Health-Promoting Compounds in Cape gooseberry (Physalis Peruviana L.): Review from a supply chain perspective

Article *in* Trends in Food Science & Technology · September 2016

DOI: 10.1016/j.tifs.2016.09.009

CITATIONS
2

READS
168

4 authors, including:

Mary Luz Olivares Tenorio
Fundacion Universitaria Agraria de Colombia
14 PUBLICATIONS **4** CITATIONS
SEE PROFILE

Matthijs Dekker
Wageningen University & Research
199 PUBLICATIONS **4,624** CITATIONS
SEE PROFILE

Ruud Verkerk
Wageningen University & Research
149 PUBLICATIONS **3,248** CITATIONS
SEE PROFILE

Trends in Food Science & Technology 57 (2016) 83–92

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: http://www.journals.elsevier.com/trends-in-food-science-and-technology

Review

Health-promoting compounds in cape gooseberry (*Physalis peruviana L.*): Review from a supply chain perspective

Mary-Luz Olivares-Tenorio [a, b, *], Matthijs Dekker [a], Ruud Verkerk [a], Martinus A.J.S. van Boekel [a]

[a] Wageningen University, Food Quality and Design Group, The Netherlands
[b] Fundación Universitaria Agraria de Colombia, UNIAGRARIA, Colombia

ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form
5 September 2016
Accepted 19 September 2016
Available online 21 September 2016

Keywords:
Antioxidant activity
β-carotene
Flavonoids
Phenolic compounds
Phytochemicals
Supply chain
Vitamin C

ABSTRACT

Background: The fruit of *Physalis peruviana L.*, known as Cape Gooseberry (CG) is a source of a variety of compounds with potential health benefits. Therefore, CG has been subject of scientific and commercial interest.

Scope and approach: This review paper evaluates changes of such health-promoting compounds and antioxidant activity in CG, based on published literature and from a supply chain perspective, considering pre-harvest, post-harvest, processing (thermal and not thermal) and storage steps to give an insight of contents at consumption stage.

Key findings and conclusions: CG has vitamin C (20 and 35 mg 100 g^{-1} FW), β-carotene (up to 2.0 mg.100 g^{-1} FW), total phenolic compounds TPC (50–250 gallic acid equivalents.100 g^{-1} FW), phenolic acids (caffeic, gallic, chlorogenic, ferulic and *p*-cumaric acids), flavonoids (quercetin, rutin, myricetin, kaempferol, catechin and epicatechin) and antioxidant activity. There is not yet evidence of presence of physalins and withanolides in CG as previous review papers have stated. The ripeness stage of CG is a relevant factor affecting the content of many phytochemicals. Vitamin C and β-carotene contents are directly proportional to ripeness stage. The reported data in literature showed a large variation, likely caused by different raw material properties (origin, ripeness stage, growing conditions etc.) and differences in the employed analytical methods. Thermal and non-thermal processing have an effect on the extractability of the phytochemicals but also on the decrease of compounds and antioxidant activity. Relative stability to certain phytochemicals to processing suggest an opportunity to add value to supply chain with processed food containing health-promoting compounds.

1. Introduction

Cape gooseberry (CG), also known as goldenberry, is the fruit of the plant *Physalis peruviana L.* that belongs to Solanaceae family and genus *Physalis*. This plant is native from the Andean Region and is cultivated currently in South American countries, especially Colombia, Peru and Ecuador. CG is a fruit with approximately 1.25–2.50 cm of diameter, 4–10 g of weight, orange yellow skin and juicy pulp containing numerous small yellowish seeds (Fischer, 1995).

Consumption of fruits and vegetables is inversely associated to the risk of cardiovascular (CVD), respiratory and digestive diseases and certain cancers (Hjartåker, Knudsen, Tretli, & Weiderpass, 2015; Leenders et al., 2014). Although, other studies did not find these associations (Norat, Aune, Chan, & Romaguera, 2014), the increase of fruit and vegetable consumption is advisable (Terry, Terry, & Wolk, 2001). Anti-tumour, anti-diabetic, anti-inflammatory, anti-hypertension activities and cardio-protective effects have been associated with the consumption of berry fruits such as strawberries, blueberries, blackberries, raspberries and cranberries (Hjartåker et al., 2015; Mursu, Virtanen, Tuomainen, Nurmi, & Voutilainen, 2014) and have also been related to the plant *Physalis peruviana* (leaf and stems) and CG (Abdel Moneim et al., 2014; Areiza-Mazo, Maldonado, & Rojano, 2013; Da Silva Pinto et al., 2009; Osman, AL-seeni, Alkhatib, & Al-shreef, 2013;

* Corresponding author. Wageningen University, Food Quality and Design Group, Bornse Weilanden 9, 6708WG, Wageningen, The Netherlands; UNIAGRARIA, Programa Ingeniería de Alimentos Calle 170 No. 54A - 10 Bogotá, Colombia.
E-mail addresses: maryluz.olivarestenorio@wur.nl, maryluzolivares@hotmail.com (M.-L. Olivares-Tenorio).

http://dx.doi.org/10.1016/j.tifs.2016.09.009
0924-2244/

Rodríguez & Rodríguez, 2007; Yen et al., 2010). The associations to health benefits are related to the content of phytochemicals such as vitamins, minerals, phenolic compounds, withanolides and physalins. Nevertheless, knowledge about health protective mechanisms is limited.

This review gives an overview of the state of art of changes of health-promoting compounds of CG in a supply chain perspective, evaluating pre-harvest, post-harvest, processing and storage steps, giving an insight of compounds content at consumption stage (fresh and processed) and identifying knowledge gaps. The observed high variation in the reported data will be discussed, including the discrepancies and uncertainties in analytical methods that were used for the determination of the compounds.

2. Cape gooseberry supply chain

CG is the most exported tropical fruit in Colombia, after banana (Agronet, 2016), while the main CG market is the European Union, especially the Netherlands, followed by Belgium and Germany (Agronet, 2016). Although most of the fruit is exported as fresh fruit, the physical and chemical characteristics of CG make it a suitable raw material for numerous products such as juices, jam, pulp, desserts, dried fruit, etc (MADR, UNAL, & CORPOICA, 2009; Rabie, Soliman, Diaconeasa, & Constantin, 2015; Ramadan & Moersel, 2007). which are currently available in the domestic and international markets. The Colombian CG supply chain essentially involves 4 main stages: production, processing, distribution/marketing and consumption (Olivares-Tenorio, Linnemann, Pascucci, Verkerk, & van Boekel, 2014).

A supply chain approach in food quality is important to guarantee safety and quality from farm to table (consumption). Nowadays, consumers are increasingly interested about what they eat in terms of nutritional and health promoting properties. Actors in agri-food supply chains should not make unsubstantiated health claims that can mislead consumers, but provide accurate information about the nutritional and health-promoting compounds in products (Ponte & Gibbon, 2005). A report from the Colombian government has stated the need to have information about health-promoting compounds in CG, not only in the fruit after harvesting, but also at consumption stage (fresh or processed) (MADR et al., 2009). For the purpose of this review and what is reported in literature, the CG supply chain evaluation has been focused on pre-harvest, post-harvest, processing and storage. In the CG supply chain, like in any other agri-food supply chain, several factors affect the content of health-promoting compounds, such as the varieties of fruits, cultivation conditions, harvest time, storage, processing and consumer processing (Dekker, Verkerk, & Jongen, 2000). An analysis of these factors on compounds in CG will be discussed based on published data.

3. Pre- harvest and post-harvest

3.1. Vitamin C

Vitamin C is the most abundant water-soluble antioxidant in the body. This nutrient is associated to the protection against cancer and CVC diseases, and to the beneficial effects on immune functions (Grosso et al., 2013). The theoretical mechanisms related to those benefits are essentially, the scavenging activity against free radicals and reactive oxygen species, the role in promoting collagen formation in the body, the inhibition of formation of *N*-nitroso compounds (carcinogenic nitrosamines), the participation as cosubstrate in catecholamine and carnitine biosynthesis and the protection of low density lipoprotein (LDL) cholesterol against oxidation (Grosso et al., 2013).

Comparing various studies, a very high variation of data is observed, which is illustrated in Fig. 1 amounting up to 50-fold differences, ranging from of 18–929 mg 100 g^{-1} FW (fresh weight) of vitamin C.

The variation of vitamin C content can be caused by the used *analytical methods*. Titration method and HPLC are frequently used methods in reported studies. Titration is known to lack sensitivity and can lead to an overestimation of vitamin C content (Brause, Woollard, & Indyk, 2003; Odriozola-Serrano, Hernández-Jover, & Martín-Belloso, 2007). Besides, differences in extraction procedures might cause variability in both, titration and HPLC methods (Hernández, Lobo, & González, 2006). Barcia, Jacques, Pertuzatti, and Zambiazi (2010) probably overestimated the content of vitamin C with an amount of 929 mg 100 g^{-1} FW. Overestimation can be caused by a failure to separate interferences from the ascorbic acid peak in HPLC (Tarrago-Trani, Phillips, & Cotty, 2012).

Another cause of variation of vitamin C content can be the different *varieties/cultivars/ecotypes* used in cultivation. Due to the fact that information on cultivars is often missing in literature, the effect of them on vitamin C remains unclear. Differences in vitamin C content where found in cultivars from South Africa, *Giant, Inka* and *Golden Berry* (Rop, Mlcek, Jurikova, & Valsikova, 2012), but for three ecotypes *Colombia*, *Kenya* and *South Africa* there were no significant differences (Fischer, Ebert, & Ludders, 2000). Reported studies on vitamin C in CG from Ecuador, Peru and Argentina are not comparable due to difference in experimental conditions or lack of reported information (Novoa, Bojacá, Galvis, & Fischer, 2006; Rop et al., 2012; Valdenegro, 2013; Valdenegro, Fuentes, Herrera, & Moya-León, 2012). *Location of cultivation* might me another cause of variation in results. Nevertheless, studies on CG from different countries (South American countries, Egypt, Germany and Czech Republic) were not comparable because of the lack of detailed information about cultivation conditions. The altitude of cultivation did not have a significant effect on vitamin C content in CG (Fischer et al., 2000). During *post-harvest,* presence of the calyx allowed the vitamin C stability (Valdenegro et al., 2012).

An estimation of ripening stages was attempted to be able to compare results, using standard NTC 4580 (ICONTEC., 1999). This standard classifies ripeness stage, according to colour, measured visually; °Brix, measured by refractometry and acidity, reported as % acid citric and measured by titration with a scale from 0 to 6, where 6 is the highest ripeness stage (ICONTEC., 1999). In Fig. 2, normalized data of vitamin C contents have been plotted as a function of ripeness stage. Only studies evaluating vitamin C in various ripeness stages were included.

Some studies indicated a directly proportional association of vitamin C to ripeness stage (Gutierrez, Trinchero, Cerri, Vilella, & Sozzi, 2008; Repo de Carrasco & Encina, 2008; Valdenegro et al., 2012). Normalized data showed significant differences between means of vitamin C at the 6 stages ($P < 0.05$). Ascorbic acid can increase because of biochemical synthesis during the ripening process (Repo de Carrasco & Encina, 2008) as has been reported for tomatoes, peppers and guava (Gomez & Lajolo, 2008; Navarro, Flores, Garrido, & Martinez, 2006; Raffo et al., 2002).

CG at the edible ripening stages (4–6) contains between 20 and 50 mg 100 g^{-1} FW of vitamin C. Therefore, CG is a good source of vitamin C compared with other common sources, such as mango (15–36 mg 100 g^{-1} FW), comparable to orange (50 mg 100 g^{-1} FW), but less than guava (120–228 mg 100 g^{-1} FW) or marula (120 mg 100 g^{-1} FW) (Gomez & Lajolo, 2008; Hiwilepo-van Hal, Bosschaart, van Twisk, Verkerk, & Dekker, 2012; Sogi, Siddiq, Roidoung, & Dolan, 2012; USDA., 2014). Following international nutritional recommendations, the daily intake of vitamin C should be between 15 and 90 mg per day (depending on gender and age), thus, to comply this consumption with only CG as vitamin C source,

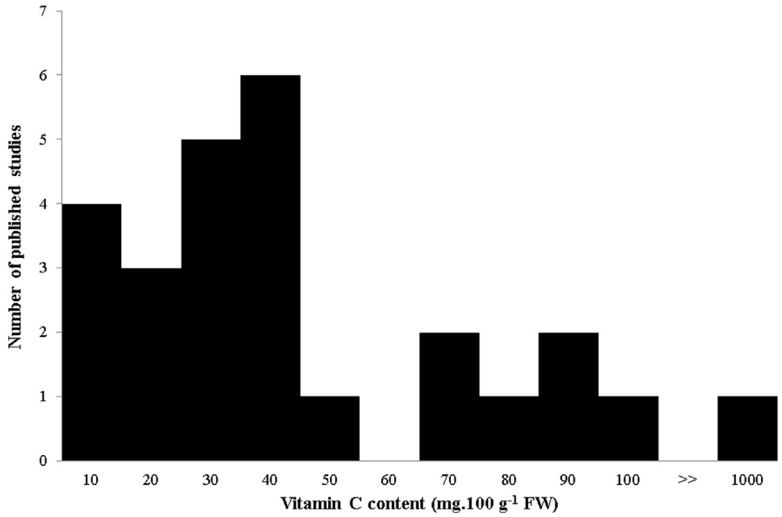

Fig. 1. Histogram of Vitamin C values reported in literature for CG (*Physalis peruviana L*).

approximately 200 g (approx. 20–50 berries) should be eaten (CEC., 1993; Johnston, 2012; USDA & HSS, 2010).

3.2. Total phenolic compounds

Phenolic compounds form a group of secondary metabolites widely occurring in plants. These compounds may play a role in the inhibition carcinogenesis by affecting the molecular events in the initiation, promotion, and progression stages, especially, thanks to their antioxidant capacity. However, precision of the mechanism involved are still unclear (Valdés et al., 2015). There are four main groups of phenolic compounds: phenolic acids, flavonoids, stilbenes, and lignans (Balasundram, Sundram, & Samman, 2006).

Total Phenolic Compounds (TPC) contents in CG and similar species have been reported showing a wide range of 2.5–934.9 mg 100 g^{-1} FW, usually expressed as gallic acid equivalents. This large variation is illustrated in Fig. 3.

The large variation of TPC contents might be caused by the different use of *varieties/cultivars/ecotypes* (K. Bravo, Sepulveda-Ortega, Lara-Guzman, Navas-Arboleda, & Osorio, 2015; Rop et al., 2012). *Maturity stages* show higher phenolic compound contents when the fruit was still in the plant (Bravo et al., 2015; Mier & Cáez, 2011; Narváez-Cuenca, Mateus-Gómez, & Restrepo-Sánchez, 2014; Severo et al., 2010; Valdenegro et al., 2012). So far, there is not more published information about TPC content of CG during pre-harvest and post-harvest. Variation of TPC content also can be due to *method of analysis*. Folin ciocalteau is the most widely used method. Nevertheless, there are variations in type of extraction solvent, extraction conditions, reaction time, standards used and wavelength. Studies reported low contents of TPC when no extraction was performed (Ramadan & Moersel, 2007; Valdenegro et al., 2012). TPC can also be underestimated when they are in bound forms because usually they are excluded from analysis (Balasundram et al., 2006). From data reported for CG, gallic acid is the most common standard used to quantify phenolic compounds and differences can arise when the standard used is caffeic acid (or other). Gallic acid can be less reactive to folin ciocalteau than caffeic acid, giving lower absorbance and affecting final results (Stratil, Klejdus, & Kubán, 2006).

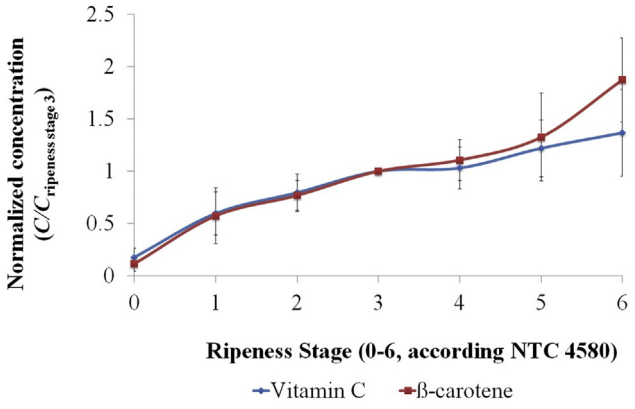

Fig. 2. Normalized data of vitamin C and β-carotene contents in CG (*Physalis peruviana L*) for ripeness stages (according to NTC 4580, 1999). Verticals bars represent standard deviations of estimated means (n = 3–4). Data sources: Bravo et al., 2015; Fischer & Martínez, 1999; Gutierrez et al., 2008; Mier & Cáez, 2011; Repo de Carrasco & Encina, 2008; Severo et al., 2010; Valdenegro et al., 2012.

In Fig. 4, TPC contents have been plotted in relation to ripeness stages of the fruit according to NTC 4580 (ICONTEC., 1999), using the same criteria as in Section 3.1.

In Fig. 4, there are discrepancies in the trend of TPC during ripening and changes of normalized data are not significant ($P > 0.05$). Contradictory results in Figs. 3 and 4, do not allow identifying the trend of TPC during maturity and ripening in CG.

TPC contents of CG at edible ripening stage (50–250 gallic acid equivalents.100 g^{-1} FW) are higher than what is reported for mango (56–193 gallic acid equivalents.100 g^{-1} FW) pineapple (94.3 gallic acid equivalents.100 g^{-1} FW) and banana (11.8–90.4 gallic acid equivalents.100 g^{-1} FW); similar to other fruits such as strawberry (160 gallic acid equivalents.100 g^{-1} FW), raspberry (114–178 gallic acid equivalents.100 g^{-1} FW), plums (174–375 gallic acid equivalents.100 g^{-1} FW) and cherry (105.4 ± 27.0 gallic acid equivalents.100 g^{-1} FW) (Balasundram et al., 2006); but lower than what is reported in blackberry (417–555 gallic acid equivalents.100 g^{-1} FW) (Balasundram et al., 2006; Ma et al., 2011; Vasco, Ruales, & Kamal-Eldin, 2008).

3.2.1. Phenolic acids and flavonoids

Phenolic acids are believed to participate in the inhibition of tumour promotion and progression, therefore, they might be efficient preventing cancer in humans rather than helping in carcinogen treatment. However, mechanisms are still unclear.

Flavonoids are well-known to be able to scavenge a wide range

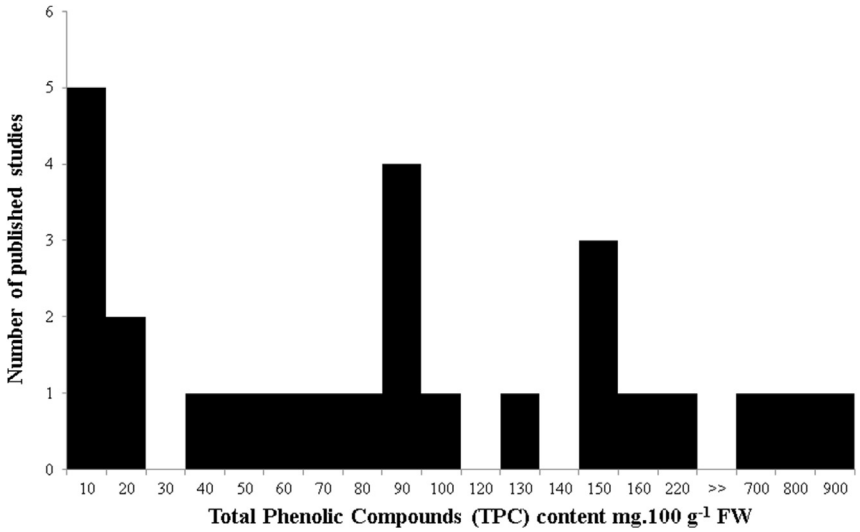

Fig. 3. Histogram of Total Phenolic Compounds TPC values reported in literature for CG (*Physalis peruviana L*).

of reactive oxygen, nitrogen, and chlorine species, such as superoxide, hydroxyl radical, peroxyl radicals, hypochlorous acid, and peroxynitrous acid. They can also chelate metal ions, often decreasing metal ion prooxidant activity, contributing with the prevention of major age-related diseases (Del Rio et al., 2013).

Main phenolic acids identified in CG are caffeic, chlorogenic, ferulic, *p*-coumaric and gallic acids (Mier, 2012; Muñoz-Jáuregui, Ramos-Escudero, & Fernando, 2007; Namiesnik et al., 2014; Rockenbach et al., 2009; Vega-Gálvez, López et al., 2014; Vega-Gálvez, Puente-Díaz et al., 2014). However, there is not agreement in contents, probably due to differences in *method of analysis*. Main flavonoids identified and quantified in CG are quercetin (0.1–10.9 mg Kg^{-1}), rutin (1.7–6.7 mg Kg^{-1}), myricetin (1.1–1.3 mg Kg^{-1}), epicatechin (0.2–0.6 mg Kg^{-1}), and catechin (3.8–6.7 mg Kg^{-1}). Morine was not detected (Licodiedoff, André, Koslowski, & Ribani, 2013; Licodiedoff, Koslowski, & Ribani, 2013; Mier, 2012; Muñoz-Jáuregui et al., 2007; Namiesnik et al., 2014; Pillai & Sathyadevi, 2015). In hydrolysed CG extracts, rutin (78.64 mg L^{-1}), myricetin (4.67 mg L^{-1}) and kaempferol (2.38 mg L^{-1}) were found (Licodiedoff, André et al., 2013; Licodiedoff, Koslowski et al.,2013). Rutin is unexpected because this is a glycoside of quercetin, thus it should be gone after hydrolysis. Contents of quercetin hereby reported are lower than in other berries and myricetin and kaempferol are present in CG, while they were not detected in other berries (Häkkinen, Kärenlampi, Heinonen, Mykkänen, & Törrönen, 1999). The total flavonoid content assessed with a colorimetric assay was of 487 mg catechin equivalent.100 g^{-1} DW (dried weight) of extract (Areiza-Mazo et al., 2013) and 241 mg g^{-1} DW of fruit (Pillai & Sathyadevi, 2015). Differences in *analytical procedures* and *samples conditions* give variation in reported results. Thus, there is a remaining knowledge gap about what are the most important phenolic acids and flavonoids in CG. Several studies reported flavonoids in *Physalis peruviana L.* leaves; however, they do not belong to the scope of this review.

3.3. Carotenoids

Carotenoids are convertible to vitamin A (approx. 10%) by enzymatic cleavage in the body. Thus carotenoids are believed to

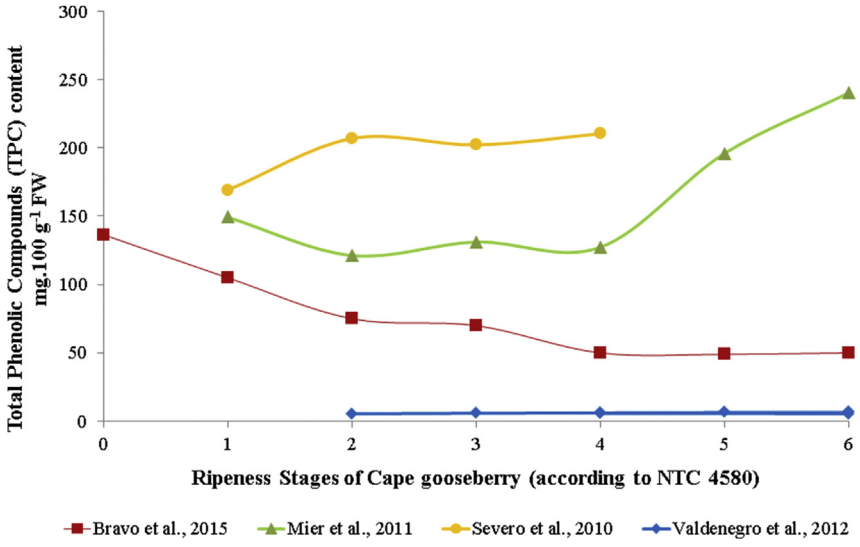

Fig. 4. Total phenolic compounds TPC in CG (*Physalis peruviana L*) for ripeness stages (according to NTC 4580, 1999).

participate in cancer prevention because of their provitamin A activity, since this is essential for the normal maintenance epithelial cellular differentiation (Fiedor & Burda, 2014). β-carotene is a quencher of singlet oxygen and also can inhibit lipid peroxidation. However, beta-carotene is a relatively weak antioxidant. (Fiedor & Burda, 2014).

The most important carotenoid in CG is β-carotene being responsible of the yellow orange colour (Fischer et al., 2000). Large variation is observed in reported data ranging from 0.2 to 1074.7 mg β-carotene.100 g^{-1} FW, which is illustrated in Fig. 5.

The variation causes are different *varieties/cultivars/ecotypes*, *cultivation conditions*, and *ripeness stage* as explained for previous compounds. β-carotene content can vary depending on chosen *methods for extraction and analysis* (Machmudah & Goto, 2013). Unfortunately, sometimes authors use incorrect extinction coefficients in their calculation of carotenoids contents. Besides, carotenoids are sensitive to light, heat, air (oxygen), and active surfaces (with biological activity) (Scott, 2001), thus apart of taking precautions during extraction and analysis; the *standard used* needs to be checked to evaluate actual purity and avoid miscalculation of contents. Nevertheless, references evaluated in this review do not provide information about this evaluation. Fig. 2 represents the normalize data of contents of carotenoids or β-carotene in different ripeness stages according to NTC 4580, as explained in Section 3.1.

There is an increase of β-carotene content with ripeness in some studies (K. Bravo et al., 2015; Mier & Cáez, 2011; Severo et al., 2010). Normalized data showed significant differences of β-carotene between ripeness stages ($P < 0.05$). The increase is expected in accordance with the development of the colour with ripening (from green to orange), which is found with NTC 4580 and in other studies (Fischer & Martínez, 1999; Fischer, 1995; ICONTEC., 1999). Methods of analyses did not have significant differences ($P > 0.05$).

From the results evaluated in this review, the concentration of β-carotene in fresh and ripen (stage 5–6) CG is $\leq$ 2.0 mg.100 g^{-1} FW, despite the substantial variation of data previously mentioned. USDA database reports as the most important sources of β-carotene, the sweet potato and carrot with 8.3–8.5 mg 100 g^{-1} FW. Within fruits group, the highest contents of β-carotene are in raw melon with 2.0 mg 100 g^{-1} FW and apricot with 1.1 mg 100 g^{-1} FW (USDA., 2014). CG is not included in the USDA database, however, Briones-Labarca, Giovagnoli-Vicuña, Figueroa-Alvarez, Quispe-Fuentes, and Pérez-Won (2013) reported a content of 1075 mg 100 g^{-1} FW β-carotene, thus this value could be an overestimation or misreport. There is no specific recommended intake for β-carotene but there is for the REA (retinol activity equivalents) which is 400–950 μg/day (USDA & HSS, 2010). The ratio of conversion of the β-carotene obtained from a food matrix to vitamin A in oil is 12:1 (Lindshield, 2012). Therefore, a diet with 5–10 mg (depending on age and gender) of β-carotene would be recommended per day. That means that a portion of 50 g of CG (10–15 berries) could provide 10–20% of the recommended daily intake of vitamin A.

3.4. Vitamins E and B_3 and B_6

As carotenoids, vitamin E (tocopherol) is a fat-soluble compound. The mechanisms involved in the health promotion are, as vitamin C, the inhibition of the formation of *N*-nitroso compounds in the stomach, the protection of selenium against reduction and polyunsaturated fatty acids in lipid membranes from oxidative damage. Vitamin E is thought to be the most important antioxidant found within lipid membranes in the body (Mocchegiani et al., 2014).

In CG, there is not consensus about tocopherol content. Total tocopherol of 1.5 μg g^{-1} of fruit was reported (Barcia et al., 2010) and considering that 2% of the fruit is the lipid part (Ramadan & Mörsel, 2003). This amount is equivalent to 7.5 mg 100 g^{-1} lipid part. However, total tocopherols (including α+β+γ+δ) was reported to be 32.7 g Kg^{-1} lipid part, corresponding to 3270 mg 100 g^{-1} lipid part, being extremely higher (Ramadan & Mörsel, 2003). Restrepo, Cortés, and Márquez (2009) considered the content of vitamin E in CG as negligible, while Vega-Gálvez et al. (2016) reported an amount of 10.70 ± 0.28 g kg^{-1} (1070 mg 100 g^{-1}) of α-tocopherol in the lipid portion of CG fruit. δ-tocopherol was not detected in CG (Vega-Gálvez et al., 2016). β-tocopherol and γ-tocopherol were the major components in whole berry and seed oils, whereas δ–tocopherol and α-tocopherol were the main constituents in pulp and skin oil. The amounts of tocopherols in pulp oil found were (g kg^{-1}): α-tocopherol 28.3 ± 0.45, β-tocopherol 15.2 ± 0.85, γ -tocopherol 45.5 ± 2.35, δ -tocopherol

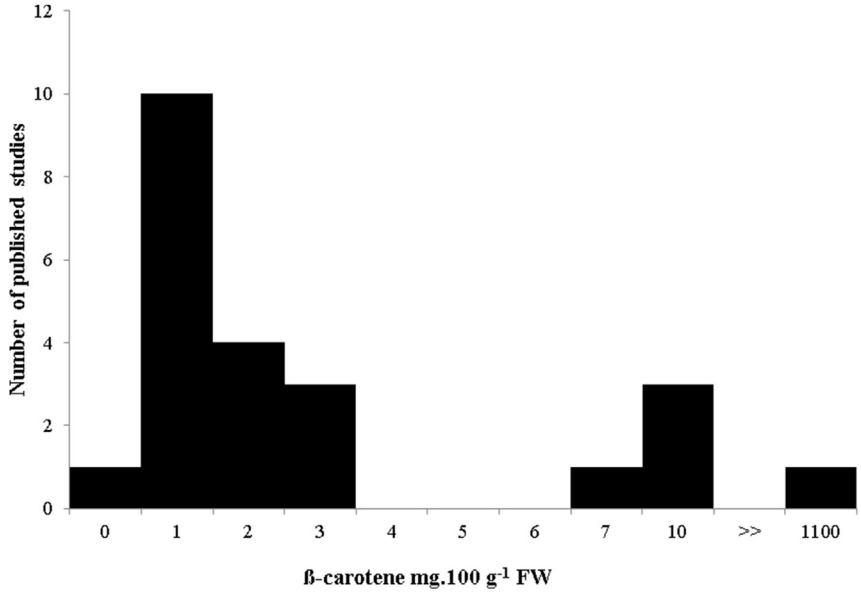

Fig. 5. Histogram of β-carotene values reported in literature for CG (*Physalis peruviana L*).

1.50 ± 0.05 (Ramadan & Moersel, 2007), corresponding to a total tocopherol of 90.5 g kg^{-1} (9050 mg.100 g^{-1}). These values are so high in comparison to what is reported by USDA database, where the source with highest amount of vitamin E (α-tocopherol) is wheat germ oil with 149.4 mg 100 g^{-1} (USDA., 2015). These discrepancies do not allow to draw conclusions about vitamin E in CG.

Vitamin B6 (pyridoxine) and B3 (niacin) help the body convert carbohydrates to produce energy, help in the metabolism of fats and proteins and also help to regulate the nervous system. Contents of vitamins B_3 and B_6 reported for CG pulp are 26.6 ± 0.9 mg 100 g^{-1} DW and 24.8 ± 0.2 mg 100 g^{-1} DW, respectively (Vega-Gálvez et al., 2016).

3.5. Minerals

Reported results on the mineral content of CG are shown in Table 1. CG has high content of potassium and phosphorus compared to other fruits (Florez, Fischer, & Sora, 2000; Rodríguez & Rodríguez, 2007; USDA., 2015). K is predominantly an intracellular cation, participating in the cellular uptake of molecules against electrochemical and concentration gradients, to the electrophysiology of nerves and muscle, and to acid-base regulation. P is used in a large variety of phosphorylated compounds which are needed for metabolic energy transfer and storage processes, enzyme activation and control (Gupta & Gupta, 2014).

Contents of Ca, Fe, Mn, Mg and Zn are low, in contrast with what has been claimed by some authors (Restrepo et al., 2009). Contents of Mn, Zn, Cu, Se, Co, Ni, Cr, Na, Al, Ba, Sr, Rb were very low in the fruit (Leterme, Buldgen, Estrada, & Londoño, 2006; Rodrigues et al., 2009; Torres-Ossandón et al., 2015), and Se was not detected (Leterme et al., 2006).

3.6. Withanolides

Withanolides form a group of naturally steroids usually found in plants of the Solanaceae family and have received increasing attention from researchers because of its complex structural characteristics, potential bioactivity and large variety of health properties (Mirjalili, Moyano, Bonfill, Cusido, & Palazón, 2009; Yen et al., 2010). Research on the isolation and identification of these compounds is still ongoing and a number of withanolides have been obtained and characterized from *Physalis peruviana L* plant parts (Fang, Li, & Liu, 2009; Fang, Liu, & Li, 2012). Nevertheless, there is no evidence of withanolides presence in CG fruit (Fang et al., 2012), therefore, presumptive health benefits from these compounds cannot be claimed from CG consumption as suggested in literature (Ramadan, 2011).

Table 1
Content of minerals in cape gooseberry *(Physalis peruviana L.)*.

Mineral	Content (mg 100 g^{-1} FW)
Iron (Fe)	0.1–3.9
Magnesium (Mg)	34.7–120.1
Calcium (Ca)	7.0–37.7
Potassium (K)	55.3–501.9
Phosphorous (P)	34.0–54.9
Sodium (Na)	52.7
Zinc (Zn)	1.5
Copper (Cu)	0.7
Manganese (Mn)	0.7

Data sources: (Capus, Tenezaca, & Redrobn, Leterme et al., 2006; Ramadan & Moersel, 2007; Repo de Carrasco & Encina, 2008; Rodrigues et al., 2009; Torres-Ossandón et al., 2015).

3.7. Physalins

Physalins are pseudo-steroids that have been isolated from plant of the genus *Physalis sp.* (M. B. P. Soares et al., 2006). These compounds have been associated to anti-tumour, antibacterial and immunosuppressive activities (He et al., 2013; Li et al., 2012; M. B. Soares, Bellintani, Ribeiro, Tomassini, & dos Santos, 2003; M. B. P.; Soares et al., 2006; Wu et al., 2012). The studies, however, as with withanolides, have not been conducted on the fruit but on the plant *Physalis.* So, there is no information on physalin content in CG, nor evidence of mechanisms of beneficial activities of oral consumption of physalin compounds.

3.8. Antioxidant activity

Antioxidant activity is a property discussed widely in literature because oxidation has been related to several diseases like cancer, among others (Gülçin, 2012; Max Leenders et al., 2014). CG was reported to have less antioxidant activity than blueberries and cranberries (Namiesnik et al., 2013). Antioxidant activities determined by four methods, being DPPH assay the most used method. Reported data for antioxidant activity also have large variation in numbers, unit expressions and assays. These variation come from previous aspects discussed for antioxidant compounds. In Fig. 6, antioxidant activity has been plotted according to ripeness stage of the CG, as explained in Section 3.1.

However, this information is not enough evidence to make associations of specific health-promoting compound with antioxidant activity.

4. Processing and storage

Nowadays, CG is available as dried fruit and in juices and jam. In this section, storage effect on health-promoting compounds is assessed as well as the effect of processing such as drying, pasteurization, enzymatic treatment and high pressure, according to availability of data.

4.1. Storage

In CG packed in expanded polystyrene covered to vinyl film during 8 days of storage at 20 °C, carotenoids increased from 124 to 170 μg g^{-1}, and at 4 °C, the increase was from 124 to 142 μg g^{-1}. Similar effect was observed for phenolic compounds contents which at 20 °C increased from 210 to 360 mg GAE 100 g^{-1}, while at 4 °C, the increase reached an amount of 300 mg GAE 100 g^{-1} (Severo et al., 2010). Antioxidant activity, however, remained stable at 20 °C and decreased at 4 °C from 1.55 to 1.3 μmol TE g^{-1}, assessed by 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) ABTS assay (Severo et al., 2010). These results suggested that cooling temperatures do not favour health-promoting compounds contents. Unfortunately, it is not mentioned whether the fruits were contained in the calyx or not. Vitamin C (from 28.58 to 31.65 to 13.05–13.24 mg 100 g^{-1}), phenolic compounds (from 6.12 to 6.02 mg GAE 100 g^{-1}) and antioxidant activity decreased (0.31–0.26 mM TE.Kg^{-1}) during 14 days of storage at 20 °C without calyx (Valdenegro et al., 2012). These results, in addition to studies on ripening, previously discussed, suggest that calyx plays an important role in protecting the health-promoting compounds of the fruit. Preservation of antioxidant activity (0.31–0.32 - mM TE.Kg^{-1}) assessed by ABTS assay was obtained with the use of 1-methylcyclopropene as inhibitor of ethylene biosynthesis on the fruit during post-harvest (Valdenegro et al., 2012).

Storage of pasteurized CG juice lead to a reduction of carotenoids (from 70.1 to 68.66 mg ml^{-1}), antioxidant activity (from 416.9

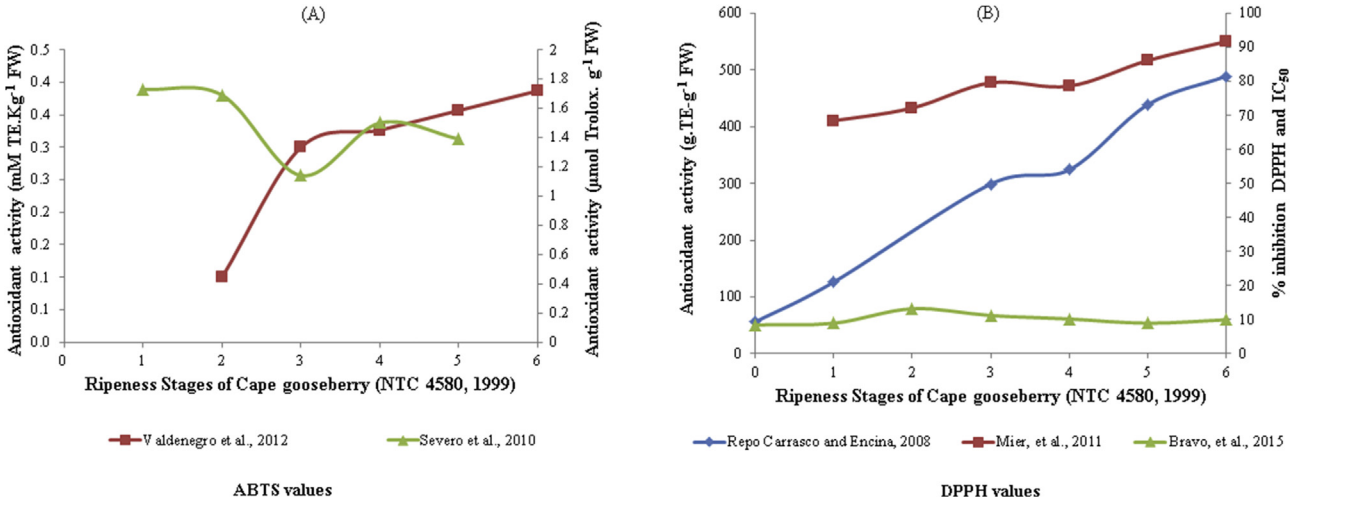

Fig. 6. Antioxidant activity of CG (*Physalis peruviana L*) assayed with ABTS method (8A) and DPPH method (8B) for ripeness stages (according NTC 4580, 1999) and reported data. In 8A, units are Trolox Equivalents. Kg^{-1} FW (Valdenegro et al., 2012) and µmol Trolox. g^{-1} FW (Licodiedoff, André et al., 2013; Severo et al., 2010). In 8B, units are g Trolox Equivalents. g^{-1} FW (Repo de Carrasco & Encina, 2008); % inhibition DPPH (Mier & Cáez, 2011) and IC50 g L^{-1} (Bravo et al., 2015).

to 298 µM TE.100 g^{-1}) assessed by DPPH assay, TPC (from 0.65 to 0.66 mg GAE.100 g^{-1}) and vitamin C (from 38.9 to 30.2 mg.100 g^{-1}) after 21 days of storage at 4 °C (Rabie et al., 2015). However, presented data are not consistent with carotenoids, TPC and antioxidant activity (DPPH) values reported in other researches as shown in Sections 3.2, 3.3 and 3.8. Vitamin C content in the CG powder obtained by spray drying was affected by storage temperature and vacuum conditions. At 30 °C, vitamin C reduced (from 36.68 to 10.34 mg.100 g^{-1}) after six months under non-vacuum conditions. This reduction was lower reaching values of 25.64 and 21.78 mg.100 g^{-1} at 4 and 20 °C, respectively. The used of vacuum, under the same conditions, reduced the losses of vitamin C from 0.7 to 12%, having more effect at 30 °C rather than at 4 °C (Hernández-Sandoval, Cortés-Rodríguez, & Ciro-Velásquez, 2014).

Total carotenoids (up to 6 mg.100 g^{-1}) and total phenolic compound (up to 90 mg GAE.100 g^{-1}) were stable in alginate coated fruits after 21 days of storage at 2 °C. Antioxidant activity (assay with ABTS), however decreased (from 120 to 80 mg TE 100 g^{-1}) after one week. Authors did not find significant differences with control samples (Carvalho, Villaño, Moreno, Serrano, & Valero, 2015).

Effect of storage after high hydrostatic pressure processing will be discussed further on, at evaluation of non-thermal processing in CG.

Scattered data on storage of fresh and processed CG does not allow having a clear insight of health-promoting compounds during this stage.

4.2. Thermal processing

Thermal processing is the most common method to process CG. Literature is mainly focused on drying (convection, drum, and freeze drying). Traditional pasteurization (low temperature, long time) and jam production has been studied as well (Rutz, Voss, Pertuzatti, Barcia, & Zambiazi, 2012).

TPC of dried CG processed with microwave and convective methods showed a drastic decrease of these compounds (from 863 to 237 mg GAE.100 g^{-1} DW). There were not significant differences in the degradation of TPC, probably because polyphenol oxidases and peroxidases are not immediately inactivated during microwave drying, therefore they can speed up the degradation of TPC in the same way heat treatment does (İzli, Yıldız, Ünal, Işık, & Uylaşer, 2014). Antioxidant activity evaluated by DPPH assay also decreased (from 47.2 to 11.5 µmol TE g^{-1} DW), probably as a consequence of TPC decrease.

β-carotene content increased in convection drying when increasing temperature (López et al., 2013), probably for a better extractability caused by heat treatment (van het Hof, West, Weststrate, & Hautvast, 2000). In contrast, studies of convection drying reported degradations of 30–55% (Narváez-Cuenca et al., 2014). Carotenoids increased in a combined osmodrying–heat treatment processing, because of the temperature rather than because of concentration of osmotic solutions (Luchese, Gurak, & Marczak, 2015). Discrepancies in results of β-carotene do not allow understanding the effect of heat treatment on β-carotene nor the content of this compound in thermal processed food.

Retention of antioxidant activity (DPPH method) for jam and juice was higher at 90 °C after approx. 30 min (about 9.7 µmol TE.g^{-1}) (Rabie et al., 2015; Ramadan & Moersel, 2007; Rutz et al., 2012). For drying processes, lowest retention of antioxidant activity (approx. 25%) was reported for microwave, convection and combined drying method (not plotted) (İzli et al., 2014). Highest retention was reported for pasteurization, which has to do with shorter times of heat exposure (Rabie et al., 2015; Ramadan & Moersel, 2007; Rutz et al., 2012). Participation of β-carotene in the antioxidant activity is apparently low because even with the increase of β-carotene content, antioxidant activity is stable. The gathered information does not allow associating antioxidant activity and health-promoting compounds.

In addition to thermal processing, the use of enzymes such as pectinase-arabanase, polygalacturonase, pectinase, hemicellulase and cellulose, has been tested to improve the yield in juice extraction. No significant decrease of TPC, ascorbic acid and antioxidant activity resulted of enzymes addition, but related to pasteurization treatment (80 °C and 10 min) (Ramadan & Moersel, 2007).

In summary, there is dispersed information on the effect of thermal processing on the health-promoting compounds in CG with high discrepancies in results, thus behaviour of compounds during thermal process are still unclear.

4.3. Non-thermal processing

While research on thermal processing of CG is still in

development, research about non-thermal processing is just emerging. The effect high hydrostatic pressure HHP for three pressures (control, 300 Mpa, 400 Mpa and 500 Mpa) and three processing times (1 min, 3 min and 5 min) on total phenolic compounds TPC, phenolic acids, antioxidant activity (ORAC, FRAP, DPPH), tocopherols, fibres, and vitamin B_3 and B_6 and minerals; and three pressures (control, 300, 400 and 500 Mpa) and 5 min of processing time on vitamin C, β-carotene and antioxidant activity (ORAC and DPPH) have been reported for CG pulp (Torres-Ossandón et al., 2015; Vega-Gálvez et al., 2016; Vega-Gálvez López et al., 2014; Vega-Gálvez, Puente-Díaz et al., 2014). In summary, after HHP treatment, the pulps had contents of about 17.5 mg of vitamin C 100 g^{-1} FW, 194.92–232.5 of β-carotene μg g^{-1} FW, antioxidant activity values of 116.7–210.2 μg TE g^{-1} and TPC of 164.68–268.7 mg GAE 100 g^{-1}. Comparing to initial values, vitamin C and β-carotene were stable to HHP treatment which is different from what is reported for tomato (400 Mpa/15 min/25 °C) where β-carotene increased remarkably (80%) given improvement of extractability and bioavailability (Sánchez-Moreno, Plaza, de Ancos, & Cano, 2006). Antioxidant activity increased and TPC decreased.

Effect on storage after HHP process was also evaluated at 4 °C for 30 and 60 days. Content of TPC in CG pulp had contradictory results. After HHP treatment, an experiment showed an increase of TPC and a decrease after 60 day of storage at 4 °C (Vega-Gálvez et al., 2016). However, same authors reported another experiment where is not clear behaviour of TPC after HHP and storage (Vega-Gálvez López et al., 2014; Vega-Gálvez, Puente-Díaz et al., 2014). Neither way no significant differences were found in TPC contents between pressures and between process times after HHP processing and storage ($P > 0.05$).

Antioxidant activity decreased during 30 and 60 days of storage at 4 °C (with some samples exceptions) (Torres-Ossandón et al., 2015; Vega-Gálvez et al., 2016; Vega-Gálvez López et al., 2014; Vega-Gálvez, Puente-Díaz et al., 2014). No significant differences were found in changes of antioxidant activity between pressures and times of processing, after processing and during storage ($P > 0.05$).

Vitamin C decreased approx. 81% after 30 days of storage at 4 °C. (Torres-Ossandón et al., 2015). No significant differences were found in changes of vitamin C between pressures, after processing and during storage ($P > 0.05$).

β-carotene decreased after 30 days of storage (Torres-Ossandón et al., 2015). HHP treatment has an effect on the content of α-tocopherol but not on (β+γ)-tocopherol. Higher pressure used, higher reduction of α-tocopherol during storage time (Vega-Gálvez et al., 2016). There were significant differences of α-tocopherol at day 30 between pressures ($P < 0.05$), but not between processing times ($P > 0.05$).

B3 and B6 were reported to increase after HHP treatment (Vega-Gálvez et al., 2016). Significant differences between pressures after HHP treatment were found only for B6, and after 30 days of storage at 4 °C for B3 and B6 ($P < 0.05$). No significant differences with processing time were found ($P > 0.05$).

There was no clear pattern for insoluble dietary fibre, soluble dietary fibre and total dietary fibre after HHP (Vega-Gálvez et al., 2016). Therefore, effect of HHP on fibres is unknown.

In summary, HHP processing has shown to improve extractability of health-promoting compounds in CG (Briones-Labarca et al., 2013), especially, vitamins B3 and B6 and antioxidant activity (Vega-Gálvez et al., 2016; Vega-Gálvez López et al., 2014; Vega-Gálvez, Puente-Díaz et al., 2014). HHP might disrupt cell walls, increasing permeability and allowing solvent penetration and therefore, improve extractability and bioavailability of some compounds (Prasad, Yang, Yi, Zhao, & Jiang, 2009). This effect could be positive when it relates to the bioavailability of the compounds at consumption. However, more information is required to make a proper assessment about behaviour of health-promoting compounds of CG during HHP processing.

5. Conclusions

Health-promoting compounds of CG have been reviewed from a supply-chain perspective, involving pre-harvest, post-harvest, processing and storage, in order to get an understanding of the presence of compounds at consumption stage. According to reported data, CG is a source of vitamin C (20 and 35 mg.100 g^{-1} FW), β-carotene (up to 2.0 mg 100 g^{-1} FW), total phenolic compounds TPC (50–250 gallic acid equivalents.100 g^{-1} FW), phenolic acids (caffeic, gallic, chlorogenic, ferulic and *p*-cumaric acids), flavonoids (quercetin, rutin, myricetin, kaempferol, catechin and epicatechin) and antioxidant activity. Presence of tocopherols, vitamins B3 and B6, minerals and fibre have been also reported. Contents of health-promoting compounds in CG are relevant compared to other fruit sources for every type of compound. Consumption of fresh CG provides a diversity of compounds, especially when the fruit fully ripened, as reported in this review. Contents of withanolides and physalins in CG are not well studied yet, therefore it is not possible to make assumptions about the presence of those compounds in CG, let alone whether there are health benefits.

Large variability of data has been found especially due to differences in methods of extraction and analysis, making a comparison of reported data an uneasy task. Moreover, varieties/cultivars/ecotypes and location of cultivation can have an effect of health-promoting compounds. In post-harvest, there are discrepancies in reported data. The effect of storage and calyx presence on health-promoting compounds and antioxidant activity remains unclear. Therefore, the contents of those compounds of fresh and processed CG after storage are unknown.

Vitamin C is reported to be the most sensitive compound to thermal and non-thermal treatment. β-carotene did not show a clear pattern in processing, decreasing or increasing, probably because enhance of extractability or oxidations reactions. TPC and antioxidant activity were stable in thermal processing (90 °C) and antioxidant activity increased in non-thermal treatment. HHP seems to improve the extractability of compounds. However, there is no systematic information yet to infer the effect of these processing on health-promoting compounds; therefore, more research into the content and bioavailability of these compounds at the consumption stage of processed CG is needed.

6. Suggestion for future research

Because of the variety of health-promoting compounds in CG and the large list of factors affecting their contents from cultivation to consumption, more research on this fruit is relevant. It is important to identify the effects of varieties/cultivars/ecotypes, cultivation and harvest conditions on phytochemicals and nutrients of CG. The understanding of post-harvest physiology of the CG is needed to know the role of calyx in health-promoting compounds preservation or degradation. Because processing is part of the supply chain, there is a big field of work for scientific research. Behaviour of phytochemicals and nutrients in CG during storage, thermal and non-thermal processes requires more research. Last but not least, bioavailability of health-promoting compounds and the relation with antioxidant activity need to be researched in order to evaluate potential health benefits when CG is consumed, so consumers can have the right information.

Acknowledgments

This work was supported by NUFFIC Netherlands Universities Foundation for International Cooperation (NFD-PhD.11/830).

References

Abdel Moneim, A. E., Bauomy, A. A., Diab, M. M. S., Shata, M. T. M., Al-Olayan, E. M., & El-Khadragy, M. F. (2014). The protective effect of *Physalis peruviana L.* against cadmium-induced neurotoxicity in rats. *Biological Trace Element Researchs, 160*, 392–399.

Agronet. (2016). *Estadisticas sector agropecuario* (Vol. 2016). Ministerio de Agricultura y Desarrollo Rural. http://www.agronet.gov.co/Paginas/estadisticas.aspx. Red de Información y Comunicación del Sector Agropecuario. Colombia. Assessed April 2016.

Areiza-Mazo, N., Maldonado, M. E., & Rojano, B. (2013). Extracto acuoso de uchuva (*Physalis peruviana*): Actividades antiproliferativa, apoptótica y antioxidante. *Perspectivas en Nutrición Humana, 15*, 41.

Balasundram, N., Sundram, K., & Samman, S. (2006). Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food Chemistry, 99*, 191–203.

Barcia, M. T., Jacques, A. C., Pertuzatti, P. B., & Zambiazi, R. C. (2010). Determination by HPLC of ascorbic acid and tocopherols in fruits. *Semina.Ciências Agrárias, 31*, 381–390.

Brause, A. R., Woollard, D. C., & Indyk, H. E. (2003). Determination of total vitamin C in fruit juices and related products by liquid chromatography: Interlaboratory study. *The Journal of AOAC International, 86*, 367–374.

Bravo, K., Sepulveda-Ortega, S., Lara-Guzman, O., Navas-Arboleda, A. A., & Osorio, E. (2015). Influence of cultivar and ripening time on bioactive compounds and antioxidant properties in Cape gooseberry (*Physalis peruviana L.*). *Journal of the Science of Food and Agriculture, 95*, 1562–1569.

Briones-Labarca, V., Giovagnoli-Vicuña, C., Figueroa-Alvarez, P., Quispe-Fuentes, I., & Pérez-Won, M. (2013). Extraction of β-carotene, vitamin C and antioxidant compounds from *Physalis peruviana* (Cape Gooseberry) assisted by high hydrostatic pressure. *Food and Nutrition Sciences, 2013*, 109–118.

Capus, C. P., Tenezaca, E. R. J., & Redrobán, O. P. L. Evaluación nutricional de la uvilla (Physalis peruviana L.) deshidratada, a tres temperaturas mediante un deshidratador de bandejas. Revista Perfiles, 15.

Carvalho, C. P., Villaño, D., Moreno, D. A., Serrano, M., & Valero, D. (2015). Alginate edible coating and cold storage for improving the physicochemical quality of cape gooseberry (*Physalis peruviana L.*). *Journal of Food Science and Nutrition, 1*.

CEC.. (1993). Food science and techniques. In *Reports of the scientific committe for food: Commission of the european communities*.

Da Silva Pinto, M., Ranilla, L. G., Apostolidis, E., Lajolo, F. M., Genovese, M. I., & Shetty, K. (2009). Evaluation of antihyperglycemia and antihypertension potential of native Peruvian fruits using in vitro models. *Journal of Medicinal Food, 12*, 278–291.

Dekker, M., Verkerk, R., & Jongen, W. M. F. (2000). Predictive modelling of health aspects in the food production chain: A case study on glucosinolates in cabbage. *Trends in Food Science & Technology, 11*, 174–181.

Del Rio, D., Rodriguez-Mateos, A., Spencer, J. P., Tognolini, M., Borges, G., & Crozier, A. (2013). Dietary (poly) phenolics in human health: Structures, bioavailability, and evidence of protective effects against chronic diseases. *Antioxidants & redox signaling, 18*, 1818–1892.

Fang, S. T., Li, B., & Liu, J.-K. (2009). Two new withanolides from *Physalis peruviana*. *Helvetica Chimica Acta, 92*, 1304–1308.

Fang, S. T., Liu, J. K., & Li, B. (2012). Ten new withanolides from *Physalis peruviana*. *Steroids, 77*, 36–44.

Fiedor, J., & Burda, K. (2014). Potential role of carotenoids as antioxidants in human health and disease. *Nutrients, 6*, 466–488.

Fischer, G. (1995). *Effect of root zone temperature and tropical altitude on the growth, development and fruit q Valdenegro, Fuentes, Herrera, & Moya-León, 2012 uality of cape gooseberry (Physalis peruviana L.)*. Berlin. Germany: Humboldt-Universität zu Berlin.

Fischer, G., Ebert, G., & Ludders, P. (2000). Provitamin A carotenoids, organic acids and ascorbic acid content of cape gooseberry (*Physalis peruviana L.*) ecotypes grown at two tropical altitudes. *Acta Horticulturae*, 263–268.

Fischer, G., & Martínez, O. (1999). Calidad y madurez de la uchuva (*Physalis peruviana L.*) en relación con la coloración del fruto. *Agronomía Colombiana, 16*, 35–39.

Florez, V., Fischer, G., & Sora, A. (2000). *Producción, Poscosecha y Exportación de la Uchuva (Physalis peruviana L.). Bogotá. Colombia*. Universidad Nacional de Colombia, Sección Imprenta.

Gomez, M. L., & Lajolo, F. M. (2008). Ascorbic acid metabolism in fruits: Activity of enzymes involved in synthesis and degradation during ripening in mango and guava. *Journal of the Science of Food and Agriculture, 88*, 756–762.

Grosso, G., Bei, R., Mistretta, A., Marventano, S., Calabrese, G., Masuelli, L., et al. (2013). Effects of vitamin C on health: A review of evidence. *Frontiers in Bioscience, 18*, 1017–1029.

Gülçin, İ. (2012). Antioxidant activity of food constituents: An overview. *Archives of Toxicology, 86*, 345–391.

Gupta, U. C., & Gupta, S. C. (2014). Sources and deficiency diseases of mineral nutrients in human health and nutrition: A review. *Pedosphere, 24*, 13–38.

Gutierrez, M. S., Trinchero, G. D., Cerri, A. M., Vilella, F., & Sozzi, G. O. (2008). Different responses of goldenberry fruit treated at four maturity stages with the ethylene antagonist 1-methylcyclopropene. *Postharvest Biology and Technology, 48*, 199–205.

Häkkinen, S. H., Kärenlampi, S. O., Heinonen, I. M., Mykkänen, H. M., & Törrönen, A. R. (1999). Content of the flavonols quercetin, myricetin, and kaempferol in 25 edible berries. *Journal of Agricultural and Food Chemistry, 47*, 2274–2279.

Hernández-Sandoval, G. R., Cortés-Rodríguez, M., & Ciro-Velásquez, H. J. (2014). Effect of storage conditions on quality of a functional powder of cape gooseberry obtained by spray drying. *Revista UDCA Actualidad & Divulgación Científica, 17*, 139–149.

Hernández, Y., Lobo, M. G., & González, M. (2006). Determination of vitamin C in tropical fruits: A comparative evaluation of methods. *Food Chemistry, 96*, 654–664.

He, H., Zang, L.-H., Feng, Y.-S., Chen, L.-X., Kang, N., Tashiro, S.-i., et al. (2013). Physalin A induces apoptosis via p53-Noxa-mediated ROS generation, and autophagy plays a protective role against apoptosis through p38-NF-κB survival pathway in A375-S2 cells. *Journal of Ethnopharmacology, 148*, 544–555.

Hiwilepo-van Hal, P., Bosschaart, C., van Twisk, C., Verkerk, R., & Dekker, M. (2012). Kinetics of thermal degradation of vitamin C in marula fruit (Sclerocarya birrea subsp. caffra) as compared to other selected tropical fruits. *LWT- Food Science and Technology, 49*, 188–191.

Hjartåker, A., Knudsen, M. D., Tretli, S., & Weiderpass, E. (2015). Consumption of berries, fruits and vegetables and mortality among 10,000 Norwegian men followed for four decades. *European Journal of Nutrition, 54*, 599–608.

van het Hof, K. H., West, C. E., Weststrate, J. A., & Hautvast, J. G. (2000). Dietary factors that affect the bioavailability of carotenoids. *Jounal of Nutrition, 130*, 503–506.

ICONTEC.. (1999). *NTC 4580. Fresh fruits. Cape Gooseberry. Specifications*. Bogota. Colombia: Colombian Standard.

İzli, N., Yıldız, G., Ünal, H., Işık, E., & Uylaşer, V. (2014). Effect of different drying methods on drying characteristics, colour, total phenolic content and antioxidant capacity of goldenberry (*Physalis peruviana L.*). *International Journal of Food Science & Technology, 49*, 9–17.

Johnston, C. S. (2012). *Vitamin C, in present Knowledge in nutrition* (10th ed.). Oxford, UK: Wiley-Blackwell.

Leenders, M., Boshuizen, H. C., Ferrari, P., Siersema, P. D., Overvad, K., Tjønneland, A., et al. (2014). Fruit and vegetable intake and cause-specific mortality in the EPIC study. *European Journal of Epidemiology, 29*, 639–652.

Leterme, P., Buldgen, A., Estrada, F., & Londoño, A. M. (2006). Mineral content of tropical fruits and unconventional foods of the Andes and the rain forest of Colombia. *Food Chemistry, 95*, 644–652.

Licodiedoff, S., André, L., Koslowski, D., & Ribani, R. H. (2013). Flavonols and antioxidant activity of *Physalis peruviana L.* fruit at two maturity stages. *Acta Scientiarum Technology, 35*, 393–399.

Licodiedoff, S., Koslowski, L. A. D., & Ribani, R. H. (2013). Flavonol rates of gosseberry fruits *Physalis peruviana* determined by HPLC through the optimization and validation of the analytic method. *International Journal of Food Science and Nutrition, 3*, 1–6.

Lindshield, B. L. (2012). *Carotenoids, in present Knowledge in nutrition* (10th ed.). Oxford, UK: Wiley-Blackwell.

Li, X., Zhang, C., Wu, D., Tang, L., Cao, X., & Xin, Y. (2012). In vitro effects on intestinal bacterium of physalins from *Physalis alkekengi var. Francheti*. *Fitoterapia, 83*, 1460–1465.

López, J., Vega-Gálvez, A., Torres, M. J., Lemus-Mondaca, R., Quispe-Fuentes, I., & Di Scala, K. (2013). Effect of dehydration temperature on physico-chemical properties and antioxidant capacity of goldenberry (*Physalis peruviana L.*). *Chilean Journal of Agricultural Research, 73*, 293–300.

Luchese, C. L., Gurak, P. D., & Marczak, L. D. F. (2015). Osmotic dehydration of *physalis* (*Physalis peruviana L.*): Evaluation of water loss and sucrose incorporation and the quantification of carotenoids. *LWT- Food Science and Technology, 63*, 1128–1136.

Machmudah, S., & Goto, M. (2013). Methods for extraction and analysis of carotenoids. In *Natural products* (pp. 3367–3411). Springer.

MADR, UNAL, CORPOICA. (2009). *Agenda prospectiva de investigación y desarrollo tecnológico para la cadena productiva de la uchuva en fresco para exportación en colombia*. Bogotá: Universidad Nacional de Colombia. Ministerio de Agricultura y Desarrollo Rural, Corporación Colombiana de Investigación Agropecuaria. Available in http://conectarural.org/sitio/sites/default/files/documentos/AGENDA%20CADENA%20UCHUVA.pdf.

Ma, X., Wu, H., Liu, L., Yao, Q., Wang, S., Zhan, R., et al. (2011). Polyphenolic compounds and antioxidant properties in mango fruits. *Scientia Horticulturae, 129*, 102–107.

Mier, H. (2012). *Evaluación del contenido de polifenoles y carotenos en extractos de frutos de Physalis peruviana y su potential antioxidante, citotóxico e inmunomodulador in vitro*. Colombia: Universidad de la Sabana, Bogotá.

Mier, H. J., & Cáez, R. G. (2011). Contenido de polifenoles, carotenos y capacidad antioxidante en fruos de uchuva (*Physalis peruviana*) en relación con su estado de maduración. *ReCiTeIA, 11*, 103–112.

Mirjalili, M. H., Moyano, E., Bonfill, M., Cusido, R. M., & Palazón, J. (2009). Steroidal lactones from Withania somnifera, an ancient plant for novel medicine. *Molecules, 14*, 2373–2393.

Mocchegiani, E., Costarelli, L., Giacconi, R., Malavolta, M., Basso, A., Piacenza, F., et al. (2014). Vitamin E–gene interactions in aging and inflammatory age-related

diseases: Implications for treatment. A systematic review. *Ageing research reviews, 14*, 81–101.
Muñoz-Jáuregui, A. M., Ramos-Escudero, D., & Fernando, A. O. U. (2007). Evaluación de la capacidad antioxidante y contenido de compuestos fenólicos en recursos vegetales promisorios. *Revista de la Sociedad Química del Perú, 73*, 142–149.
Mursu, J., Virtanen, J. K., Tuomainen, T.-P., Nurmi, T., & Voutilainen, S. (2014). Intake of fruit, berries, and vegetables and risk of type 2 diabetes in finnish men: The kuopio ischaemic heart disease risk factor study. *The American Journal of Clinical Nutrition, 99*, 328–333.
Namiesnik, J., Vearasilp, K., Kupska, M., Ham, K. S., Kang, S. G., Park, Y. K., et al. (2013). Antioxidant activities and bioactive components in some berries. *European Food Research and Technology, 237*, 819–829.
Namiesnik, J., Vearasilp, K., Leontowicz, H., Leontowicz, M., Ham, K. S., Kang, S. G., et al. (2014). Comparative assessment of two extraction procedures for determination of bioactive compounds in some berries used for daily food consumption. *International Journal of Food Science & Technology, 49*, 337–346.
Narváez-Cuenca, C., Mateus-Gómez, A., & Restrepo-Sánchez, L. (2014). Antioxidant capacity and total phenolic content of air-dried cape gooseberry (*Physalis peruviana L.*) at different ripeness stages. *Agronomía Colombiana, 32*, 232–237.
Navarro, J. M., Flores, P., Garrido, C., & Martinez, V. (2006). Changes in the contents of antioxidant compounds in pepper fruits at different ripening stages, as affected by salinity. *Food Chemistry, 96*, 66–73.
Norat, T., Aune, D., Chan, D., & Romaguera, D. (2014). Fruits and vegetables: Updating the epidemiologic evidence for the WCRF/AICR lifestyle recommendations for cancer prevention. In *Advances in nutrition and cancer* (pp. 35–50). Springer.
Novoa, R., Bojacá, M., Galvis, J., & Fischer, G. (2006). La madurez del fruto y el secado del cáliz influyen en el comportamiento poscosecha de la uchuva, almacenada a 12 C (*Physalis peruviana L.*). *Agronomía Colombiana, 24*, 77–86.
Odriozola-Serrano, I., Hernández-Jover, T., & Martín-Belloso, O. (2007). Comparative evaluation of UV-HPLC methods and reducing agents to determine vitamin C in fruits. *Food Chemistry, 105*, 1151–1158.
Olivares-Tenorio, M., Linnemann, A., Pascucci, S., Verkerk, R., & van Boekel, M. (2014). Misaligned preferences and perceptions on quality attributes of cape gooseberry *(Physalis peruviana L)* supply chain actors. In *Conference proceedings Part 4 international food marketing research symposium 2014* (pp. 106–112).
Osman, N. N., AL-seeni, M. N., Alkhatib, M. H., & Al-shreef, H. A. (2013). Modulation of radiation injury by *Physalis peruviana. Life Science Journal, 4*, 10.
Pillai, S. S., & Sathyadevi, M. (2015). Extraction, isolation and characterization of bioactive flavonoids from the fruits of *Physalis peruviana Linn* extract. *Asian Journal of Pharmaceutical and Clinical Research, 8*.
Ponte, S., & Gibbon, P. (2005). Quality standards, conventions and the governance of global value chains. *Economics society, 34*, 1–31.
Prasad, K. N., Yang, E., Yi, C., Zhao, M., & Jiang, Y. (2009). Effects of high pressure extraction on the extraction yield, total phenolic content and antioxidant activity of longan fruit pericarp. *Innovative Food Science and Emerging Technologies, 10*, 155–159.
Rabie, M., Soliman, A., Diaconeasa, Z., & Constantin, B. (2015). Effect of pasteurization and shelf life on the physicochemical properties of *physalis* (*Physalis peruvianaL.*) juice. *Journal of Food Processing and Preservation, 39*, 1051–1060.
Raffo, A., Leonardi, C., Fogliano, V., Ambrosino, P., Salucci, M., Gennaro, L., et al. (2002). Nutritional value of cherry tomatoes (Lycopersicon esculentum cv. Naomi F1) harvested at different ripening stages. *Journal of Agricultural and Food Chemistry, 50*, 6550–6556.
Ramadan, M. F. (2011). Bioactive phytochemicals, nutritional value, and functional properties of cape gooseberry (*Physalis peruviana*): An overview. *Food Research International, 44*, 1830–1836.
Ramadan, M. F., & Moersel, J. T. (2007). Impact of enzymatic treatment on chemical composition, physicochemical properties and radical scavenging activity of goldenberry (*Physalis peruviana L.*) juice. *Journal of the Science of Food and Agriculture, 87*, 452–460.
Ramadan, M. F., & Mörsel, J.-T. (2003). Oil goldenberry (*Physalis peruviana L.*). *Journal of Agricultural and Food Chemistry, 51*, 969–974.
Repo de Carrasco, R., & Encina, C. R. (2008). Determinación de la capacidad antioxidante y compuestos bioactivos de frutas nativas peruanas. *Revista de la Sociedad Química del Perú, 74*, 108–124.
Restrepo, A. M., Cortés, M., & Márquez, C. J. (2009). Uchuvas (*Physalis peruviana L.*) mínimamente procesadas fortificadas con vitamina E. *Vitae, 16*, 19–30.
Rockenbach, I. I., Rodrigues, E., Cataneo, C., Gonzaga, L. V., Lima, A., Mancini-Filho, J., et al. (2009). Ácidos fenólicos e atividade antioxidante em fruto de *Physalis peruviana l. Alimentos e Nutrição Araraquara, 19*, 271–276.
Rodrigues, E., Rockenbach, I. I., Cataneo, C., Gonzaga, L. V., Chaves, E. S., & Fett, R. (2009). Minerals and essential fatty acids of the exotic fruit *Physalis peruviana L. Ciencia e Tecnologia de Alimentos, 29*, 642–645.
Rodríguez, S., & Rodríguez, E. (2007). Effect of *Physalis peruviana* (goldenberry) on postprandial glycemia in young adults. *Revista Médica Vallejiana, 4*, 43–52.
Rop, O., Mlcek, J., Jurikova, T., & Valsikova, M. (2012). Bioactive content and antioxidant capacity of Cape gooseberry fruit. *Central European Journal of Biology, 7*, 672–679.
Rutz, J. K., Voss, G. B., Pertuzatti, P. B., Barcia, M. T., & Zambiazi, R. C. (2012). Geleia de *Physalis peruviana L.* : Caracterização bioativa, antioxidante e sensorial. *Alimentos e Nutrição, 23*, 369–375.
Sánchez-Moreno, C., Plaza, L., de Ancos, B., & Cano, M. P. (2006). Impact of high-pressure and traditional thermal processing of tomato purée on carotenoids, vitamin C and antioxidant activity. *Journal of the Science of Food and Agriculture, 86*, 171–179.
Scott, K. J. (2001). Detection and measurement of carotenoids by UV/VIS spectrophotometry. In *Current protocols in food analytical chemistry*. John Wiley and Sons, Inc.
Severo, J., Lima, C. S. M., Coelho, M. T., Rufatto, A. D. R., Rombaldi, C. V., & Silva, J. A. (2010). Atividade antioxidante e fitoquímicos em frutos de *Physalis* (*Physalis peruviana, L.*) durante o amadurecimento e o armazenamento. *Revista Brasileira de Agrociências, 16*, 77–82.
Soares, M. B., Bellintani, M. C., Ribeiro, I. M., Tomassini, T. C., & dos Santos, R. R. (2003). Inhibition of macrophage activation and lipopolysaccaride-induced death by seco-steroids purified from *Physalis angulata L. European Journal of Pharmacology, 459*, 107–112.
Soares, M. B. P., Brustolim, D., Santos, L., Bellintani, M., Paiva, F., Ribeiro, Y., et al. (2006). Physalins B, F and G, seco-steroids purified from *Physalis angulata L.*, inhibit lymphocyte function and allogeneic transplant rejection. *International Immunopharmacology, 6*, 408–414.
Sogi, D. S., Siddiq, M., Roidoung, S., & Dolan, K. D. (2012). Total phenolics, carotenoids, ascorbic acid, and antioxidant properties of fresh-cut mango (mangifera indica L., cv. Tommy Atkin) as affected by infrared heat treatment. *Journal of Food Science, 77*, 1197–1202.
Stratil, P., Klejdus, B., & Kubán, V. (2006). Determination of total content of phenolic compounds and their antioxidant activity in vegetables evaluation of spectrophotometric methods. *Journal of Agricultural and Food Chemistry, 54*, 607–616.
Tarrago-Trani, M. T., Phillips, K. M., & Cotty, M. (2012). Matrix-specific method validation for quantitative analysis of vitamin C in diverse foods. *Journal of Food Composition and Analysis, 26*, 12–25.
Terry, P., Terry, J., & Wolk, A. (2001). Fruit and vegetable consumption in the prevention of cancer: An update. *Journal of Internal Medicine, 250*, 280–290.
Torres-Ossandón, M. J., López, J., Vega-Gálvez, A., Galotto, M. J., Perez-Won, M., & Di Scala, K. (2015). Impact of high hydrostatic pressure on physicochemical characteristics, nutritional content and functional properties of cape gooseberry pulp *(Physalis peruvianaL.). Journal of Food Processing and Preservation, 39*, 2844–2855.
USDA, & HSS.. (2010). *Dietary guidelines for Americans*. USA: US Department of Agriculture & US Department of Health and Human Services.
USDA.. (2014). *National nutrient database for standard reference release 26. Nutrients: Vitamin C, total ascorbic acid (mg)*. USA: United States Department of Agriculture.
USDA.. (2015). *National nutrient database for standard reference release 27. Nutrients: K (mg) and P (mg)*. United States Department of Agriculture.
Valdenegro, E. (2013). The effects of drying processes on organoleptic characteristics and the health quality of food ingredients obtained from goldenberry fruits *(Physalis peruviana). Open Access Scientific Reports, 2*.
Valdenegro, M., Fuentes, L., Herrera, R., & Moya-León, M. A. (2012). Changes in antioxidant capacity during development and ripening of goldenberry (*Physalis peruviana L.*) fruit and in response to 1-methylcyclopropene treatment. *Postharvest Biology and Technology, 67*, 110–117.
Valdés, L., Cuervo, A., Salazar, N., Ruas-Madiedo, P., Gueimonde, M., & González, S. (2015). The relationship between phenolic compounds from diet and microbiota: Impact on human health. *Food & function, 6*, 2424–2439.
Vasco, C., Ruales, J., & Kamal-Eldin, A. (2008). Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. *Food Chemistry, 111*, 816–823.
Vega-Gálvez, A., Díaz, R., López, J., Galotto, M. J., Reyes, J. E., Perez-Won, M., et al. (2016). Assessment of quality parameters and microbial characteristics of Cape gooseberry pulp (*Physalis peruviana L.*) subjected to high hydrostatic pressure treatment. *Food and Bioproducts Processing, 97*, 30–40.
Vega-Gálvez, A., López, J., Torres-Ossandón, M. J., Galotto, M. J., Puente-Díaz, L., Quispe-Fuentes, I., et al. (2014). High hydrostatic pressure effect on chemical composition, color, phenolic acids and antioxidant capacity of Cape gooseberry pulp (*Physalis peruviana L.*). *LWT- Food Science and Technology, 58*, 519–526.
Vega-Gálvez, A., Puente-Díaz, L., Lemus-Mondaca, R., Miranda, M., & Torres, M. J. (2014). Mathematical modeling of thin-layer drying kinetics of cape gooseberry *(Physalis peruvianaL.). Journal of Food Processing and Preservation, 38*, 728–736.
Wu, S.-Y., Leu, Y.-L., Chang, Y.-L., Wu, T.-S., Kuo, P.-C., Liao, Y.-R., et al. (2012). Physalin F induces cell apoptosis in human renal carcinoma cells by targeting NF-kappaB and generating reactive oxygen species. *PLoS One, 7*, e40727.
Yen, C.-Y., Chiu, C.-C., Chang, F.-R., Chen, J. Y.-F., Hwang, C.-C., Hseu, Y.-C., et al. (2010). 4beta-Hydroxywithanolide E from *Physalis peruviana* (golden berry) inhibits growth of human lung cancer cells through DNA damage, apoptosis and G2/M arrest. *BMC cancer, 10*, 46–46.