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Physalis peruviana L. Growth, Yield and Phytochemical Content: A Review

Wiwin Sumiya Dwi Yamika, Nurul Aini, Budi Waluyo

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ABSTRACT

Physalis peruviana is one of the species in genus Physalis which is often cultivated in various regions including Indonesia. In Indonesia, *P. peruviana* is often called ciplukan. *P. peruviana* plants produce various phytochemical compounds which have benefical medicinal properties. *P. peruviana* plants have not been widely cultivated commercially as the information about cultivation practices of this plant are still limited. Many research activities have been done to study about its chemical and biological properties, but they are still not widely spread. Therefore, an effort has been made to compile the available inforamtion in this paper.

Key words: Ciplukan, Cultivation, Phtochemical, Physalin.

Physalis is a genus of plants belonging to the Solanaceae family (USDA, 2012). *Physalis* is known in Indonesian as "*ciplukan*". *Physalis* is known to be almost similar to several species such as blueberry, raspberry, cherry, blackberry and pitaya (Rodrigues *et al*., 2014). The genus *Physalis* consists of approximately 100 species of plants in the world. One of the species that is most often found and cultivated in various regions is *Physalis peruviana. P. peruviana* is thought to have originated from the Americas, specifically in the region of Colombia, Peru and Ecuador. Commercial cultivation of *P. peruviana* began in 1985 in Colombia (Muniz *et al.,* 2014). It is cultivated in an area of 800-1000 hectares, with a productivity of 15 to 28 tonnes/ha in Colombia. *Physalis* is primarily cultivated in Colombia, Kenya, Zimbabwe, Australia, New Zealand, India and Ecuador. In addition, in several countries such as United States, Brazil, Venezuela, Bolivia, Peru, Chile, Mexico, Costa Rica, Panama, Jamaica, South Africa, Gabon, Egypt, China, Japan, Malaysia, Philippines, England and Indonesia, *P. peruviana* is being cultivated but not yet intensively.In many regions where it is found, *P. peruviana* has several common names, such as cape gooseberry, golden berry, giant groundcherry, African ground cherry, Aztec berry, Peruvian cherry, etc.

In Indonesia, *P. peruviana* grows naturally in bushes, fields and even on the edges of forests. The *P. peruviana* fruit is nutritionally rich with high contents of vitamins, minerals and antioxidants (Pereda *et al.,* 2018). *P. peruviana* is known to be able to produce vitamins A and B as well as various compounds such as alkaloids, flavonoids, carotenoids and other bioactive compounds. In addition to its fruit known for being exotic and expensive, various parts of the plant such as the roots, leaves and calyces also possess commercial value. All parts of the plant may be utilized as raw material for medicines. The *P. peruviana* plant has a good prospect to be cultivated widely. It has a high economic value and high demands in all parts of the world as a fruit that has a high nutritional value and functional value as medicine. The fruit of *P. peruviana* can be consumed in fresh fruit form or made into various processed foods such as jams, juices, etc. The cultivation of *P. peruviana* is not too difficult, as this plant has good adaptive capabilities in hot as well as cool climates (Oliveira *et al*., 2016). *P. peruviana* was also reported belong to moderately tolerant crop to several environmental stress conditions such as salinity (Miranda *et al.,* 2010) and cadmium contaminant (Thiebeauld *et al.,* 2005). Though it has a great potential, the *P. peruviana* plant is still not cultivated widely and instead left to grow as wild crop. It is important to research further about the various species of *P. peruviana*, one of them being *P. peruviana*, to obtain appropriate information and to support the wide spread cultivation of *P. peruviana*.

Department of Agronomy, Universitas Brawijaya, Malang-65145, East Java, Indonesia.

Corresponding Author: Wiwin Sumiya Dwi Yamika, Department of Agronomy, Universitas Brawijaya, Malang-65145, East Java, Indonesia, Email: wiwinyamika@gmail.com

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MORPHOLOGY

P. peruviana is a herbaceous, semi-bushy annual plant in its region of origin i.e., subtropics. *P. peruviana* forms a bush in the shape of a dome that can grow up to 1 m in height. *P. peruviana* has a branched root system that is 10 to 15 cm deep and fibrous, with the primary root length being between 50 and 80 cm. The primary stem of *P. peruviana* is green colored and composed of 8 to 12 nodes. Each node produces 2 sprouts, a vegetative sprout and a flowering sprout. The leaf of *Physalis* is heart-shaped and alternating, with a length of 5 to 15 cm and has a width of 4 to 10 cm. *P. peruviana* has uniquely shaped flowers, which are pedunculated and hermaphrodite, originating from an axillary sprout with 5 yellow petals. The fruit of the *Physalis* is berry-shaped, similar in form to a globe with a green to yellow color and has a diameter of 13-20 mm, weight of 2-4 g and fruit hardness of 5-10 N (Yildiz *et al.,* 2015). One *P. peruviana* fruit

contains approximately 100-300 seeds. The fruits are small in size, colored bright orange and sweet when ripe. The most characteristic part of the *Physalis* fruit is the calyx, a fruit petal that enlarges to resemble a lantern and wraps around the fruit. The calyx is green, composed of 5 sepals of 5 cm length. The primary function of the calyx is to protect the fruit from insects, birds, diseases and unfavorable climatic conditions. The calyx will change its color when the fruit ripens. The calyx will stop growing in size 20 to 25 days after the fruit formation (Fischer *et al*., 2011).

GROWTH AND CULTIVATION

Growth requirements

P. peruviana possesses good adaptive capabilities toward a wide variety of soils and climatic conditions. In its area of origin, *P. peruviana* is cultivated at high land. In India physalis can be cultivated at elevation of 1200-1800 m above sea level. The elevation of a place has a significant effect on the growth of *P. peruviana*. An increase in exposure to UV rays and a decrease in air temperature will affect the morphology of the plant, for which the plant becomes smaller in size andthe leaves become smaller and thicker. Temperature plays an important role in the growth and development of *P. peruviana*. Basically, *P. peruviana* is a crop cultivated in warm season. The optimal temperature for the growth of *P. peruviana* 21°C. Very high temperatures (>30°C) can disrupt the phases of flowering and fruit formation and accelerate senescence; very low temperatures (<10°C) can also inhibit the growth of the plant. In addition to temperature, sunlight also has an important role, being one of the requirements of photosynthesis. *P. peruviana* needs approximately 1500-2000 hours of sunlight in a year (Ali and Singh, 2013).

P. peruviana is ideally cultivated in an area receiving rainfall between 1000-1800 mm and a relative humidity of 70-80%. The water needs of *Physalis* plant is 800 mm during the period of growth. An increase in soil moisture can aggravate the development of diseases, negatively affect pollination and cause the leaves to turn yellow and fall (Muniz *et al*., 2014). The soil having sandy clay texture with good drainage is ideal for *Physalis* cultivations. *P. peruviana* is sensitive to water logging. The soil should be rich in organic matter (> 4%). The pH should be between 5.5-6.8. The soils that have been previously used to cultivate other species of the Solanaceae family should be avoided (Tyagi, 2016).

Cultivation technology

The *P. peruviana* exhibits indeterminate growth (Fischer *et al*., 2011). The plant can grow up to a height of 1-1.5 to 2 m. The plant can remain productive up to an age of 9 to 11 months from the first harvest. After this point, both productivity and fruit quality will decrease. The growth phases of *P. peruviana* can be grouped into 7 stages *viz*., sprouting, leaf growth, formation of lateral shoots, budding, flowering, development of fruit and fruit and seed ripening (Ramirez *et al*., 2013).

The *P. peruviana* plant may be propagated both sexually through the seeds and asexually through *in vitro* culture and grafting. Production through seeds is the most common method. The seeds of *Physalis* exhibit 85 to 90% of germination and the process of transplanting seedlings starts after 10 to 15 days growth. The germination of *Physalis* seeds are also affected by temperature. Germination will be normal at temperatures of 7-13°C at night and 22-28°C in the day time.

Before sowing the seeds are first extracted by crushing the fruit and allowing it to dry for 48 hours. After that the seeds are rinsed with air and left to dry on filter paper. Before sowing, the seeds ought to be disinfected with the fungicide to prevent the diseases of *Clostridium*, *Phoma*, *Alternaria*, *Pythium*, *Botrytis* and *Colletotrichum*. Before transplanting the seedlings, pruning may be carried out. The pruning of seedlings may be performed when the plant reaches a height of 15-20 cm and possesses 3-4 leaves. This pruning of seedlings reduces transpiration.

P. peruviana plants may be transplanted in field or planted in a polybag. When planted directly on the field, a plant distance of 0.5 x 1.5 m may be followed (Tyagi, 2016). Planting should be carried out in the afternoon to avoid plant dehydration. The necessary maintenance for cultivation of *P. peruviana* is not much different as compared to other plants. The plant needs to be watered with 2-6 liters of water per plant per day. The *P. peruviana* crop need about 150 kg N, 100 kg P and 60 kg K/ha (Deepti *et al.,* 2018; El-Tohamy *et al.,* 2009). Half of the doses of N and K and the entire dose of P is given as basal dose and the rest is top dressed at 30 days after planting. Beside of fertilizer management, application of plant growth regulator is a technology for improving growth and Yield of *P. peruviana*. Kaur and Kaur (2016) reported that application of 20 ppm GA_3 was able to improve growth yield and fruit quality in *P. peruviana.*

P. peruviana plant forms many branches that widely spread and as such, the plant requires a support system that consists of structures of wood and/or ropes to support plant growth. Pruning is also necessary to increase fruit yield and quality (size in particular). Pruning also optimize the absorption of sunlight to increase photosynthesis and to increase water use efficiency. There are four kinds of pruning: (1) formation, the thinning of primary stems and elimination of sprouts; (2) maintenance, cutting off branches that are not productive; (3) sanitation, cutting off branches that are attacked by pests and diseases; and (4) maturation, cutting off parts of the plant to renew the plant from branches that have grown old.

The control of pests and diseases on *P. peruviana* plants may be done chemically or with integrated pest management. The pests that are most often found in the cultivation of *P. peruviana* included *Spodoptera* sp., *Agrotis* sp. and *Feltia* sp. on the ground and *Liriomyza* sp., *Epitrix cucumeris*, *Aphys* sp., *Myzus* sp., *Frankliniella* sp. and*Trialeurodes* on the leaves. The most important disease that attacks *P. peruviana* plants is *Fusarium oxysporum* (Muniz *et al*., 2014).

The visual indicator of harvesting time for *Physalis* fruits can be seen in the color of the calyx. When a fruit ripens, its calyx will change color to yellow-green. At the physiological ripeness that occurs 56 days after anthesis, the *P. peruviana* fruit shows a Brix value of 12.7°, pH of 3.52 and citric acid of 12.12 g/100 g. *P. peruviana* is a climacteric fruit, for which respiration continues to occur in the fruit although the fruit

has been picked. The fruits may be harvested 2 to 3 times in a week. Harvesting may be performed in the morning or afternoon, when temperatures are not too high. Harvesting may also be done while sunny or in conditions other than rain. The fruit may be stored up to 1 month with the calyx and 4 to 5 days without the calyx [1] (Muniz *et al*., 2014; Fischer *et al*., 2011).

CHEMICAL COMPONENTS

General components

The chemical content of *P. peruviana* fruits grown in the turkey and harvestes in summer season included 17-20 % water, 1.2-2.05% titrated acids, 63-65 g/kg total sugars, 13.70-14.30° Brix total soluble solids, 57-59% antioxidant capacity, 1.5-1.8% protein and12-16% carbohydrates (Yildiz *et al*., 2015; Puente *et al*., 2011). Other contents of *P. peruviana* fruit grown in Brazil included 3.16 g/100 g total lipids, 1.85 g/100 g proteins and 13.22 g/100g total carbohydrates (Rodrigues *et al*., 2009). The fruits of *P. peruviana* contain three kinds of sugars that are dominated by sucrose with the largest amount, followed by glucose. The sugar in the least amount by percentage in the fruit is fructose. The glucose content in fruits of *P. peruviana* is almost similar to fruits of other genera of Solanaceae, with an amount around 0.5%. The sugar content of fruit is usually s in the form of reducing sugar. Reducing sugars are a group of carbohydrates that can reduce compounds that accept electrons. Examples of reducing sugars are glucose and fructose. Ozturk *et al*. (2017) reported that the content of reducing sugars in *P. peruviana* ranges from 6.55-7.80%.

Minerals

Minerals play an important role in physiological and biochemical processes as co-factors of enzymes and are linked to energy efficiency, fertility, mental stability and immunity. *P. peruviana* contains minerals such as K, Mn, Mg, Fe and Zn with higher amounts in comparison to several other kinds of fruits such as papayas, apples, oranges, strawberries and acerola. The Fe content was recorded up to 1.47 mg/100 g, far higher than papayas (0.2 mg/100 g), apples (0.1 mg/100g), oranges (0.1mg/100g), strawberries (0.3 mg/100g) and acerola (0.2 mg/100g). The Mg content was recorded up to 34.70 mg/100g and it was far higher than papayas (17 mg/100g), apples (5 mg/100g), oranges (14 mg/100g), strawberries (10 mg/100g) and acerola (13 mg/100g). Similarly the K content was around 347 mg/100 g, higher than papayas (222 mg/100 g), apples (117 mg/ 100 g), oranges (158 mg/100 g), strawberries (184 mg/100 g) and acerola (165 mg/100g). Zn content of *P. peruviana* and the five comparison fruits stated above are nearly the same in a range of 0.1-0.2 mg/100 g. The Ca content was around 9.00 mg/100 g. Compared to the other five fruits, this value is only higher than apples (3 mg/100g) and lower than the other four fruits, papaya (25 mg/100 g), oranges (34 mg/100 g), strawberries (11 mg/100 g) and acerola (13 mg/100 g). The Na content is 1.1 mg/100 g, nearly equivalent to that of apples and oranges (1 mg/100g), but lower than papayas (3 mg/100 g) (Rodrigues *et al*., 2009). In another study, Pereda *et al*. (2018) reported that the mineral content of *P. peruviana* fruits per 100 g fresh fruit weight consists of 375 mg K, 48.7 mg Mg, 11.17 mg Ca, 8.78 mg Na and0.35 mg Cu. Considering the analysis of all parts of the plant, Ozturk *et al*. (2017) reported that the mineral content of *P. peruviana* plant per 100 g total dry weight consists of 1160-1460 mg N, 178.46-233.49 mg P, 1794.98-19.68 mg K, 34.12-43.65 mg Ca, 102.50-122.51 mg Mg, 3.68-4.09 mg Fe, 0.59-0.78 mg Mn, 1.78-2.32 mg Zn and2.19-3.28 mg Cu.

Fatty acids

The juice of *P. peruviana* fruits is known to contain 0.2% fatty acids. The primary fatty acids are composed of linoleic acid, oleic acid, palmitic acid, γ-linolenic acid and palmitoleic acid. In addition, there are several other identified fatty acids, including gadoleic, dihomo-γ-linolenic, erucic, lignoceric andnervonic acids. Ramadhan and Morsel (2007) reported that the content of linoleic acid was 70.5% and oleic acid was 12.87% in *P. peruviana*.

Vitamins

P. peruviana contains vitamin C in high amounts. The ascorbic acid content of *P. peruviana* juice was around 46 mg/100 g (Zhang *et al*., 2013). The findings of Ozturk *et al*. (2017) indicated that the ascorbic acid content of *P. peruviana* ranges from 31.40-35.10 mg/100 g and approximates the results of Pereda *et al*. (2018) who reported that the ascorbic acid content of 32.21 mg/100 g. The vitamin C content of *P. peruviana* fruits ranged from 20-50 mg/100 g. This value is considered high when compared to mangoes (15-36 mg/100 g) and oranges (50 mg/100 g) but still below guavas (120-228 mg/100 g) or marula (120 mg/100 g) (Olivares-Tenorio *et al*., 2016; Hiwilepo-van Hal *et al*., 2012; Sogi *et al*., 2012). Apart from vitamin C, the vitamin E content is considerably high. The vitamin E content in the oil extracted from the pulp and peel of *P. peruviana* fruit is greater than the oil content in the seeds. The vitamin A content of *P. peruviana* fruit was around 103.33 RAE/100g (Pereda *et al*., 2018).

Carotenes

The juice of *P. peruviana* is known to contain β-carotene. Etzbach *et al*. (2018), reported that 53 carotenoids were detected at different levels of ripeness (unripe, ripe and overripe) and different parts of the fruit (skin, pulp and calyx). The composition of carotenoids is dominated by (all-E)-β-carotene. Results from other studies also indicated that carotenoids of *P. peruviana* are composed of 76.8% trans-β-carotene and approximately 3.6 and 3.5% are 9-cis-β-carotene and all-trans-α-cryptoxanthin, respectively (De Rosso and Mercadante, 2007). The carotenoid content is low enough which is <0.5 mg/100 g (Breithaupt and Bamedi, 2001). β-carotene has an important role in vision, cell division and differentiation and reproduction in human beings. In *P. peruviana* fruit, the β-carotene content ranges from 0.34-1.77 mg/100 g (Pereda *et al*., 2018).

Flavonoids and polyphenols

The total phenol content in the juice of *P. peruviana* fruit grown in Czech Republic which has altitude 340 masl, determined by the Folin-Ciocalteu method was approximately 4.09 to 6.30 mg/100 g (Rob *et al*., 2012). It

was lower compared to another commodity such as carrot which had reach 29-31 mg/100g (Kaur and Aggarwal, 2015). The most dominant phenolic compound was quercetin, followed by myricetin and kaempferol. Total phenolic content was affected by fruit size and maturity stage. Full maturity stage had higher phenolic than start of maturity (Licodeidoff *et al.,* 2013). The phenolic content was also found in leaf and shoot. The phenolic content found in shoot extract was lower than in leaf extract (Cakir *et al.,* 2014). Processing of fruit will effect on phytochemical of fruit including total phenolic content. It was reported by Tanwar *et al.* (2014), processing fig fruit pulp into jam and nectar decreased total phenolic, falovonoid and anthocyanin of fruit.

Withanolides

Withanolides are natural lactone steroids that are produced by most plants in the Solanaceae family. These compounds have antimicrobial, antitumor, anti-inflammatory, hepatoprotective or immunomodulatory activity, as well as insect antifeedant property. It was reported by Goztok and Zengin (2013) that extract of *P. peruviana* fruit showed antimicrobial activities against most of bacteria, yeast and dermatophyta. Withanolide glycosides that have been isolated from various parts of the *P. peruviana* plant included perulactone, perulactone B, blumenol A and (þ) (S)-dehydrovomifoliol.

Physalins

Physalins are a series of pseudo-steroids that have been isolated and characterized from the *Physalis* plant. The primary compounds of *P. peruviana* included physalin A, B, D, F and glycoside that indicate anticancer activity as well as antioxidant and anti-inflammatory activities (Zhang *et al*., 2013).

CONCLUSION

From this review, it may be concluded that research work need to be carried out mainly on cultivation aspects to standardize the productin technologies on *P. peruviana* so that its production can be enahanced under different agro-climatic conditions. Further there is a need for detailed studies on pharmacological aspects to utilize the *P. peruviana* which is rich in phytochemicals and bioactive compounds for human health.

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