Received: 2 November 2023 | Revised: 22 January 2024 | Accepted: 26 January 2024

DOI: 10.1002/fft2.372

FOOD FRONTIERS Open Access

REVIEW ARTICLE

Exploring the impact of cold plasma treatment on the antioxidant capacity, ascorbic acid, phenolic profile, and bioaccessibility of fruits and fruit juices

Sina Zargarchi[1] | **Johann Hornbacher**[1] | **Sherif M. Afifi**[1,2] | **Solmaz Saremnezhad**[3] | **Deniz Günal-Köroğlu**[4] | **Esra Capanoglu**[4] | **Tuba Esatbeyoglu**[1]

[1]Department of Molecular Food Chemistry and Food Development, Institute of Food and One Health, Gottfried Wilhelm Leibniz Universität Hannover, Hannover, Germany

[2]Pharmacognosy Department, Faculty of Pharmacy, University of Sadat City, Sadat City, Egypt

[3]Department of Food Sciences and Technology, Faculty of Pharmacy, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

[4]Department of Food Engineering, Faculty of Chemical and Metallurgical Engineering, Istanbul Technical University, Istanbul, Turkiye

Correspondence
Tuba Esatbeyoglu, Department of Molecular Food Chemistry and Food Development, Institute of Food Science and Human Nutrition, Gottfried Wilhelm Leibniz Universität Hannover, Hannover, Germany.
Email: esatbeyoglu@lw.uni-hannover.de

Funding information
Leibniz Universität Hannover; Leibniz University, the project funder, exclusively funded the Open Access fee

Abstract

In recent years, cold plasma (CP) has emerged as a promising preservation technology for fruit products. Several CP sources include dielectric barrier discharge, plasma jets, corona discharges, micro-discharges, glow discharges, and gliding arc discharges. However, the effects of these different types of CP on the chemical compounds of fruits and juices are not fully understood. In this review, we summarize (I) the current knowledge on the use of CP for the preservation and processing of fruits and juices; (II) the diverse types of CP sources and explore their applications within a scientific context; (III) the physicochemical transformations that take place in fruits and juices following CP treatment; and (IV) the changes observed in antioxidant activity, vitamin C content, phenolic compounds, and their bioaccessibility. Numerous studies have explored CP's influence on microbial contamination, shelf life, enzymes, and various physicochemical changes. This review uniquely centers its attention on the impact of CP on bioactive phenolic compounds, their bioaccessibility, vitamin C content, and antioxidant activity in different types of fruits and fruit juices. Additionally, this review delves into the assessment of selected sensory properties, notably color, which is an important parameter for consumer acceptance. By focusing on these particular aspects, we aim to provide a targeted and comprehensive analysis of CP's effects on essential nutritional and quality attributes of fruits and fruit juices, distinct from the broader spectrum covered in the existing literature.

KEYWORDS
anthocyanin, nonthermal treatment, oxidative stress, polyphenol, sensory characteristics

Sina Zargarchi and Johann Hornbacher contributed equally to this work.

1 | INTRODUCTION

Phenolic compounds are found in plant-based products and may serve as antioxidants. Phenolic compounds include flavonoids (flavones, isoflavones, flavonols, flavanones, anthocyanins, flavan-3-ols, dihydro flavonols, and proanthocyanidins) and non-flavonoids (tannin, hydroxybenzoic acids, hydroxycinnamic acids, curcumins, lignans, stilbenes, and chalcones). Thousands of derivatives with simple to complicated structures, such as hydroxyl, methoxyl, and glycosyl derivatives, are also present. Phenolic compounds are primarily found in two forms: free (soluble) and bound. Free phenolic compounds are found in vacuoles, whereas bound phenolic compounds conjugate with proteins, lignin, and cellulose through ester and glycosidic linkages in the cell wall (La Rosa et al., 2019). Procedures, such as peeling, cutting, and shredding of fruits, cause disruption of cellular structure. Enzymes, such as polyphenol oxidase (PPO) and peroxidases, affect the color and lead to texture loss during processing and storage (Tappi et al., 2014). On the other hand, due to the tissue disruption during the processing of fresh fruits, their protective structures are destroyed, and it becomes easier for microbes to access the nutritional elements in the tissue. Thus, they become more susceptible to microbial spoilage (Chen et al., 2019).

The food industry has traditionally used preservatives or thermal processing to extend the shelf life of fresh-cut fruits and fruit juices/pulps. Decreases in nutritional values (i.e., vitamins, phenolic compounds, etc.) or losses in physicochemical properties (color and flavor) are among the adverse effects of thermal applications (Castro et al., 2020; Liao et al., 2018). Meanwhile, researchers and the food industry search for safe and efficient nonthermal food processing technologies that preserve the nutritional value and organoleptic properties of foods,also considering the consumer demands for good-quality, safe, and healthy foods with sufficient nutritional elements containing little or no food preservatives.

Cold plasma (CP) has been accepted as a promising nonthermal technique. A partially or totally ionized gas transformed into a variety of active species, such as atoms, charged particles, free radicals, electrons, and UV photons in their low-energy and high-energy states, is what produces plasma. In CP, electrons are the driving force in creating reactive species, which are produced in two stages. In the first stage, electrons collide, resulting in ionization, dissociative ionization, attachment, dissociative attachment, excitation, and dissociation of electrons. In the second stage, heavy particles collide, forming nitrogen oxides and highly reactive and strongly oxidizing species, such as hydroxyl radicals (Whitehead, 2016). These active ingredients are generally thought to be responsible for microbial inactivation via DNA, protein, and lipid damage (Chen et al., 2019; Dasan & Boyaci, 2018; Liao et al., 2018). According to researchers, CP technology ensures microbial inactivation (Chen et al., 2019; Dasan & Boyaci, 2018; Gan et al., 2021; Li et al., 2019; Liao et al., 2018; Misra, 2015; Pankaj et al., 2017; Puligundla et al., 2018; Won et al., 2017) and pesticide degradation (Phan et al., 2018; Sarangapani et al., 2017) in fresh-cut fruits and their juice/pulp.

CP is composed of reactive species that interact with substrate molecules. The heightened concentration of charges results in an electrostatic force, promoting the rupture of cell walls and the liberation of bound phenolics from cellulose, pectin, or lignin residues within vacuoles (Paixão et al., 2019). These interactions could affect the structure of phenolic compounds, for instance, which could alter their bioactivity (Chen et al., 2019). Plant cell walls that have been disrupted may allow the solvent to enter cellular components more quickly and thoroughly, improving mass transfer and enhancing the extraction of bioactive compounds (Castro et al., 2020; Khoshkalam Pour et al., 2022). Because the treatment is carried out at lower temperatures (<70°C), sensory qualities and bioactive ingredients of the final product are preserved (Dasan & Boyaci, 2018; Paixão et al., 2019). For example, when the rate of regeneration of vitamin C exceeds the rate of its destruction, its content increases due to CP (Castro et al., 2020). Meanwhile, it has also been reported that phenolics and vitamins are better preserved in CP compared to thermal applications (Elez Garofulić et al., 2015; Gan et al., 2021; Pankaj et al., 2017).

Pigments (anthocyanins, carotenoids, and betalains) are responsible for color, especially in fruits. The degradation of these compounds by oxidation and the formation of reactive species reduces the product's quality and significantly impacts consumer preference. An overall color change is expected to be less than the threshold value of $\Delta E > 3$ for human visual perception, where ΔE quantifies the perceptual color difference (Paixão et al., 2019). The efficiency of plasma treatment depends on operational factors, such as the plasma flow rate, duration, and voltage. Eventually, they also impact the nutritional value of foods, including vitamin and phenolic content and antioxidant activity (Castro et al., 2020; Dantas et al., 2021; Elez Garofulić et al., 2015; Khoshkalam Pour et al., 2022; Misra, 2015; Paixão et al., 2019; Pankaj et al., 2017; Phan et al., 2018; Rodríguez et al., 2017; Sarangapani et al., 2017; Wu et al., 2021).

Nevertheless, the processing homogeneity of CP technology has not yet attained optimal levels. The surface of fresh-cut fruits exhibits notable irregularities, and there are difficulties in uniformly distributing the effect of CP to each area of the liquid volume of fruit juices. In order to obtain vital knowledge for the improvement of future CP processing, it is crucial to investigate the changes in quality aspects of fruits or their juice during the CP process (Fernandes & Rodrigues, 2021). Numerous studies have delved into the impact of CP treatments on parameters such as shelf life, food safety, and microbiological alterations. However, this review emphasizes previously underexplored facets, specifically the content and bioaccessibility of phenolic compounds, color variations, and other chemical changes that warrant comprehensive investigation and thus provide beneficial information to better understand the effect and mechanism of this novel technology.

2 | SOURCES OF ATMOSPHERIC COLD PLASMA

Plasma can be created using different energy sources that can ionize gas. These sources include electrical power, thermal energy, optical means (such as UV light), radioactive materials (like gamma radiation), and electromagnetic radiation in the X-ray spectrum. However, only

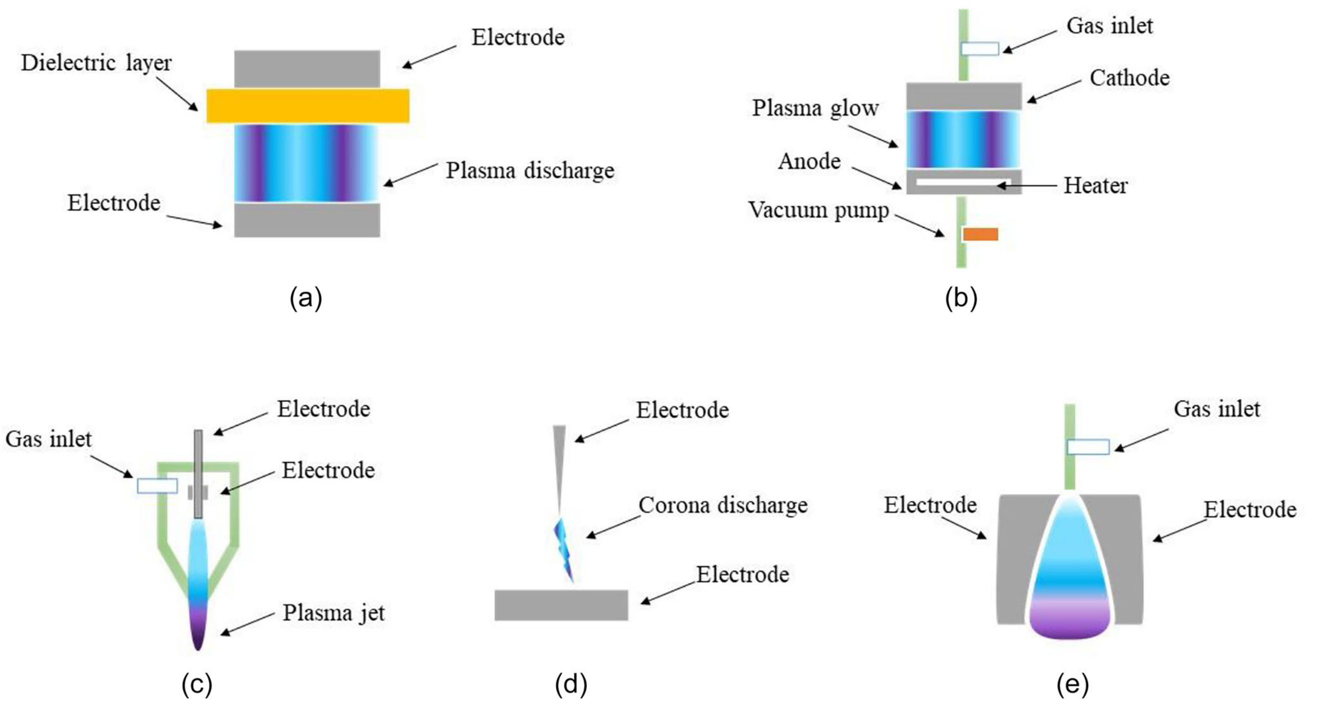

FIGURE 1 Different kinds of cold plasma devices: (a) dielectric barrier discharge; (b) glow discharge; (c) plasma jet; (d) corona discharge; (e) gliding arc plasma.

electrical or electromagnetic fields are commonly utilized to create plasma. The availability of different plasma-generating devices enables innovative designs that can be integrated into existing food industry equipment, such as packaging machines (Pankaj et al., 2018). The subsequent section of this review article will cover the most prevalent forms of CP in food science.

2.1 | Dielectric barrier discharge

It is one of the most common forms of atmospheric CP. Discharged plasma is produced by two parallel electrodes (Figure 1a). A dielectric layer covers either one or both electrodes (Klockow & Keener, 2009). Dielectric barrier discharge (DBD) has advantages such as straightforward design, versatility in gas selection and electrode dimensions, and uniform discharge initiation (Chizoba Ekezie et al., 2017). The device can handle various gas pressures, featuring adjustable electrode gaps spanning from 0.1 cm to several cm (Lu et al., 2016). However, DBD can be nonuniform, damaging the treated food. Furthermore, DBD is short-lived; therefore, a constant supply of reactive species might not be supplied to ensure the microbial safety of foods (Gadri et al., 2000).

2.2 | Glow discharge

Glow discharge has two different types: atmospheric and low pressure. Low pressure proves to be particularly advantageous in food science, as treatments can be conducted at more moderate temperatures, minimizing adverse effects on sensitive compounds. The vacuum conditions, facilitated by a vacuum pump coupled with a selective or ambient gas composition, can be employed. The gas flow rate influences the plasma beam's color (Farooq et al., 2023). The plasma generation needs a minimum of 100 V of power and 1–1000 Pa of pressure (Figure 1b). The primary benefit of this system lies in its substantial treatment capacity (Sakudo et al., 2020).

2.3 | Plasma jet

A plasma jet is created when an excited gas stream passes two electrodes. In contrast to other devices, a plasma jet leaves the area between the electrodes because of the high flow rate of the used gas, enabling different applications outside an enclosed area (Figure 1c). Therefore, a more precise control of the plasma properties, such as the plasma density, temperature, and composition, is possible (Fridman & Friedman, 2013). The plasma jet is a promising approach for treating materials in which narrow and hard-to-reach regions require processing. Although this technology provides high-precision, its coverage area is limited. The research to increase the treated surface area is ongoing, and similar to other CP treatments, it is suitable for heat-sensitive products (Lu et al., 2012; Tappi et al., 2019).

2.4 | Corona discharges

During a corona discharge, ionization occurs at atmospheric pressure in a high-field region around the electrode. As a result, a flow of charged particles is formed and accelerated due to an electric field

(Figure 1d). This form of plasma is produced by introducing specific gases like argon, carbon dioxide, or air into the gap between the electrodes and applying a high current to the electrodes (Ebnesajjad, 2009). The generated plasma by corona discharge is inhomogeneous because of the small plasma area around the electrode and the subsequent ion drift emitted by the plasma (Dubrovin et al., 2023). Therefore, generated reactive species are also created nonuniformly, making corona discharge unsuitable for specific applications (Gadri et al., 2000).

2.5 | Atmospheric pressure, glow discharge, gliding arc plasma

Gliding arc plasma is formed by subjecting a gas flowing between two electrodes to a high voltage, and it is characterized as nonthermal plasma (Figure 1e). Compared to the other CP types, producing under atmospheric pressure is more manageable, making it practical for industries. Gas flow plays a critical role in generating the gliding arc plasma beam. It determines the velocity and direction of the plasma and significantly impacts temperature and composition (Darvish et al., 2020). This allows for the achievement of a heightened plasma beam intensity or a more finely controlled beam while simultaneously reducing the gas flow rate. A low gas flow rate can be used to generate a highly concentrated and reactive plasma for surface modification and cleaning applications. On the other hand, a higher gas flow rate can be used for larger-scale treatments such as drying or processing, where a less reactive and more stable plasma is required (Mousavi et al., 2022; Wang et al., 2018).

3 | APPLICATION OF COLD PLASMA ON FRUITS AND FRUIT JUICES

The food processing industry faces challenges in the preservation of fruits and juices while maintaining their quality and extending their shelf life. Traditional methods like chlorine-based compounds, washing, and thermal treatments are commonly used but have drawbacks such as high energy consumption, chemical use, and wastewater production, leading to environmental concerns (Feliziani et al., 2016). On the other hand, different food processes including CP, may lead to the degradation and oxidation of natural compounds, potentially affecting product quality (Zargarchi & Saremnezhad, 2019). Therefore, it is crucial to study how CP affects the nutritional composition of fruits and juices (Table 1). The impact of CP exposure manifests both positive and negative effects on phenolic compounds and antioxidant activity (Cao et al., 2021). Prevalent transformations (oxidation, reduction, and photochemical reactions, etc.) occur during CP exposure. These reactions are facilitated by carrier gases like O_2, N_2, and other commonly employed gases. Notably, deactivation of phenylalanine ammonia-lyase, a pivotal enzyme in the biosynthesis of phenolic compounds, may be observed.

Conversely, CP treatment enhances the bioavailability of bioactive compounds by inducing damage to cell membranes and subsequent etching effects or activating the enzymes responsible for the biosynthesis of phenolic compounds (Castro et al., 2020). The ongoing exploration of diverse strategies, from chemical modifications like hydroxylation and glycosylation to advanced technologies such as nanotechnology and lyophilization, underscores the dynamic efforts to enhance polyphenol stability in food processing. These innovative approaches, coupled with insights into cooking and storage conditions, pave the way for a comprehensive understanding of how to preserve the valuable properties of polyphenols, ensuring the sustained quality of food products (Cao et al., 2021).

3.1 | Pome fruits

Pome fruits constitute a category of fruits classified within the Rosaceae family and the Pomoideae subfamily. This group encompasses fruits like apples, pears, and quinces, all of which are abundant in phenolic compounds, including flavonoids (such as quercetin and catechin), phenolic acids (such as chlorogenic acid), and procyanidins (Xiang et al., 2017).

Apples account for a larger share of the global fruit supply due to their market availability and the large number of extant cultivar variations and apple-based goods (fresh fruit, fruit juice, cider, and crushed apples) (Acquavia et al., 2021). Apples (*Malus domestica*) are a great source of polyphenols, such as catechin, procyanidin B2, protocatechuic acid, *p*-coumaric acid, and quercetin, which are responsible for their well-known antioxidant properties (Acquavia et al., 2021; Huber & Rupasinghe, 2009). Research has demonstrated that the type of plasma used and the treatment duration can significantly impact the quality characteristics of apples. Fresh-cut apples (*M. domestica* cv. "Pink Lady") ($40 \times 10 \times 10$ mm^3) were subjected to an atmospheric gas plasma treatment using a DBD generator operating at a low frequency of 12.7 kHz and 150 W. Treatment durations included 10 min (5 min per side), 20 min (10 min per side), and 30 min (15 min per side). The results indicated that the CP-treated samples exhibited higher tenderness levels than the control samples immediately after treatment and after a storage period of 6 h. The plasma treatment reduced the browning effect and decreased the activity of PPO (Tappi et al., 2014).

Apple juice was treated with DBD at 90 W for 40–200 s (Xiang et al., 2018), and the changes were compared to those of the control group. The changes in total phenolic content (TPC) were insignificant, and the pH was decreased (3.96–2.98) (Xiang et al., 2018). In contrast, treating apple juice with atmospheric CP showed lower TPC by increasing the exposure time (Liao et al., 2018). The treatment with 50 W significantly decreased the TPC from 41.7 to 32.4 mg GAE (gallic acid equivalents) 100 g^{-1} for 30 s. This decrease was attributed to the presence of reactive oxygen species and reactive nitrogen species (Liao et al., 2018). The L^* value is reduced by increasing the treatment time. In contrast, the a^* and b^* values were increased after the treatment; furthermore, the total color difference increased significantly after 30 s with 50 W (Liao et al., 2018), causing the polymerization of phenolic compounds (Bursać Kovačević et al., 2016).

Another frequently processed pome fruit is pear. Pears (*Pyrus communis*) are among the most widely consumed fruits globally, known for

TABLE 1 Recent studies on the changes in quality parameters of fruits and juices induced by cold plasma **(CP)** treatment.

Fruit/fruit juice	Cold plasma source	Treatment conditions	Quality parameters	Bioactive content	Antioxidant capacity	Reference
Pome fruits						
Apple (fresh cut) (*Malus domestica*)	Dielectric barrier discharge	150 W for 30 min	Polyphenol oxidase ↓ Browning incidence ↓		Antioxidant activity ↑ DPPH ↑ FRAP ↑ ABTS ↑ Slightly lower antioxidant activity via 3-min treatment compared to 1 min but still higher than control	Tappi et al. (2014)
Apple juice	Dielectric barrier discharge	50 W for 40 s	*Escherichia coli* ↓ Concentration of reactive species: H_2O_2, O_2, and NO_2 ↑ ΔE ↑ (color improved)	Total phenolic content ↓	Antioxidant activity (DPPH) ↓	Liao et al. (2018)
Pear (*Pyrus communis*)	Plasma-activated water	10 kV for 5 min	Aerobic bacteria, yeast, and mold ↓	Vitamin C ↔ Total phenolic content ↓	Antioxidant activity (DPPH and ABTS) ↔ At the end of storage: ABTS values of the control and the sodium hypochlorite-added pears, 6, 8, and 10-kV-treated samples ↓	Chen et al. (2019)
Berries						
Açai pulp (*Euterpe oleracea*)	Atmospheric cold plasma	20 kV for 5, 10, and 15 min	Polyphenol oxidase ↓ Peroxidase activity ↓ ΔE: in the range of 3.35–6.63 (5–15 min)	Total phenolic content ↓ Total monomeric anthocyanin content ↓	Antioxidant activity ↑ ORAC ↓ DPPH ↓	Dantas et al. (2021)
Blueberry (*Vaccinium* sp.)	High-voltage dielectric barrier discharge plasma	80, 230 V for 1, 5 min	Pesticides: boscalid and imidacloprid ↓	Total phenolic and flavonoid content for 1 min treatment↑ Total phenolic and flavonoid content for 5 min ↓ Total anthocyanin content ↓ Highest vitamin C: 80 kV for 1 min		Sarangapani et al. (2017)

(Continues)

TABLE 1 (Continued)

Fruit/fruit juice	Cold plasma source	Treatment conditions	Quality parameters	Bioactive content	Antioxidant capacity	Reference
Chokeberry juice (*Aronia melanocarpa*)	Cold plasma jet	9 kV for 15 s	*Escherichia coli* ↓ *Saccharomyces cerevisiae* ↓ Δ*E*: 1.45↓ Compared to thermal treatment: Δ*E* ↓	Compared to thermal treatment: Vitamin C ↑ Total phenolic ↑ Anthocyanin content ↑	Antioxidant activity ↑ DPPH ↑ OH-scavenging activity ↑ O_2^- anion scavenging activity ↑	Gan et al. (2021)
Grape (*Vitis vinifera*)	High-voltage atmospheric cold plasma	80 kV for 1, 2, 3, and 4 min	*Saccharomyces cerevisiae* ↓ Δ*E*: 2.38–4.22 and non-browning color ↑	Total phenolic ↓ Flavonoid content ↓ Total flavonols content ↑	Antioxidant activity ↓ DPPH ↓	Pankaj et al. (2017)
Strawberry (*Fragaria x ananassa*)	Dielectric barrier plasma discharge	60 kV for 5 min	Total aerobic mesophilic bacteria, yeast, and mold ↓	Vitamin C ↓ only at higher voltage Total anthocyanin content ↔		Misra et al. (2015)
Tropical fruits						
Pomegranate juice (*Punica granatum*)	Cold plasma treatment	2.5 kV for 3, 5, and 7 min and 0.75, 1, and 1.25 dm^3/min (Ar)	Δ*E*: 0.32–4.56	Individual and total anthocyanin content ↑		Bursać Kovačević et al. (2016)
Pitaya (*Selenicereus undatus*)	Cold plasma treatment	60 kV for 5 min	Total aerobic bacterial counts ↓	Individual phenolic acid content except for caffeic acid ↑ Total phenolic content ↓	Antioxidant activity (DPPH) At the beginning and after 48 h ↑	Li et al. (2019)
Kiwi fresh cut (*Actinidia deliciosa*)	Atmospheric double-barrier discharge plasma	19 V for 20 min	Chlorophyll a and b ↓ Total carotenoid content ↓ Improving color retention ↑ Darkened area formation after 4 days storage ↓	Hydrophilic extract: Vitamin C ↑ Total phenolic content ↑ Amphiphilic extract: Total phenolic content ↓	Hydrophilic extract: Antioxidant activity (ABTS)↑ At the beginning and after 4 days of storage Amphiphilic extract Antioxidant activity (ABTS ↓ DPPH ↑, and FRAP↓)	Ramazzina et al. (2015)
Siriguela juice (*Spondias purpurea*)	Glow-discharge plasma	80 W for 15 min	Pigments ↑ Vitamin B_3 and B_6 ↑ Polyphenol oxidase ↓	Total phenolic content ~ Vitamin C ↓ Total carotenoid content ↑ *β*-carotene ↑ lycopene ↑	Antioxidant activity (DPPH & ABTS) ↑	Paixão et al. (2019)

(Continues)

TABLE 1 (Continued)

Fruit/fruit juice	Cold plasma source	Treatment conditions	Quality parameters	Bioactive content	Antioxidant capacity	Reference
Cashew apple juice (*Anacardium occidentale*)	Indirect cold plasma treatment with N_2 gas	80 kHz for 15 min		Vitamin C ↑ Total phenolic content ↑	Antioxidant activity (FRAP, DPPH, & ABTS) ↑	Rodríguez et al. (2017)
Camu–camu juice (*Myrciaria dubia*)	Atmospheric dielectric barrier discharge	960 Hz for 15 min	Polyphenol oxidase ↓ Peroxidase activity ↓ Δ*E*: 1.1	Vitamin C ↑ Total phenolic ↑ anthocyanin content ↑	Antioxidant activity (FRAP, DPPH, & ABTS) ↑	de Castro et al. (2020)
Mango fresh cut (*Mangifera indica*)	Gliding arc discharge with argon gas	600 W for 10 min	Pesticides: Chlorpyrifos ↓ Cypermethrin ↓ Δ*E*: 2.4	Total phenolic content ↓ Total carotenoid content ↑		Phan et al. (2018)
Banana, fresh cut (*Musa acuminata*)	Atmospheric cold plasma	6.9 kV for 46 s	Vitamin B_6 ↑ Polyphenol oxidase ↓ Peroxidase activity ↓	Total phenolic ↓ Flavonoid content ↓		Khoshkalam Pour et al. (2022)
Stone fruits						
Sour cherry juice (*Prunus cerasus*)	Plasma jet with argon gas	6 W for 3 min		Individual cyanidin derivatives ↑ Total anthocyanin content ↑ *p*-Coumaric acid, caffeic acid, and total phenolic acid content ↑ Total anthocyanin and phenolic content ↑		Elez Garofulić et al. (2015)
Sweet cherry (*Prunus avium*)	Atmospheric cold plasma	80 kV for 140 s	Total colony counts ↓ *a** Value of color ↓	Total phenolic, flavonoid, and anthocyanin content ↔		Wu et al. (2021)
Citrus						
Kumquat (*Citrus japonica*)	Intermittent corona discharge plasma jet	8 kV for 90 s	Aerobic bacteria, yeast, and mold ↓	Vitamin C ↑ Total phenolic content ↑	Antioxidant activity (DPPH) ↑ After 15 days of storage: 50% of initial levels of DPPH remain unchanged	Puligundla et al. (2018)
Mandarin (*Citrus reticulata*)	Micro waved power cold plasma (N_2)	900 W for 10 min	Peel: *Penicillium italicum* ↓	Peel: Total phenolic content ↑ Flesh: Vitamin C ↔ Total phenolic content ↔	Peel: Antioxidant activity (DPPH) ↑ Flesh: Antioxidant activity (DPPH) ↔	Won et al. (2017)
Orange juice (*Citrus sinensis*)	Atmospheric cold plasma	650 W for 2 min	*Escherichia coli* ↓ Δ*E*: 1.64	Total phenolic content ~		Dasan and Boyaci (2018)

Note: ~, variable results according to the operation conditions; ↑, upregulation; ↓, downregulation; ↔, no obvious change; →, from the control sample value to the lowest value of the treatment. Δ*E*, color difference; ABTS, 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid scavenging assay; DPPH, 2,2-diphenyl-1-picryl-hydrazyl-hydrate radical scavenging activity; FRAP, ferric reducing antioxidant power; ORAC, oxygen radical absorbance capacity.

their significant contents of carotenoids, vitamin C, and phenolic compounds (i.e., chlorogenic acid, epicatechin, caffeic acid, and *p*-coumaric acid) (Hussain et al., 2021; Tanrıöven & Ekşi, 2005). In a study, Huangguan pears (*Pyrus bretschneideri* cv. Huangguan) were treated for 5 min at 6, 8, and 10 kV and then stored in a biosafety-cabinet for 12 days (Chen et al., 2019). The 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) and α,α-diphenyl-β-picrylhydrazyl (DPPH) assays were used to evaluate the antioxidant activity. For both the untreated and plasma-activated water-treated samples, DPPHand ABTS values were decreased over the entire storage time. A minor reduction in DPPH-radical scavenging activity was observed with 6 and 8 kV treatment of pears in the first 4 days of storage in comparison to the control, while a higher DPPH-radical scavenging activity was observed with 10 kV treatment in the first 6 days. The ABTS assay showed higher antioxidant activity for 6 and 10 kV treated pears in the first 4 days of storage. In contrast, it was decreased for untreated samples. However, both treated and untreated groups showed no significant difference in their ABTS-radical scavenging activity after 6 days of storage. After 12 days, the ABTS-radical scavenging activity of untreated and treated samples with 6, 8, and 10 kV decreased by 26.38%, 19.27%, 4.18%, and 32.71%, respectively, in contrast to the control group. The ascorbic acid content decreased significantly during the early storage phase due to oxidation compared to the control. The treatment with 10 kV delayed the ascorbic acid reduction significantly (Chen et al., 2019).

3.2 | Berries

Berries are distinguished by their abundant phenolic compounds, which impart vibrant color, flavor, and aroma while offering potential health benefits. Within this botanical cohort, flavonoids such as anthocyanins, quercetin, and kaempferol, alongside other phenolic compounds like ellagic acid and caffeic acid, as well as tannins, vitamins, and dietary fiber, collectively endow berries with a profile of bioactive constituents. This botanical wealth positions berries as a nutritionally dense source, underscoring their significance as a health-promoting dietary component (Skrovankova et al., 2015).

CP studies on açai, blueberry, chokeberry, and grape belong to the berry group. The demand for açai has recently been growing due to its nutritional qualities and bioactive chemicals in the domestic and international markets. Açai (*Euterpe oleracea*) is a rich source of anthocyanins (de Jesus et al., 2020). The remarkable antioxidant activity of açai can be attributed to the presence of procyanidin A2, procyanidin B2, epicatechin gallate, rutin, gallic acid, and chlorogenic acid (Dantas et al., 2021). Application of atmospheric CP with different frequency levels (50, 500, and 750 Hz) was performed for 5, 10, and 15 min. The TPC increased by 38.8% in CP-treated samples at 500 Hz for 5 min compared to untreated samples. The higher frequency did not affect the anthocyanin content, similar to the untreated sample. The analysis of bioaccessibility for catechin, epicatechin, epigallocatechin gallate, procyanidin B1, rutin, caffeic acid, and chlorogenic acid in comparison to the control group revealed a remarkable increase of 194.7%, 83.44%, 68.84%, 130.71%, 16.84%, 341.48%, and 57.63%, respectively (Dantas et al., 2021). The bioaccessibility was analyzed by in vitro digestion models utilizing dialysis membranes mimicking the intestinal barrier (Dantas et al., 2019). The authors attributed the higher bioaccessibility of the phenolic compounds to the depolymerization of procyanidins and the subsequent release of monomeric phenolic compounds by the CP treatment.

Blueberries (*Vaccinium* sp.) are a great source of anthocyanins, antioxidants, and vitamins such as ascorbic acid (Nindo et al., 2005; Wang, Guo, et al., 2017). Applying 80 kV CP to the blueberries for 5 min did not show any significant difference in color parameters. However, the firmness as a physical quality factor decreased significantly compared to the control (Sarangapani et al., 2017), probably due to cell wall damage (Tappi et al., 2016). On the other hand, TPC and total flavonoid content (TFC) values were increased significantly (Sarangapani et al., 2017). The putative stimulation of the expression and activity of phenylalanine ammonia-lyase, an essential enzyme to the biosynthesis of phenolic compounds such as flavonoids, by the CP treatment might explain this augmentation. It was previously reported that this enzyme is activated by wounding stress, indicating that CP might have similar effects (Horvitz, 2017; Wang et al., 2009). The vitamin C content in blueberries increased significantly from 8.91 mg·100 g^{-1} to 14.01 mg·100 g^{-1} after 1 min of CP treatment at 80 kV. Time and power positively increased ascorbic acid content, whereas the anthocyanin content decreased after the treatment (Wang et al., 2009). In another study, blueberry (*Vaccinium corymbosum*) juice was treated with a CP jet with 11 kV voltage and 1 kHz frequency [oxygen (0%, 0.5%, and 1%)] for 2, 4, and 6 min. Results showed that the TPC was consistently higher in samples treated longer. In contrast, the treatment reduced the anthocyanin content, dependent on the duration of plasma exposure (Hou et al., 2019). The authors relatedthis result to the oxidative degradation of anthocyanins during the plasma treatment (Bursać Kovačević et al., 2016).

Chokeberries are used in various products, including juices, nectars, wines, and liqueurs. Chokeberries (*Aronia melanocarpa*) contain procyanidins, flavonols, and phenolic acids (Peng et al., 2022). An atmospheric CP jet, utilizing a single electrode configuration with a 4 W power output, and argon flow rate of 0.75 dm^3/min for 3 and 5 min, was used to process the chokeberry juice samples prepared via cold press extraction. After the 5-min treatment, a 23% reduction in anthocyanin content was observed due to the generation of reactive species by the CP. Conversely, the neochlorogenic acid content increased after the treatment compared to the untreated juice. Plasma treatment for 3 min resulted in the most significant accumulation of quercetin-3-*O*-rutinoside and quercetin-3-*O*-glucoside (Bursać Kovačević et al., 2016). In another study, a CP jet with argon gas (1.5 L min^{-1}) at 9 kV and 1500 Hz was applied to chokeberry juice for 1, 2, 3, 4, and 5 min. The anthocyanins changed insignificantly, and phenolic contents were slightly increased from 21.0 to 22.8 μg/mL (Gan et al., 2021). The antioxidant activity increased compared to the untreated sample. Moreover, ascorbic acid contents decreased significantly after the CP treatment (Canene-Adams et al., 2007; Gan et al., 2021).

Strawberries (*Fragaria x ananassa*) have high amounts of bioactive compounds like anthocyanins and other phenolic compounds (Newerli-

Guz et al., 2023). The high perishability of strawberries makes them extremely sensitive to mechanical damage and subsequent decay. As a result, it is crucial for farmers to carefully package the strawberries immediately after harvest and ensure rapid distribution to prevent quality degradation (Hernández-Martínez et al., 2023). The application of DBD to strawberries was used under atmospheric conditions in a polyethylene terephthalate tray for 1 and 5 min at 80 kV. The changes in the colorimetry parameters (L^*–a^*–b^*) were tracked, and the results showed no significant changes among the treated samples with in-package CP treatment and the control after storage for 24 h. Both treated and untreated samples lost their tenderness due to the soft tissue of strawberries (Misra et al., 2015). According to the results, samples treated with 80 kV had a lower amount of ascorbic acid than those treated with 60 kV. However, within the 80 kV category, treatment time did not significantly impact changes observed in ascorbic acid content (Misra et al., 2015). The generation of reactive species might be responsible for the loss of vitamins after the CP-treatment since the penetration through the perforated skin of strawberries can be easier (Misra et al., 2014).

One of the most harvested fruits is grape (*Vitis vinifera*), which has numerous phytochemicals, such as anthocyanins, resveratrol, and flavonoids. Raisins, the dried form of grapes, are produced in many countries, including Türkiye, United States, Iran, and Greece (Adiletta et al., 2016; Wang, Mu, et al., 2017). Grape skin is the bottleneck for drying, acting as a diffusion barrier by limiting water loss (Di Matteo et al., 2000; Doymaz & Pala, 2002). It is possible to increase skin permeability chemically by soaking in an alkaline solution (e.g., sodium hydroxide) and non-chemically through skin abrasion to improve the drying process (Adiletta et al., 2016; Bai et al., 2013; Wang, Mu, et al., 2017). However, chemical abrasion may cause leaching and oxidation of vitamins, and the chemicals can remain on the treated product if not cleaned properly, which in turn exacerbates the leaching problem (Wang, Mu, et al., 2017).

Alternatively, gliding arc plasma was applied to seedless grapes (*V. vinifera* cv. Asgari) for 10, 20, 30, 40, 50, and 60 s under atmospheric conditions at 27 kV. The results showed that the treated samples showed a faster drying rate of 4.71%–26.27% compared to the untreated samples. The faster drying time might be attributed to micro-lesion formation during the treatment, resulting in an 11 h shorter drying process in samples treated for 50 s compared to untreated samples (Miraei Ashtiani et al., 2020). Untreated samples retained less vitamin C than the treated samples. This implies that CP effectively improved vitamin C retention during the drying of grapes. Treating for 10 and 50 s resulted in the lowest (17.94%) and highest (40.90%) vitamin C retention rates in the plasma-treated group, respectively. The higher ascorbic acid retention might be attributed to the shorter drying time. Therefore, a shorter exposure to oxygen in an aqueous environment leads to its oxidation (Chen et al., 2018; Rodríguez et al., 2018). The treated samples also showed a higher concentration of TPC and a brighter color than the untreated samples. This can also be explained by the shorter drying time, resulting in less oxidation and degradation of phenolic compounds and, therefore, less browning (Miraei Ashtiani et al., 2020). On the other hand, high-voltage atmospheric cold plasma processing (ACP) was applied to grape juice at 80 kV for 1–4 min. This treatment significantly reduced TPC and TFC at higher treatment times compared to the control group. Although there were no significant changes in the L^* value, the a^* and b^* values were increased (Pankaj et al., 2017).

3.3 | Tropical fruits

Tropical fruits are renowned for their extensive biodiversity, distinctive flavors, aromas, and appearances. Their nutritional profile highlights abundant vitamins (C, A, K, etc.), minerals, and dietary fiber. Among the prevalent flavonols in tropical fruits are quercetin, kaempferol, and catechin (Lim et al., 2007).

Pomegranate (*Punica granatum* L.) is native to Central Asian countries, such as Iran, Afghanistan, and Pakistan, and is one of the world's most well-known ancient fruit trees and traditional medicinal herbs. Pomegranate contains anthocyanins, including delphinidin-3-*O*-glucoside, cyanidin-3-*O*-glucoside, pelargonidin-3-*O*-glucoside, delphinidin-3,5-*O*-diglucoside, cyanidin-3,5-*O*-glucoside, and pelargonidin-3,5-*O*-glucoside (Zhao & Yuan, 2021). Gallotannins and ellagitannins, like punicalagin, are the prominent hydrolysable tannins in pomegranates (Čolić et al., 2022). The stability of phenolic compounds in pomegranate juice treated with a constant jet plasma stream (4 W) from argon was investigated. After the treatment for 3, 5, and 7 min, concentrations of delphinidin-3,5-diglucoside, cyanidin-3,5-diglucoside, and total anthocyanin content were increased significantly compared to the untreated samples (Bursać Kovačević et al., 2016) owing to the higher extractability of treated samples. However, this explanation is questionable, considering that the fruit was not treated with CP, but the already-produced juice was, and no color change was observed after the treatment.

Pitaya (*Selenicereus undatus*) is a tropical fruit from southern Mexico (Lim et al., 2012). The predominant phenolic compounds of pitaya are gallic acid, *p*-coumaric acid, *p*-hydroxybenzoic acid, caffeic acid, and protocatechuic acid (Li et al., 2019). A trial with 60 kV DBD plasma treatment significantly increased the contents of gallic acid, protocatechuic acid, *p*-hydroxybenzoic acid, caffeic acid, and *p*-coumaric acid by 106.9%, 132.3%, −6.8%, −16.7%, and 108.8%, respectively, 36 h after the treatment (Li et al., 2019). The study suggests that treating fresh-cut pitaya fruit with CP could potentially improve the accumulation of phenolics and antioxidant activity following cutting. The authors attributed the increased contents of phenolic compounds to an increase in gene expression in the phenylpropanoid pathway (Li et al., 2019).

Kiwi (*Actinidia*) has exceptionally high ascorbic acid contents and encompasses additional nutrients, including dietary fiber, potassium, tocopherol, and folate (Satpal et al., 2021). DBD CP was applied on sliced kiwi fruits for 20 and 40 min (each side) at atmospheric pressure, and the samples were stored at 10°C with 95% humidity for 4 days. The Trolox Equivalent Antioxidant Capacity, DPPH, and FRAP values did not change significantly after the treatment, indicating that the plasma treatment did not significantly affect the antioxidant contents and antioxidant activity (Ramazzina et al., 2015). Furthermore, the authors reported that the maintenance of color lightness was better during the storage of plasma-treated samples, resulting in a lighter final product (Ramazzina et al., 2015), probably due to the high concentration of ascorbate and the putatively low activity of the PPO in the treated kiwifruit slices (Agar et al., 1999).

Siriguela (*Spondias purpurea*) is a fruit known for its high content of antioxidants and phenolic compounds, including tannins, phenolic acids, and flavonoids (Barreiros et al., 2018). In a study by Paixão et al. (2019), glow discharge plasma treatment was applied to siriguela juice samples using nitrogen gas at 50 kHz and 80 W. The results showed no significant difference in the TPC of the treated samples compared to the control. However, when the nitrogen gas flow rate was increased to 30 mL/min, the TPC of the treated samples decreased by 30% after 10 min of treatment. The plasma treatment did not significantly affect the vitamin C content of the samples, nor did it significantly affect the redness (a^*) of the samples compared to the control samples. Optimal conditions for maximizing pigment content in siriguela juice through plasma processing were achieved using a low nitrogen gas flow rate of 10 mL/min and moderate processing times ranging from 8 to 12 min. The carotenoid content increased by approximately 30% in total. Specifically, the levels of β-carotene, a provitamin A compound, and lycopene increased by 50%. These findings prove that plasma processing effectively enhances the concentration of precursor pigments and vitamins in siriguela juice (Paixão et al., 2019).

Camu–camu (*Myrciaria dubia*) is a popular Amazonian fruit containing ascorbic acid, tocopherols, antioxidants, and phenolic compounds (Santos et al., 2022). The treatment of samples with CP at 24 kV for 15 min with different frequencies (200, 400, 583, 698, or 960 Hz) showed that the TPC of camu-camu juice increased significantly after the treatment at 960 Hz compared to the control. The vitamin C content decreased with all treatment modes, and the highest degradation was observed at 960 Hz (de Castro et al., 2020). The colorimetric analysis indicated a significant reduction in the L^* value. The higher frequency treatments decreased the a^* value, probably resulting from loss of anthocyanins. Furthermore, the b^* value decreased significantly at the highest frequency (de Castro et al., 2020).

Mango (*Mangifera indica*) is native to tropical and sub-tropical zones. It contains carotenoids, phenolic compounds, and vitamin C (Martínez et al., 2012). After argon treatment for 10 min and 8 L/min flow rate, the TPC descended significantly compared to the control from 183 to 137 mg GAE·100 g^{-1} fresh weight (FW). However, an increasing trend was observed in the carotenoid content in comparison to the control from 2.0 to 2.8 mg·100 g^{-1} FW after 10 min of treatment and 8 L/min Ar flow rate. The overall color and b^* index changes were insignificant compared to the control (Phan et al., 2018). However, further studies are required to quantify and identify the changes in phenolics and other antioxidants after different treatments with different CP models.

Cashew apple (*Anacardium occidentale*) is a plant harvested mainly for its seeds, known as cashew nuts (Silveira et al., 2012). However, the fruit is a good source of flavonoids, carotenoids, anacardic acid, tannins, and ascorbic acid (Azevedo & Rodrigues, 2005). The cashew apple juice was subjected to treatment with CP and nitrogen gas (10, 30, and 50 mL/min flow rate) (Rodríguez et al., 2017). The ascorbic acid content increased by 10.4% and 10.8% after treatment for 5 and 10 min, with 10 mL/min of N_2, respectively. The results indicated an increase in TPC by 108% and 101% compared to the control group. Vitamin C and TPC changed insignificantly after treatment for 5, 10, and 15 min. It is associated with activating the enzyme dehydroascorbate reductase, explicitly belonging to the NADH class of enzymes. The dehydroascorbic acid molecule represents the oxidized state of ascorbic acid and undergoes a natural conversion back to ascorbic acid facilitated by dehydroascorbate reductase within the ascorbate–glutathione cycle. For N_2 flow rates of 10 and 30 mL/min, the TPC increased by an average of 108% and 101%, with no significant time effect. However, at a flow rate of 50 mL/min, a significant increase in TPC was observed with longer treatment times (114%, 121%, and 128% for 5, 10, and 15 min, respectively). TFC was lower for the 10 mL/min flow rate, and higher flow rates (30 and 50 mL/min) showed a positive time effect, although overexposure reduced relative TFC (Rodríguez et al., 2017).

Banana (*Musa acuminata*) is cultivated in more than 130 countries, making it one of the most popular fruits worldwide. The DBD treatments used to blanch samples had the power of 4.8–6.9 kV, a frequency of 12–22 kHz, for 35–155 s. The TPC increased from 26.85 to 46.71 mg·100 g^{-1} FW. With increasing voltage from 4.8 to 6.9 kV, the contents of phenolic compounds increased significantly from 30.57 to 43 mg · 100 g^{-1} FW. The findings indicated that time had a more substantial impact on polyphenol content than voltage. The TPC increased from 26.85 to 46.71 mg 100 g^{-1} FW as the duration extended from 35 to 155 s. Similarly, the quantity of polyphenols rose from 30.57 to 43 mg 100 g^{-1} FW with an increase in voltage from 4.8 to 6.9 kV. The TFC, in alignment with total phenolics, exhibited an upward trend with both time and voltage. The interactive effect of voltage and time significantly influenced TFC. Notably, TFC changes were subtle with increasing voltage at shorter times, whereas at longer durations, the TFC varied from 4.73 to 6.25 mg 100 g^{-1} FW with an increase in voltage from 4.8 to 6.9 kV. It was observed that increasing the voltage and treatment time beyond 4 kV caused burning while applying a voltage weaker than 4 kV was insignificant to deactivating the peroxidase (POD) and PPO (Khoshkalam Pour et al., 2022). Plasma treatment significantly reduced PPO and POD enzyme activities. PPO activity decreased from 86% to 30% with increased voltage (4.8 to 6.9 kV) and from 88% to 29% with longer treatment times (35 to 155 s). The POD deactivation was more time-dependent, with voltage-reducing activity from 92% to 51%. Complete POD deactivation occurred only at 155 s (Khoshkalam Pour et al., 2022). The enzyme inactivation may be linked to changes in secondary structure, like decreased α-helix and increased β-sheet structures (Surowsky et al., 2013). In addition, oxidation of the amino acid cysteine can decrease the number of sulfhydryl groups and inactivate the enzyme (Dong et al., 2021).

3.4 | Stone fruits

Stone fruits are characterized by their fleshy exterior, enveloping a hard pit. These fruits exhibit diverse phenolic compounds and

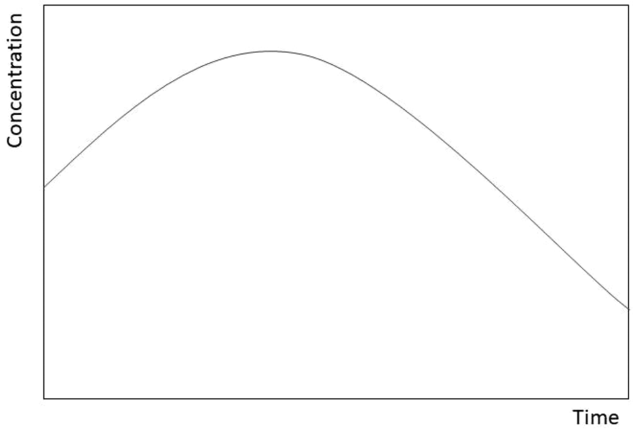

FIGURE 2 Effects of concentration and time on the antioxidant activity during cold plasma (CP) treatment. *Source*: Adapted from Fernandes and Rodrigues (2021).

flavonoids, including quercetin, kaempferol, catechins, chlorogenic acid, ellagic acid, and anthocyanins, imparting visual allure and potential health benefits. Noteworthy vitamins in stone fruits, such as vitamin C, β-carotene (provitamin A), and vitamin K, further enhance their nutritional value. This combination of bioactive compounds and essential vitamins emphasizes the scientific significance of stone fruits, making them not only flavorful but also nutritionally valuable (Redondo et al., 2021). This section describes the effect of CP on the bioactive composition of acerola, sour cherry, and sweet cherry.

Acerola (*Malpighia glabra*) is a remarkable source of ascorbic acid and phenolic compounds, such as benzoic acid, phenylpropanoids, flavonoids, anthocyanins, and carotenoids. It has attracted attention as a nutraceutical and functional food (Da Silva et al., 2022). Fernandes et al. (2019) applied a nitrogen glow discharge plasma to acerola juice samples with various gas flow rates (10, 15, and 20 mL/min) for 5, 10, and 15 min. Treatment time and flow rate negatively affected the phenolic content compared to the control (Figure 2). The antioxidant capacity did not change after different treatment durations, but an adverse trend was observed depending on the gas flow rate. Increasing the flow rate impacted the total carotenoid and tocopherol content, with both parameters showing an upward trend compared to the control group. However, the vitamin C content and juice hue did not change significantly (Fernandes et al., 2019).

Sour cherry (*Prunus cerasus*) is a rich source of bioactive compounds, including phenolic compounds, anthocyanins, organic acids, melatonin, and vitamin C (Hussain et al., 2021). In a study by Elez Garofulić et al. (2015), a plasma jet treatment was utilized to process sour cherry juice using a single electrode device and argon gas at a flow rate of 1.5 L/min and a frequency of 25 kHz for treatment durations of 3, 4, and 5 min. The significant anthocyanins (cyanidin-3-sophoroside, cyanidin-3-glucosylrutinoside, cyanidin-3-glucoside, and cyanidin-3-rutinoside) and phenolic acids (neochlorogenic acid, *p*-coumaric acid, and caffeic acid) remained consistent. The anthocyanin content varied from 139.50 to 223.96 mg 100 g^{-1} d.m., with longer plasma treatment durations yielding lower concentrations. Larger sample volumes resulted in higher anthocyanin content, but the impact of treatment time was more pronounced. Phenolic acid amounts ranged from 93.85 to 163.36 mg 100 g^{-1} d.m., with the shortest treatment time producing the highest concentration. Gas flow did not significantly affect the anthocyanins and phenolic acids in the treated juices (Elez Garofulić et al., 2015).

Sweet cherry (*Prunus avium*) contains high amounts of phenolic compounds and anthocyanins (Gonçalves et al., 2004; Kim et al., 2005). Among them, cyanidin-3-*O*-rutinoside, cyanidin-3-*O*-glucoside, and other compounds, such as hydroxycinnamic acid, neochlorogenic acid, and *p*-coumaroylquinic acid, can be found (Kim et al., 2005). CP has been applied at 40, 60, and 80 kV for 60, 80, 100, and 140 s on sweet cherries (Wu et al., 2021). The results indicated no significant changes in TPC after the treatment at 40 and 60 kV, but treatment at 80 kV caused a significant decrease in TPC compared to the control, probably due to oxidation (Wu et al., 2021).

3.5 | Citrus fruits

Citrus fruits, members of the Rutaceae family, are characterized by their juicy, segmented flesh and signature tangy flavor. These fruits boast notable phenolic compounds and flavonoids, such as hesperidin, naringin, quercetin, and rutin. These compounds contribute to antioxidant and anti-inflammatory properties. *Citrus* fruits are particularly abundant in essential vitamins, with vitamin C being a hallmark component (Sun et al., 2019).

Kumquat (*Citrus japonica*) contains high amounts of flavanone glycoside and polymethoxylated flavones, making it an excellent source of antioxidants (Ragheb et al., 2023). Traditional medicines are an anti-inflammatory remedy against respiratory illnesses (Barreca et al., 2011; Lin et al., 2008). The peel of Kumquats is the distinctive feature of this *Citrus* fruit, as it is consumed together with the flesh. The peel's sweet taste is more palatable than the *citrus* peels, posing a rich source of phenolic compounds (Chen et al., 2017). Kumquat fruits were treated with intermittent corona discharge plasma jets for 2 min at 8 kV direct current at different current levels (2.0, 3.0, and 4.0 A). After storage for 10 days, the contents of phenolic compounds in treated samples with 3.0 and 4.0 A showed no significant changes. However, a significant reduction was observed in the untreated and 2.0 A-treated samples. A similar trend was observed for the DPPH scavenging activity. Both treated and untreated samples significantly reduced the ascorbic acid content (Puligundla et al., 2018). Insignificant changes were observed in color, aroma, taste, and texture between the treated and untreated samples.

Mandarins' (*Citrus reticulata*) fruit and peel have high amounts of bioactive compounds, such as β-cryptoxanthin, vitamins, flavonoids, and other phenolic compounds (Wang et al., 2016). The peel color is the primary quality factor for market distribution (Lado et al., 2014). Research showed that microwave-powered CP-treated Satsuma mandarins (*Citrus unshiu*) showed no difference in their TPC, antioxidant activity, ascorbic acid content, and the color of the mandarin's flesh and peel after treatment for 2, 5, and 10 min with nitrogen when compared to controls (Won et al., 2017). The N_2-CP treatment at 900 W and 20 min has been listed as an efficient method to prevent blue and green mold infections caused by *Penicillium italicum* in the postharvest period. The results showed insignificant changes in the phenolic content of the mandarin flesh between the treated and untreated samples in different treatment conditions (Won et al., 2017).

In contrast, the content of phenolic compounds in the peel was significantly higher in treated samples when compared to controls, which was caused by the UV radiation of plasma penetrating epidermal cells and causing an increase in phenolic compounds by boosting biosynthesis (Grzegorzewski et al., 2011). The peel's antioxidant activity has exhibited a subsequent augmentation attributable to the amplified presence of phenolic compounds. The fruit's antioxidant and phenolic compound changes were insignificant, which can be elucidated by the thick peel of mandarin that prevents the CP from penetrating the fruit. There were no significant changes in the color after the CP treatment (Won et al., 2017).

Orange (*Citrus sinensis*) is one of the richest sources of vitamin C. However, it also includes significant levels of sugar, carotenoids (i.e., norisoprenoids, α-ionone, β-ionone, β-cyclocitral, and β-damascenone), flavonoids (i.e., hesperidin, etc.), essential oils (i.e., limonene), and minerals (i.e., Zn, Fe, Cu, K, etc.) (Campolo et al., 2016). Dasan & Boyaci (2018) aimed to assess the effects of applying ACP at 650 W with different treatment durations (30, 60, 90, and 120 s) on orange juice quality and according to the results, samples treated for 120 s had a higher TPC than the control samples. At the beginning of the treatment, the TPC value decreased, but after 90 s treatments, a significant increase was observed (Dasan & Boyaci, 2018). The increase in TPC values might be explained by the ability of reactive species to break covalent bonds, leading to subsequent depolymerization of complex phenols like tannins and other structures associated with phenolic compounds. This would lead to a higher content of free phenolic compounds, as observed in the study of Herceg et al. (2016). The application of CP did not significantly affect the pH nor the colorimetric results (Dasan & Boyaci, 2018). In another study, the vitamin C content was analyzed in samples treated with low-temperature DBD plasma, resulting in nonsignificant differences between the control and treated samples (Shi et al., 2011). The application of CP on orange juice by-products as a dietary fiber and fat replacer (Saremnezhad et al., 2020) offers a compelling area for research, particularly in decontamination and enhancing nutraceutical compounds.

It is common to mix and consume orange juice with carrot juice. Carrots (*Daucus carota*) are a significant source of natural antioxidants, including vitamin C, carotenoids (such as α and β-carotene, lutein), and phenolic compounds (e.g., chlorogenic, *p*-hydroxybenzoic, or ferulic acid) (Christofi et al., 2022). Applying a high-voltage electric field CP (HVCP) to carrot juice enhanced total carotenoids and color. HVCP also preserved the red color of juices due to better preservation of carotenoids compared to untreated samples; however, treating for 4 min at 70 kV showed the best color improvement compared to other treatment conditions. This might be attributed to enzyme deactivation, which in turn might prevent the degradation of carotenoids. The TPC of the control sample was 9.77 μg/g GAE and 10.45 μg/g GAE in samples that were treated for 4 min at 80 kV. Additionally, vitamin C contents were higher in treated samples (25.50 mg 100 mL^{-1}) when compared to controls (24.11 mg 100 mL^{-1}). The pH, acidity, and Brix showed no significant difference compared to the control. The L^* and b^* values were significantly lower in treated samples, whereas the a^* value was higher after the treatment with 60 kV plasma treatment for 3 min (Umair et al., 2019).

4 | THE EFFECT OF COLD PLASMA ON THE BIOACCESSIBILITY/BIOAVAILABILITY OF PHENOLIC COMPOUNDS AND VITAMIN C

The portion of a bioactive compound that is liberated from the food matrix in the gastrointestinal tract and made available for absorption is known as the bioaccessible fraction. Therefore, the bioaccessibility of bioactive substances is more significant than their concentrations at the moment of consumption (Leite et al., 2021; Linhares et al., 2020). It is crucial to assess how processing conditions affect bioactive chemical release, transformation, and absorption (Linhares et al., 2020). By using CP treatment, the simultaneous events of covalently bound chemical release from plant cell walls, polyphenol depolymerization, and reduced scavenging compounds may increase or decrease the amount and bioactivity of secondary plant metabolites (Oner et al., 2023).

Leite et al. (2021) stated that ACP did not affect the bioaccessibility of total phenolics in cashew apple juice, and more than 90% bioaccessibility of phenolics was recorded for all cashew apple juice. However, higher excitation frequencies of atmospheric CP processing increased the bioaccessibility of vitamin C in cashew apple juice (Leite et al., 2021) and camu–camu juice (de Castro et al., 2020; Castro et al., 2020). Lower pH values (evidenced by quick ascorbic acid degradation in the stomach phase and exposure to oxygen), are associated with high ascorbic acid degradation during digestion (Castro et al., 2020). The bioaccessibility of bioactive substances improved as a result of these emerging technologies. This enhancement is attributed to the low processing temperature and the damage generated in the plant cell membranes, which release bioactive chemicals and increase their availability for human absorption (de Castro et al., 2020).

Phenolic compounds decompose in the gastrointestinal tract due to the pH and electrolyte effect of the digestion fluids and enzymes. Eventually, phenolic compounds interact/bind with other compounds; therefore, different breakdown products, such as phenolic acids (protocatechuic acid), are formed (Bohn, 2014). Therefore, examining the bioavailability of different phenolic groups and the total phenolic bioavailability may be more beneficial. Dantas et al. (2021) clarified that procyanidin B1 (130.71%), rutin (16.84%), caffeic acid (341.5%), chlorogenic acid (57.63%), and catechin (194.7%), as well as epicatechin (383.4%) and epigallocatechin gallate (68.07%), were more bioaccessible after 50 Hz/10 min of ACP treatment than untreated açai pulp samples, as well as antioxidant activity. The depolymerization of procyanidins, which are polymeric and oligomeric complexes of catechin and epicatechin, brought a rise in monomeric phenolics. Procyanidin B2 (135.6%) and quercetin-3-glucoside (74.77%) had higher bioaccessibility when processing time was extended at the same frequency (50 Hz/15 min). Procyanidin B1, caffeine, and catechin all had lower bioaccessibility indices. The ACP processing positively impacted the caffeine acid content, improving its bioaccessibility after being treated at 50 Hz for 10 min and 500 Hz for 15 min (Dantas et al., 2021).

Some bioactive chemicals are more sensitive to ACP processing, especially at a higher frequency. Therefore, using optimization techniques and a combination of other technologies may help to prevent the unfavorable impact of specific quality parameters on fruits and fruit juices (Dantas et al., 2021). Although CP ensures the rise in phenolic concentration, the outcomes rely on the food matrix. Nonthermal processing can change the chemical composition of the food matrix and enhance the nutritional value of fruits and vegetables. Indeed, bioactive compounds may become more bioaccessible (Leite et al., 2021). Combining nonthermal processing methods could have benefits including increased enzyme and microorganism inactivation and a decrease in detrimental effects on the food matrix (Linhares et al., 2020). It was revealed that the bioaccessibility of total phenolics and anthocyanins in açai juice was lowered to 40% of the unprocessed juice by the combined ultrasound and low-pressure plasma processing (Linhares et al., 2020).

5 | DISCUSSION

CP technology holds tremendous promise for extending shelf life and augmenting the nutritional value, antioxidant activity, and bioactives, including phenolics and vitamin C. However, the effectiveness of CP is contingent upon adjusting various influencing factors. Although CP technology has garnered approval for its significant potential across various targets, carefully selecting an appropriate CP model is crucial to achieving the desired outcomes. CP has the potential to provide several advantages, but adverse effects should also be considered. Consequently, scientists are urged to investigate meticulous discernment in selecting treatment parameters, emphasizing a precise approach to attain the intended results. This underscores the importance of precision in experimental design and the application of CP treatments to strike a delicate balance between positive effects and potential drawbacks. The technology has proven effective as a nonthermal method for decontamination, providing an alternative to traditional technologies. However, food matrix, interactions between components, product surface characteristics, processing variables, and intrinsic factors should all be considered for the improvement of the efficiency of this technology.

The cumulative antioxidant effect of various bioactive compounds influences the aggregate's antioxidant capacity and phenolic compounds. It is important to note that an increase in overall phenolic content or other groups of bioactive chemicals does not necessarily lead to a proportional escalation in antioxidant capacity. Instances where the concentration of compounds with high antioxidant capacity diminishes while those with lower antioxidant capacity increase may result in a higher overall concentration of bioactive compounds but a lower concentration of antioxidant capacity. The breakdown of antioxidant compounds occurs due to factors such as oxidation, exposure to light, and enzymatic reactions. Enzymatic degradation, primarily instigated by enzymes like ascorbate oxidase, PPO, cytochrome oxidase, and peroxidase, plays a significant role in this process. While applying plasma may amplify antioxidant capacity up to a specific processing duration, prolonged exposure to plasma species and their free radicals may eventually diminish the antioxidant capacity of the product. This decline could be attributed to the potential overexposure and subsequent detrimental impact of plasma species, emphasizing the delicate balance required for optimizing antioxidant benefits through plasma treatment (Figure 1). In a study on the germination of paddy rice, a decreasing trend in antioxidant activity and phenolic compounds was observed. This decline could be linked to the inactivation of phenylalanine ammonia-lyase, a key enzyme in phenolic compound biosynthesis (Zargarchi & Saremnezhad, 2019). On the other hand, the liberation and synthesis of phenolic compounds involve specific mechanisms. Notably, phenolic entities, such as hydroxycinnamates, form associations with non-starch polysaccharides within cell walls, creating bonds like ester and ether linkages. The catalytic action of cell wall-degrading enzymes, particularly esterases, actively contributes to the release of previously bound phenolic compounds. Simultaneously, investigations have reported the activation of phenylalanine ammonia-lyase, a pivotal enzyme in the biosynthesis of phenolic compounds. This dual dynamic of enzymatic bond cleavage and enzymatic activation offers a nuanced understanding of the regulatory processes governing phenolic compound dynamics during various developmental stages (Perales-Sánchez et al., 2014). In addition, CP treatment exhibits the potential to maintain the sensory quality of food products while minimizing the effects of heat on their nutritious qualities (Schnabel et al., 2019). However, the efficacy of CP treatment in food processing is subject to several influential factors. These include the type of gas, relative humidity, temperature, flow rate, frequency, material, thickness, and spacing of electrodes and barrier, treatment and storage time, headspace and volume ratio product in-package, product rolling, direct and remote exposure, and hurdle treatment (synergism of different technologies). Furthermore, product features such as surface characteristics, product type (plant or animal-based), composition, and water content, along with microbiological factors including initial count, type of pathogen, and growth rate, can impact the effectiveness of CP treatment (Bagheri & Abbaszadeh, 2020). The study underscores the importance of optimizing product surface characteristics and processing variables for a more efficient CP application. In short, the studies that have been conducted so far emphasize the need for a holistic understanding and careful adjustment of these factors to unlock the full potential of CP technology in food processing.

6 | CONCLUSION

The utilization of CP technology in fruit and fruit juice preservation and processing resulted in a wide range of effects, either an increase or a decrease, on their physicochemical and nutritional properties, specifically concerning antioxidant activity and phenolic compounds. This highlights the need for additional investigations to unravel the underlying mechanisms governing these variations, considering factors such as the type of CP used, the method of generation, and environmental conditions. Although there are many studies in the literature about the bioavailability of bioactive compounds in fruits and their products, studies on the effect of nonthermal technological processes, especially CP, are minimal. Although CP technology has garnered approval for its significant potential across various targets, carefully selecting an appropriate CP model is crucial to achieving desired outcomes. CP exhibits a dual nature, presenting both positive and potentially undesirable effects.

Consequently, scientists are urged to exercise meticulous discernment in selecting treatment parameters, emphasizing a precise approach to attain intended results. This underscores the importance of precision in experimental design and the application of CP treatments to strike a delicate balance between positive effects and potential drawbacks. The technology has proven effective as a nonthermal method for decontamination, providing an alternative to traditional technologies. Conducting comparative analyses between CP treatment and traditional preservation methods such as pasteurization, sterilization, or other emerging technologies for fresh fruits or their products would provide valuable insights in terms of the feasibility of CP technology as a potential alternative to current approaches while identifying its advantages and limitations.

ACKNOWLEDGMENTS

The publication of this article was funded by the open access fund of Leibniz Universität Hannover. E.C. and T.E. thank to Alexander von Humboldt Foundation (Germany) for supporting with Georg Forster Award.

Open access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

ORCID

Sina Zargarchi https://orcid.org/0000-0002-9406-5563
Johann Hornbacher https://orcid.org/0000-0001-5302-475X
Deniz Günal-Köroğlu https://orcid.org/0000-0002-8642-9160
Esra Capanoglu https://orcid.org/0000-0003-0335-9433
Tuba Esatbeyoglu https://orcid.org/0000-0003-2413-6925

REFERENCES

Acquavia, M., Pascale, R., Foti, L., Carlucci, G., Scrano, L., Martelli, G., Brienza, M., Coviello, D., Bianco, G., & Lelario, F. (2021). Analytical methods for extraction and identification of primary and secondary metabolites of apple (*Malus domestica*) fruits: A review. *Separations*, *8*(7), 91. https://doi.org/10.3390/separations8070091

Adiletta, G., Russo, P., Senadeera, W., & di Matteo, M. (2016). Drying characteristics and quality of grape under physical pretreatment. *Journal of Food Engineering*, *172*, 9–18. https://doi.org/10.1016/j.jfoodeng.2015.06.031

Agar, I. T., Massantini, R., Hess-Pierce, B., & Kader, A. A. (1999). Postharvest CO_2 and ethylene production and quality maintenance of fresh-cut kiwifruit slices. *Journal of Food Science*, *64*(3), 433–440. https://doi.org/10.1111/j.1365-2621.1999.tb15058.x

Azevedo, D. C. S., & Rodrigues, A. E. (2005). Separation of fructose and glucose from cashew apple juice by SMB chromatography. *Separation Science and Technology*, *40*(9), 1761–1780. https://doi.org/10.1081/SS-200064559

Bagheri, H., & Abbaszadeh, S. (2020). Effect of cold plasma on quality retention of fresh-cut produce. *Journal of Food Quality*, *2020*, 8866369, 1–8. https://doi.org/10.1155/2020/8866369

Bai, J.-W., Sun, D.-W., Xiao, H.-W., Mujumdar, A. S., & Gao, Z.-J. (2013). Novel high-humidity hot air impingement blanching (HHAIB) pretreatment enhances drying kinetics and color attributes of seedless grapes. *Innovative Food Science & Emerging Technologies*, *20*, 230–237. https://doi.org/10.1016/j.ifset.2013.08.011

Barreca, D., Bellocco, E., Caristi, C., Leuzzi, U., & Gattuso, G. (2011). Kumquat (*Fortunella japonica* Swingle) juice: Flavonoid distribution and antioxidant properties. *Food Research International*, *44*(7), 2190–2197. https://doi.org/10.1016/j.foodres.2010.11.031

Barreiros, M. L., Jesus, R. A. D., Barreiros, A., Sandes, T. S., Ramalho, S. A., & Narain, N. (2018). Evaluation of the antioxidant activity of eight tropical fruits by DPPH method. *Acta Horticulturae*, *1198*(1198), 185–192. https://doi.org/10.17660/ActaHortic.2018.1198.29

Bohn, T. (2014). Dietary factors affecting polyphenol bioavailability. *Nutrition Reviews*, *72*(7), 429–452. https://doi.org/10.1111/nure.12114

Bursać Kovačević, D., Putnik, P., Dragović-Uzelac, V., Pedisić, S., Režek Jambrak, A., & Herceg, Z. (2016). Effects of cold atmospheric gas phase plasma on anthocyanins and color in pomegranate juice. *Food Chemistry*, *190*, 317–323. https://doi.org/10.1016/j.foodchem.2015.05.099

Campolo, O., Romeo, F. V., Algeri, G. M., Laudani, F., Malacrinò, A., Timpanaro, N., & Palmeri, V. (2016). Larvicidal effects of four citrus peel essential oils against the arbovirus vector *Aedes albopictus* (*Diptera*: *Culicidae*). *Journal of Economic Entomology*, *109*(1), 360–365. https://doi.org/10.1093/jee/tov270

Canene-Adams, K., Lindshield, B. L., Wang, S., Jeffery, E. H., Clinton, S. K., & Erdman, J. W. (2007). Combinations of tomato and broccoli enhance antitumor activity in dunning r3327-h prostate adenocarcinomas. *Cancer Research*, *67*(2), 836–843. https://doi.org/10.1158/0008-5472.CAN-06-3462

Cao, H., Saroglu, O., Karadag, A., Diaconeasa, Z., Zoccatelli, G., Conte-Junior, C. A., Gonzalez-Aguilar, G. A., Ou, J., Bai, W., Zamarioli, C. M., de Freitas, L. A. P., Shpigelman, A., Campelo, P. H., Capanoglu, E., Hii, C. L., Jafari, S. M., Qi, Y., Liao, P., Wang, M., … Xiao, J. (2021). Available technologies on improving the stability of polyphenols in food processing. *Food Frontiers*, *2*(2), 109–139. https://doi.org/10.1002/fft2.65

Castro, D. R. G., Mar, J. M., Da Silva, L. S, Da Silva, K. A., Sanches, E. A., Araújo Bezerra, J. A., Rodrigues, S., Fernandes, F. A. N., & Campelo, P. H. (2020). Improvement of the bioavailability of Amazonian juices rich in bioactive compounds using glow plasma technique. *Food and Bioprocess Technology*, *13*(4), 670–679. https://doi.org/10.1007/s11947-020-02427-8

de Castro, D. R. G., Mar, J. M., da Silva, L. S., da Silva, K. A., Sanches, E. A., de Araújo Bezerra, J., Rodrigues, S., Fernandes, F. A. N., & Campelo, P. H. (2020). Dielectric barrier atmospheric cold plasma applied on camu–camu juice processing: Effect of the excitation frequency. *Food Research International*, *131*, 109044. https://doi.org/10.1016/j.foodres.2020.109044

Chen, C., Liu, C., Jiang, A., Guan, Q., Sun, X., Liu, S., Hao, K., & Hu, W. (2019). The effects of cold plasma-activated water treatment on the microbial growth and antioxidant properties of fresh-cut pears. *Food and Bioprocess Technology*, *12*(11), 1842–1851. https://doi.org/10.1007/s11947-019-02331-w

Chen, J., Venkitasamy, C., Shen, Q., McHugh, T. H., Zhang, R., & Pan, Z. (2018). Development of healthy crispy carrot snacks using sequential infrared blanching and hot air drying method. *LWT*, *97*, 469–475. https://doi.org/10.1016/j.lwt.2018.07.026

Chen, M.-H., Yang, K.-M., Huang, T.-C., & Wu, M.-L. (2017). Traditional small-size citrus from Taiwan: Essential oils, bioactive compounds and antioxidant capacity. *Medicines*, *4*(2), 28. https://doi.org/10.3390/medicines4020028

Chizoba Ekezie, F.-G., Sun, D.-W., & Cheng, J.-H. (2017). A review on recent advances in cold plasma technology for the food industry: Current applications and future trends. *Trends in Food Science & Technology*, *69*, 46–58. https://doi.org/10.1016/j.tifs.2017.08.007

Christofi, M., Pavlou, A., Lantzouraki, D. Z., Tsiaka, T., Myrtsi, E., Zoumpoulakis, P., Haroutounian, S. A., Mauromoustakos, A., Biliaderis, C. G., & Manganaris, G. A. (2022). Profiling carotenoid and phenolic compounds in fresh and canned fruit of peach cultivars: Impact of genotype and canning on their concentration. *Journal of Food Composition and Analysis*, *114*, 104734. https://doi.org/10.1016/j.jfca.2022.104734

Čolić, M., Mihajlović, D., Bekić, M., Marković, M., Dragišić, B., Tomić, S., Miljuš, N., Šavikin, K., & Škrbić, R. (2022). Immunomodulatory activity of punicalagin, punicalin, and ellagic acid differs from the effect of pomegranate peel extract. *Molecules (Basel, Switzerland)*, *27*(22), 7871. https://doi.org/10.3390/molecules27227871

da Silva Severino Lima, J., da Silva, L. M. R., Fonteles, T. V., de Figueiredo, E. A. T., Mendes, A. E. P., de Oliveira Souza, T., Campos, J. O. S., Ricardo, N. M. P. S., & de Sousa, P. H. M. (2022). Bioaccessibility, antioxidant and antibacterial potentials of phenolic compounds ultrasonically extracted from acerola *Malpighia glabra* DC coproduct. *Current Bioactive Compounds*, *18*(4), e161221196727. https://doi.org/10.2174/1574893616666210922121641

Dantas, A. M., Batista, J. D. F., dos Santos Lima, M., Fernandes, F. A., Rodrigues, S., Magnani, M., & da Borges, G. S. C. (2021). Effect of cold plasma on açai pulp: Enzymatic activity, color and bioaccessibility of phenolic compounds. *LWT*, *149*, 111883. https://doi.org/10.1016/j.lwt.2021.111883

Dantas, A. M., Mafaldo, I. M., Oliveira, P. M. D. L., Lima, M. D. S., Magnani, M., & da Borges, G. S. C. (2019). Bioaccessibility of phenolic compounds in native and exotic frozen pulps explored in Brazil using a digestion model coupled with a simulated intestinal barrier. *Food Chemistry*, *274*, 202–214. https://doi.org/10.1016/j.foodchem.2018.08.099

Darvish, F., Mostofi Sarkari, N., Khani, M., Eslami, E., Shokri, B., Mohseni, M., Ebrahimi, M., Alizadeh, M., & Dee, C. F. (2020). Direct plasma treatment approach based on non-thermal gliding arc for surface modification of biaxially-oriented polypropylene with post-exposure hydrophilicity improvement and minus aging effects. *Applied Surface Science*, *509*, 144815. https://doi.org/10.1016/j.apsusc.2019.144815

Dasan, B. G., & Boyaci, I. H. (2018). Effect of cold atmospheric plasma on inactivation of *Escherichia coli* and physicochemical properties of apple, orange, tomato juices, and sour cherry nectar. *Food and Bioprocess Technology*, *11*(2), 334–343. https://doi.org/10.1007/s11947-017-2014-0

di Matteo, M., Cinquanta, L., Galiero, G., & Crescitelli, S. (2000). Effect of a novel physical pretreatment process on the drying kinetics of seedless grapes. *Journal of Food Engineering*, *46*(2), 83–89. https://doi.org/10.1016/S0260-8774(00)00071-6

Dong, S., Fan, L., Ma, Y., Du, J., & Xiang, Q. (2021). Inactivation of polyphenol oxidase by dielectric barrier discharge (DBD) plasma: Kinetics and mechanisms. *LWT*, *145*, 111322. https://doi.org/10.1016/j.lwt.2021.111322

Doymaz, İ., & Pala, M. (2002). The effects of dipping pretreatments on air-drying rates of the seedless grapes. *Journal of Food Engineering*, *52*(4), 413–417. https://doi.org/10.1016/S0260-8774(01)00133-9

Dubrovin, I. A., Emanuel, E., Lazra, Y., & Cahan, R. (2023). Effects of atmospheric plasma corona discharge on saccharomyces cerevisiae: Viability, permeability, and morphology. *Foods*, *12*(2), 381. https://doi.org/10.3390/foods12020381

Elez Garofulić, I., Režek Jambrak, A., Milošević, S., Dragović-Uzelac, V., Zorić, Z., & Herceg, Z. (2015). The effect of gas phase plasma treatment on the anthocyanin and phenolic acid content of sour cherry marasca (*Prunus cerasus* var. marasca) juice. *LWT—Food Science and Technology*, *62*(1), 894–900. https://doi.org/10.1016/j.lwt.2014.08.036

Farooq, S., Dar, A. H., Dash, K. K., Srivastava, S., Pandey, V. K., Ayoub, W. S., Pandiselvam, R., Manzoor, S., & Kaur, M. (2023). Cold plasma treatment advancements in food processing and impact on the physiochemical characteristics of food products. *Food Science and Biotechnology*, *32*(5), 621–638. https://doi.org/10.1007/s10068-023-01266-5

Feliziani, E., Lichter, A., Smilanick, J. L., & Ippolito, A. (2016). Disinfecting agents for controlling fruit and vegetable diseases after harvest. *Postharvest Biology and Technology*, *122*, 53–69. https://doi.org/10.1016/j.postharvbio.2016.04.016

Fernandes, F. A. N., & Rodrigues, S. (2021). Cold plasma processing on fruits and fruit juices: A review on the effects of plasma on nutritional quality. *Processes*, *9*(12), 2098. https://doi.org/10.3390/pr9122098

Fernandes, F. A. N., Santos, V. O., & Rodrigues, S. (2019). Effects of glow plasma technology on some bioactive compounds of acerola juice. *Food Research International*, *115*, 16–22. https://doi.org/10.1016/j.foodres.2018.07.042

Fridman, A. A., & Friedman, G. (2013). *Plasma medicine* (p. 1). Chichester, UK: John Wiley & Sons.

Gadri, R. B., Roth, J., Montie, T. C., Kelly-Wintenberg, K., Tsai, P. P.-Y., Helfritch, D. J., Feldman, P., Sherman, D. M., Karakaya, F., & Chen, Z. (2000). Sterilization and plasma processing of room temperature surfaces with a one atmosphere uniform glow discharge plasma (OAUGDP). *Surface and Coatings Technology*, *131*(1–3), 528–541. https://doi.org/10.1016/S0257-8972(00)00803-3

Gan, Z., Feng, X., Hou, Y., Sun, A., & Wang, R. (2021). Cold plasma jet with dielectric barrier configuration: Investigating its effect on the cell membrane of *E. coli* and *S. cerevisiae* and its impact on the quality of chokeberry juice. *LWT*, *136*, 110223. https://doi.org/10.1016/j.lwt.2020.110223

Gonçalves, B., Landbo, A.-K., Knudsen, D., Silva, A. P., Moutinho-Pereira, J., Rosa, E., & Meyer, A. S. (2004). Effect of ripeness and postharvest storage on the phenolic profiles of cherries (*Prunus avium* L.). *Journal of Agricultural and Food Chemistry*, *52*(3), 523–530. https://doi.org/10.1021/jf030595s

Grzegorzewski, F., Ehlbeck, J., Schlüter, O., Kroh, L. W., & Rohn, S. (2011). Treating lamb's lettuce with a cold plasma–Influence of atmospheric pressure Ar plasma immanent species on the phenolic profile of *Valerianella locusta*. *LWT*, *44*(10), 2285–2289. https://doi.org/10.1016/j.lwt.2011.05.004

Herceg, Z., Kovačević, D. B., Kljusurić, J. G., Jambrak, A. R., Zorić, Z., & Dragović-Uzelac, V. (2016). Gas phase plasma impact on phenolic compounds in pomegranate juice. *Food Chemistry*, *190*, 665–672. https://doi.org/10.1016/j.foodchem.2015.05.135

Hernández-Martínez, N. R., Blanchard, C., Wells, D., & Salazar-Gutiérrez, M. R. (2023). Current state and future perspectives of commercial strawberry production: A review. *Scientia Horticulturae*, *312*, 111893. https://doi.org/10.1016/j.scienta.2023.111893

Horvitz, S. (2017). Postharvest handling of berries. In I. Kahramanoglu (Ed.), *Postharvest handling* (pp. 107–123). InTech. https://doi.org/10.5772/intechopen.69073

Hou, Y., Wang, R., Gan, Z., Shao, T., Zhang, X., He, M., & Sun, A. (2019). Effect of cold plasma on blueberry juice quality. *Food Chemistry*, *290*, 79–86. https://doi.org/10.1016/j.foodchem.2019.03.123

Huber, G. M., & Rupasinghe, H. P. V. (2009). Phenolic profiles and antioxidant properties of apple skin extracts. *Journal of Food Science*, *74*(9), C693–C700. https://doi.org/10.1111/j.1750-3841.2009.01356.x

Hussain, S. Z., Naseer, B., Qadri, T., Fatima, T., & Bhat, T. A. (2021). Pear (*Pyrus communis*)—Morphology, taxonomy, composition and health benefits. In S. Z. Hussain, B. Naseer, T. Qadri, T. Fatima, & T. A. Bhat (Eds.), *Fruits grown in highland regions of the Himalayas* (pp. 35–48). Springer International Publishing. https://doi.org/10.1007/978-3-030-75502-7_3

de Jesus, A. L. T., Cristianini, M., dos Santos, N. M., & Maróstica, M. R. Jr. (2020). Effects of high hydrostatic pressure on the microbial inactivation and extraction of bioactive compounds from açaí (*Euterpe oleracea*

Martius) pulp. *Food Research International*, *130*, 108856. https://doi.org/10.1016/j.foodres.2019.108856

Leite, A. K. F., Fonteles, T. V., Miguel, T. B. A. R., Silvestre da Silva, G., Sousa de Brito, E., Alves Filho, E. G., Fernandes, F. A. N., & Rodrigues, S. (2021). Atmospheric cold plasma frequency imparts changes on cashew apple juice composition and improves vitamin C bioaccessibility. *Food Research International*, *147*, 110479. https://doi.org/10.1016/J.FOODRES.2021.110479

Khoshkalam Pour, A., Khorram, S., Ehsani, A., Ostadrahimi, A., & Ghasempour, Z. (2022). Atmospheric cold plasma effect on quality attributes of banana slices: Its potential use in blanching process. *Innovative Food Science & Emerging Technologies*, *76*, 102945. https://doi.org/10.1016/j.ifset.2022.102945

Kim, D.-O., Heo, H. J., Kim, Y. J., Yang, H. S., & Lee, C. Y. (2005). Sweet and sour cherry phenolics and their protective effects on neuronal cells. *Journal of Agricultural and Food Chemistry*, *53*(26), 9921–9927. https://doi.org/10.1021/jf0518599

Klockow, P. A., & Keener, K. M. (2009). Safety and quality assessment of packaged spinach treated with a novel ozone-generation system. *LWT—Food Science and Technology*, *42*(6), 1047–1053. https://doi.org/10.1016/j.lwt.2009.02.011

La Rosa, L. A. D., Moreno-Escamilla, J. O., Rodrigo-García, J., & Alvarez-Parrilla, E. (2019). Phenolic compounds. In *Postharvest physiology and biochemistry of fruits and vegetables* (pp. 253–271). Elsevier. https://doi.org/10.1016/B978-0-12-813278-4.00012-9

Lado, J., Rodrigo, M. J., & Zacarías, L. (2014). Maturity indicators and citrus fruit quality. *Stewart Postharvest Review*, *10*(2), 1–6.

Li, X., Li, M., Ji, N., Jin, P., Zhang, J., Zheng, Y., Zhang, X., & Li, F. (2019). Cold plasma treatment induces phenolic accumulation and enhances antioxidant activity in fresh-cut pitaya (*Hylocereus undatus*) fruit. *LWT*, *115*, 108447. https://doi.org/10.1016/j.lwt.2019.108447

Liao, X., Li, J., Muhammad, A. I., Suo, Y., Chen, S., Ye, X., Liu, D., & Ding, T. (2018). Application of a dielectric barrier discharge atmospheric cold plasma (DBD-ACP) for *Eshcerichia coli* inactivation in apple juice. *Journal of Food Science*, *83*(2), 401–408. https://doi.org/10.1111/1750-3841.14045

Lim, H.-K., Tan, C.-P., Bakar, J., & Ng, S.-P. (2012). Effects of different wall materials on the physicochemical properties and oxidative stability of spray-dried microencapsulated red-fleshed pitaya (*Hylocereus polyrhizus*) seed oil. *Food and Bioprocess Technology*, *5*(4), 1220–1227. https://doi.org/10.1007/s11947-011-0555-1

Lim, Y. Y., Lim, T. T., & Tee, J. J. (2007). Antioxidant properties of several tropical fruits: A comparative study. *Food Chemistry*, *103*(3), 1003–1008. https://doi.org/10.1016/j.foodchem.2006.08.038

Lin, C.-C., Hung, P.-F., & Ho, S.-C. (2008). Heat treatment enhances the NO-suppressing and peroxynitrite-intercepting activities of kumquat (*Fortunella margarita* Swingle) peel. *Food Chemistry*, *109*(1), 95–103. https://doi.org/10.1016/j.foodchem.2007.12.053

Linhares, M. D. F. D., Alves Filho, E. G., Silva, L. M. A., Fonteles, T. V., Wurlitzer, N. J., de Brito, E. S., Fernandes, F. A. N., & Rodrigues, S. (2020). Thermal and non-thermal processing effect on açai juice composition. *Food Research International*, *136*, 109506. https://doi.org/10.1016/J.FOODRES.2020.109506

Lu, P., Cullen, P. J., & Ostrikov, K. (2016). Atmospheric pressure nonthermal plasma sources. In *Cold* plasma in food and agriculture (pp. 83–116). Elsevier. https://doi.org/10.1016/B978-0-12-801365-6.00004-4

Lu, X., Laroussi, M., & Puech, V. (2012). On atmospheric-pressure non-equilibrium plasma jets and plasma bullets. *Plasma Sources Science and Technology*, *21*(3), 34005. https://doi.org/10.1088/0963-0252/21/3/034005

Martínez, R., Torres, P., Meneses, M. A., Figueroa, J. G., Pérez-Álvarez, J. A., & Viuda-Martos, M. (2012). Chemical, technological and in vitro antioxidant properties of mango, guava, pineapple and passion fruit dietary fibre concentrate. *Food Chemistry*, *135*(3), 1520–1526. https://doi.org/10.1016/j.foodchem.2012.05.057

Miraei Ashtiani, S.-H., Rafiee, M., Mohebi Morad, M., Khojastehpour, M., Khani, M. R., Rohani, A., Shokri, B., & Martynenko, A. (2020). Impact of gliding arc plasma pretreatment on drying efficiency and physicochemical properties of grape. *Innovative Food Science & Emerging Technologies*, *63*, 102381. https://doi.org/10.1016/j.ifset.2020.102381

Misra, N. N. (2015). The contribution of non-thermal and advanced oxidation technologies towards dissipation of pesticide residues. *Trends in Food Science & Technology*, *45*(2), 229–244. https://doi.org/10.1016/j.tifs.2015.06.005

Misra, N. N., Pankaj, S. K., Frias, J. M., Keener, K. M., & Cullen, P. J. (2015). The effects of nonthermal plasma on chemical quality of strawberries. *Postharvest Biology and Technology*, *110*, 197–202. https://doi.org/10.1016/j.postharvbio.2015.08.023

Misra, N. N., Patil, S., Moiseev, T., Bourke, P., Mosnier, J. P., Keener, K. M., & Cullen, P. J. (2014). In-package atmospheric pressure cold plasma treatment of strawberries. *Journal of Food Engineering*, *125*, 131–138. https://doi.org/10.1016/j.jfoodeng.2013.10.023

Mousavi, M., Hosseini, S. M., Hosseini, H., Abedi, A.-S., Khani, M., Heshmati, A., Abhari, K., Shahraz, F., Taghizadeh, M., & Akhavan, A. (2022). Gliding arc plasma discharge conditions on microbial, physicochemical, and sensory properties of shrimp (*Litopenaeus vannamei*): In vivo and in vitro studies. *Food and Bioprocess Technology*, *15*(10), 2327–2343. https://doi.org/10.1007/s11947-022-02886-1

Newerli-Guz, J., Śmiechowska, M., Drzewiecka, A., & Tylingo, R. (2023). Bioactive ingredients with health-promoting properties of strawberry fruit (*Fragaria x ananassa* Duchesne). *Molecules (Basel, Switzerland)*, *28*(6), 2711. https://doi.org/10.3390/molecules28062711

Nindo, C. I., Tang, J., Powers, J. R., & Singh, P. (2005). Viscosity of blueberry and raspberry juices for processing applications. *Journal of Food Engineering*, *69*(3), 343–350. https://doi.org/10.1016/j.jfoodeng.2004.08.025

Oner, M. E., Gultekin Subasi, B., Ozkan, G., Esatbeyoglu, T., & Capanoglu, E. (2023). Efficacy of cold plasma technology on the constituents of plant-based food products: Principles, current applications, and future potentials. *Food Research International*, *172*, 113079. https://doi.org/10.1016/j.foodres.2023.113079

Paixão, L. M. N., Fonteles, T. V., Oliveira, V. S., Fernandes, F. A. N., & Rodrigues, S. (2019). Cold plasma effects on functional compounds of siriguela juice. *Food and Bioprocess Technology*, *12*(1), 110–121. https://doi.org/10.1007/s11947-018-2197-z

Pankaj, S. K., Wan, Z., & Keener, K. M. (2018). Effects of cold plasma on food quality: A review. *Foods*, *7*(1), 4. https://doi.org/10.3390/foods7010004

Pankaj, S. K., Wan, Z., Colonna, W., & Keener, K. M. (2017). Effect of high voltage atmospheric cold plasma on white grape juice quality. *Journal of the Science of Food and Agriculture*, *97*(12), 4016–4021. https://doi.org/10.1002/jsfa.8268

Peng, M., Jiang, C., Jing, H., Du, X., Fan, X., Zhang, Y., & Wang, H. (2022). Comparison of different extraction methods on yield, purity, antioxidant, and antibacterial activities of proanthocyanidins from chokeberry (*Aronia melanocarpa*). *Journal of Food Measurement and Characterization*, *16*(3), 2049–2059. https://doi.org/10.1007/s11694-022-01319-z

Perales-Sánchez, J. X. K., Reyes-Moreno, C., Gómez-Favela, M. A., Milán-Carrillo, J., Cuevas-Rodríguez, E. O., Valdez-Ortiz, A., & Gutiérrez-Dorado, R. (2014). Increasing the antioxidant activity, total phenolic and flavonoid contents by optimizing the germination conditions of amaranth seeds. *Plant Foods for Human Nutrition*, *69*(3), 196–202. https://doi.org/10.1007/s11130-014-0430-0

Phan, K. T. K., Phan, H. T., Boonyawan, D., Intipunya, P., Brennan, C. S., Regenstein, J. M., & Phimolsiripol, Y. (2018). Non-thermal plasma for elimination of pesticide residues in mango. *Innovative Food Science & Emerging Technologies*, *48*, 164–171. https://doi.org/10.1016/j.ifset.2018.06.009

Puligundla, P., Lee, T., & Mok, C. (2018). Effect of intermittent corona discharge plasma treatment for improving microbial quality and shelf life of kumquat (*Citrus japonica*) fruits. *LWT*, *91*, 8–13. https://doi.org/10.1016/j.lwt.2018.01.019

Ragheb, A. Y., Masoud, M. A., El Shabrawy, M. O., Farid, M. M., Hegazi, N. M., Mohammed, R. S., Marzouk, M. M., & Aboutabl, M. E. (2023). MS/MS-based molecular networking for mapping the chemical diversity of the pulp and peel extracts from *Citrus japonica* Thunb.; in vivo evaluation of their anti-inflammatory and anti-ulcer potential. *Scientific African*, *20*, e01672. https://doi.org/10.1016/j.sciaf.2023.e01672

Ramazzina, I., Berardinelli, A., Rizzi, F., Tappi, S., Ragni, L., Sacchetti, G., & Rocculi, P. (2015). Effect of cold plasma treatment on physico-chemical parameters and antioxidant activity of minimally processed kiwifruit. *Postharvest Biology and Technology*, *107*, 55–65. https://doi.org/10.1016/j.postharvbio.2015.04.008

Redondo, D., Gimeno, D., Calvo, H., Venturini, M. E., Oria, R., & Arias, E. (2021). Antioxidant activity and phenol content in different tissues of stone fruits at thinning and at commercial maturity stages. *Waste and Biomass Valorization*, *12*(4), 1861–1875. https://doi.org/10.1007/s12649-020-01133-y

Rodríguez, Ó., Eim, V., Rosselló, C., Femenia, A., Cárcel, J. A., & Simal, S. (2018). Application of power ultrasound on the convective drying of fruits and vegetables: Effects on quality. *Journal of the Science of Food and Agriculture*, *98*(5), 1660–1673. https://doi.org/10.1002/jsfa.8673

Rodríguez, Ó., Gomes, W. F., Rodrigues, S., & Fernandes, F. A. (2017). Effect of indirect cold plasma treatment on cashew apple juice (*Anacardium occidentale* L.). *LWT*, *84*, 457–463. https://doi.org/10.1016/j.lwt.2017.06.010

Sakudo, A., Misawa, T., & Yagyu, Y. (2020). Equipment design for cold plasma disinfection of food products. In *Advances in cold plasma applications for food safety and preservation* (pp. 289–307). Elsevier. https://doi.org/10.1016/B978-0-12-814921-8.00010-4

Santos, I. L., Miranda, L. C. F., Da Cruz Rodrigues, A. M., Da Silva, L. H. M., & Amante, E. R. (2022). Camu–camu *Myrciaria dubia* (HBK) McVaugh: A review of properties and proposals of products for integral valorization of raw material. *Food Chemistry*, *372*, 131290. https://doi.org/10.1016/j.foodchem.2021.131290

Sarangapani, C., O'Toole, G., Cullen, P. J., & Bourke, P. (2017). Atmospheric cold plasma dissipation efficiency of agrochemicals on blueberries. *Innovative Food Science & Emerging Technologies*, *44*, 235–241. https://doi.org/10.1016/j.ifset.2017.02.012

Saremnezhad, S., Zargarchi, S., & Kalantari, Z. N. (2020). Calcium fortification of prebiotic ice-cream. *LWT*, *120*, 108890. https://doi.org/10.1016/j.lwt.2019.108890

Satpal, D., Kaur, J., Bhadariya, V., & Sharma, K. (2021). *Actinidia* deliciosa (kiwi fruit): A comprehensive review on the nutritional composition, health benefits, traditional utilization, and commercialization. *Journal of Food Processing and Preservation*, *45*(6), e15588. https://doi.org/10.1111/jfpp.15588

Schnabel, U., Handorf, O., Yarova, K., Zessin, B., Zechlin, S., Sydow, D., Zellmer, E., Stachowiak, J., Andrasch, M., Below, H., & Ehlbeck, J. (2019). Plasma-treated air and water-assessment of synergistic antimicrobial effects for sanitation of food processing surfaces and environment. *Foods*, *8*(2), 55. https://doi.org/10.3390/foods8020055

Shi, X.-M., Zhang, G.-J., Wu, X.-L., Li, Y.-X., Ma, Y., & Shao, X.-J. (2011). Effect of low-temperature plasma on microorganism inactivation and quality of freshly squeezed orange juice. *IEEE Transactions on Plasma Science*, *39*(7), 1591–1597. https://doi.org/10.1109/TPS.2011.2142012

Silveira, M. S., Fontes, C. P. M. L., Guilherme, A. A., Fernandes, F. A. N., & Rodrigues, S. (2012). Cashew apple juice as substrate for lactic acid production. *Food and Bioprocess Technology*, *5*(3), 947–953. https://doi.org/10.1007/s11947-010-0382-9

Ebnesajjad, S. (2009). Material surface preparation techniques. In *Adhesives technology handbook* (pp. 37–46). Elsevier. https://doi.org/10.1016/B978-0-8155-1533-3.50006-2

Skrovankova, S., Sumczynski, D., Mlcek, J., Jurikova, T., & Sochor, J. (2015). Bioactive compounds and antioxidant activity in different types of berries. *International Journal of Molecular Sciences*, *16*(10), 24673–24706. https://doi.org/10.3390/ijms161024673

Sun, Y., Tao, W., Huang, H., Ye, X., & Sun, P. (2019). Flavonoids, phenolic acids, carotenoids and antioxidant activity of fresh eating citrus fruits, using the coupled in vitro digestion and human intestinal $HepG_2$ cells model. *Food Chemistry*, *279*, 321–327. https://doi.org/10.1016/j.foodchem.2018.12.019

Surowsky, B., Fischer, A., Schlueter, O., & Knorr, D. (2013). Cold plasma effects on enzyme activity in a model food system. *Innovative Food Science & Emerging Technologies*, *19*, 146–152. https://doi.org/10.1016/j.ifset.2013.04.002

Tanrıöven, D., & Ekşi, A. (2005). Phenolic compounds in pear juice from different cultivars. *Food Chemistry*, *93*(1), 89–93. https://doi.org/10.1016/j.foodchem.2004.09.009

Tappi, S., Berardinelli, A., Ragni, L., Dalla Rosa, M., Guarnieri, A., & Rocculi, P. (2014). Atmospheric gas plasma treatment of fresh-cut apples. *Innovative Food Science & Emerging Technologies*, *21*, 114–122. https://doi.org/10.1016/j.ifset.2013.09.012

Tappi, S., Gozzi, G., Vannini, L., Berardinelli, A., Romani, S., Ragni, L., & Rocculi, P. (2016). Cold plasma treatment for fresh-cut melon stabilization. *Innovative Food Science & Emerging Technologies*, *33*, 225–233. https://doi.org/10.1016/j.ifset.2015.12.022

Tappi, S., Ragni, L., Tylewicz, U., Romani, S., Ramazzina, I., & Rocculi, P. (2019). Browning response of fresh-cut apples of different cultivars to cold gas plasma treatment. *Innovative Food Science & Emerging Technologies*, *53*, 56–62. https://doi.org/10.1016/j.ifset.2017.08.005

Umair, M., Jabbar, S., Nasiru, M. M., Sultana, T., Senan, A. M., Awad, F. N., Hong, Z., & Zhang, J. (2019). Exploring the potential of high-voltage electric field cold plasma (HVCP) using a dielectric barrier discharge (DBD) as a plasma source on the quality parameters of carrot juice. *Antibiotics*, *8*(4), 235. https://doi.org/10.3390/antibiotics8040235

Wang, C., Lu, Z., Li, D., Xia, W., & Xia, W. (2018). Effect of the magnetic field on the magnetically stabilized gliding arc discharge and its application in the preparation of carbon black nanoparticles. *Plasma Chemistry and Plasma Processing*, *38*(6), 1223–1238. https://doi.org/10.1007/s11090-018-9915-1

Wang, C. Y., Chen, C.-T., & Wang, S. Y. (2009). Changes of flavonoid content and antioxidant capacity in blueberries after illumination with UV-C. *Food Chemistry*, *117*(3), 426–431. https://doi.org/10.1016/j.foodchem.2009.04.037

Wang, H., Chen, G., Guo, X., Abbasi, A. M., & Liu, R. H. (2016). Influence of the stage of ripeness on the phytochemical profiles, antioxidant and antiproliferative activities in different parts of *Citrus reticulata* Blanco cv. Chachiensis. *LWT*, *69*, 67–75. https://doi.org/10.1016/j.lwt.2016.01.021

Wang, H., Guo, X., Hu, X., Li, T., Fu, X., & Liu, R. H. (2017). Comparison of phytochemical profiles, antioxidant and cellular antioxidant activities of different varieties of blueberry (*Vaccinium* spp.). *Food Chemistry*, *217*, 773–781. https://doi.org/10.1016/j.foodchem.2016.09.002

Wang, J., Mu, W.-S., Fang, X.-M., Mujumdar, A. S., Yang, X.-H., Xue, L.-Y., Xie, L., Xiao, H.-W., Gao, Z.-J., & Zhang, Q. (2017). Pulsed vacuum drying of Thompson seedless grape: Effects of berry ripeness on physicochemical properties and drying characteristic. *Food and Bioproducts Processing*, *106*, 117–126. https://doi.org/10.1016/j.fbp.2017.09.003

Whitehead, J. C. (2016). The chemistry of cold plasma. In *Cold plasma in food and agriculture* (pp. 53–81). Elsevier. https://doi.org/10.1016/B978-0-12-801365-6.00003-2

Won, M. Y., Lee, S. J., & Min, S. C. (2017). Mandarin preservation by microwave-powered cold plasma treatment. *Innovative Food Science & Emerging Technologies*, *39*, 25–32. https://doi.org/10.1016/j.ifset.2016.10.021

Wu, X., Zhao, W., Zeng, X., Zhang, Q.-A., Gao, G., & Song, S. (2021). Effects of cold plasma treatment on cherry quality during storage. *Food Science and Technology International = Ciencia Y Tecnologia De Los Alimentos Internacional*, *27*(5), 441–455. https://doi.org/10.1177/1082013220957134

Xiang, Q., Liu, X., Li, J., Liu, S., Zhang, H., & Bai, Y. (2018). Effects of dielectric barrier discharge plasma on the inactivation of *Zygosaccharomyces rouxii* and quality of apple juice. *Food Chemistry*, *254*, 201–207. https://doi.org/10.1016/j.foodchem.2018.02.008

Xiang, Y., Huang, C.-H., Hu, Y., Wen, J., Li, S., Yi, T., Chen, H., Xiang, J., & Ma, H. (2017). Evolution of *Rosaceae* fruit types based on nuclear phylogeny in the context of geological times and genome duplication. *Molecular Biology and Evolution*, *34*(2), 262–281. https://doi.org/10.1093/molbev/msw242

Zargarchi, S., & Saremnezhad, S. (2019). Gamma-aminobutyric acid, phenolics and antioxidant capacity of germinated indica paddy rice as affected by low-pressure plasma treatment. *LWT*, *102*, 291–294. https://doi.org/10.1016/j.lwt.2018.12.014

Zhao, X., & Yuan, Z. (2021). Anthocyanins from pomegranate (*Punica granatum* L.) and their role in antioxidant capacities in Vitro. *Chemistry & Biodiversity*, *18*(10), e2100399. https://doi.org/10.1002/cbdv.202100399

How to cite this article: Zargarchi, S., Hornbacher, J., Afifi, S. M., Saremnezhad, S., Günal-Köroğlu, D., Capanoglu, E., & Esatbeyoglu, T. (2024). Exploring the impact of cold plasma treatment on the antioxidant capacity, ascorbic acid, phenolic profile, and bioaccessibility of fruits and fruit juices. *Food Frontiers*, 1–18. https://doi.org/10.1002/fft2.372