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Conservation advances on *Physalis peruviana* L. and *Spondia purpurea*: a review

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Abstract

This research aims to describe the different methodologies that have been developed for the conservation of two fruits (*Physalis peruviana* L. and *Spondia purpurea*) present in the Ecuadorian highlands, as well as in other American countries. Information has been collected regarding the development of alternative and efficient technologies for the conservation of these fruits and their bioactive compounds. The studies performed to date are associated with the effect that the different conservation methods have shown in the post-harvest behavior (color, antioxidant potential, polyphenols, etc.) of the fruits, as well as its characterization in different maturation stages (soluble solids, acidity, pH, etc.). The contrast and comparison of this information will support choosing the most appropriate methodology according to the objectives to be achieved and the available resources. The research concludes that the knowledge about the healthy components in fruits increase their consumption and therefore motivates, the research to preserve these components for a longer time, reducing costs and waste.

Keywords: food preservation; characterization; preservation effect.

Practical Application: The fruits in this research are substantially studied but there is yet some unknown ground.

1 Introduction

Among fruits valued by their consumers due to their health benefits, *Physalis peruviana* L. and *Spondia purpurea* have special relevance due to their polyphenolic content, ascorbic acid, and carotenoids among others, which provide antioxidant properties. Through the years, fruit production and consumption have increased. A 4.2% annual growth was reported in South and Central America, while in Ecuador between 2013 and 2018, goldenberry farming showed a growth of 10%, with an increment of 160% in its exportation from 2015 to 2016 (Moreno-Miranda et al., 2019).

This behavior brings up the need for carrying out research on the conservation of the fruit's properties, so sensorial and functional characteristics of the fruits can compete in international market. This review collects the latest advances in research about characterization and fruit conservation of *Physalis peruviana* L. and *Spondia purpurea*, with emphasis in their functional and nutritional properties depending on their maturity and postharvest conservation technology. Health benefits and the chronology of the conservation method on fruit properties were also included.

1.1 Characterization

Among the most notorious factors that affect fruits physicochemical and functional properties are: farming zone, and edaphological and climate conditions to which the fruit is exposed. Many times, fruit properties are different even if they are of the same variety, as it is shown in this paper. *Physalis peruviana* L. from Argentina (Bazalar Pereda et al., 2019), Colombia (Bravo & Osorio, 2016), Peru (Maruenda et al., 2018), Brazil (Licodiedoff et al., 2016), South Africa (Carvalho et al., 2015), Egypt, South Africa, India, New Zeeland, Australia and Great Britain (Ramadan et al., 2015) have been reported. But among countries, the most advanced research is found in Colombia, where a normative (Norma Técnica Colombiana, 1999) to identify fruit maturity according to its color has been developed.

The research spectrum for *Spondia purpurea* is not extensive, and most observations are performed in Brazil (da Silva et al., 2016; Solorzano-Morán et al., 2015) and Mexico (Álvarez-Vargas et al., 2017), even when the farming region covers Venezuela, Colombia, Ecuador, Peru and Central America. Most studies have been focused on functional, nutritional and physicochemical characterization, and the application of conservation technology. Due to differences in data, the information on properties will be compared in tables for easier interpretation. Table 1 shows proximate analysis (g/100 g fresh weight) and physicochemical properties such as pH, acidity (%w/w citric acid), soluble solids (SS), humidity, and maturity indices (MI).

Table 1 shows MI, they are different so are their properties, this factor is the most relevant to characterize a fruit. Table 2 shows mineral (mg/100 g fresh weight) and the functional content of *Physalis peruviana* L. as vitamin A, C, carotenoids, polyphenols, and antioxidant activity (aa). These last properties are widely studied, due to their relevance; aa is expressed as

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μmol Trolox/g fresh weight, vitamin A as mg equivalent retinol activity (ERA)/100 g fresh weight (fw), vitamin C as mg acid ascorbic/100 g fw and polyphenols as mg gallic acid equivalent (EGA)/100 g fw.

Table 1. Physicochemical characteristics and proximate analysis of *Physalis peruviana* L.

Property	Muñoz et al. (2017)	Bazalar Pereda et al. (2019)
pH	3.947 ± 0.012	3.92 ± 0.03
Acidity	0.943 ± 0.030	1.85 ± 0.02
Soluble solids, SS (°Brix)	13.40 ± 0.10	14.80 ± 0.10
Humidity (%)	-	79.11 ± 1.24
Maturity indices, MI	14.4	8.00
Carbohydrates	-	14.22 ± 0.69
Protein	-	1.35 ± 0.05
Lipids	-	0.39 ± 0.01
Fiber	-	4.12 ± 0.10
Ash	-	0.81 ± 0.03

Table 2. Mineral and functional content of *Physalis peruviana* L.

Property	Olivares-Tenorio et al. (2016)	Bazalar Pereda et al. (2019)
K	55.3-501.9	373.25 ± 15.50
Mg	34.7-120.1	48.7 ± 2.40
Na	52.7	8.78 ± 0.40
Ca	7.0-37.7	11.17 ± 0.50
Cu	0.7	0.35 ± 0.02
Mn	0.7	-
Fe	0.1-3.9	-
P	34.0-54.9	-
Carotenoids	0-1100	1.24 ± 0.06
Vitamin A	-	103.33 ± 5.01
Vitamin C	10-1000	33.35 ± 0.37
Polyphenols	6.12	15.2
Antioxidant activity, aa (2,2' – azino - bis(3 – ethylbenzothiazoline – 6 - sulfonic acid, ABTS)	-	0.0376
aa (Ferric reducing ability of plasma, FRAP)	-	0.1112

Mineral content depends on the farming zone, that is why a considerable variation on these parameters is expected. The wide range for functional properties could be attributed to different extraction and quantification methodologies, as it is known that extraction solution or quantification procedure can be modified from one author to another. This would affect data and so will the MI, climacteric fruits (as goldenberry) keep maturing and fluctuating functional components affecting aa.

There was characterization research on goldenberry either in juice or powder, where its functional properties were evaluated (Ordóñez-Santos et al., 2017), trying to maintain the original qualities, over different treatments (heat pasteurization or sonication). Table 3 shows properties of gooseberry juice without treatment.

Mexican plum (*Spondia purpurea*) does not have many studies but in Mexico and Brazil some of its physicochemical characteristics were described. It is known that among its functional properties has vitamin C, polyphenols, and carotenoids; the properties of the last ones are reflected on the epidermis. It possesses a high senescence rate, that is, in a few days it is no longer suitable for consumption. Research on conservation is increasing by trying to preserve its properties or studying new alternatives of consumption while, maintaining its sensorial, nutritional, and functional properties (Muñoz-López et al., 2018). Table 4 shows physicochemical and functional properties of *Spondia purpurea*.

Physalis peruviana L. and *Spondia purpurea* have benefits for health consumers due to their aa. The increase in cardiovascular diseases in recent decades (World Health Organization, 2017) has also boosted interest in foods that contain bioactive compounds with aa. These health problems are mostly caused by oxidative stress, due to oxygen reactive species (ORS) augmentation, produced by the oxidation of macromolecules with endothelial dysfunction, converting oxidative stress on a disbalance mediator between vasodilator and vasoconstrictor mechanism. It is also associated with chronic degenerative diseases such as cancer, diabetes, and premature aging. Functional components of goldenberry

Table 3. Properties of *Physalis peruviana* L. juice

Property	Value
L*	37.73 ± 0.74
Chrome	20.55 ± 0.75
Hue (°)	83.14 ± 2.50
pH	3.98 ± 0.18
Titrable acid (g citric acid/100 mL juice)	0.71 ± 0.30
SS (°Brix)	6.82 ± 0.70
Total phenol content (μg EGA/g juice)	801.45 ± 10.91
Ascorbic acid (mg/100 mL)	17.17 ± 0.80

Table 4. Physicochemical and functional properties of *Spondia purpurea*.

Property	Maldonado-Astudillo et al. (2014)	Solorzano-Morán et al. (2015)	Álvarez-Vargas et al. (2017)
L*	-	40.88	43.93 ± 7.65
Chroma	-	43.17	36.77 ± 14.71
Hue°	-	42.86	43.55 ± 23.51
pH	2.6-6	-	-
Tritable acidity (%)	0.01-1.98	-	0.23 ± 0.10
SS (°Brix)	3.2-2.7	16.65	16.87 ± 4.16
Polyphenols (µg EGA/g fw)	1000-2300	500-3000	420.73
Carotenoids (µg/g fw)	171.2-243.79	61-327	197.84
Ascorbic acid (mg/100 g)	7.36-88.1	60-210	-
aa 2,2 – diphenyl – 1 – picrylhydrazyl, DPPH (mg AAE/100 g)	1.5 µM/g	0.5-1.6 mM AAE/g	54.8
aa ABTS (mg AAE/100 g)	6.25 µM/g	-	127.9
aa FRAP (mg AAE/100 g)	-	-	91.28

and Mexican plum neutralize ORS, reducing its accumulation in cells and further damage.

It is known that of almost 40 carotenoids found on human blood, the most abundant are β-carotenes, lutein, zeaxanthin, lycopene, among others (Zimmer & Hammond, 2007 cited by Eggersdorfer & Wyss, 2018). β-carotene blocks low density lipoproteins oxidation and transforms into vitamin A (retinol). Lutein and zeaxanthin are known as macular pigments that absorb blue light, protecting retina from photochemical damage and neutralize ORS, so their consumption reduce macular degeneration risk (Barker et al., 2011 cited by Eggersdorfer & Wyss, 2018).

The difference in mineral content between *Spondia purpurea* (Table 5) and *Physalis peruviana* (Table 2) is not significant, but it is observed that the variety of these minerals contributes to the osmotic balance of the cell, as well as to the proper functioning of enzymes that require these micronutrients.

Table 5. Mineral content of *Spondia purpurea* (mg/100 g fw).

Property	Ramírez et al. (2008 cited by Villarreal-Fuentes et al. (2019)	Koziol & Macía (1998 cited by Álvarez-Vargas et al., 2017)
Ca	2.50-5.10	6.00-25.00
P	1.30-2.70	32.00-56.00
Fe	1.57-4.73	0.09-1.22
K	6.20-24.00	230.00-270.00
Na	-	2.00-9.00
Zn	1.03-1.77	0.02
Mn	0.27-0.53	-
Cu	0.43-0.97	-
Mg	2.60-4.50	-
N	4.00-9.50	-

1.2 Storage methods comparation

Massive production brought new conservation technics without specialized equipment, that is why there is a special emphasis in chitosan (Bautista-Baños et al., 2006 cited by Bautista-Baños et al., 2017). This is a semipermeable film which prolongs life of fruit and vegetable products with lower infection levels than any other technic, and this has been reported on Chitosan treated plums (2.0 and 2.5%) at 12 °C. Table 6 shows a variety of experiments in the last years, conservation elements are specified so as process characteristics and fruit exposure conditions.

The use of plastics of different densities remains as the best preservation method, despite researchers' questions and the appearance of smart packaging. Due to the easy acquisition and lower production cost of polyethylene packages, considering that storage conditions play a fundamental role in obtaining the best storage effectiveness, research shows that food has been kept in perfect condition for 15 days when combined with temperatures ranging between 10 degrees Celsius, it is also necessary to mention that light conditions to which these packages are exposed interfere with the shelf life.

Table 6. Conservation mechanism.

Conservation method	Characteristics	Conditions	Author
Chitosan	Semipermeable film	2 and 2.5% concentration 12 °C, 12 days 4 °C, 21 days 28 °C, 6 days	Bautista-Baños et al. (2006 cited by Bautista-Baños et al., 2017) Muñoz et al. (2017)
Polystyrene	Disinfected plastic	13 °C	Vanegas (2005 cited by Mohammed et al., 2019)
PVC	Film/recipient	Relative Humidity, RH 85-90% Freeze -20 °C (immature fruits) 9.5 °C (mature fruits)	Maldonado-Astudillo et al. (2014 cited by Marisco & Pungartnik, 2015) Navarro et al. (2016)
		23 - 25 °C/2-4 days 9 - 10 °C/until 10 days	Coltro et al. (2014)
		20 °C, RH 82%/4 days 15 °C, RH 73%/10 days 10 °C, RH 69%/15 days	Maldonado-Astudillo et al. (2014 cited by Marisco & Pungartnik, 2015)
Hermetic recipient	In the presence or absence of light and air	16 °C 12 Light hours/w/o light 24 Light hours/w/o light Best condition 14 days w/o light	Montalvo-Gonzalez et al. (2011 cited by Mohammed et al., 2019)
Freeze Dryer	Freeze/Lyophilization	20 °C and -5 °C 0.05 and 0.1 mbar	Muñoz-López et al. (2018)
1 - Methylcyclopropene (1 - MCP)	Synthesis vegetal regulator acting as an ethylene action inhibitor	Dose: 100, 200, 300 nL/L 12 hours, 3 days and ambient T	Osuna-García et al. (2011 cited by Suárez-Vargas et al., 2017)
		22 °C ± 2 °C, 70 ± 10% RH 12 days	Osuna-García et al. (2011 cited by Suárez-Vargas et al., 2017)
Ethylene and 1-methylcyclopropene	Synthesis vegetal regulator	20 °C, RH 75%, 11 days	Balaguera-Lopez et al. (2017)
Alginate 1%	Edible coating	2 °C, 21 days	Carvalho et al. (2015)
Gelatin and calcium chloride	Edible coating	5 °C, 21 days 20 °C, 14 days	Licodiedoff et al. (2016)
Polyethylene terephthalate (PET) trays and polypropylene (PP) baskets	Disinfected plastic	4, 8 and 12 °C, RH 80%	Olivares-Tenorio et al. (2017)
Osmosis	Osmotic agents	18 and 25 °C, sucrose, mannitol, and sorbitol	Rezende et al. (2018)

2 Conclusion

Technological developments have allowed to establish several preliminary tests to predict the physicochemical composition of the plum and goldenberry (in Mexico especially), which contributes significantly to the conservation methods used by making them more effective, optimizing the transfer times to the final consumer, and motivating the generation of new preservation alternatives; that through various research have shown better results of product storage at more favorable reproducibility conditions for the food industry, particularly those which work with large volumes of food worldwide.

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