Review

# *Physalis peruviana* Linnaeus, the multiple properties of a highly functional fruit: A review

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A B S T R A C T

The main objective of this work is to spread the physicochemical and nutritional characteristics of the *Physalis peruviana* L. fruit and the relation of their physiologically active components with beneficial effects on human health, through scientifically proven information. It also describes their optical and mechanical properties and presents micrographs of the complex microstructure of *P. peruviana* L. fruit and studies on the antioxidant capacity of polyphenols present in this fruit.

**Contents**



## 1. Introduction

*Physalis peruviana*, also known as uchuva in Colombia, uvilla in Ecuador, aguaymanto in Perú, topotopo in Venezuela and goldenberry in English speaking countries are some of the multiple names for this fruit around the world.

The botanical name of the plant is *P. peruviana* Linnaeus, belonging to the family Solanaceae and genus *Physalis*, there are more than 80 varieties that can be found in the wilderness (Cedeño & Montenegro, 2004). *P. peruviana* L. is an herbaceous, semi-shrub, upright, and perennial in subtropical zones plant, it can grows until reach 0.6 to 0.9 m and in some cases can grow up to 1.8 m. The flower can be easily pollinated by insects, wind and also by auto-pollination. The fruit is a juicy berry with ovoid shape and a diameter between 1.25 to 2.50 cm, 4 and 10 g weight, containing inside around 100 to 200 small seeds, the fruit is protected by the calyx or fruit basket which completely

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covers the fruit along their development and ripening, protecting it against insects, birds, diseases and adverse climatic situations. Moreover, this structure represents an essential source of carbohydrates during the first 20 days of growth and development (Tapia & Fries, 2007).

*P. peruviana* L. is a native plant from the Andes region, transcending the history of the pre-Incan and Incan periods, throughout South America. This plant has been kept intact and without apparent changes in the structure of their germplasm. The centre of origin according to Legge in 1974 (Legge, 1974) were the Peruvian Andes, but according to a study made by the countries belonging to the Andres Bello Convention in 1983, a larger area was identified as the origin of the fruit of *P. peruviana* L. including the Ecuadorian Andes (Brito, 2002).

Although growing of *P. peruviana* L. extends all over the South American Andes and it has been found for two decades in markets from Venezuela to Chile (National Research Council (NRC), 1989), is in Colombia where it is grown for export and the country reached the lead as the largest producer followed by South Africa (Mazorra, 2006). Colombia produces 11,500 ton/year of *P. peruviana* L. fruit, but the surplus of fruit, not intended for export reached 50% of total production, this fruit is not exportable due to its size, so it is used for new dehydrated products (Castro, Rodriguez, & Vargas, 2008).

The species *P. peruviana* L. was introduced in South Africa by the Spanish and from there moved to different countries of the tropic and sub-tropics where it is grown commercially. Commercial varieties have been reported in the U.S. and New Zealand (Mazorra, 2006).

*P. peruviana* L. is able to grow in a wide range of altitude from 3300 m above sea level. It can withstand low temperatures, but suffer irreparable damage below 0 °C, their growth is affected if temperatures remain under 10 °C. The optimum temperature is 18 °C. Very high temperatures can affect flowering and fruiting. It requires high luminescence and must be protected from excessive wind. It must have enough water during the initial growth, but not during fruit ripening. It is a plant with high potential, since it grows in poor soil, but well-drained and has low requirement of fertilization. *P. peruviana* L. thrives best in slightly acid soil, although it tolerates well pH values between 5.5 and 7.3 with good organic matter content and rainfall between 1000 and 2000 mm. It does not tolerate clay soils because it has superficial roots (Tapia & Fries, 2007).

The time between the initiation of germination and the first crop is approximately nine months. The serviceable life of the plant production goes from nine to eleven months from the time of the first harvest, since thereafter both the productivity and fruit quality decrease (Tapia & Fries, 2007). The shelf life of the fruit of *P. peruviana* L. with calyx is one month while without calyx is 4 to 5 days or so (Cedeño & Montenegro, 2004).

*P. peruviana* L. has been classified into ecotypes or plants from different regions or countries, which are differentiated by size, colour and taste, shape of the flower head and the height and size of the plant. Three types are currently grown from *P. peruviana* L. originating from Colombia, Kenya and South Africa (Almanza & Espinosa, 1995). The Colombian type is characterized by small fruits with an average weight of 5 g, with more vivid colour and higher sugar content compared with ecotypes of Kenya and South Africa, these features make it more palatable to the markets (Almanza & Espinosa, 1995; Fischer, Florez, & Sora, 2000), in addition to other morphological characteristics as diverse as the calyx, the postharvest behaviour and taste (Almanza et al., 1995).

This work consists of a literature review about the fruit of *P. peruviana* L., from general topics and agro-food, mechanical, physicochemical, nutritional and medicinal features. The development of functional products from the fruit of *P. peruviana* L., represents another alternative for the exploitation of this resource, to supplement their nutritional value and promote new export channels (Sloan & Stiedemann, 1996). Thus, one can establish a niche for future scientific research, being a fruit used in Andean folk medicine since ancient times, most existing information is not guaranteed by scientific studies, so the collection is necessary mainly to filter the most important and reliable information. This work is intended primarily to describe the mechanical, physicochemical, nutritional and medicinal properties associated with the fruit of *P. peruviana* L. and to determine the functionality of the fruit by previous studies. In addition it seeks to highlight the use of the fruit in regions such as Chile where it is not known massively, so a new industry and a research item as a fruit it can be set up in this region.

## 2. Uses and medicinal properties of the fruit

Generally, the fruit of *P. peruviana* L. is consumed fresh; it provides an acid-sweet balance of fruit and vegetable salads. Also, the whole fruit can be used in syrup and dried as it becomes a "very nice raisin". The fruit of *P. peruviana* L. is also used in sauces and glazes for meats and seafood. Also it can be used as preservative for jams and jellies (National Research Council (NRC), 1989).

Currently, there are different products processed for the fruit of *P. peruviana* L., such as, jams, raisins and chocolate-covered candies. It can also be processed for juice (Ramadan & Moersel, 2007), pomace (Ramadan & Moersel, 2009) and other products sweetened with sugar as a snack. In European markets, it is used as ornaments in meals, salads, desserts and cakes (Cedeño et al., 2004).

The juice of the ripe fruit of *P. peruviana* L. is high in pectinase, reducing costs in the preparation of jams and other similar preparations (Corporación Colombia Internacional (CCI), 2001).

Many medicinal properties are attributed to *P. peruviana* L. such as antispasmodic, diuretic, antiseptic, sedative, analgesic, helping to fortify the optic nerve, throat trouble relief, elimination of intestinal parasites and amoeba. There have also been reported antidiabetic properties, recommending the consumption of five fruits a day. So far, there are no studies that indicate possible adverse effects (Rodríguez & Rodríguez, 2007). In different regions of Colombia, some of its medicinal properties are to purify blood of kidneys, decrease albumin, clean the cataract, to calcify and control amebiasis (Corporación Colombia Internacional (CCI), Universidad de los Andes, & Departamento de Planeación Nacional, 1994).

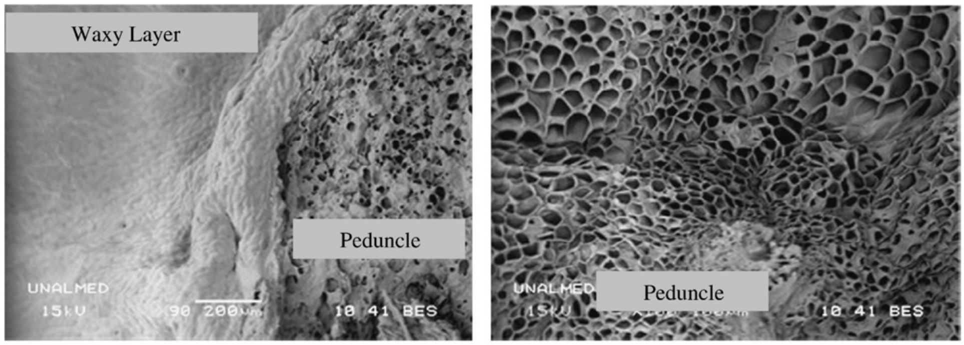
In Peruvian traditional medicine the fruit of *P. peruviana* L., is used empirically to treat cancer and other diseases like hepatitis, asthma, malaria and dermatitis, however, their properties have not been scientifically proven (Zavala et al., 2006).

There are studies indicating that eating the fruit of *P. peruviana* L. reduces blood glucose after 90 min postprandial in young adults, causing a greater hypoglycemic effect after this period (Rodríguez & Rodríguez, 2007).

The calyces of *P. peruviana* L. are widely used in folk medicine for its properties as anticancer, antimicrobial, antipyretic, diuretic, and anti-inflammatory immunomodulator (Franco, Matiz, Calle, Pinzon, & Ospina, 2007).

## 3. Microstructural analysis

The surface of the fruit of *P. peruviana* L. has low permeability to fluid exchange through it, this is due to microstructural complexity which hinders the use of techniques such as vacuum impregnation to incorporate new functional characteristics of the fruit, as well as osmotic dehydration process and hot air drying. The fruit surface represents 95% of fruit which is a waxy film composed mainly of resin terpenes, however, the area of the peduncle, corresponding to the breaking point of the calyx, has a porous microstructure. In micrographs A and B taken by scanning electron microscopy (SEM) to 90× and 100× of magnification respectively from *P. peruviana* L. (See Fig. 1), it is possible to identify a totally different microstructure between two zones, one for compact, waxy and impermeable film,




Source: Marín, 2009.

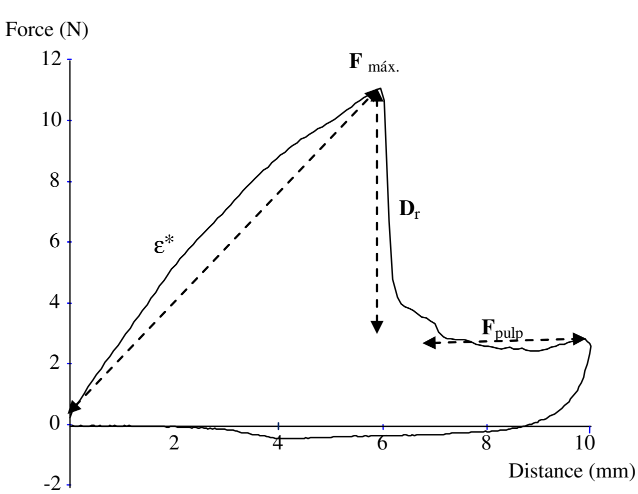
**Fig. 1.** Micrographs of *Physalis peruviana* L. obtained by SEM microscopy.

and the other around the stems which are porous (Marín, 2009). The latter is currently used to generate added value to this fruit, incorporating physiologically active components within their structure, using techniques as matrix engineering methodology to obtain functional foods from fresh fruits and vegetables (Botero, 2008; Marín, 2009; Restrepo, 2008).

## 4. Mechanical properties of the fruit

Firmness is the resistance of a material to deformation or penetration, where each material is characterized by a deformation curve in response to varying levels of force or pressure. Authors such as Ciro, Buitrago, and Pérez (2007), indicate that strong force is the best index on the practical level to determine the ripeness of a fruit at different stages, allowing to establish the optimal levels of consumption, transport and handling of product and additionally is a good predictor of its potential shelf life and degree of softening.

Botero (2008) conducted tests to assess the strength puncture the fruit of *P. peruviana* L. The graph shows a typical force–distance curve in this type of testing; it can be seen that this curve has a linear behaviour at the start of the test, which denotes the elastic behaviour of the waxy film that protects the fruit. It also shows that after the breakpoint of the surface film that protects the fruit, there is a very uniform behaviour in the texture of the flesh (see Fig. 2). The parameters evaluated by different authors in this type of test are: maximum force ($F_{max}$) to which the external film of the fruits breaks, breaking distance of this film (Dr), slope (ε*) and average force pulp




Source: Botero, 2008.

**Fig. 2.** Typical curve of force–distance in a puncture test of the fruit of *Physalis peruviana L.*

($F_{pulp}$) (See Table 1). The evolution of the force with penetration distance identifies the break point of the surface film, which corresponds to the maximum force or breaking force ($F_{max}$) and breaking distance ($D_r$).

According to studies conducted by Ciro et al. (2007), resistance to fracture mechanics and strength of firmness in fruits of *P. peruviana* L. decrease during postharvest time, that originated primarily by the process of maturation and softening of the fruit. The fruit of *P. peruviana* L. with a greater degree of ripeness is more susceptible to mechanical damage at postharvest compared to immature fruit.

## 5. Optical properties of the fruit

Recent studies (Marín, 2009) have indicated that the fresh fruit of *P. peruviana* L. presents two homogeneous groups, one includes the samples measured in the area of the peduncle and the other equatorial regions and the apex. At all times, samples of the area around the peduncle are clearer (>L*), less red (<a*) and more yellow (<b*) than other areas, this behaviour is attributed to the lower concentration of carotenoids in the area of the peduncle and physiological changes during fruit ripening process. Authors such as Botero (2008) have studied the colour of the fresh fruit of *P. peruviana* L. (degree of ripeness: 3–4), using spectrophotometry to determine the reflection spectrum of the samples, thus obtaining colour coordinates of CIE L* a* b* coordinates and psychometric chroma or saturation (C*) and hue (h*) (See Table 2), where L* is an indicator of luminosity. The parameter a* indicates chromaticity on the green axis (−) to red (+) and b* chromaticity in the blue axis (−) to yellow (+).

## 6. Antioxidant properties of fruit

Interest in the antioxidant properties of fruits is relatively recent (Liu, Qiu, Ding, & Yao, 2008; Vijaya Kumar Reddy, Sreeramulu, & Raghunath, 2010), some of the medicinal properties of the fruit of *P. peruviana* L. are associated with the antioxidant capacity of polyphenols present in the fruit. Some authors have reported values of the antioxidant capacity of the fruit of *P. peruviana* L. (See Table 3), determined in terms of activity DPPH free radical scavenger (DPPH method), the concentration of total phenols (Folin–Ciocalteu method) and the FRAP assay (Ferric Reducing / Antioxidant Power).

**Table 1**
Textural characterization of the fruit of *Physalis peruviana* L.

| Parameter | Restrepo (2008) | Botero (2008) |
|---|---|---|
| ε (N/mm) | 1.40 ± 0.10 | 3.16 ± 0.36 |
| Fr (N) | 9.75 ± 0.18 | 9.48 ± 0.90 |
| Fp (N) | 2.72 ± 0.32 | 2.73 ± 0.32 |

**Table 2**
Optical characterization of the fresh fruit of *Physalis peruviana* L.

| Parameter | Restrepo (2008) | Botero (2008) |
|---|---|---|
| L* | 71.37 ± 1.10 | 70.31 ± 0.39 |
| a* | 15.20 ± 0.48 | 14.31 ± 1.28 |
| b* | 61.76 ± 1.34 | 60.84 ± 3.10 |
| C* | 63.61 ± 1.40 | 62.50 ± 3.26 |
| h* | 76.20 ± 0.26 | 76.77 ± 0.57 |

**Table 4**
Physicochemical parameters for fresh fruit of *Physalis peruviana* L.

| Physicochemical parameter | Content | | |
|---|---|---|---|
| | Marín (2009) | Restrepo (2008) | Botero (2008) |
| ºBrix | 14.30 ± 0.80 | 13.80 ± 0.32 | 13.73 ± 0.49 |
| pH | 3.39 ± 0.06 | 3.39 ± 0.06 | 3.67 ± 0.12 |
| Acidity[a] (%) | 2.05 ± 0.15 | 2.10 ± 0.26 | 1.90 ± 0.26 |
| $a_w$ | 0.988 ± 0.002 | 0.985 ± 0.002 | 0.989 ± 0.030 |

[a] Expressed as % citric acid.

These results may change during storage due to degradation of vitamin C and phenolic compounds, diminishing the ability to scavenging free radicals (Banias, Oreopoulou, & Thomopoulos, 1992; Peyrat-Maillard, Bonnely, Rondini, & Berset, 2001). Other authors have found that DPPH methodology is affected by some as reducing the Vitamin C and some organic acids naturally present in fruits (Kayashima & Katayama, 2002; Scalzo, Politi, Pellegrini, Mezzetti, & Battino, 2005). The process of oxidation of ascorbic acid depends on the presence of transition metals such as copper or iron (Burdurlu, Koca, & Karadeniz, 2006), temperature, concentration of salts, sugars and pH in addition, the presence of oxygen, enzymes, metal catalysts, amino acids, oxidizing and reducing inorganic (Cheel, Theoduloz, Rodríguez, Caligari, & Schmeda-Hirschmann, 2007).

## 7. Physicochemical and nutritional composition of the fruit

According to studies by Marín (2009), the fresh fruit of *P. peruviana L.* presents values of bulk density, 1.038 ± 0.0054 g/mL and water activity of 0.988 ± 0.002. The fruit of *P. peruviana* L. with a level of ripeness 4 (according to colour specifications of the Colombian Technical Standard NTC 4580 (Instituto Colombiano de Normas Técnicas y Certificación (ICONTEC), 1999) shows physicochemical characteristics with a pH of 3.7, between 13 to 15 °Brix and acidity with a percentage between 1.6 and 2.0. As the fruit ripens °Brix and pH decrease, while the percentage of acidity increases (pH: 3.5/°Brix: 9 to 13/%Acidity: 2.0–2.1) (Osorio & Roldan, 2003; Salazar, Jones, Chaves, & Cooman, 2008). Recent studies have reported physicochemical parameters of fresh fruit of *P. peruviana* L. (See Table 4).

The benefits associated of the fruit of *P. peruviana* L., are mainly due to their nutritional composition (see Table 5) because, besides having good nutritional characteristics contains biologically active components that provide health benefits and reduce risk for certain diseases. Among its major components are its high amounts of polyunsaturated fatty acids, vitamins A, B and C and phytosterols, as well as the presence of essential minerals, vitamins such as E and K1, withanolides and physalins, which together would give them medicinal properties described above.

### *7.1. Proteins and carbohydrates*

Proteins are molecules composed of amino acids necessary for growth and repair of body tissues, their importance lies mainly in that they are an essential constituent of cells and how they may need replaced over time, it is essential to protein intake. To determine the protein quality of food is necessary to know the total protein content, what kinds of amino acids has and how many of them are essential (Latham, 2002a).

**Table 3**
Antioxidant capacity of the fruit of *Physalis peruviana* L.

| Parameter | Antioxidant activity | |
|---|---|---|
| | Restrepo (2008) | Botero (2008) |
| DPPH (μmoltrolox/100 g sample) | 210.82 ± 9.45 | 192.51 ± 30.13 |
| Total phenol content (mg galic acid/100 g sample) | 40.45 ± 0.93 | 39.15 ± 5.43 |
| FRAP (mg ascorbic acid/100 g sample) | 56.53 ± 1.38 | 54.98 ± 7.14 |

El Sheikha, Zaki, Bakr, El Habashy, and Montet (2010) studied the protein content of the juice of the fruit of *Physalis pubescens* L., showing a 31.8% of essential amino acids, mainly leucine, lysine and isoleucine. However, there are no similar studies for the juice of the fruit *P. peruviana* L.. Rodríguez et al. (2007) indicated that the fruit of *P. peruviana* L. has good protein content, there is no detailed record of the amino acids that would bring how many of these would be essential and therefore the protein quality of the fruit, or the benefits of a healthy consumption of protein from the fruit of *P. peruviana* L could not be determined.

As pointed out by Latham (2002a), carbohydrates are the main energy source for Asians, Africans and Latin American people. Carbohydrates are found in the human diet mainly as starch and various sugars, the latter can be divided into three groups according to their complexity: monosaccharides, disaccharides and polysaccharides.

Novoa, Bojacá, Galvis, and Fischer (2006) evaluated three sugars in the fruit of *P. peruviana* L. being sucrose (disaccharide) the most abundant sugar after glucose (monosaccharide) and finally fructose (monosaccharide) with limited presence in the fruit. They also noticed that the glucose content in the fruit of *P. peruviana* L. is very similar to other Solanaceae fruits, with a value close to 0.5%.

### *7.2. Lipids*

According to studies by Ramadan and Morsel (2003) the fruit of *P. peruviana* L. containing 2% oil, of which 1.8% is extracted from the seeds and 0.2% owned by the pulp and fruit skin. The oils extracted from fruits of *P. peruviana* L. consist of 15 fatty acids, among which are linoleic acid, oleic, palmitic and stearic acids, which constitute 95% of total fatty acids. Linoleic acid is the dominant fatty acid followed by oleic acid, where the ratio of linoleic and oleic acid in pulp and skin is 2:1, and 5:1 seed. It is well known that dietary lipids rich in linoleic acid prevent cardiovascular disorders such as coronary heart disease, atherosclerosis and hypertension. Linoleic acid derivatives serve as structural components of the plasma membrane as precursors and metabolic regulators of some components.

There are also significant amounts of saturated fatty acids of normal chain. Palmitic acid (9%) and stearic acid (~2.5%) are saturated fatty acids mainly found in oils extracted from the fruit of *P. peruviana* L. (Ramadan & Morsel, 2003). As Ramadan reported, the oil extracted from skin and pulp of the fruit of *P. peruviana* L. could contains triens such as γ-linolenic acid (GAL), α-linolenic and acid Dihomo γ-linolenic acids (DHGLA) being a good source of this type of polyunsaturated fatty acids (PUFA). Linolenic acid, being as healthy as the linoleic acid, is considered an essential fatty acid (EFA), since they are necessary for good health. EFAs are important in the synthesis of many cellular structures and several biologically important compounds (Latham, 2002a). Moreover, polyunsaturated fatty acids are essential for the human body, performing many functions such as maintenance of cell membranes and production of prostaglandins (regulators of many body processes, including inflammation and blood clotting). Fats are also needed in the diet as input for fat-soluble vitamins in foods (A, D, E and K) and can be absorbed to regulate

**Table 5**
Average nutritional facts of *Physalis peruviana* L.

| Nutritional content | Content (each 100 g fruit) | | | | |
|---|---|---|---|---|---|
| | National Research Council (NRC) (1989) | Fischer et al. (2000) | CCI (2001) | Osorio and Roldan (2003) | Repo de Carrasco and Zelada (2008) |
| Energy (cal) | 73.0 | 49.0 | 54.0 | 49.0 | 76.8 |
| Water (g) | 78.9 | 85.5 | 76.9 | 85.9 | 79.8 |
| Protein (g) | 0.3 | 1.5 | 1.1 | 1.5 | 1.9 |
| Fat (g) | 0.2 | 0.5 | 0.4 | 0.5 | 0.0 |
| Carbohydrates (g) | 19.6 | 11.0 | 13.1 | 11.0 | 17.3 |
| Fiber (g) | 4.9 | 0.4 | 4.8 | 0.4 | 3.6 |
| Ash (g) | 1.0 | 0.7 | 0.7 | 0.7 | 1.0 |

cholesterol metabolism (Pinazo-Durán, Zanón-Moreno, & Vinuesa-Silva, 2008).

The fatty acid composition and high amounts of polyunsaturated fatty acids found in oils extracted from *P. peruviana* L. make this fruit ideal for nutrition (Ramadan et al., 2003) (see Table 6).

According to the results obtained by Ramadan et al. (2003), the oils extracted from the fruit of *P. peruviana* L. also contain nine species of triacylglycerols (TAG) molecules, but three species, C54: 3, C52: 2 and C54: 6, represent at least 91% of the total.

### 7.3. Phytosterols

The scientific and medical literature describes phytosterols as suppliers of a wide variety of physiological effects. They attributed anti-inflammatory, antitumor, antibacterial and antifungal. However, the effect best characterized and scientifically proven, is the hypocholesterolemic effect, both total cholesterol and LDL cholesterol (Valenzuela & Ronco, 2004).

Phytosterols are of great interest because of its antioxidant capacity and impact on health (Ramadan et al., 2003). The oil extracted from the skin and pulp of the fruit of *P. peruviana* L. has high levels of plant sterols (see Table 7).

According to Valenzuela and Ronco (2004) previous work has shown that consumption of margarine enriched with α-sitosterol, campesterol and stigmasterol administered to moderately hypercholesterolemic individuals (220–240 mg/dL cholesterol), produces a reduction of circulating cholesterol around 10% on average and 8% in LDL cholesterol without affecting HDL-cholesterol and triglyceride levels. As shown in Table 7, campesterol is the most abundant phytosterol in the oils from *P. peruviana* L., moreover contains β-sitosterol and stigmasterol as the presence of these sterols in the fruit of *P. peruviana* L. could be responsible for the fruit's ability to reduce cholesterol levels.

### 7.4. Minerals

Minerals have many functions in the human body. Some mineral elements are needed in very small amounts in human diets, but are vital for metabolic purposes, they are called essential trace elements (Latham, 2002b). The nutritional elements are essential or required for the normal functioning of the body and are classified according to their relative amounts or requirements: Magnesium (Mg), Calcium (Ca), Potassium (K), Sodium (Na) and Phosphorus (P) are classified as macronutrients, while the Iron (Fe) and Zinc (Zn), for example, are considered as micronutrients (Szefer & Nriagu, 2007).

The presence of macro and micronutrients in foods is important for the development and maintenance of vital body functions, as they are involved in all aspects of growth, health and reproduction, and also participate in the formation of cells, tissues and organs (Szefer & Nriagu, 2007). Fruits and vegetables are valuable sources of minerals. Diets high in fruits and vegetables are associated with decreased risk for illnesses like diabetes and cancer, as its consumption should be widely promoted (Leterme, Buldgen, Estrada, & Londoño, 2006).

The fruit of *P. peruviana* L. contains Phosphorus, Iron, Potassium and Zinc (Rodríguez et al., 2007). In humans, Phosphorus and Calcium have a role as major components of the skeleton. They have also important metabolic functions related to muscle function, hormonal and nerve stimulation (Latham, 2002b), the fruit of *P. peruviana* L. has an exceptionally high Phosphorus content for a fruit, but Calcium levels are low (National Research Council (NRC), 1989).

Iron is found in foods of plant and animal origin. The main biological function of Iron is the transport of oxygen to the body, consequently the lack of this mineral in the diet leads to anaemia. Repo de Carrasco and Zelada (2008) reported an Iron content in the fruit of *P. peruviana* L. close to 1.2 mg.

According to Mayorga, Knapp, Winterhalter, and Duque (2001) the fruit of *P. peruviana* L. has been used as a source of minerals, especially Iron and Potassium. Potassium, like Sodium, plays an important role in the physiological functions of animals and is abundantly distributed in the human diet (Szefer et al., 2007). Musinguzi, Kikafunda, and Kiremire (2007) compared the mineral content between *P. peruviana* L. and *Physalis minima* L. finding that *P. peruviana* L. is highly rich in Potassium, with a value close to 210 mg, whereas, *Physalis minima* L., has only 2.43 mg.

According to Wu et al. (2005) Zinc is a mineral that acts as a non-enzymatic antioxidant, so that its consumption helps prevent oxidative damage of the cell. Authors such as Repo de Carrasco and Zelada (2008) indicate the presence of this micronutrient in small doses in the fruit *of P. peruviana* L., but would be in small doses; this mineral would contribute to the antioxidant activity of fruit.

**Table 6**
Fatty acids composition in oil extracted from *Physalis peruviana* L. fruit.

| Component (%) | Seed oil | Pulp and skin oil |
|---|---|---|
| Saturated fatty acids | 11.30 | 16.10 |
| Monoens total | 12.20 | 27.70 |
| Diens total | 76.10 | 44.40 |
| Triens total | 0.33 | 11.70 |

Source: Radamán et al., 2003.

**Table 7**
Phytosterol composition of oils extracted from the fruit of *Physalis peruviana* L.

| Phytosterols (g per kg of total lipids) | Seed oil | Pulp and skin oil |
|---|---|---|
| Campesterol | 6.48 | 11.50 |
| β-sitosterol | 5.71 | 4.99 |
| Δ5-avenasterol | 4.57 | 11.80 |
| Lanosterol | 2.27 | 7.44 |
| Stigmasterol | 1.32 | 6.17 |
| Δ7-avenasterol | 1.11 | 2.68 |
| Ergosterol | 1.04 | 8.62 |
| Total esteroles | 22.50 | 53.20 |

Source: Ramadán et al., 2003.

**Table 8**
Mineral content in the fruit of *Physalis peruviana* L.

| Mineral | Content in mg (each 100 g of pulp) | | | |
|---|---|---|---|---|
| | National Research Council (NRC) (1989) | Leterme et al. (2006) | Musinguzi et al. (2007) | Repo de Carrasco et al. (2008) |
| Sodium | 1.00 | 6.00 | 2.00 | – |
| Potassium | 320.00 | 467.00 | 210.00 | 292.65 |
| Calcium | 8.00 | 23.00 | 28.00 | 10.55 |
| Magnesium | – | 19.00 | 7.00 | – |
| Phosphorus | 55.00 | 27.00 | 34.00 | 37.90 |
| Iron | 1.20 | 0.09 | 0.30 | 1.24 |
| Zinc | – | 0.28 | – | 0.40 |

Table 8 shows the mineral content in 100 g of *P. peruviana* L., it is possible to observe its high content of Potassium, plus the presence of macronutrients as described above.

### 7.5. Vitamins

Vitamins are organic substances present in very small quantities in food, but necessary for metabolism. They are grouped together not because they are chemically related or have similar physiological functions, but because they are vital factors in the diet and they all were discovered in connection with the diseases that cause its lack (Latham, 2002c).

The fruit of *P. peruviana* L. is highly nutritious, having high levels of vitamins A, B and C (see Table 9). Vitamin A plays a crucial role in the growth and development of young people is important for cellular differentiation, including the hematologic system, lysosomal membrane stabilization, maintenance of epithelial tissue integrity and has an immunostimulatory effect (Ombwara, Wamosho, & Mugai, 2005).

The main active components of vitamin A in fruits are α-carotene, β-carotene and β cryptoxanthin (Fischer, Ebert, & Lüdders, 2000). The most common carotenoids is β-carotene, because none of the other carotenoids is present in provitamin A which has half the activity of β-carotene, also is less extensive in nature. Carotenoids are responsible for the orange colour in the fruit of *P. peruviana* L. (Ramadan et al., 2003). β-carotene is very important in the prevention of certain human diseases such as cancer. The reason that carotenoids prevent cancer is related to the antioxidant activity that deactivates free radicals generated in tissues (Castro et al., 2008). Ascorbic acid is widely distributed in fresh fruits and vegetables. It is classified as a hidro-soluble vitamin, which is the reason why it is abundant in fruits with water content that exceeds 50% (Gutiérrez, Hoyos, & Páez, 2007). This would explain the high level of ascorbic acid (vitamin C) in the fruit of *P. peruviana* L. This vitamin plays an important role in human nutrition, including growth and maintenance of tissues, the production of neurotransmitters, hormones and immune system responses. Vitamin C is an important dietary antioxidant, since it reduces the adverse effects of reactive oxygen and reactive nitrogen that can cause damage to macromolecules such as lipids, DNA and proteins, which are related to cardiovascular disease, cancer and neurodegenerative diseases (Naidu, 2003).

**Table 9**
Vitamin composition of the fruit of *Physalis peruviana* L.

| Vitamin | Content (each 100 g of pulp) | | | |
|---|---|---|---|---|
| | National Research Council (NRC) (1989) | CCI (1994) | Fischer et al. (2000) | Osorio and Roldan (2003) |
| Betacarotene (vit. A) | 1460 mg | 648 U.I. | 1730 U.I. | |
| Tiamin (vit. B1) in mg | 0.10 | 0.18 | 0.10 | |
| Riboflavin (vit. B2) in mg | 0.03 | 0.03 | 0.17 | |
| Niacin (vit. B3) in mg | 1.70 | 1.30 | 0.80 | |
| Ascorbic acid (vit. C) in mg | 43.00 | 26.00 | 20.00 | |

**Table 10**
Levels of vitamins $K_1$ and E in oils extracted from the fruit *Physalis peruviana* L.

| Component (g per kg of total lipids) | Seed oil | Pulp and skin oil |
|---|---|---|
| Vitamin $K_1$ | 0.12 | 2.12 |
| Vitamin E | 29.70 | 86.30 |
| α-tocopherol | 0.88 | 22.50 |
| β-tocopherol | 11.30 | 13.10 |
| γ-tocopherol | 9.08 | 50.40 |
| δ-tocopherol | 8.44 | 0.30 |

Source: Ramadán et al., 2003.

The oils extracted from fruits of *P. peruviana* L. were characterized by high levels of vitamin $K_1$, also called phylloquinone. The requirement of phylloquinone for an adult human is extremely low. The addition of phylloquinone-rich oils in the process of foods poor in vitamins make oils are potentially important dietary sources of vitamins (Ramadan et al., 2003).

According to Ramadan et al. (2003) levels of vitamin E in the oil extracted from fruit pulp and skin from *P. peruviana* L. are extremely high compared to the amount present in seed oil (see Table 10). The same author studied four tocopherols in oils extracted from fruits of *P. peruviana* L. these were: α, β, γ and δ. However, other authors reported no significant levels of compounds with vitamin E activity in the fruit, so it has been strengthened using the technique of vacuum impregnation with positive results (Restrepo, Cortés, & Márquez, 2009). The effectiveness of tocopherols (vitamin E) and lipid antioxidants has been attributed mainly to its ability to prevent cell membrane damage by free radicals, by reducing the levels of lipid peroxides (Rodríguez et al., 2007). α-Tocopherol is the most efficient of these components (Ramadan et al., 2003).

α-Tocopherol is a natural antioxidant that can eliminate reactive oxygen species. It is located within the phospholipid bi-layer of cell membranes to protect against lipid peroxidation. β-tocopherol is between 25 and 50% of the antioxidant activity of the α-tocopherol and γ-tocopherol between 10 and 35% (Dillard, Gavino, & Tappel, 1983).

### 7.6. Physalins

Immunosuppressive substances are widely used to inhibit unwanted immune responses in autoimmune diseases, allergies and organ transplants. Although a variety of immunosuppressive drugs are currently available, their prolonged use is often accompanied by unwanted effects. Natural products have been a source of compounds with pharmacological activities. A series of pseudo-steroids known as Physalins, were isolated from *Physalis* sp. and characterized (Soares et al., 2006). The same author notes that purified extract from *Physalis angulata* physalin has a suppressive activity on macrophages stimulated by lipopolysaccharide and γ interferon.

Zavala et al. (2006) showed that the ethanol extract of leaves and stems of *P. peruviana* L. is capable of inhibiting tumor cell growth. The presence of bioactive compounds, possibly as found by Chiang in 1992 (Chiang, Jaw, Chen, & Kan, 1992) showed that, by dividing the ethanol extract of *Physalis angulata*, isolated Physalin has cytotoxic activity in vitro.

The main active constituents of *P. peruviana* L. are Physalins A, B, D, F and glycosides, which show anticancer activity (Wu et al., 2004). 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 immune-mediated diseases. This suggests that some of the effects observed in traditional medicine plants in the genus *Physalis*, may be partly due to the action of these pseudo-steroids with immunoinflammatory action (Rodríguez et al., 2007).

### 7.7. Withanolides

The withanolides are steroidal lactones mainly produced by Solanaceous plants. Its components have antimicrobial properties, antitumor, anti-inflammatory, hepatoprotective or inmunomodulatory and antiparasitic activity (Ahmad, Malik, Afza, & Yasmin, 1999). Lan et al. (2009) noticed seventeen withanolides found in *P. peruviana* L. Seven were recently discovered phyperunolid A, phyperunolid B, phyperunolid C, phyperunolid D, peruvianoxid, phyperunolid E, and phyperunolid F. And ten correspond to withanolides previously known: 4β-hidroxiwithanolid E, withanolid E, withanolid S, withanolid C, withaperuvin, physalolactone, withaphysanolid, physalactona, withaperuvin D and loliolid.

Phyperunolid A, 4-β hidroxiwithanolid E, withanolid E and withanolid C present cytotoxic activity against lung cancer, breast cancer and liver cancer (Lan et al., 2009).

## 8. Conclusions

The mechanical, optical, chemical and nutritional properties of the fruit *P. peruviana* L. and its health effects were described in this paper.

The fruit of *P. peruviana* L. has complex microstructural features, this is because the waxy film that surrounds it is quite impermeable, which has hindered the use of techniques that would improve their nutritional characteristics such as vacuum impregnation, the stalk being the area most susceptible to the incorporation of nutrients.

In colour it may be concluded that the top of the fruit is brighter, has more yellow and less red in the bottom, which is mainly due to lower content of carotenoids and fruit ripening.

The bioactive components present in the fruit of *P. peruviana* L. make this to be considered as a natural functional food, because the physiological properties associated with its nutritional composition. Phytosterols are found in high levels in the oils extracted from the fruit of *P. peruviana* L., they would give them properties such as antioxidant and hypocholesterolemic effects, the presence of three specific phytosterols: campesterol, β-sitosterol and stigmasterol would be responsible for lower levels of blood cholesterol. Furthermore, the antioxidant activity associated with this result is due to the high levels of polyphenols and high in vitamins A and C. Finally, the presence of exclusive *Physalis*-gender Physalins and withanolides specific from the Solanaceae family would give the fruit of *P. peruviana* L. anti-inflammatory, antimicrobial and anticancer properties, making them substances of great interest for future research.

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