safe (GRAS), and it yields microbial-inactivated, contaminant-free, tailor-made extracts of superior organoleptic profile and longer shelf life with highly potent active ingredients. The SFE technique ensures high consistency and reliability in the quality and safety of bioactive heat-sensitive botanical products as it does not alter the delicate balance of bioactivity of natural molecules. All of these advantages are almost impossible with conventional processes. Therefore, SFE technology using SC-CO_2 as the solvent is an ideal alternative to the conventional techniques for the extraction of bioactive ingredients from spices.

3. Conclusion

Morinda citrifolia L., commonly known as noni, has a long history of widespread use as a food in tropical regions from Indonesia to the Hawaiian Islands, and it is used as an herbal remedy for multiple diseases. Its fruit, leaves, seeds, bark and roots have been traditionally used for the prevention or improvement of various diseases, including arthritis, infections, colds, cancer, and diabetes. It has been found that *Morinda citrifolia L.*, has antioxidant potential equivalent or similar to that of synthetic antioxidants, such as BHT and BHA, which are currently used as food additives. The antioxidants which are found in *Morinda citrifolia L.*, have no side effects, and thus they could replace synthetic antioxidants in the food processing industry and have potential for use in preventive medicine. Thus, this fruit can be used as an antioxidant additive in the food processing industry.

4. Acknowledgements

The authors wish to acknowledge the financial support of MOSTI Malaysia. This work was carried out under e-science grant number SCF0049-IND-2007.

5. References

Ahmad, V.U. & Bano, S. (1980). Isolation of β-sitosterol and ursolic acid from *Morinda citrifolia* Linn, *Journal of the Chemical Society of Pakistan,* Vol.2, pp. 71, ISSN 0253-5106

Ames, B.M.; Shigena, M.K. & Hagen, T.M. (1993). Oxidants, antioxidants and the degenerative diseases of aging, Proceedings of the National Academy of Science of the United States America, Vol.90, pp. 7915-7922

Atkinson, N. (1956). Antibacterial substances from flowering plants. 3. Antibacterial activity of dried Australian Plants by rapid direct plate test, *Australian Journal of Experimental Biology,* Vol.34, pp. 17-26, ISSN 0004-945X

Basu, S. & Hazra, B. (2006). Evaluation of nitric oxide scavenging activity, *in vitro* and *ex vivo*, of selected medicinal plants traditionally used in inflammatory diseases, *Phytotherapy Research,* Vol.20, pp. 896-900, ISSN 1099-1573

Burton, G.W. & Ingold, K.U. (1989). Mechanisms of antioxidant action: preventive and chain-breaking antioxidants, In J. Miquel, A.T. Quintanilha, & H. Weber (Eds.). Handbook of free radicals and antioxidants in biomedicine (Vol. 2, No. 29). Boca Raton, FL: CRC Press

Bushnell, O.A.; Fukuda, M. & Makinodian, T. (1950). The antibacterial properties of some plants found in Hawaii, *Pacific Science*, Vol.4, pp. 167-183, ISSN 0030-8870

Calzuola, I.; Gianfranceschi, G.L. & Marsili, V. (2006). Comparative activity of antioxidants from wheat sprouts, *Morinda citrifolia*, fermented papaya and white tea, *International Journal of Food Sciences and Nutrition,* Vol.57, pp. 168-177, ISSN 0963-7486

Cardon, D. (2003). Le Monde des Teintures Naturelles, Belin, Paris

Carini, R.; Poli, G.; Diazini, M.U.; Maddix, S.P.; Slater, T.F. & Cheesman, K.H. (1990). Comparative evaluation of the antioxidant activity of a-tocopherol, α-tocopherol poly ethylene glycol 1000 succinate and a-tocopherol succinate in isolated hepatocytes and liver microsomal suspensions, *Biochemical Pharmacology,* Vol.39, pp. 1597-1601, ISSN 0006-2952

Chan-Blanco, Y.; Vaillant, F.; Perez, A.M.; Reynes, M.; Brillouet, J.M. & Brat, P. (2006). The noni fruit (*Morinda citrifolia* L.): A review of Agricultural research, nutritional and therapeutic properties, *Journal of Food Composition Analysis,* Vol.19, pp. 645-654, ISSN 0889-1575

Chong, T.M.; Abdullah, M.A.; Fadzillah, N.M.; Lai, O.M. & Lajis, N.H. (2004). Anthraquinones production, hydrogen peroxide level and antioxidant vitamins in Marinda elliptica cell suspension cultures from intermediary and production medium strategies, *Plant Cell Reports,* Vol.22, pp. 951-958, ISSN 0721-7714

Chunhieng, M.T. (2003). Developpement de nouveaux aliments santé tropical: application a la noix du Bresil Bertholettia excels et au fruit de Cambodge *Morinda citrifolia*, Ph.D thesis. INPL, France

Deng, S.; Palu, A.K.; West, B.J.; Su, C.X.; Zhou, B.N. & Jensen, J.C. (2007). Lipoxygenase inhibitory constituents of the fruits of Noni (*Morinda citrifolia*) collected in Tahiti, *Journal of Natural products,* Vol.70, pp. 859-862, ISSN 0974-5211

Dittmar, A. (1993). *Morinda citrifolia* L.-use in indigenous Samoan medicine, *Journal of Herbs, Spices and Medicine Plants,* Vol.1, pp. 77-92, ISSN 1049-6475

Dixon, A.R.; McMillen, H.; Etkin, N.L. (1999). Ferment this: the transformation of Noni, a traditional Polynesian medicine (*Morinda citrifolia*, Rubiaceae), *Ecological Botony,* Vol.53, pp. 51-68

Duncan, S.H.; Flint, H.J.; Stewart, C.S. (1998). Inhibitory activity of gut bacteria against Escherichia coli O157 mediated by dietary plant metabolites, *FEMS Microbiology Letters,* Vol.164, pp. 258-283, ISSN 1574-6968

Elkins, R. (1998). Hawaiian Noni (*Morinda citrifolia*) Prize Herb of Hawaii and the South Pacific, Woodland Publishing. Utah

European Commission. Scientific Committee of Food (2002). Opinion of the Scientific Committee on Food of Tahitian Noni juice, SCF/CS/Dos/18 ADD 2. Belgium

Farine, J.P.; Legal, L.; Moreteau, B.; Le Quere, J.L. (1996). Volatile components of ripe fruits of *Morinda citrifolia* and their effects on Drosophila, *Phytochemistry,* Vol.41, pp. 433-438, ISSN 0031-9422

Garcia-Mediavilla, V.; Crespo, I.; Callodo, P.S.; Esteller, A.; Sanchez-Campos, S.; Tunon, M.J. et al. (2006) The anti-inflammatory flavones quercetin and Kaempferol cause inhibition of inducible nitric oxide synthase, cyclooxygenase-2 and reactive C-protein, and down-regulation of the nuclear factor kappaB pathway in Chang Liver cells, *European Journal of Pharmacology,* Vol.557, pp. 221-229, ISSN 0014-2999

Halliwell, B. (1994). Free radicals and antioxidants: a personal view, *Nutrition Review,* Vol.52, pp. 253-265, ISSN 1753-4887

Heinicke, R.M. (1985). The pharmacologically active ingredient of Noni, Bulletin of the National Tropical Botanical Garden, Vol.15, pp. 10-14

Heinicke, R. (2001). The Xeronine system: a new cellular mechanism that explains the health promoting action of Noni and Bromelian, Direct source publishing

Hiramatsu, T.; Imoto, M.; Koyano, T.; Umezawa, K. (1993). Induction of normal phenotypes in RAS transformed cells by damnacanthal from *Morinda citrifolia*, *Cancer letters,* Vol.73, pp. 161-166, ISSN 0304-3835

Hirazumi, A.; Furusawa, E.; Chou, S.C.; Hokama, Y. (1994). Anticancer activity of *Morinda citrifolia* on intraperitoneally implanted Lewis lung carcinoma in syngenic mice, Proceedings of the Western Pharmacological Society, Vol.37, pp. 145-146

Hirazumi, A.; Furusawa, E.; Chou, S.C.; Hokama, Y. (1996). Immunomodulation contributes to the anticancer activity of *Morinda citrifolia* (Noni) fruit juice, Proceedings of the Western Pharmacological Society, Vol.39, pp. 7-9

Hirazumi, A.; Furusawa, E. (1999). An immunomodulatory polysaccharide-rich substance from the fruit juice of *Morinda citrifolia* (Noni) with antitumor activity, *Phytotherapic Research,* Vol.13, pp. 380-387, ISSN 1099-1573

Inoue K.; Nayeshiro, H.; Inouye, H. & Zenk, M. (1981). Anthraquinones in cell suspension culture of *Morinda citrifolia*, *Phytochemisry,* Vol.20, pp. 1693-1700, ISSN 0031-9422

Jeffers, P.; Kerins, S.; Baker, C.J. & Kieran, P.M. (2007). Generation of reactive oxygen and antioxidant species by hydrodynamically stressed suspensions of *Morinda citrifolia*, *Biotechnology Progress,* Vol.23, pp. 138-145, ISSN 8756-7938

Kamiya, K.; Tanaka, Y.; Endang, H.; Umar, M.; Satake, T. (2004). Chemical constituents of *Morinda citrifolia* fruits inhibit copper-induced Low-Density Lipoprotein oxidation, *Journal of Agriculture and Food Chemistry,* Vol.52, pp. 5843-5848, ISSN 0021-8561

Kampkotter, A.; Nkwonkam, C.G.; Zurawski, R.F.; Timpel, C.; Chovolou, Y.; Watjen, W. et al. (2007). Investigations of protective effects of the flavonoids quercetin and rutin on stress resistance in the model organism Caenorhabditis elegans, *Toxicology,* Vol.234, pp. 113-123, ISSN 0300-483X

Krishnaiah, D.; Sarbatly, R.; Nithyanandam, R.R., (2011). A review of the antioxidant potential of medicinal plant species. *Food and Bioproducts Processing,*Vol.89, pp. 217-233, ISSN 0960-3085

Levand, O.; Larson, H.O. (1979). Some chemical constituents of *Morinda citrifolia*, *Planta Medica,* Vol.36, pp. 186-187, ISSN 0032-0943

Liu, G.; Bode, A.; Ma, W.Y.; Sang, S.; Ho, C.T.; Dong, Z. (2001). Two novel glycosides from the fruits of *Morinda citrifolia* (Noni) inhibit AP-1 transactivation and cell transformation in the mouse epidermal JB6 cell line, *Cancer Research,* Vol.61, pp. 5749-5756, ISSN 1538-7445

Locher, C.P.; Burch, M.T.; Mower, H.F.; Berestecky, H.; Davis, H.; Van Polel, B.; Lasure, A.; Vander Berghe, D.A.; Vlieti-Nick, A.J. (1995). Anti-microbial activity and anti-complement activity of extracts obtained from selected Hawaiian medicinal plants, *Jounal of Ethnopharmacology,* Vol.49, pp. 23-32, ISSN 0378-8741

Luberck, W.; Hannes, H. (2001). Noni. El Valioso Tesoro Curativo de Los mares del Sur. Editorial EDAF S.A., Madrid

Mc Clatchey, W. (2002). From Polynesian healers to health food stores: Changing perspectives of *Morinda citrifolia* (Rubiaceae), *Integrative Cancer Therapies,* Vol.1, pp. 110-120, ISSN 1534-7354

Mckoy, M.L.G.; Thomas, E.A.; Simon, O.R. (2002). Preliminary investigation of the anti-inflammatory properties of an aqueous extract from *Morinda citrifolia* (noni), *Pharmacological Society,* Vol.45, pp. 76-78, ISSN 1757-8175

Meyer, A.S.; Heinonen, M. & Frankel, E.N. (1998). Antioxidant interactions of catechin, cyaniding, caffeic acid quercetin and ellagic acid on human LDL oxidation, *Food Chemistry,* Vol.67, pp. 71-75, ISSN 0308-8146

Mohd. Z.; Abdul-Hamid, A.; Osman, A. (2001). Antioxidative activity extracts from Mengkudu (*Morinda citrifolia* L.) root, fruit and leaf, *Food Chemistry,* Vol.78, pp. 227-231, ISSN 0308-8146

Morton, J.F. (1992). The ocean-going Noni, or Indian mulberry (*Morinda citrifolia, Rubiaceae*) and some of its 'colorful' relatives, *Ecological Botony,* Vol.46, pp. 241-256

Moure, A.; Cruz, J.M.; Franco, D.; Dominguez, J.M.; Sineiro, J.; Dominguez, H.; Nunez, M.J.; Parajo, J.C. (2001). Natural antioxidants from residual sources, *Food Chemistry,* Vol.72, pp. 145-171, ISSN 0308-8146

Nelson, S.C. (2001). Noni cultivation in Hawaii, *Fruit and Nuts,* Vol.4, pp. 1-4

Nelson, S.C. (2003). Noni cultivation and production in Hawaii, In: Proceedings of the 2002 Hawaii Noni conference. University of Hawaii at Nanoa. College of Tropical Agriculture and Human resources. Hawaii

Perry, L.M. & Metzger, J. (1980). Medical plant of East and South East Asia-attribute properties and uses, Cambridge: The MIT Press

Pietta, P.; Simonetti, P. & Mauri, P. (1998). Antioxidant activity of selected medicinal plants, *Journal of Agricultural and Food Chemistry,* Vol.46, pp. 4487-4490, ISSN 0021-8561

Ross, I.A. (2001). Medicinal plants of the world. Chemical Constituents, Tropical and Modern Medical Uses, Humana Press, New Jersey

Saludes, J.P.; Garson, M.J.; Franzblau, S.G. & Aguinaldo, A.M. (2002). Antitubercular constituents from the hexane fraction of *Morinda citrifolia* Linn. (*Rubiaceae*), *Phytotherapy Research,* Vol.16, pp. 683-685, ISSN 1099-1573

Samoylenko, V.; Zhao, J.; Dunbar, D.C.; Khan, I.A.; Rushing, J.W. & Muhammad, I. (2006). New constituents from Noni (*Morinda citrifolia*) fruit juice, *Journal of Agricultural and Food Chemistry,* Vol.54, pp. 6398-6402, ISSN 0021-8561

Sang, S.; Cheng, X.; Zhu, N.; Stark, R.E.; Badmaev, V.; Ghai, G.; Rosen, R.; Ho, C.T. (2001a). Flavonol glycosides and novel iridoid glycoside from the leaves of *Morinda citrifolia*, *Journal of Agriculture and Food Chemistry,* Vol.49, pp. 4478-4481, ISSN 0021-8561

Sang, S.; Cheng, X.; Zhu, N.; Wang, M.; Jhoo, J.W.; Stark, R.E., et al. (2001b). Iridoid glycosides from the leaves of *Morinda citrifolia*, *Journal of Natural products,* Vol.64, pp. 799-800, ISSN 0974-5211

Sang, S.; He, K.; Liu, G.; Zhu, N.; Cheng, X.; Wang, M., et al. (2001c). A new unusual iridoid with inhibition of activator protein-1 (AP-1) from the leaves of *Morinda citrifolia* L., *Organic Letters,* Vol.3, pp. 1307-1309, ISSN 1523-7060

Sang, S.; He, K.; Liu, G.; Zhu, N.; Wang, M.; Jhoo, J.W., et al. (2001d). Citrofolinin A, a new unusual iridoid with inhibition of activator protein-1 (AP-1) from the leaves of Noni (*Morinda citrifolia* L.), *Tetrahedron Letters,* Vol.42, pp. 1823-1825, ISSN 0040-4039

Sang, S.; Wang, M.; He, K.; Liu, G.; Dong, Z.; Badmaev, V.; Zheng, Q.Y.; Ghai, G.; Rosen, R.T.; Ho, C.T. (2002). Chemical components in Noni fruits and leaves (*Morinda citrifolia* L.) In: Ho, C.T., Zheng, Q.Y. (Eds.), Quality Management of Nutraceuticals, ASC Symposium Series 803, American Chemistry Society, Washington, DC, pp. 134-150

Sang, S.; Liu, G.; He, K.; Zhu, N.; Dong, Z.; Zheng, Q., et al. (2003).New unusual iridoids from the leaves of noni (*Morinda citrifolia* L.)show inhibitory effect on ultraviolet B-induced transcriptional activator protein-1 (AP-1) Activity, *Bioorganic and Medicinal Chemistry,* Vol.11, pp. 2499-2502, ISSN 0968-0896

Shovic, A.C.; Whistler, W.A. (2001). Food sources of provitamin A and vitamin C in the American Pacific, *Tropical Science,* Vol.41, pp. 199-202, ISSN 1556-9179

Solomon, N. (1999). The Noni Phenomenon, Direct Source Publishing, Utah

Srivastava, M.; Singh, J. (1993). A new anthraquinone glycoside form *Morinda citrifolia*, *Pharmaceutical Biology,* Vol.31, pp. 182-184, ISSN 1744-5116

Su, B.N.; Pawlus, A.D.; Jung, H.A.; Keller, W.J.; McLaughlin, J.L. & Kinghorn, A.D. (2005). Chemical constituents of the fruits of *Morinda citrifolia* (Noni) and their antioxidant activity, *Journal of Natural Products,* Vol.68, pp. 592-595, ISSN 0974-5211

Su, C.; Wang, M.; Nowicki, D.; Jensen, J.; Anderson, G. (2001). Selective COX-2 inhibition of *Morinda citrifolia* (Noni) *in vitro*, In: the Proceedings of the Eicosanoids and other Bioactive Lipids in Cancer. Inflammation and Related Disease. The 7th Annual Conference, 2001 October 14-17. Loews Vanderbilt Plaza, Nashville, Tennessee, USA

Takashima, J.; Ikeda, Y.; Komiyama, K.; Hayashi, M.; Kishida, A. & Ohsaki, A. (2007). New constituents from the leaves of *Morinda citrifolia*, Chemical and Pharmaceutical Bulletin, Vol.55, pp. 343-345

Thomson, R.H. (1971). Naturally occurring quinines (2nd ed.), London and New York: Academic Press (Appropriate sections)

Vinson, J.A.; Dabbag, Y.A.; Serry, M.M. & Jang, J. (1995). Plant flavonoids, especially tea flavonols, are powerful antioxidants using an *in vitro* oxidation model for heart disease, *Journal of Agricultural and Food Chemistry,* Vol.43, pp. 2800-2802, ISSN 0021-8561

Wang, M.; Kikuzaki, K.C.; Boyd, C.D.; Maunakea, A.; Fong, S.F.T.; Ghai, G.R.; Rosen, R.T.; Nakatani, N.; Ho, C.T. (1999). Novel trisaccharide fatty acid ester identified from the fruits of *Morinda citrifolia* (Noni), *Journal of Agriculture and Food Chemistry,* Vol.47, pp. 4880-4882, ISSN 0021-8561

Wang, M.Y.; Su, C. (2001). Cancer preventive effect of *Morinda citrifolia* (Noni), Annals of the New York Academy of Sciences, Vol.952, pp. 161-168, ISSN 1749-6632

Wang, M.Y.; West, B.; Jensen, C.J.; Nowicki, D.; Su, C.; Palu, A.K.; Anderson, G. (2002). *Morinda citrifolia* (Noni): a literature review and recent advances in Noni research, *Acta Pharmacologica Sinica,* Vol.23, pp. 1127-1141, ISSN 1671-4083

West, B.J.; Tani, H.; Palu, A.K.; Tolson, C.B. & Jensen, C.J. (2007). Safety tests and antinutrient analyses of noni (*Morinda citrifolia* L.) leaf, *Journal of the Science of Food and Agriculture,* Vol.87, pp. 2583-2588, ISSN 0022-5142

Willet, W.C. (1994). Diet and health-what should we eat?, *Science,* Vol.264, pp. 532-537

Yang, J.; Paulino, R.; Janke-Stedronsky, S. & Abawi, F. (2007). Free-radical-scavenging activity and total phenols of noni (*Morinda citrifolia* L.) juice and powder in processing and storage, *Food Chemistry,* Vol.102, pp. 302-308, ISSN 0308-8146

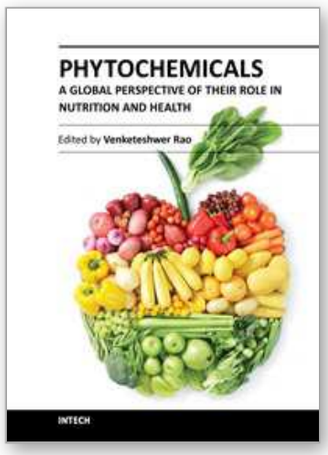
Yen, G. & Hsieh, C. (1998). Antioxidant activity of extracts from Duzhong (Eucommia ulmoides) towards various lipid peroxidation models *in vitro*, *Journal of Agricultural and Food Chemistry,* Vol.46, pp. 3952-3957, ISSN 0021-8561

Younos, C.; Rolland, A.; Fleurentin, J.; Lanhers, M.C.; Misslin, R.; Mortier, F. (1990). Analgesic and behavioral effects of *Morinda citrifolia*, *Planta Medicine,* Vol.56, pp. 430-434, ISSN 0032-0943

Yu, B.P. (1994). Cellular defences against damage from reactive oxygen species, *Physiological Reviews,* Vol.76, pp. 139-162, ISSN 0031-9333

Zenk, M.H.; El-Shagi, H. & Schulte, U. (1975). Anthraquinone production by cell suspension cultures of *Morinda citrifolia*, *Planta Medica. Suppl.*, pp. 79-101, ISSN 0032-0943

Zin, Z.M.; Abdul-Hamid, A. and Osman, A. (2002). Antioxidative activity of extracts from Mengkudu (*Morinda citrifolia* L.) root, fruit and leaf, *Food Chemistry,* Vol.78, pp. 227-231, ISSN 0308-8146



Phytochemicals - A Global Perspective of Their Role in Nutrition and Health

Edited by Dr Venketeshwer Rao

ISBN 978-953-51-0296-0
Hard cover, 538 pages
Publisher InTech
Published online 21, March, 2012
Published in print edition March, 2012

Phytochemicals are biologically active compounds present in plants used for food and medicine. A great deal of interest has been generated recently in the isolation, characterization and biological activity of these phytochemicals. This book is in response to the need for more current and global scope of phytochemicals. It contains chapters written by internationally recognized authors. The topics covered in the book range from their occurrence, chemical and physical characteristics, analytical procedures, biological activity, safety and industrial applications. The book has been planned to meet the needs of the researchers, health professionals, government regulatory agencies and industries. This book will serve as a standard reference book in this important and fast growing area of phytochemicals, human nutrition and health.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Duduku Krishnaiah, Rajesh Nithyanandam and Rosalam Sarbatly (2012). Phytochemical Constituents and Activities of Morinda citrifolia L., Phytochemicals - A Global Perspective of Their Role in Nutrition and Health, Dr Venketeshwer Rao (Ed.), ISBN: 978-953-51-0296-0, InTech, Available from: http://www.intechopen.com/books/phytochemicals-a-global-perspective-of-their-role-in-nutrition-and-health/phytochemical-constituents-and-activities-of-morinda-citrifolia-l-

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

IntechOpen