Passiflora edulis

Scientific Name

***Passiflora edulis* Sims.**

Synonyms

Passiflora edulis var. *pomifera* (M. Roem.) Mast., *Passiflora edulis* var. *rubricaulis* (Jacq.) Mast., *Passiflora edulis* var. *verrucifera* (Lindl.) Mast., *Passiflora diaden* Vell., *Passiflora gratissima* A. St.-Hil., *Passiflora incarnata* L., *Passiflora iodocarpa* Barb. Rodr., *Passiflora middletoniana* Paxton, *Passiflora minima* Blanco, *Passiflora pallidiflora* Bertol., *Passiflora picroderma* Barb. Rodr., *Passiflora pomifera* M. Roem., *Passiflora rigidula* J. Jacq., *Passiflora rubricaulis* J. Jacq., *Passiflora vernicosa* Barb. Rodr., *Passiflora verrucifera* Lindl.

Family

Passifloraceae

Common/English Names

Black Passionfruit, Granadilla, Maracuya, Passion Fruit, Purple Granadilla, Purple Passion Fruit, Purple Water Lemon, Red Passionfruit, Sweet Cup, Yellow Passionfruit.

Vernacular Names

Passiflora edulis: Sims f. *flavicarpa*
Afrikaans: Grenadella;
Brazil: Flor-Da-Paixão, Granadilho, Maracuj, Maracujá, Maracujá-Comum, Maracujá-De-Comer, Maracujá-De-Ponche, Maracujá-Do-Mato, Maracujá-Doce, Maracujá-Mirim, Maracujá-Peroba, Maracujá-Preto, Maracujá-Redondo (Portuguese);
Chinese: Ji Dan Guo;
Colombia: Curuba, Curuba Redonda, Gulupa;
Cook Islands: Ka'Atene Papa'Ā, Katingapapa'Ā, Pārapōutini Papa'Ā (Maori);
Cuba: Ceibey;
Czech: Mučenka Jedlá;
Danish: Granatblomst, Gul Passionsblomst, Passionsfrugt;
Dutch: Eetbare Passiebloem, Paarse-Passievrucht, Passiebloem, Passievrucht, Passie Vrucht;
Eastonian: Purpur-Kannatuslill;
Fijian: Qarandila;
Finnish: Kärsimyshedelmä, Passiohedelmä;
French: Grenadille, Fruit De La Passion, Grenadille Pourpre, Maracaju Pourpre, Maracudja, Passiflore Comestible, Gouzou, Pomme-Liane Violette;
French Guiana: Couzou;
German: Maracuja, Purpurgranadille Purpur-Granadille, Granadilla, Passionsfrucht;
Hawaiian: Liliko'I;
Hungarian: Golgotavirág Gyümölcse;
India: Louki;

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Indonesia: Buah Negeri, Markisa, Pasi, Konyal;
Italian: Granadiglia, Frutto Della Passione, Passiflora Commestibile, Granatiglia;
Japanese: Kudamonotokeiso;
Kenya: Matunda;
Laos: Linmangkon;
Malaysia: Buah Susu, Markisa;
Mexico: Granadita De China;
Palauan: Kudamono;
Philippines: Maraflora, Pasionaria;
Pohnpeian: Pompom;
Polish: Meczennica Jadalna;
Portuguese: Maracujá, Maracujá-Pequeno, Maracujá-Roxo, Maracujá-Suspiro;
Puerto Rico: Fruta De La Pasión, Parcha;
Samoan: Pasio;
Slovenian: Granadilja, Marakuja, Pasijonka;
Spanish: Granadilla Morada, Maracuyá, Maracuyá Púrpura, Granadilla China, Parchita Maracuyá;
Swedish: Passionsfrukt;
Taiwan: Xi Fan Lian;
Thailand: Lin Mang Kon Saowarot;
Tongan: Vaine Tonga;
Venezuela: Parchita, Fruta De La Pasión, Parcha;
Vietnam: Chum Bap;
West Indies: Couzou;
Passiflora edulis: Sims f. *edulis*
Dutch: Paarse-Passievrucht, Passievrucht;
English: Black Passionfruit, Passion Fruit, Purple Granadilla, Purple Passionfruit, Red Passionfruit;
Eastonian: Purpur-Kannatuslill;
French: Fruit De La Passion, Grenadille, Grenadille Pourpre, Maracaju Pourpre, Pomme-Liane Violette;
German: Eßbare, Passionsfrucht, Purpurgranadille, Purpur-Granadilla;
Indonesia: Markisa;
Malaysia: Markisah;
Portuguese Maracujá;
Spanish: Fruta De La Passion, Granada De Castilla, Granadilla, Maracu.
Passiflora edulis Sims f. flavicarpa O. Deg.
Dutch: Gele-Passievrucht;
English: Brown-Seeded Passionfruit, Clock Flower, Clock Plant, Golden Passionfruit, Malaysian Passionfruit, Philippines Passionfruit, Thai Passionfruit, Yellow Granadilla, Yellow Passionfruit;
French: Grenadille À Fruit Jaune, Pomme Liane Jaune;
German: Gelbe Grenadille;
Indonesia: Konyal;
Portuguese: Maracujá-Amarelo, Maracujá-Azedo;
Spanish: Maracuyá Amarillo, Parcha Amarilla;
Suriname: Maracuja.

Origin/Distribution

Passiflora edulis is native to south America. There are two distinct forms: f. *edulis* with purple fruits and f. *flavicarpa* Degener with larger yellow fruits; f. *flavicarpa* occurs in the tropical lowlands, f. *edulis* occurs in cooler regions at higher altitudes. The purple passion fruit is indigenous from southern Brazil through Paraguay to northern Argentina. It has been stated that the yellow form is of unknown origin, or perhaps native to the Amazon region of Brazil, or is a hybrid between *P. edulis* and *P. ligularis*. Cultivated and escaped worldwide in tropical and subtropical areas, purple passionfruit is widely grown in India, New Zealand, the Caribbean, Brazil, Ecuador, California, southern Florida, Hawaii, Australia, East Africa, Israel, South Africa, and in Fujian, Guangdong, Yunnan (China) and Taiwan. It is also grown in the cooler highlands in tropical areas of southeast Asia and Papua New Guinea. The yellow form is grown pan-tropically usually in the warmer lowlands.

Agroecology

The purple passionfruit is subtropical in its climatic requirement and thrive at altitudes above 1,100–2,000 m. It prefers cool, frost free climate but does tolerate mild frost but does not flower below 1,000 m and perform poorly in intense summer heat. It will grow in areas with 900 mm annual precipitation that is well distributed throughout the year.

The yellow passionfruit is near tropical in its requirement, is intolerant of frost and grows best in the warmer lowlands from near seal level to 800 m. It grows well in areas with more than 1,500–2,500 mm annual rainfall. Both types need protection from strong winds.

Both types are adaptable to a wide range of soils, including clayey and sandy soils, the former requiring drainage and the latter needs manuring. Both do best in a free-draining, friable, moist and fertile soil rich in organic matter.

Edible Plant Parts and Uses

The ripe aromatic fruit is eaten fresh and the best way is to cut the fruit in halves and scoop out the aril (pulp) with seeds intact with a spoon or eaten with ice-cream, yoghurt and in fruit salads. The arils are also processed into juice, nectar, syrup, cordial and carbonated drinks, sherbets, jams, jellies or used in pastries and cakes or to flavour ice-cream and yoghurt. Passion fruit juice or syrup is an essential ingredient of some cocktails, such as the hurricane and the Peruvian maracuya sour. In Brazil, passion fruit is made into a common dessert passion fruit "mousse", and the seeds are routinely used to decorate the tops of certain cakes. Passion fruit juice is also widely consumed. In the Dominican Republic, passionfruit is used to make juice, jams, and the chinola flavoured syrup which is used on shaved ice. The fruit is also commonly eaten raw sprinkled with sugar. In Australia, passionfruit is sold commercially fresh and canned. It is usually eaten fresh on its own or in fruit salads, and used as topping for desserts like pavlova (a meringue cake), cheesecake, and vanilla slice. The juice is also made into mixed fresh fruit juices, nectar, cordial and carbonated drinks. In South Africa, passion fruit is used to flavour yogurt. It is also used to flavour soft drinks such as Schweppes Sparkling Granadilla and numerous cordial drinks. In Hawaii, passion fruit flavoured syrup is a popular topping for shave ice. Ice cream and mochi are also flavoured with passionfruit as well as many other desserts such as cookies, cakes, and ice cream. Passionfruit is also processed into jam, jelly, as well as a butter. In Indonesia, passion fruit is consumed fresh or the juice is strained and cook with sugar to form a thick syrup which is diluted with water and served with ice-cubes. The yellow variety is used usually for juice processing, while the purple variety is sold in fresh fruit markets.

Botany

A robust, glabrous, herbaceous perennial climber, woody at base with slender, striate green stem armed with rameal, axillary tendrils. Leaves alternate, glossy green, membranous, 6–13 cm by 8–13 cm, deeply trilobed, middle lobe ovate, lateral lobes ovate-oblong, margin glandular-serrate, apex acute, acuminate, distinctly 3-nerved with prominent laterals, stipules small, linear-lanceolate to 10 mm long. Flowers solitary, axillary, fragrant, whitish or pale violet, 4–7 cm across, on 5–7 cm long trigonous pedicel subtending 3 large, foliaceous bracts at the top of the pedicel, hypanthium 1 × 1.2 cm. Calyx, tubular-campanulate, whitish green with 5 lobes patent or reflexed. Corolla 5, white inserted at the margin of the calyx tube. Corona at the fringe of the calyx tube, 5-seriate, two outer row with long radiating, curly white tipped with purple base threads and the 3 inner rows with shorter white-puple threads. Stamens 5 with large yellowish anther, ovary ovoid, yellowish with trifid style and reniform pale green stigma. Fruit globose (4–6 cm) or ovoid (6–10 cm by 5–7 cm), smooth, glabrous, glossy green and dotted when young turning to yellow (yellow form) or dark purple (purple form) when mature with a tough rind. Seeds numerous (up to 250) small, hard, dark brown or black, pitted, ovoid seeds in the fruit cavity. Each seed enclosed in a juicy, orange, sweet to acid-sweet, aromatic aril (pulp). There are also hybrid cultivars with pink and maroon-coloured fruits.

P. edulis* f. *edulis (Plates 1, 2, 3, 4 and 5) – purple passionfruit has purple or reddish fruit, fruits are usually globose to subglobose, 4–6 cm diameter, with green tendrils and leaves. Purple passion fruit is self-fertile, but pollination is best under humid conditions.

***P. edulis* f. *flavicarpa* Degener** (Plates 6, 7, 8 and 9) – yellow passionfruit has canary yellow and larger globose to ovoid fruit, 6–10 cm by 5–7 cm, reddish purple tinged tendrils and leaves, more showy flowers with deeper violet corona and more vigorous growth. The flowers of the yellow form are perfect but self-sterile and require cross pollination.

Plate 1 Immature purple passionfruit and trilobed leaves

Plate 4 Red passionfruit

Plate 2 Purple passionfruit on sale in a local market

Plate 5 Red passionfruit halved showing the pulp and seeds

Plate 3 Ripe purple passionfruit

Plate 6 Immature yellow passionfruit and leaves

Plate 7 Close-view of immature yellow passionfruit

Plate 8 Ripening yellow passionfruit

Plate 9 Ripe yellow passionfruit

Nutritive/Medicinal Properties

Nutrient value per 100 g edible portion of the pulp and seeds of purple skinned passionfruit, *Passiflora edulis* f. *edulis* comprised the following (Wills et al. 1986): energy 304 KJ, moisture 74.4 g, nitrogen 0.48 g, protein 3.0 g, fat 0.3 g, ash 0.6 g, fructose 1.9 g, glucose 2.3 g, sucrose 1.5 g, total sugars 5.7 g, available carbohydrate 5.7 g, total dietary fibre 13.9 g; minerals – calcium 10 mg, iron 0.6 mg, magnesium 28 mg, potassium 200 mg, sodium 19 mg, zinc 0.8 mg; vitamins – thiamin 0.03 mg, riboflavin 0.14 mg, niacin 2.5 mg, niacin derived from tryptophan or protein 0.5 mg, niacin equivalents 3.0 mg, vitamin c 18 mg, alpha carotene 410 µg, beta carotene 360 µg, cryptoxanthin 370 µg, beta carotene equivalents 750 µg, retinol equivalents 125 µg; organic acids – citric acid 3.5 g and malic acid 0.5 g.

Another analysis conducted in USA reported the following nutrient value of purple passion fruit, *Passiflora edulis* f. *edulis,* per 100 g edible portion minus 48% shell refuse (USDA 2011): water 72.93 g, energy 97 kcal (406 kJ), protein 2.20 g, total lipid 0.70 g, ash 0.8 g, carbohydrate 23.38 g, total dietary fibre 10.4 g, total sugars 11.20 g, Ca 12 mg, Fe 1.60 mg, Mg 29 mg, P 68 mg, K 348 mg, Na 28 mg, Zn 0.10 mg, Cu 0.08 mg, Se 0.6 µg, vitamin C 30 mg, thiamine 0 mg, riboflavin 0.130 mg, niacin 1.5 mg, vitamin B-6 0.1 mg, total folate 14 µg, total chloline 7.6 mg, vitamin A, 64 µg RAE, vitamin A 1271 IU, β-carotene 743 µg, β-cryptoxanthin 41 µg, vitamin E (α-tocopherol) 0.02 mg, vitamin K (phylloquinone) 0.7 µg, total saturated fatty acids 0.059 g, 16:0 (palmitic) 0.045 g, 18:9 (stearic) 0.014 g; total monounsaturated fatty acids 0.086 g, 18:1 undifferentiated (oleic) 0.086 g; total polyunsaturated fatty acids 0.411 g, 18:2 undifferentiated (linoleic) 0.410 and 18:3 undifferentiated (linolenic) 0.001 g.

Fresh passion fruit is known to be high in provitamin A (α-, β-carotenes), potassium, and dietary fibre and also has moderate levels of vitamin C and niacin.

Yellow passion fruit, *Passiflora edulis* f. *flavicarpa,* juice was reported to have the following nutrient composition per 100 g (USDA 2011): water 84.21 g, energy 60 kcal (251 kJ), protein 0.67 g, total lipid 0.18 g, ash 0.49 g, carbohydrate 14.45 g, total dietary fibre 0.2 g, total sugars 14.25 g, Ca 4 mg, Fe 0.36 mg, Mg 17 mg, P 25 mg, K 278 mg, Na 6 mg, Zn 0.06 mg, Cu 0.050 mg, Se 0.1 µg, vitamin C 18.2 mg, thiamine 0 mg, riboflavin 0.101 mg, niacin 2.240 mg, vitamin

B-6 0.060 mg, total folate 8 μg, total chloline 4 mg, vitamin A, 47 μg RAE, vitamin A 943 IU, β-carotene 525 μg, α-carotene 35 μg, β-cryptoxanthin 47 μg, vitamin E (α-tocopherol) 0.01 mg, vitamin K (phylloquinone) 0.4 μg, total saturated fatty acids 0.015 g, 16:0 (palmitic) 0.012 g, 18:9 (stearic) 0.004 g; total monounsaturated fatty acids 0.022 g, 18:1 undifferentiated (oleic) 0.022 g; total polyunsaturated fatty acids 0.106 g and 18:2 undifferentiated (linoleic) 0.105 g.

Other Fruit Phytochemicals

Yellow passion fruit rind was found to be a potentially rich source of naturally low-methoxyl pectin (Yapo and Koffi 2006). The extracted pectins were found to be rich in an hydrogalacturonic acid and had a low degree of methyl esterification, low contents of acetyl groups, neutral sugar and proteinaceous material. Their gelling ability and viscoelastic properties were comparable to those of a commercial citrus low-methoxyl pectin. The extraction of safe pectin products with good functional properties from yellow passion fruit by-product, was developed using two natural acid extractants, namely, pure lemon juice and citric acid solvent (Yapo 2009). The results showed that both of them solubilise, from cell wall material, pectins characterised by high galacturonic acid content (64–78% w/w), degree of esterification (52–73), viscosity-average molecular weight (70–95 kDa) and capable of forming gels in the presence of high soluble solids (sucrose) content and acid.

The total dietary fibre in alcohol-insoluble material from yellow passion fruit (YPF) rind was found to be >73% dry matter of which insoluble dietary fibre accounted for >60% (w/w) (Yapo and Koffi 2008). Non-starchy polysaccharides were the predominant components (approximately 70%, w/w), of which cellulose appeared to be the main fraction. The water holding and oil holding capacities of the fibre-rich material were >3 g of water/g of fibre and >4 g of oil/g of fibre, respectively.

A total of 51 volatile components were identified in yellow passion fruit essence including 20 alcohols, 20 esters, 2 aldehydes, 4 ketones, 1 acetal, 1 furan and 1 hydrocarbon (Jordan et al. 2000). Alcohols were the major components comprising 56.94% of the total components. The most abundant compounds identified were linalool (15.3%) (characterised by its floral, citrus and lemon flavour),1-octanol (11.51%) (fatty, citrus and green), 1-hexanol (9.03%) (herbaceous, fragrant and sweet) and α-terpineol (fragrant, floral and lilac). Other alcohols above 1% include 3-methyl-1-butanol (2.80%), geraniol (2.44%), benzyl alcohol (1.6%) undecanol (1.45%), cis-3-Hexen-1-ol (1.17%) and terpinene-4-ol (1.05%). A new alcohol identified was 3-methyl-2-buten-1-ol. The next most abundant compounds were the esters comprising 30.38% of the total volatile compounds; ethyl hexanoate (11.11%), ethyl butanoate (9.44%), ethyl benzoate (3%) and phenylmethyl acetate (1.44%) were the predominant esters. The two aldehydes made up 4.59% of the total volatile components and comprised benzene acetaldehyde (0.22%) and benzaldehyde (4.57%). Ketones comprised 3.3% of the total with cyclopentanone (1.5%) and 3-hydroxy-2-butanone (1%) predominating. The acids made up 1.2% of the total volatiles – hexanoic acid (0.9%) and octanoic acid (0.4%). Of the miscellaneous components, the acetal 1,1-Diethoxy ethane (1.06%) was important for its contribution to a strong, tart, fruity, refreshing green odour. The furan identified was cis-linalool oxide (0.62%) and the hydrocarbon methyl cyclopentane (1.77%).

(+)-cis-2-methyl-4-propyl-1,3-oxathiane, the main component responsible of the passion fruit aroma was enantioselective synthesised (Scafato et al. 2009). Together with 3-mercaptohexan-1-ol and 3-mercaptohexyl acetate, already known to contribute to the aroma of passion fruit (*Passiflora edulis*), 3-mercapto-3-methylbutan-1-ol and 3-mercapto-3-methylbutyl acetate were identified for the first time in passion fruit (Tominaga and Dubourdieu 2000). The precursor of 3-mercaptohexan-1-ol as S-(3-hexan-1-ol)-L-cysteine, in the form of trimethylsilylated derivatives from the juice of this fruit was also identified. The presence of free and combined forms of these volatile thiols in this fruit was also reported. A thioesterase activity towards volatile organosulfur

compounds (VOSCs) was identified in ripening purple passion fruit (Tapp et al. 2008). VOSCs are high impact aroma chemicals characteristic of tropical fruits which are active as both free thiols and the respective thioesters. The major thioesterase in the fruit was found to be a wall-bound protein in the mesocarp. The results suggested that cell wall hydrolases in tropical fruit may have additional useful roles in biotransforming VOSCs.

About 150 volatiles were identified in purple passion fruit with esters and terpenoids being the most abundant classes of flavour compounds (Whitfield and Last 1986). Among the terpenoids numerous monoterpenes were found as degradation products of non-volatile precursor compounds such as hydroxylated linalool derivatives as well as monoterpene glycosides. The carotenoid-derived C13 nortepenoids have been suggested to be derived by similar pathways. Juice of purple passion fruit contains a wide range of terpenoids (Winterhalter 1990). In addition to the main component linalool and the other monoterpenoids, the following C_{13} nortepenoid aglycones were identified: 4-hydroxy-β-ionol; 4-oxo-β-ionol; 4-hydroxy-7,8-dihydro-β-ionol; 4-oxo-7,8-dihydro-β-ionol; 3-oxo-α-ionol; isomeric 3-oxo retro-α-ionols, 3-oxo-7,8-dihydro-α-ionol; 3-hydroxy-1,1,6 – trimethyl-1,2,3, 4-tetrahydronaphthalene; vomifoliol and dehydrovomifoliol. Other strong odoriferous flavour compound in purple passion fruit included C13 norisoprenoids i.e. 4 isomers of megastigma-4,6,8-triene (Whitfield and Last 1986) and isomeric edulan I and II (Whitfield et al. 1973; Whitfield and Stanley 1977) key flavour components of purple passion fruit juice (Winterhalter 1990). The precursor to the isomeric edulans in purple passion fruit was identified as 3-hydroxyl-retro α-ionol (Herderich and Winterhalter 1991). The novel C_{13}-glucoside β-ionyl-β-D-glucopyranoside was identified in purple passionfruit as a genuine precursor of isomeric megastigma-4,6,8-trienes (Herderich et al. 1993).

The majority of the volatiles components in purple-skinned passionfruit identified were esters derived largely from combinations of the alkan-1-ols ($C_{1,2,4,6,8}$) the alkan-2-ols ($C_{5,7}$),(Z)-and (E)-hex-3-en-1-ol,(2)-hex-4-en-1-ol,and benzyl alcohol, with acids of even carbon number (acetic, butanoic, hexanoic, octanoic, hex-3-enoic, oct-3-enoic, and 3-hydroxyhexanoic) (Murray et al. 1972). The non-ester constituents included many of the above free alcohols, acetaldehyde, alkan-2-ones ($C_{3,5,7,9,11}$), monoterpenes ((E)-β-ocimene, 1,8-cineole, linalool, α-terpineol, citronellol, geraniol, citronellyl acetate, (Z) and(E) five-membered ring linalool oxides), and 1,1,6-trimethyl- l,2-dihydronaphthalene, β-ionone, γ-hexanolac-tone, γ-octanolactone, and the lactone of 2-hydroxy-2,6,6-trimethylcyclohexylidene-acetic acid. Preliminary odour assessment of the constituents indicated volatile passionfruit flavour to be complex and made up of many components, especially certain esters.

Passiflora edulis was reported to be rich in glycosides and phenols. From the fruit of *P. edulis*, 6-O-α-L-arabinopyranosyl-β-D-glucopyranosides of linalool, benzyl alcohol and 3-methyl-but-2-en-1-ol were identified (Chassagne et al. 1996b) Cyanogenic β-rutinoside ((R)-mandelonitrile α-*L*-rhamnopyranosyl-β-D-glucopyranoside) was isolated (Chassagne and Crouzet 1998); β-D-glucopyranoside and 6-*O*-α-L-rhamnopyranosyl-β-D-glucopyranoside of methyl salicylate and the β-D-glucopyranoside of eugenol were characterized in purple passion fruit (Chassagne et al. 1997). Prunasin was found to be the most important cyanogenic glycoside in peel (285 mg/kg for *P. edulis* f. *flavicarpa*), whereas amygdalin (31 mg/kg for *P. edulis*) and the two compounds tentatively identified as mandelonitrile rhamnopyranosyl β-D-glucopyranosides were mostly found in the juice (99 mg/kg for *P. edulis* f. *flavicarpa).* Different amounts of sambunigrin were found in the juice and the peel (from 0.4 mg/kg in *P. edulis* juice to 15.5 mg/kg in *P. edulis* f. *flavicarpa* peel) (Chassagne et al. 1996a). The glycoside 2,5-Dimethyl-4-hydroxy-3-(2H) furanone (furaneol) was identified for the first time in bound form in purple (*P. edulis*) and yellow passion fruit (*P. edulis* f. *flavicarpa*) (Chassagne et al. 1999). Several terpene diols: 2,6-dimethyl-1,8-octanediol, (E)- and (Z)-2,6-dimethylocta-2,7-diene-1,6-diol, 2,6-dimethylocta-3,7-dien-2,6-diol and 2,6-dimethylocta-1,7-dien-3,6-diol were identified in both purple and yellow passion fruit

(Chassagne et al. 1999). α-ionol derivatives oxygenated in position 3 seemed to be characteristic of purple passion fruit whereas β-ionol compounds oxygenated in position 3 were the major norisoprenoids identified as the aglycone in yellow passion fruit. Significant concentrations of bound aromatic alcohols were found in purple and yellow passion fruit whereas phenolics could be considered as characteristic of purple varieties. C-glycosylflavonoids identified as isoorientin, vicenin-2, spinosin, and 6,8-di-C-glycosylchrysin were also present in the yellow passion fruit pericarp (Sena et al. 2009). Two new ionones I and II were isolated for from purple passion fruit (Naf et al. 1977).

Anthocyanins identified in the passion fruit rind included cyanidin 3-glucoside (97%), small amounts of cyanidin 3-(6″-malonylglucoside) (2%) and pelargonidin 3-glucoside (1%) (Kidoy et al. 1997) and cyanidin-3-*O*-galactopyranoside (Chang and Su 1998). The following 13 carotenoids from yellow passion fruit (*Passiflora edulis*) were identified: phytoene, phytofluene, ζ-carotene (principal carotenoid), neurosporene, β-carotene, lycopene, prolycopene, monoepoxy-β-carotene, β-cryptoxanthin, β-citraurin, antheraxanthin, violaxanthin, and neoxanthin (Mercadente et al. 1998) and from passion fruit α-carotene, γ-carotene, β-cryptoxanthin, β-apo-10'-carotenol (Goday and Rodriguez 1994). Other volatile compounds identified in the fruit rind of *P. edulis* included 2-tridecanone, (62.9%), (9Z)-octadecenoic acid (16.6%), 2-pentadecanone, (6.2%), hexadecanoic acid (3.2%), 2-tridecanol (2.1%), octadecanoic acid (2%) and caryophyllene oxide (2%) (Arriaza et al. 1997).

Proximate analysis showed that 'Tainung No. 1' passion fruit seeds had a high amount of protein (10.8%) and were rich in oil (23.40%) (Liu et al. 2008). The seeds were found to be a good source of minerals. They contained considerable amounts of sodium (2.980 mg/g), magnesium (1.540 mg/g), potassium (0.850 mg/g), and calcium (0.540 mg/g). The passion fruit seeds contained the 17 amino acids found naturally in plant protein (except for tryptophan which was not analyzed). The essential amino acids accounted for 34% of the 17 amino acids. The amino acid score of passion fruit seeds protein was 74 and the limiting amino acids were methionine and cystine. The oil extracted by solvent and supercritical dioxide carbon was liquid at room temperature and the color was golden-orange. The specific gravity of the oil was about 0.917. Fatty acid composition of the seed oil indicated that the oil contained two essential fatty acids (linoleic acid and linolenic acid), but the content of linoleic acid (72.69%) was by far greater than that of linolenic acid (0.26%). The present analytical results indicated that passion fruit seed to be a potentially valuable non-conventional source for high-quality oil.

Phytochemicals in Leaf and Stem

Phytochemical analysis revealed the presence of carbohydrates, glycosides, flavonoids, resins and balsams, alkaloids, and phenolic compounds in all the plant parts of *P. edulis* (Akanbi et al. 2011). Tannins were present in the leaf and fruit extracts but absent in the stem whereas saponins were present in the leaf and stem but not detected in the fruit sample. Terpenes were not detected in any part of the plant. C-glycosyl flavonoids namely orientin, isoorientin, vitexin and isovitexin were found in the leaves and pericarp of *P. edulis* var. *flavicarpa*, and *P. edulis* var. *edulis* (Zucolotto et al. 2011).

Glucosides were also found in the leaves and stem. The new cyanogenic glycosides (2R)–β-Dallopyranosyloxy-2-phenylacetonitrile and (2S)–β-D-allopyranosyloxy-2-phenylacetonitrile plus (2R)–prunasin and (2S)-sambunigrin the major cyanogens of the fruits and the alloside of benzyl alcohol were found in leaf and stem material of *P. edulis* (Seigler et al. 2002). Leaves also contained benzylic β-D-allopyranosides 1 and 2, representatives of a rare class of natural glycosides with D-allose as the only sugar constituent (Christensen and Jaroszewski 2001). The glycoside 1 was the first known cyanogenic glycoside containing a sugar different from D-glucose attached directly to the cyanohydrin center. The methanol extract of air dried leaves, yielded

a cyclopropane triterpine glycoside named Passiflorine (22*R*), (24*S*)-22,31-epoxy-24-methyl-1α,3β,24,31-tetrahydroxy-9,19-*cyclo*-9β-lanostan-28-oic acid β-d-glucosyl ester (Bombardelli et al. 1975). C-glucosylflavones isolated from the butanolic fraction of an aqueous extract of *P. edulis* var. *flavicarpa* leaves included isoorientin, vicenin-2 and spinosin (Zucolotto et al. 2009). *P. edulis* also contained flavonoid glycosides, viz., luteolin-6-C-chinovoside, luteolin-6-C-fucoside (Mareck et al. 1991); cyclopentenoid cyanohydrin glycosides passicapsin and passibiflorin (Olafsdottir et al. 1989); three cyanogenic glycosides, passicoriacin, epicoriacin and epitetraphyllin B, the structure of which were reassigned as epivalkenin, taraktophyllin and volkenin respectively, based on a reinterpretation of their spectral data (Seigler and Spencer 1989). Passionfruit leaves also contained C-deoxyhexosyl flavonoids which had antioxidant activity (Ferreres et al. 2007). Sixteen apigenin or luteolin derivatives were characterized, which included four mono-C-glycosyl, eight O-glycosyl-C-glycosyl, and four O-glycosyl derivatives. With the exceptions of C-hexosyl luteolin and C-hexosyl apigenin, all the compounds exhibited a deoxyhexose moiety. The flavanoids orientin and isoorientin were also detected in the leaves (Pereira et al. 2004).

Four cycloartane triterpenoids and six related saponins were reported from *Passiflora edulis* (Yoshikawa et al. 2000a). Four cycloartane triterpenes, cyclopassifloic acids A, B, C and D, and six related saponins, cyclopassiflosides I, II, III, IV, V and VI, were isolated from the leaves and stems of *Passiflora edulis*. Cyclopassifloic acids A-D were assigned as 22(R), 24(S)-1α,3β,22,24, 31-pentahydroxy-24-methylcycloartan -28-oic acid; 24(S)-1α,3β,24, 31-tetrahydroxy-24-methylcycloartan-28-oic acid; 20(S),24(S)-1α, 3β,21, 24,31-pentahydroxy-24-methylcycloartan-28-oic acid; and 22(R)-1α,3β,22-trihydroxy-24-oxocycloartan-28-oic acid, respectively. Cyclopassiflosides I–VI, in turn, were established as the28-O-βa-D-glucopyranosidesofcyclopassifloic acids A–D. Finally, cyclopassiflosides III and V were demonstrated as the 28, 31-bis-O-β-D-glucopyranosides of cyclopassifloic acids B and C, respectively. Also obtained were the known compounds passiflorin and passifloric acid. Three newcycloartane triterpenes, cyclopassifloic acids E, F and G, and their saponins, cyclopassiflosides VII, VIII, IX, X and XI, were isolated from the leaf and stem parts of *Passiflora edulis* (Yoshikawa et al. 2000b).

P. edulis leaves were found to contain alkaloids. The alkaloid identified included harmine, harmalol, harmaline and harman, a β-carboline alkaloid, with highest concentration (0.12 mg%) in the leaves (Slaytor and McFarlane 1968; Lutomski and Malek 1975; Lutomski et al. 1975). *P. edulis* aqueous extracts, also contained coumarin, long-chain fatty acids and lactones (Khanh et al. 2006).

Six compounds identified as luteolin 6-C-β-D-glucopyranoside,luteolin6-C-β-D-chinovoside, luteolin 6-C-β-L-fucoside, apigenin 8-C-β-D-glucopyranoside, apigenin-6-C-β-D-glucopyrano-4′-O-α-L-rhamnopyranoside and 5,8-epidioxyergosta-6, 22-dien-3ol were isolated from the stem of *P. edulis* f. *flavicarpa* (Zhou et al. 2009).

Scientific studies have shown *P. edulis* to have numerous pharmacological properties that supported all its traditional medicinal uses.

Antioxidant Activity

The leaves of *Passiflora alata* and *Passiflora edulis*, traditionally used in American countries to treat both anxiety and nervousness by folk medicine, were found to be rich in polyphenols, which had been reported as natural antioxidants (Rudnicki et al. 2007). Studies verified the antioxidant activities of *P. edulis* and *P. alata* hydroalcoholic leaf extracts in in-vitro and ex-vivo assays. *P. alata* showed a higher total reactive antioxidant potential than did *P. edulis*. The antioxidant activities of both extracts were significantly correlated with polyphenol contents. In addition, both extracts attenuated ex-vivo iron-induced cell death, quantified by lactate dehydrogenase leakage, and effectively protected against

protein damage induced by iron and glucose. These findings demonstrated that the *P. alata* and *P. edulis* leaf extracts had potent in-vitro and ex-vivo antioxidant properties.

Passionfruit leaves also contained C-deoxyhexosyl flavonoids which exhibited antioxidant activity (Ferreres et al. 2007). Sixteen apigenin or luteolin derivatives were characterized, which included four mono-C-glycosyl, eight O-glycosyl-C-glycosyl, and four O-glycosyl derivatives. With the exceptions of C-hexosyl luteolin and C-hexosyl apigenin, all the compounds exhibited a deoxyhexose moiety. Moreover, the uncommon C-deoxyhexosyl derivatives of luteolin and apigenin were also identified for first time in *P. edulis* leaves. The antioxidative capacity of passion fruit leaves was determined against DPPH radical and several reactive oxygen species (superoxide radical, hydroxyl radical, and hypochlorous acid), revealing it to be concentration-dependent, although a pro-oxidant effect was observed for hydroxyl radical.

The petroleum ether and chloroform fractions of ethanol extract of leaf and stem from *Passiflora edulis* showed potent antioxidant activity, of which the chloroform and petroleum ether fraction of stem demonstrated the strongest antioxidant activity with the IC_{50} value of 51.28 and 54.01 μg/ml, respectively using DPPH free radical assay (Ripa et al. 2009). Ethanol extract of *Passiflora edulis* leaves showed strong potential antioxidant activity in 1,1-diphenyl-2-picryl hydrazyl radical reducing power method assay exhibiting an IC_{50} value of 875 μg/ml (Sunitha and Devaki 2009).

The polyphenolic compound piceatannol which occurs in passion fruit seeds in high amount and its dimer, scirpusin B exhibited potent antioxidant activity (1,1-diphenyl-2-picrylhydrazyl (DPPH)) and vasorelaxant effect when tested in rat thoracic aorta (Sano et al. 2011). Sscirpusin B exerted a greater antioxidant activity and vasorelaxant effect compared with piceatannol. Additionally, the vasorelaxation effects of the compounds were induced via the NO derived from the endothelium. The results suggested the potential of polyphenols in passion fruit seeds to be used against cardiovascular diseases (CVDs).

Antiinflammatory and Wound Healing Activities

In Brazilian countryside, cataplasm made from *Passiflora edulis* leaves was reported to be used by the population as a healing agent for infections and skin inflammations (Garros et al. 2006). No significant difference in the rate of wound healing was detected in rats with wounds treated with *Passiflora edulis* hydro-alcoholic extract or in control rats treated with distilled water (Garros et al. 2006). However, a significant increase in the number of fibroblastic cells was seen on the 7th post-operative day, and significantly greater collagen deposition was observed on the 14th day post-operative day in rats from the *Passiflor*a group. In separate studies, *Passiflora edulis* leaf extract (250 mg/kg) administered by intraperitoneal route (i.p.) was found to inhibit the leukocyte, neutrophils, myeloperoxidase, nitric oxide, TNFalpha and IL-1beta levels in the pleurisy induced by carrageenan (Montanher et al. 2007). The extract (250–500 mg/kg, i.p.) also inhibited total and differential leukocytes in the pleurisy induced by bradykinin, histamine or substance P. Several mechanisms, including the inhibition of pro-inflammatory cytokines (TNFalpha, IL-1beta), enzyme (myeloperoxidase) and mediators (bradykinin, histamine, substance P, nitric oxide) release and/or action, appeared to account for *Passiflora edulis'* activities. Vargas et al. (2007) reported that the aqueous leaves extracts of *Passiflora alata* (100–300 mg/kg, i.p.) *and Passiflora edulis* (100–1,000 mg/kg, i.p.) possessed significant antiinflammatory activity on carrageenan-induced pleurisy in mice. Treatment with the extracts inhibited leukocyte migration and reduced the formation of exudate. Further, a significant inhibition of myeloperoxidase and adenosine-deaminase activities was observed at the doses tested (100 or 250 mg/kg, i.p.). At the same doses, a significant decrease of serum C-reactive protein was also observed.

In the inflammation assay induced by carrageenan, aqueous extract of yellow passion fruit leaves (100 mg/kg, i.p.), butanolic fraction (50 mg/kg, i.p.), aqueous residual fraction (100 mg/kg, i.p.) and dexamethasone (0.5 mg/kg, i.p.) were found to

inhibit the leukocyte, neutrophil, myeloperoxidase, nitric oxide, and interleukin-1 beta (IL-1β) levels (Beninca et al. 2007). The aqueous extract and butanolic and aqueous residual fractions, but not dexamethasone, decreased macrophage inflammatory protein-2 (MIP-2) levels. Only dexamethasone inhibited mononuclear cells. In inflammation induced by histamine, the aqueous extract, butanolic and aqueous residual fractions, and dexamethasone inhibited total and differential leukocytes. In inflammation induced by substance P, the aqueous extract, butanolic and aqueous residual fractions, and dexamethasone also inhibited total leukocytes and mononuclears. Neutrophils were only inhibited by aqueous extract, butanolic fraction, and dexamethasone. The study indicated that the active principle(s) present in the *P. edulis* aqueous extract and its two fractions showed pronounced antiinflammatory properties, inhibiting cell migration, proinflammatory cytokines, enzymes and mediators.

Several other studies reported dry leaf extracts from *Passiflora edulis* to have an antiinflammatory effect on wound healing in rats. The intraperitoneal use of *Passiflora edulis* extract was shown to influence favorably the healing of gastric sutures in rats because of the increase in the fibroblastic proliferation on the 7th post operative day (Silva et al. 2006). All animals presented adequate healing of the abdominal wall with no clinical signs of infections or dehiscence. *Passiflora edulis* extract was also reported to enhance the healing of midline abdominal incisions in rats, especially the histological (collagenization and capillary neoformation) and tensiometric aspects i.e. maximal breaking and deformation strength (Gomes et al. 2006). In another study, the use of *Passiflora edulis* hydroalcoholic leaf extract administered by intraperitoneal injection in male wistar rats resulted in less acute inflammation, greater fibroblastic proliferation, collagenous formation and capillary neo-formation on rats' bladder wound healing (Gonçalves Filho et al. 2006). In a separate study, the peri-operative administration of the hydro-alcoholic extract of *Passiflora edulis* had a positive influence on the healing of colonic anastomosis in rats based on the following parameters evaluated macroscopic aspects of the wall and abdominal cavity, perianastomotic (adherences), bursting pressure, inflammatory tissue reaction on the anastomotic wound (Bezerra et al. 2006). The butanolic fraction obtained from an aqueous extract of *P. edulis* var. *flavicarpa* leaves (50 and 100 mg/kg, I.P.) showed antiinflammatory activity by inhibiting leukocytes and neutrophils (Zucolotto et al. 2009). Sub-fraction C showed itself to be more effective than the other sub-fractions. Isoorientin, vicenin-2 and were isolated from the active sub-fraction C derived from the butanolic fraction. The sub-fraction C (50 mg/kg, i.p.), as well as its major isolated compounds (25 mg/kg, i.p.), inhibited leukocytes and neutrophils. Additionally, the butanolic fraction and isoorientin also inhibited myeloperoxidase activity. The present study showed that the C-glucosylflavones isolated from *P. edulis* leaves could be responsible for the antiinflammatory effect of *P. edulis* on the mouse model of pleurisy induced by carrageenan. In a randomized, double-blind, placebo-controlled trial with parallel-group design of 33 patients with knee osteoarthritis, supplementation of passion fruit peel extract pills substantially alleviated osteoarthritis symptoms (Farid et al. 2010). This beneficial effect of the extract may be due to its antioxidant and antiinflammatory properties

Anticancer Activity

Fruit decoctions of *Passiflora edulis* and *P. foetida* var. *albiflora* exhibited inhibitory activity of gelatinase MMP-2 and MMP-9, two metalloproteases involved in the tumour invasion, metastasis and angiogenesis (Puricelli et al. 2003). Both water extracts, at different concentrations, inhibited the enzymes.

The phytochemical composition of passionfruit juice (PFJ) was also shown to have valuable anti-cancer activity, when tested in a BALB/c 3T3 neoplastic transformation model (Rowe et al. 2004). A higher concentration of PFJ compared with a lower concentration was effective in reducing the number, size, and invasiveness of transformed foci. When incubated with another mammalian cell line, the MOLT-4, PFJ was unable to alter the cell cycle kinetics while at the same time was

successful in inducing the activity of caspase-3, an enzyme that commits the cell to apoptosis. This suggested that phytochemicals found in PFJ were able to produce the changes in transformed foci due to apoptotic mechanisms rather than by a reduction in cell proliferation. The authors maintained that beneficial results were achieved at levels that could theoretically be attained in the plasma after consumption of the juice.

Passiflin, a novel dimeric antifungal protein from seeds of the passion fruit was found to potently inhibit proliferation of MCF-7 breast cancer cells with an IC_{50} of 15 μM (Lam and Ng 2009).

In the brine shrimp lethality bioassay, the crude chloroform and petroleum ether extracts of *P. edulis* leaf and stem possessed considerable cytotoxic activity. The chloroform and petroleum ether extracts of stem and leaf exhibited significant cytotoxic potentials with the LC_{50} value of 6.63 μg/ml, 6.89 μg/ml and 7.91 μg/ml, 11.17 μg/ml respectively (Ripa et al. 2009).

Antiviral Activity

Passiflora edulis root extract also showed antiviral activity (Müller et al. 2007). Test results were expressed as 50% cytotoxicity (CC_{50}) for MTT assay and 50% effective (EC_{50}) concentrations for viral cytopathic effect (CPE), and these were used to calculate the selectivity indices (SI = CC(50)/EC(50)) of each tested material. *Passiflora edulis* extract showed values of SI >7 against herpetic herpes simplex virus (HSV-1 KOS) and 29-R strains.

Anxiolytic Activity

Most of the pharmacological investigations of *Passiflora edulis* had been focused on the central nervous system (CNS) activities, such as anxiolytic, anticonvulsant and sedative actions. The anxiolytic activity of hydroethanol extracts of *P. alata* and *P. edulis* leaves was demonstrated using the elevated plus-maze test (Petry et al. 2001). The extracts presented anxiolytic activity in dosages around 50, 100 and 150 mg/kg. In separate studies, the spray-dried powders of *P. alata* and *P. edulis* showed anxiolytic activity in doses of 400 and 800 mg/kg supporting their use in Brazilian folk medicine for its reputed sedative and anxiolytic properties (Reginatto et al. 2006). Anti-anxiety activity of *P. edulis* was evaluated on the performance of mice in the elevated plus maze, openfield, and horizontal-wire tests (Coleta et al. 2001). Coleta et al. (2006) reported that the aqueous extracts of *P. edulis* presented an anxiolytic-like activity without any significant effect upon the motor activity whilst the total flavonoid fraction (TFF) presented an anxiolytic-like activity but compromised motor activity. Through fractionation of TFF it was possible to isolate and characterize luteolin-7-O-[2-rhamnosylglucoside] which showed an anxiolytic-like activity without compromising motor activity. The results indicated that flavonoids in the leaves were partly involved in the neuropharmalogical activity.

Phytochemical analysis showed that the content of flavonoids of the aqueous extract of *P. edulis* was almost twice that of *P. alata* and that differences in contents of flavonoids could explain the lower active doses of the aqueous extract of *P. edulis* in inducing anxiolytic-like effects compared to *P. alata* (Barbosa et al. 2008). The research findings suggested that, distinct from diazepam, the aqueous extract of both species of *Passiflora* induced anxiolytic-like effects in rats without disrupting memory process. Aqueous extract of *Passiflora edulis* had been reported to exhibit non specific CNS depressant effects in mice, rats and healthy human volunteers, whereas, it was also noted that some samples of *Passiflora edulis* had a "non-specific" CNS-depressant effect (Maluf et al. 1991). In another report on CNS depressant effects of *Passiflora edulis*, it was reported that the aqueous extract of the plant prolonged barbiturate-induced as well as morphine-induced sleep time in mice and also "partially" blocked the amphetamine-induced stimulant effects (Do et al. 1983).

In a recent study, the aerial part of *Passiflora edulis* f. *flavicarpa* was reported to be anxiolytic at low dose but sedative at high dose (Deng et al. 2010). In the elevated plus-maze (EPM) test, single-dose oral administration of ethanolic extract (EE) (300 and 400 mg/kg), n-BuOH extract (BE)

(125 and 200 mg/kg), aqueous extract (AE) (200 and 300 mg/kg), subfractions of BE BEF-I (200 mg/kg), BEF-II (200 mg/kg), BEF-III (100 mg/kg), or isoorientin (20 mg/kg), a flavonoid component isolated from BEF-III resulted in anxiolytic-like effects, but a sedative-like activity was produced at higher doses, such as 300 mg/kg of BE, 200 mg/kg of BEF-III, or 40 and 80 mg/kg of isoorientin. The results of the SA (spontaneous activity) test manifested that treatment with 400 mg/kg of EE, 300 mg/kg of BE, or 40 and 80 mg/kg of isoorientin compromised motor activity in mice, which accorded with the results of the EPM test. Flavonoids are important active constituents. Since the aqueous extract contained little flavonoids, it was conjectured that there were other components responsible for the anxiolytic effect of *Passiflora edulis* f. *flavicarpa* besides flavonoids. In a recent study, the ethanol extracts of leaves of *Passiflora edulis 'flavicarpa'* displayed anxiolytic activity at 400 mg/kg, while those of *Passiflora edulis 'edulis'* exhibited sedative effect at 400 mg/kg (Li et al. 2011). The six major flavonoid compounds isolated from the leaves of *Passiflora edulis 'flavicarpa'*, lucenin-2, vicenin-2, isoorientin, isovitexin, luteolin-6-C-chinovoside, and luteolin-6-C-fucoside, were not detected in *Passiflora edulis 'edulis.*

In another study, the aqueous extract (AE), the butanolic fraction (BF), and the aqueous residual fraction (ARF) obtained from the pericarp of *P. edulis flavicarpa* were found to be involved in the putative neuropharmacologic effects in mice (Sena et al. 2009). AE, BF, and ARF increased the total time spent in the light compartment of the light:dark box, an anxiolytic-like effect, and AE also potentiated the hypnotic effects of ethyl ether, a sedative effect. Analysis indicated the predominance of C-glycosylflavonoids in these extracts and fractions, which were identified as isoorientin, vicenin-2, spinosin, and 6,8-di-C-glycosylchrysin.

Antihypertensive Activity

Research showed that orally administered methanol extract of *Passiflora edulis* rind (10 or 50 mg/kg) or luteolin (50 mg/kg), one of constituent polyphenols of the extract, significantly lowered systolic blood pressure in spontaneously hypertensive rats (Ichimura et al. 2006). The extract was found to contain 20 μg/g dry weight of luteolin and 41 μg/g dry weight of luteolin-6-C-glucoside. It also contained gamma-aminobutyric acid (GABA, 2.4 mg/g dry weight by LC-MS/MS or 4.4 mg/g dry weight by amino acid analysis) which has been reported to be an antihypertensive material. Since the extract contained a relatively high concentration of GABA, the antihypertensive effect of the extract in the hypertensive rats might be due mostly to the GABA-induced antihypertensive effect and partially to the vasodilatory effect of polyphenols including luteolin.

The diet of spontaneously hypertensive rats supplemented with the purple passion fruit peel (PFP) extract, a mixture of bioflavonoids, phenolic acids, and anthocyanins at 50 mg/kg significantly lowered systolic blood pressure by 12.3 mm Hg and markedly decreased serum nitric oxide level by 65% compared with the control group (Zibadi et al. 2007). In a 4-week randomized, placebo-controlled, double-blind trial, the systolic and diastolic blood pressure of the PFP extract–treated group decreased significantly compared with the placebo group. No adverse effect was reported by the patients. In a rat liver toxicity assay, no hepatotoxicity was observed after 9 h incubation in the presence of PFP extract, (20 μg/ml). The PFP extract also revealed hepatoprotection against chloroform (1 mmol/L)-induced liver injury. The results suggested that the antihypertensive effect of the PFP extract may, in part, be mediated through nitric oxide modulation. The results also suggested that the PFP extract may be offered as a safe alternative treatment to hypertensive patients.

Hypocholesterolemic/ Antihyperlipidemic Activity

Studies showed that the consumption of insoluble fibre-rich fraction (FRF) diet prepared from defatted *Passiflora edulis* seed, relative to cellulose diet could effectively decrease the levels of serum triglyceride, serum total cholesterol, and liver

cholesterol, and increase the levels of total lipids, cholesterol, and bile acids in faeces (Chau and Huang 2005). The consumption of insoluble FRF also increased the faecal bulk and moisture. The marked cholesterol- and lipid-lowering effects of insoluble FRF might be partly attributed to its ability to enhance the excretion of lipids and bile acids via faeces. The results suggested that insoluble FRF could be a potential hypocholesterolemic ingredient for fibre-rich functional foods.

The offsprings of passion fruit juice treated non-diabetic rats and passion fruit juice treated streptozotocin-diabetic rats showed significantly reduced total cholesterol, triglyceride, and low-density lipoprotein cholesterol levels and an increased high-density lipoprotein cholesterol level after 30 days (Barbalho et al. 2011). The use of passion fruit juice was found to improve lipid profiles, suggesting that it may have beneficial effects in the prevention and treatment of dyslipidemias and hyperglycemia.

Studies in diabetic rats showed that pectin from *P. edulis* fruit had antiinflammatory, hypoglycemic and hypotriglyceridemic properties (Silva et al. 2011). Pectin administration decreased blood glucose and triglyceride levels in diabetic male wistar rats. Pectin also decreased edema volume and release of myeloperoxidase. It also significantly decreased neutrophil infiltration and partially decreased immunostaining for tumour necrosis factor-α and inducible nitric oxide synthase.

Antiasthmatic Activity

Most clinical symptoms of asthma of the purple passion fruit peel (PFP) extract-treated group were moderated significantly compared to the baseline (Watson et al. 2008). Purple passion fruit peel (PFP) extract comprised a novel mixture of bioflavonoids. The prevalence of wheeze, cough, as well as shortness of breath was reduced significantly in group treated with PFP extract, whereas the placebo caused no significant improvement. Purple passion fruit peel extract supplementation resulted in a marked increase in forced vital capacity as placebo showed no effect. However, no significant improvement was observed in the forced expiratory volume at 1 s of those supplemented with PFP extract. No adverse effect was reported by any of study participants. Results suggested that PFP extract may be safely offered to asthmatic subjects as an alternative treatment option to reduce clinical symptoms.

Antimicrobial Activity

Extract of *Passiflora edulis* exhibited mild in-vitro, anti-fungal activity against three keratinophilic fungi: *Microsporum gypseum, Chrysosporium tropicum* and *Trichophyton terrestre* (Qureshi et al. 1997). All the extracts (hexane, water, ethyl-acetate and methanolic extract) of the leaf, stem and fruit showed antimicrobial activity against two gram positive bacteria, *Bacillus subtilis* and *Staphylococcus aureus*, and four gram negative bacteria *Pseudomonas aeruginosa*, *Salmonella paratyphi, Klebsiella pneumoniae* and *Escherichia coli* (Akanbi et al. 2011). Amongst the extracts examined, hexane extracts significantly exhibited the highest antimicrobial activity against all the bacteria tested. The antimicrobial activity was found to be dependent on the type of solvent used for extraction as well as the part of the plant used. The methanolic leaf extract showed high in-vitro inhibitory activity against *Bacillus subtilis* and *E.coli* and was also inhibitory *Staphylococcus aureus* and *Salmonella typhi* when compared with standard ciprofloxacin under similar conditions (Kannan et al. 2011).

A novel dimeric, 67-kDa, antifungal protein from the seeds of passion fruit, designated as passiflin, impeded mycelial growth in *Rhizotonia solani* with an IC_{50} of 16 μM and potently inhibited proliferation of MCF-7 breast cancer cells with an IC_{50} of 15 μM (Lam and Ng 2009). It exhibited an N-terminal amino acid sequence closely resembling that of bovine β-lactoglobulin. Its dimeric nature was rarely found in antifungal proteins. Passiflin was found to be distinct from β-lactoglobulin. There was no cross-reactivity of passiflin with anti-β-lactoglobulin antiserum. Intact β-lactoglobulin lackedantifungal and anti-proliferative activities and was much smaller in molecular size than passiflin.

An antifungal peptide of 5.0 kDa, Pe-AFP1, purified from passion fruit (*Passiflora edulis*) seeds inhibited the development of the filamentous fungi *Trichoderma harzianum, Fusarium oxysporum*, and *Aspergillus fumigatus* with IC_{50} values of 32, 34, and 40 μg/ml, respectively, but not of *Rhizoctonia solani, Paracoccidioides brasiliensis* and *Candida albicans* (Franco 2006; Pelegrini et al. 2006). The pepetide had similarities to 2S albumin proteins.

The crude chloroform extract and petroleum ether extracts of passion fruit leaf and stem showed varying antibacterial activity ranged against twelve bacteria four Gram-positive (*Bacillus megaterium, Bacillus subtilis, Staphylococcus aureus and Sarcina lutea*) and eight Gram-negative (*Salmonella paratyphi, Salmonella typhi, Vibrio parahemolyticus, Vibrio mimicus, Escherichia coli, Shigella dysenteriae, Shigella boydii* and *Pseudomonas aeruginosa*) (Ripa et al. 2009). The crude chloroform extract of the leaf at a concentration of 500 μg/disc showed moderate activity but no activity was observed by the petroleum ether extract against most of the tested organisms, except *Bacillus megaterium* and *Pseudomonas aeruginosa* having positive effect. The crude chloroform and petroleum ether extracts of stem showed notable antibacterial activity at a concentration 500 μg/disc against twelve microorganisms. In case of the stem, the chloroform extract showed the highest activity against the growth of *Vibrio mimicus*. The extract also showed good activity against the growth of *Vibrio parahemolyticus*, *Shigella dysenteriae* and *Shigella boydii*. The petroleum ether stem extract showed moderate inhibitory activity.

Melanogenesis Inhibition Activity

The concentration of polyphenols was found to be higher in *P. edulis* seed (PF-S) than in the rind (PF-R) or pulp (PF-P) ethanol extracts (Matsui et al. 2010). Treatment of melanoma cells with PF-S led to inhibition of melanogenesis. In addition, the production of total soluble collagen was elevated in dermal fibroblast cells cultured in the presence of PF-S. PF-R and PF-P did not yield these effects. Further, the removal of polyphenols from PF-S led to the abolishment of the effects described above. Piceatannol (3,4,3′,5′-tetrahydroxy-trans-stilbene) was found to be present in passion fruit seeds in large amounts and was the major component responsible for the PF-S effects observed on melanogenesis and collagen synthesis.

Traditional Medicinal Uses

Passiflora edulis has been used as a sedative, diuretic, anthelmintic, anti-diarrheal, stimulant, tonic and also in the treatment of hypertension, menopausal symptoms, colic of infants in South America (Chopra et al. 1986; Kirtikar and Basu 1975). In Madeire, the fruit of *Passiflora edulis* is regarded as a digestive stimulant and is used as a remedy for gastric carcinoma (Watt and Breyer-Brandwijk 1962). In Nagaland (India), fresh leaves of *Passiflora edulis* are boiled in little amount of water and the extract is drunk for the treatment of dysentery and hypertension (Jamir et al. 1999).

In Brazilian folk medicine, *Passiflora edulis* has been commonly used as a sedative, tranquilizer, antiinflammatory drug, intermittent fever and also for the treatment of inflammatory cutaneous wounds, lesions and erysipelas. The pulp of the fruit is stimulant and tonic. In Suriname, the leaves of passion fruit are used to settle edgy nerves and are employed also for colic, diarrhoea, dysentery, and insomnia.

Other Uses

Studies showed that *Passilfora edulis* contained strong allelopathic potential (Khanh et al. 2006). Aqueous extracts of *P. edulis* strongly suppressed germination and growth of lettuce, radish and two major paddy rice weeds, *Echinochloa crusgalli* and *Monochoria vaginalis*. Ten newly identified substances in *P. edulis* extracts, including coumarin, long-chain fatty acids and lactones, may be responsible for the inhibitory activity of *P. edulis*. Coumarin and the lactones showed greater inhibition of germination and growth of

E. crusgalli than the fatty acids. The authors suggested that *P. edulis* may be used as a natural herbicide to reduce the dependency on synthetic herbicides.

Comments

There is a controversy over the synonym of *Passiflora incarnata* with *Passiflora edulis.* The designation by Sir William J. Hooker in 1843, followed by the citation of *P. edulis* as the synonym of *P. incarnata* in Index Kewensis of 1895, not only substantiated the controversial identity but also caused confusion to researchers. The prevailing confusion might have led to improper selection of the bioactive plant, thereby accounting for inconclusive and contradictory pharmacological reports on either of the two plants. Recently, researchers have reported that the two entities should remain as two separate species instead of being synonymous. Using a range of key identification parameters they differentiated *P. incarnata* from *P. edulis*. Various leaf constants such as vein-islet number, vein-termination number, stomatal number, and stomatal index are different for the two species. Physicochemical parameters such as ash values and extractive values and the thin layer chromatography profile of the petroleum ether extract of *P. incarnata* and *P. edulis* are also distinct and different.

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