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Review

Chemical Components and Bioactivities of Cape Gooseberry (*Physalis peruviana*)

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Abstract: Cape gooseberry (*Physalis peruviana*) is a fruit with high nutritional value and medicinal properties. The fruit has been widely used as a source of vitamins A and C, and minerals, mainly iron and potassium. *Physalis peruviana* is also a widely used herb in folk medicine for treating cancer, leukemia, hepatitis and other diseases. The whole plant, leaves and roots as well as berries and the surrounding calyx contain several bioactive withanolides. The fruit pomace contained 6.6% moisture, 17.8% protein, 3.10% ash, 28.7% crude fibre and 24.5% carbohydrates. This review summarized chemical components and bioactivities of *Physalis peruviana*.

Keywords: cape gooseberry; goldenberry; *Physalis peruviana*; chemical component; bioactivity; anticancer.

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1. Introduction

Cape gooseberry (*Physalis peruviana*) is a fruit that belongs to the Solanaceae family and Physalis genus from Amazon and Andes. It is exported from several countries including Colombia,

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Egypt, Zimbabwe, Kenya, Madagascar, South Africa and Southeast Asia, but Colombia stands out as one of the largest producers, consumers and exporters (Novoa et al., 2006). Presently, cultivation of cape gooseberry in Colombia is steadily increasing to satisfy the growing export demands, ranking it second after banana fruit exports from Colombia. It is a tropical hairy plant with fuzzy, slender-pointed, heart-shaped leaves, bearing yellowish flowers and orange edible fruits. They are protected by papery husks resembling Chinese lanterns that protects against insects, birds, and adverse conditions. Five species of Physalis are found in China.

In addition to having a future as fresh fruit, cape gooseberry can be enjoyed in many ways as an interesting ingredient in salads, cooked dishes, dessert and jam. Moreover, *P. peruviana* have been widely used in folk medicine as anticancer, antimycobacterial, antileukemic, antipyretic, immunomodulatory, and for treating diseases such as malaria, asthma, hepatitis, dermatitis, diuretic and rheumatism (Chiang et al., 1992a & b; Ismail and Alam, 2001; Lin et al., 1992; Pietro et al., 2000; Soares et al., 2003). The plant is diuretic and juice of its leaves is given in worm and bowel complaints, while heated leaves are applied as a poultice (Publication and Information Directorate, 1969). An extract of the leaves shows antibiotic activity against *Staphylococcus* (Perry and Metzger, 1980). The oleaginous fruit by-products may become one of the important oil sources. The oil is rich in essential fatty acids, natural antioxidants and phytosterols (Ramadan and Moersel, 2003). The pulp of *P. peruviana* fruit is nutritious, containing particularly high levels of carotenoids, vitamin C and minerals. Many chemical compounds viz. 28-hydroxywithanolide, withanolides, phygrine, kaempferol, and quercetin di- and tri-glycosides are reported to be present in *P. peruviana* (Dinan et al., 1997; Elliger et al., 1992; Keith et al., 1992).

The commercial interest in this fruit has grown due to its nutritional properties related to high vitamins content, minerals and antioxidants as well as its anti-inflammatory, anticancer and other medicinal properties. Despite its importance, there are only a few works in the literature concerning this fruit, and a few studies have been carried out regarding its chemical composition. This review summarized chemical components and bioactivities of *P. peruviana*.

2. Chemical Components of *Physalis peruviana*

2.1. General Components

Physalis peruviana produced in Germany showed a high total lipid content of 2% (Ramadan and Mörsel, 2003). Centesimal compositions of *P. peruviana* were expressed in g/100 g in dry weight: moisture 80.97 ± 1.65; total lipids 3.16 ± 0.32; proteins 1.85 ± 0.31; total carbohydrates 13.22; ashes 0.80 ± 0.03; energy value 88.72 kcal/372.62 kJ (Eliseu et al., 2009). Novoa et al. (2006) evaluated three sugars in the fruit of *P. peruviana*. Sucrose is the most abundant sugar after glucose and finally

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fructose with limited presence in the fruit. They also noticed that the glucose content in the fruit of *P. peruviana* is very similar to other *Solanaceae* fruits, with a value close to 0.5%. The study suggested that the yield of juice and the sugar content of the final product produced from enzymatic treated goldenberry is higher than the untreated goldenberry. Most enzymatic preparations for juice processing are composed of cellulase, hemicellulases and pectinases.

2.2. Minerals

Minerals play several important roles in human physiology and biochemistry as co-factors for enzymes, and are related to energetic efficiency, fertility, mental stability, and immunity (Mayer, 1997). When compared with papaya var. Ormosa (*Carica papaya* L.), apple (*Malus domestica*), orange var. Valência (*Citrus sinensis* L.), strawberry (*Fragaria vesca* L.), and acerola (*Malpighia glabra* L.), K, Mn, Mg, Fe, and Zn are present in higher concentrations. The iron content in *P. peruviana* was 1.47 mg/100 g, which was 5 to 15 times higher than those of another five fruits. This content is higher than that found in traditional sources such as beans (0.8 mg/100 g) and quantitatively similar to animal sources such as beef (1.8 mg/100 g). Like iron, magnesium was found in high quantities in *P. peruviana* being 2 times higher than in papaya, which is the fruit with the highest magnesium concentration among another five fruits. Another essential element, zinc, was also found in high concentration. However, when compared with the principal sources such as oysters, shrimp, beef, poultry, fish, wheat germen, and beans, the content of zinc in *P. peruviana* is lower. Concerning the calcium content, *P. peruviana* presented low concentration, and was higher than apple only. The potassium content was of 347.00 mg/100 g, which was higher than those in another five fruits. The sodium content of 1.1 mg/100 g was close to those found in apple (1 mg/100 g) and orange (1 mg/100 g) but lower than that found in papaya (3 mg/100 g). The copper content in *P. peruviana* is much higher than those found in apple, orange, strawberry, and acerola, but lower than that presented in papaya. Manganese, an essential element in the bone development and in the metabolism of amino acids, carbohydrates, and cholesterol, was found in relatively high quantities in *P. peruviana* (0.26 mg/100 g). Other fruits used for comparison presented lower values than that, except for the strawberry.

2.3. Fatty Acids

Fruit juice of *P. peruviana* was found to contain 0.2% oil, wherein linoleic acid, oleic acid, palmitic acid, γ-linolenic acid and palmitoleic acid were the main fatty acids. Five minor fatty acids, namely gadoleic, dihomo-γ-linolenic, erucic, lignoceric and nervonic acids, were also identified. Ramadan and Mörsel (2003) found a linoleic acid content of 70.5% in *P. peruviana* and an oleic acid

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content of about 13%. These authors also found a stearic acid content of 2.57%. Saturated fatty acids represented 12.87% of total fatty acids, with the palmitic acid as the main acid. The total content of trienes was about 22.7% and the oil was characterized by an extremely high level of γ-linolenic acid (18.8% of total methylesters), while ω-3 fatty acid (α-linolenic acid) and dihomo-γ-linolenic were estimated at lower levels. The major phytosterols were Δ5-avenasterol and campesterol. Moreover, β-sitosterol and stigmasterol as the presence of the sterols in the fruit of *P. peruviana* could be responsible for the fruit's ability to reduce cholesterol levels.

2.4. Vitamins

P. peruviana contains high amounts of vitamin C. The content of ascorbic acid in *P. peruviana* juice was about 46 mg/100 g. The ascorbic acid content in goldenberry on average turns out to be higher than in most common fruits such as pear (4 mg/100 g), apple (6 mg/100 g), peach (7 mg/100 g), pineapple (25 mg/100 g), plum (3 mg/100 g) and apricot (9 mg/100 g), and only slightly lower than in other fruits such as orange (50 mg/100 g) and strawberry (60 mg/100 g). Vitamin E level was extremely high, wherein γ- and α-tocopherols were the main constituents. α-Tocopherol is the most efficient antioxidant of these compounds. β-Tocopherol has 25 - 50% of the antioxidant activity of α-tocopherol and γ-tocopherol 10 - 35%. The level of vitamin E in the oil extracted from pulp and skin of *P. peruviana* are extremely high compared to the amount present in seed oil (Ramadan et al., 2003). The oils extracted from fruits of *P. peruviana* were characterized by high levels of vitamin K1, which is very low in most food (10 mg/100 g), and the majority of the vitamin is obtained from a few green and leafy vegetables (e.g. spinach) (Jakob and Elmadfa, 2000; Piironen and Mattila, 1997). Vitamin K1 comprised more than 0.2% of the total lipids in cape gooseberry pomace oil (Ramadan and Mörsel, 2003).

2.5. Carotenes

High amounts of β-carotene were detected in the juice of *P. peruviana*. Carotenoids from *P. peruviana* were determined by HPLC-PDA-MS/MS and 22 compounds have been identified. All-trans-β-carotene was the major carotenoid, contributing 76.8% to the total carotenoid, followed by 9-cis-β-carotene and all-trans-α-cryptoxanthin, contributing around 3.6 and 3.4% (De Rosso and Mercadante, 2007). The level of carotenoid esters calculated as lutein dimyristate equivalents was < 0.5 mg/100 g (Breithaupt and Bamedi, 2001).

2.6. Flavonoids and Polyphenols

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Good amounts of phenolics were estimated in goldenberry juices, where in the levels of total phenols as determined by the Folin-Ciocalteu method varied from 6.09 to 6.30 mg/100 g juice as caffeic acid equivalents. In gooseberry, quercetin is the main phenolic compound, followed by myricetin and kaempferol (Häkkinen et al., 1999). The ethanol extract of *P. peruviana* possessed higher total flavonoid and phenol contents than its hot water extract and SCEPP-0 (supercritical carbon dioxide extract), but was lower than SCEPP-4 and SCEPP-5. With increasing concentration of ethanol as modifier in SFE-CO_2, an increase in total flavonoid and phenol contents was noted. Among the different extracts, SCEPP-5 displayed the highest content in total flavonoids (226.19 ± 4.15 mg/g) and phenols (100.82 ± 6.25 mg/g).

Physalis peruviana contains many novel glycoconjugates, which can be considered as immediate progenitors of p-menth-4(8)-ene-1,2-diol and 1-phenyl-1,2-propanediol, important aroma constituents of *P. peruviana*, such as (1S,2S)-1-phenylpropane-1,2-diol 2-O-β-D-glucopyranoside and p-menth-4(8)-ene-1,2-diol 1-O-α-L-arabinopyranosyl-(1-6)-β-D-glucopyranoside. The 3-O-β-D-gluco-pyranosyl-(1→6)-β-D-glucopyranoside of ethyl 3-hydroxyoctanoate and the diastereomeric 3-O-a-l-arabinopyranosyl-(1→6)-β-D-glucopyranosides of (3R) and (3S)-butyl 3-hydroxybutanoate, respectively, were isolated by chromatographic methods from fruit of cape gooseberry harvested in Colombia. The three glycoconjugates can be considered as immediate precursors of ethyl 3-hydroxyoctanoate and butyl 3-hydroxybutanoate, which are important aroma volatiles found in the fruit.

2.7. Withanolides

Withanolides are natural steroidal lactones produced mainly by plants in the Solanaceae. Such substances often have antimicrobial, antitumor, antiinflammatory, hepatoprotective, or immunomodulatory activity and insect antifeedent property. Many withanolide glycosides have been isolated from the aerial parts of *P. peruviana*, such as perulactone, perulactone B, blumenol A, and (þ)-(S)-dehydrovomifoliol. Besides the four withanolides above, two new perulactone-type withanolides, named perulactone C and perulactone D were isolated. In recent years, other new withanolide glycosides have been isolated, including seven new withanolides, phyperunolide A, phyperunolide B, phyperunolide C, phyperunolide D, phyperunolide E, phyperunolide F, and peruvianoxide, from the extracts of *P. peruviana*, together with ten known withanolides (Lan et al., 2009). Moreover, two withanolides isolated from the whole plant material of *P. peruviana* have been characterized as (20R,22R)-5α,6β,14α,20,27-pentahydroxy-1-oxowith-24-enolide and (20S,22R)-5β,6β-epoxy-4β,14β, 15α-trihydroxy-1-oxowith-2,24-dienolide (Dinan et al., 1997), in addition to the known withanolides, withaphysanolide and viscosalactone B on the basis of spectroscopic techniques and chemical

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transformations. And other new withanolides are 17β-hydroxy-14,20-epoxy-1-oxo-[22R]-3β-[O-β-D-glucopyranosyl]-witha-5,24-dienolide, (20R,22R)-1a-acetoxy-14a,20-dihydroxywitha-5,24-dienolide-3β-(O-β-D-glucopyranoside), (20S,22R)-1a-acetoxy-27-hydroxywitha-5,24-dienolide-3β-(O-β-D-glucopyranoside), (20R,22R)-20,27-dihydroxy-1-oxowitha-5,24-dienolide-3β-(O-β-D-glucopyranoside), and (20R,22R)-14a,20,27-trihydroxy-1-oxowitha-5,24-dienolide-3β-(O-β-D-glucopyranoside) and so on.

2.8. Physalins

A series of pseudo-steroids known as physalins, were isolated and characterized from *Physalis* sp. (Soares et al., 2006). The main active constituents of *P. peruviana* L. are physalins A, B, D, F and glycosides, which show anticancer activity (Wu et al., 2004). They also showed antioxidant and anti-inflammatory activities.

3. Bioactivities of *Physalis peruviana*

3.1. Antihyperglycemia and Antihypertension Potential

The water and 12% ethanol extracts of native Peruvian fruits such as Lucuma (*Pouteria lucuma*), Pacae (*Inga feuille*), Papayita arequipeña (*Carica pubescens*), Capuli (*Prunus capuli*), Aguaymanto (*Physalis peruviana*), and Algarrobo (*Prosopis pallida*) were evaluated for total phenolics, antioxidant activity based on 2, 2-diphenyl-1-picrylhydrazyl radical scavenging assay, and functionality such as *in vitro* inhibition of α-amylase, α-glucosidase, and angiotensin I-converting enzyme (ACE) relevant for potential management of hyperglycemia and hypertension linked to type 2 diabetes. The results indicated that eating the fruit of *P. peruviana* reduced blood glucose after 90 min postprandial in young adults, causing a greater hypoglycemic effect after this period (Rodríguez and Rodríguez, 2007).

3.2. Antioxidants and Superoxide Anion Scavenging

Oxidative damage in the human body plays an important causative role in disease initiation and progression (Yamaguchi et al., 1998). *P. peruviana* has been proved to have antioxidant activities (Wu et al., 2005). The antioxidant activity of goldenberry juices is not a property of a single phytochemical compound, but the synergistic effect of different antioxidants existing in the juice. The hot water extract and extracts prepared from different concentrations of ethanol (20, 40, 60, 80 and 95% EtOH) from the whole plant were evaluated for antioxidant activities. The studies conclude that ethanol extracts of *P. peruviana* possess good antioxidant activities, and the highest antioxidant properties

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were obtained from the 95% EtOH extract of *P. peruviana*. This extract also demonstrated the strongest superoxide anion scavenging activity and inhibitory effect on xanthine oxidase. The study showed that the SCEPP-5 exhibited a scavenging effect of 47.75% at 1.0 μg/mL, 60.51% at 10 μg/mL, and 69.48% at 30 μg/mL, which were more active than that of α-tocopherol at the same concentration. The studies also indicated that 1-MCP treatment could be useful to preserve the high antioxidant capacity of goldenberry fruit during storage. A direct correlation was found between the antioxidant effectiveness of goldenberry juices and their total fat-soluble bioactive (tocopherols, sterols and carotenoids) content.

3.3. Antihepatotoxic Effect

The water, ethanol and hexane extracts of *P. peruviana* (500 mg/kg body weight) showed antihepatotoxic activities against CCl_4 induced hepatotoxicity. It may act by reducing the level of MDA and increasing the GSH level, as well as reducing the activities of the serum AST, ALT, LDH, and ALP. The water extract showed the highest activity among the different extracts and its dose-dependant study (500, 250, 125 mg/kg) revealed the antihepatotoxic activity even at a dose of 125 mg/kg (Arun and Asha, 2006). Histopathological changes induced by CCl_4 were also significantly reduced by the extracts. The antioxidant property is claimed to be one of the mechanisms of hepatoprotective effect (Bhatt and Bhatt, 1996).

3.4. Anti-inflammatory Activity

The SCEPP-5 possessed a strong anti-inflammatory activity in Raw 264.7 cells. The studies show that SCEPP-5 is an effective inhibitor of LPS induced NO generation and PGE2 production, as well as iNOS and COX-2 expression in Raw 264.7 cells. These findings provided evidence that SCEPP-5 possessed potent anti-inflammatory activity. In addition, it has been shown that physalins B and F have a potent suppressive activity by inhibiting the proliferation of lymphocytes, also has been shown to inhibit both the production of proinflammatory cytokines and activation of macrophages. These activities can help decrease inflammation and fibrosis, so it would be useful in treating immunemediated diseases.

3.5. Antitumor Activity

Several studies have shown that *P. peruviana* have antitumor potential. The studies have shown that the ethanol extract of *P. peruviana* (EEPP) inhibits growth and induces apoptotic death of human Hep G2 cells in culture through CD95/CD95L system and the mitochondrial signaling transduction pathway, whereas proliferation of the mouse BALB/C normal liver cells was not affected. The studies

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further confirmed that EEPP inhibited cell proliferation in a dose- and time-dependent manner. Moreover, supercritical carbon dioxide extract of *P. peruviana* induced cell cycle arrest and apoptosis in human lung cancer H661 cells. Among the extracts of *P. peruviana* (aqueous: HWEPP; ethanolic: EEPP; supercritical carbon dioxide: SCEPP-0, SCEPP-4 and SCEPP-5), SCEPP-5 demonstrated the most potent inhibitory effect on H661 cell proliferation. The SCEPP-5 induced cell cycle arrest at S phase, and its apoptotic induction could be mediated through the p53-dependent pathway and modification of Bax and XIAP proteins expression. The studies have isolated a number of physalins, which are believed to be the bioactive compounds of the genus Physalis (Chiang et al., 1992a & b; Ismail and Alam, 2001). Physalin B and physalin F, but not physalin D, inhibit the growth of human leukemia cells *in vitro*. The major bioactive compounds, physalins (A, B, D and F) and glycosides (such as myricetin-3-O-neohesperidoside), showed anticancer activity on HA 22T (hepatoma), HeLa (cervix uteri), and nasopharynx KB-16 cells lines.

4. Conclusions and Prospects

P. peruviana fruit is very nutritious, containing particularly high levels of carotenoids, vitamin C and minerals. In addition, various chemical compounds viz. 28-hydroxywithanolide, withanolides, phygrine, kaempferol, and quercetin di- and tri-glycosides are reported to be present in *P. peruviana*. The oil extracted from the leaves and other parts of *P. peruviana* is rich in essential fatty acids, natural antioxidants and phytosterols. *P. peruviana* pomace contained 6.6% moisture, 17.8% protein, 3.10% ash, 28.7% crude fibre and 24.5% carbohydrates. The n-hexane-extractable oil content of the raw byproducts was estimated to be 19.3%. *P. peruviana* possess many bioactivities, including antiasthmatic, diuretic, and antiseptic activities, strengthen for the optic nerve, treatment of throat affections, and elimination of intestinal parasites, amoebas as well as albumin from kidneys. The ethanol extracts and the aqueous extracts of *P. peruviana* have been proved to have antioxidant, superoxide anion scavenging, antihepatotoxic, anti-inflammatory and antitumor activities. *P. peruviana* have a bright future as a fresh fruit as well as functional food due to its high quality and quantity of nutrients and its bioactivities.

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