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Nutritional, chemical and bioactive profiles of different parts of a Portuguese common fig (*Ficus carica* L.) variety

Luís Palmeira, Carla Pereira, Maria Inês Dias, Rui M.V. Abreu, Rúbia C.G. Corrêa, Tânia C.S.P. Pires, Maria José Alves, Lillian Barros*, Isabel C.F.R. Ferreira*

Centro de Investigação de Montanha (CIMO), Instituto Politécnico de Bragança, Campus de Santa Apolónia, 5300-253 Bragança, Portugal

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ABSTRACT

This study aims to give an unprecedented contribution on the chemical composition and bioactivities of the most produced and appreciated Portuguese fig variety ("Pingo de Mel") with the view of expanding the knowledge on its potentialities. An advanced characterization of its peel and pulp parts was carried out. Four free sugars (glucose, fructose, trehalose and sucrose), 5 organic acids (oxalic, quinic, malic, citric, and succinic acids), tocopherols in all their 4 forms, besides 23 fatty acids were detected in the samples. Fifteen different phenolic components were found in the peel hydroethanolic extract; whereas 12 were detected in the pulp hydroethanolic extract. Quercetin-3-*O*-rutinoside (rutin) was the major constituent of the peel, accounting for 33.8% of its phenolic content, followed by 5-*O*-caffeoylquinic acid and vanillic acid malonyl di-deoxyhexoside. Caffeic acid derivatives, such as caffeic acid hexosides, were the major components of pulp, followed by vanillic acid derivatives and *O*-caffeoylquinic acid. Both extracts displayed promising antioxidant capacities in all methods used, namely the 2,2-diphenyl-1-picrylhydrazyl radical-scavenging, the reducing power, the inhibition of β-carotene bleaching assays, the thiobarbituric acid reactive substances assay and the oxidative haemolysis inhibition assay; however, the peel presented significantly lower IC_{50} values than pulp. The extracts showed practically identical antibacterial capacities, being effective against methicillin-sensitive *Staphylococcus aureus* (MICs = 2.5 mg/mL), besides methicillin-resistant *S. aureus*, *Escherichia coli* and *Morganella morganii* (MICs = 5 mg/mL). The obtained results evidence that the fig peel is superior to the corresponding pulp as it relates to nutritional and phenolic profiles as well as bioactivities, endorsing the urgency in valorising and exploiting this usually discarded industrial by-product.

1. Introduction

Figs are the infrutecences of trees belonging to the *Ficus* genus, family Moraceae, which comprises > 800 distinct species that adapt well to warm and dry climates (Meziant, Boutiche, Bey, Saci, & Louaileche, 2018; Arvaniti, Samaras, Gatidou, Thomaidis, & Stasinakis, 2019). The tasty and nutritive fruit of the species *Ficus carica* L., also known as common fig, have been cultivated and appreciated by humankind since ancient times (Barolo, Mostacero, & López, 2014; Rodríguez-Solana, Galego, Pérez-Santín, & Romano, 2018). The fig fruit is seasonal, harvested twice a year; its skin color may range from dark purple to green, depending on the variety (Kamiloglu & Capanoglu, 2015). Figs are substantial sources of trace minerals (above all calcium, but also iron and potassium) and vitamins (mostly thiamin and riboflavin); in addition, present a high number of essential amino acids, and great contents of fibers and antioxidant phytochemicals (especially phenolic acids, flavonoids and carotenoids) (Arvaniti et al., 2019; Viuda-Martos, Barber, Perez-Alvarez, & Fernandez-Lopez, 2015).

For millennia *F. carica* has been applied in folk medicine to treat a series of illnesses related to digestive, endocrine, reproductive, and respiratory systems; gastrointestinal tract; urinary system infection, and skin diseases (Badgujar, Patel, Bandivdekar, & Mahajan, 2014; Shi et al., 2018). Sundry bioactivities, including antihyperlipidemic, antioxidant, antibacterial, antiprofilerative, anti-diabetic, antiobesogenic and hepatoprotective (Debib et al., 2016) effects, have been assessed and confirmed on fig fruit extracts by several in vivo and in vitro studies (Debib et al., 2016; Mopuri, Ganjayi, Meriga, Koorbanally, & Islam, 2018).

Nowadays, most of the world's fig production takes place in the Middle East and Mediterranean region. In 2017, > 1.15 million tons were yielded worldwide, with Turkey accounting for almost 27% of the global supply, followed by Egypt, Algeria, Morocco, Iran, Spain and

* Corresponding authors.
E-mail addresses: lillian@ipb.pt (L. Barros), iferreira@ipb.pt (I.C.F.R. Ferreira).

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Greece (FAO - Food and Agriculture Organization, 2017). Although the Portuguese fig production represents only a small part of the European contribution, yet it is an important crop for Portugal (FAO - Food and Agriculture Organization, 2017). Culturally valued by the Portuguese people, figs are consumed *in natura* or used as raw material by wine, liquor, jelly, and jam industries (Buenrostro-Figueroa et al., 2017). In the *F. carica* industrial processing, the pulp is used whereas the peel is discarded (Kamiloglu & Capanoglu, 2015); which generates a significant volume of by-products consisting of inadequate fruits (the overripe ones) and peels (Buenrostro-Figueroa et al., 2017; Viuda-Martos et al., 2015). Since these materials are proven to be abundant in nutrients and bioactive phytochemicals, concentrating the majority of the fig's phenolic compounds, their valorization and exploitation have been recently proposed by some authors (Viuda-Martos et al., 2015; Buenrostro-Figueroa et al., 2017; Backes et al., 2018; Meziant, et al. 2018).

In the past years, several groups have investigated the polyphenol constitution of the distinct parts of *F. carica* fruits (fresh and/or dried) from Israel (Solomon et al., 2006), Italy (Del Caro & Piga, 2008), Portugal (Oliveira et al., 2009), Turkey and Greece (Kamiloglu & Capanoglu, 2015; Russo, Caporaso, Paduano, & Sacchi, 2014), Albania (Hoxha & Kongoli, 2016), Pakistan (Ajmal et al., 2016), Tunisia (Ammar, del Mar Contreras, Belguith-Hadrich, Segura-Carretero, & Bouaziz, 2015; Harzallah, Bhouri, Amri, Soltana, & Hammami, 2016), Iran (Maghsoudlou, Esmaeilzadeh Kenari, & Raftani Amiri, 2017), Spain (Pereira et al., 2017; Vallejo, Marín, & Tomás-Barberán, 2012; Wojdyło, Nowicka, Carbonell-Barrachina, & Hernández, 2016), Algeria (Mahmoudi et al., 2018; Meziant et al. 2018), India and South Africa (Mopuri et al., 2018). Some authors have studied the volatile profile of many Portuguese fig cultivars (Oliveira et al., 2010; Rodríguez-Solana et al., 2018), whereas a recent work of our group demonstrated the feasibility of recovering bioactive anthocyanin pigments from the peel of a Portuguese purple fig variety via emerging technologies (Backes et al., 2018). Nevertheless, to our best knowledge, there are still no reports on the advanced phenolic characterization of Portuguese fig fruits nor on differences in single phenolic compounds in their peel and pulp parts.

This study aims to give an unprecedented contribution on the chemical composition and bioactivities of a very common and appreciated Portuguese fig variety ("Pingo de Mel") with the view of expanding the knowledge on its potentialities. For this purpose, its peel and pulp were comparatively characterized in terms of macronutrients, free sugars, organic acids, tocopherols and fatty acids. Furthermore, the phenolic profiles of their hydroethanolic extracts were determined, as well as their antioxidant and antibacterial potentials.

2. Materials and methods

2.1. Standards and reagents

Acetonitrile 99.9% was of HPLC grade from Fisher Scientific (Lisbon, Portugal). Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), sugar, organic acid and phenolic compound standards were from Sigma (St. Louis, MO, USA). Racemic tocol (50 mg mL^{-1}) and tocopherols, were purchased from Matreya (PA, USA). 2,2-Diphenyl-1-picrylhydrazyl (DPPH) was obtained from Alfa Aesar (Ward Hill, MA, USA). Dimethylsulfoxide (DMSO) (Merck KGaA, Germany) was used as a solvent in antimicrobial assays. Ethanol and all other chemicals were of analytical grade and purchased from common sources. Water was treated in a Milli-Q water purification system (TGI Pure Water Systems, Greenville, SC, USA).

2.2. Samples

The infructescences of *F. carica* variety "Pingo de Mel" were collected from a domestic production at the municipality of Bragança, Trás-os-Montes, Northeast of Portugal, in summer 2017. Two kilos of ripped fruits were selected, washed in running potable water, sanitized with sodium hypochlorite by immersion, and manually de-pulped. The lyophilized samples were and kept at −20 °C until analysis. Then, peel and pulp materials were separately frozen at −80 °C and thereafter freeze-dried (Zirbus Technonoly VaCo 10-II, Bad Grund, Germany) at −85 °C and 0.2 mbar.

2.3. Nutritional and chemical composition

The nutritional composition of the peel and pulp parts was estimated employing standard procedures (AOAC, 2016). The crude protein (N × 6.25) was determined using the macro-Kjeldahl method and the ash content via incineration at 550 ± 15 °C. The crude fat was estimated by extracting a known weight of lyophilized sample with petroleum ether in a Soxhlet apparatus, the ash content via incineration at 550 ± 15 °C, and the total carbohydrate amount was estimated by difference. Finally, the total energy value was calculated through the equation: Energy (kcal) = 4 × ($g_{proteins}$ + $g_{carbohydrates}$) + 9 × (g_{lipids}).

Free sugars were determined via high performance liquid chromatography coupled to a refraction index detector (HPLC-RI; Knauer, Smartline system 1000, Berlin, Germany), employing melezitose as the internal standard, according to the method of Barros, Pereira, and Ferreira (2013). Results were given in g per 100 g of fresh weight (fw).

Organic acids were assessed via liquid chromatography coupled to photodiode array detector (Shimadzu 20A series UFLC, Shimadzu Cooperation), as described by Barros, Pereira, and Ferreira (2013). Detection was accomplished using 215 and 245 nm as preferred wavelengths. Quantification was done by comparison of the area of the peaks recorded at 215 nm with calibration curves obtained from commercial standards of each organic acid. The results were expressed in mg per 100 g of fresh weight (fw).

Tocopherols were analyzed in a Knauer Smartline system 1000 (HPLC, Berlin, Germany) coupled to a fluorescence detector (FP-2020; Jasco, Easton, USA) using the internal standard methodology, as described by Pereira, Barros, Carvalho, and Ferreira (2013). Identification was performed comparing the tocopherols retention times with authentic standard compounds and quantification was achieved by comparison with dose–response curves constructed from authentic standards, using the IS (tocol) method. The results were given in mg per 100 g of fresh weight.

The fatty acids (FAs) were assessed by gas chromatography coupled with a flame ionization detector (GC-FID/capillary column, DANI model GC 1000, Contone, Switzerland), a split/splitless injector and a Macherey–Nagel column; their identification was achieved by comparing the relative retention times of FAME peaks from samples with commercial standards (Barros, Pereira, et al., 2013). Results were given in relative percentage of each FA.

2.4. Preparation of the hydroethanolic extracts

The lyophilized peel and pulp samples (~1 g) were extracted with an ethanol/water extractor solution (80:20, v/v; 30 mL), at 25 °C and 150 rpm during 1 h, followed by filtration (Whatman No. 4). Subsequently, the process was repeated with the residue, and the combined extracts were then concentrated under reduced pressure at 40 °C (rotary evaporator Büchi R-210, Flawil, Switzerland). Finally, the aqueous phase was lyophilized and the dried extracts were stored under – 20 °C until analysis.

2.5. Phenolic compounds characterization

The phenolic profiles were determined via liquid chromatography with photo-diode array detection coupled to electrospray ionization tandem mass spectrometry (LC-DAD-ESI/MSn) (Dionex Ultimate 3000 UPLC, Thermo Scientific, San Jose, CA, USA), according to the protocol

established by the authors (Bessada, Barreira, Barros, Ferreira, & Oliveira, 2016). Prior to the chromatographic analysis, the lyophilized extracts were dissolved in an ethanol:water (80:20, v/v) mixture. The detection was accomplished with a photodiode array detector (DAD) with 280, 330 and 370 nm as preferred wavelengths, and in a Linear Ion Trap LTQ XL mass spectrometer (Thermo Finnigan, San Jose, CA, USA) equipped with an ESI source operating in negative mode. Identification was achieved using commercial standard compounds (when possible) or by comparison with literature data. For each standard (Extrasynthèse, Genay, France), calibration curves were built using the UV signal. Quantification was done with the most fitting compound, and results were given in mg per g of extract.

2.6. Antioxidant activity evaluation

The lyophilized extracts were re-dissolved in ethanol:water (80:20, v/v) to achieve stock solutions, which were further diluted to provide a range of concentrations. Samples' antioxidant potentials were evaluated by three classical in vitro chemical-based methods, namely the DPPH radical-scavenging, the reducing power, and the inhibition of β-carotene bleaching assays; and by two cellular antioxidant activity (CAA) tests, specifically the inhibition of the production of thiobarbituric acid reactive substances assay (TBARS), and the oxidative haemolysis inhibition assay (OxHLIA). The first four methods were executed as related by Corrêa et al. (2015), with results expressed as IC_{50} values (mg/mL), i.e., extract concentration providing 50% of antioxidant activity.

The OxHLIA method was performed according to the protocol minutely described by Lockowandt et al. (2019). The erythrocytes employed in this assay were prepared according to Evans et al. (2013). Briefly, in a 48-well microplate, 200 μL of erythrocyte solution was mixed with 400 μL of either PBS solution (control); antioxidant samples were homogenized in PBS, or water (to induce full haemolysis). After an incubation period (37 °C, 10 min, with shaking), 200 μL of 2,2′-azobis (2-methylpropionamidine) dihydrochloride (160 mM in PBS) was added and the plate was incubated once more, under identical conditions. Then, optical density was assessed at 690 nm every 10 min, with results expressed as delayed time of haemolysis (Δt) (Takebayashi, Iwahashi, Ishimi, & Tai, 2012). The obtained Δt values were correlated to the distinct sample concentrations, and from this correlation the inhibitory concentration capable of supplying 60 min and 120 min haemolysis delays (Δts) were determined. Results were given in extract concentration needed to protect 80% of the erythrocyte population from the haemolytic action caused by the oxidizing agent (IC_{80}, mg/mL).

2.7. Antibacterial activity evaluation

The minimal inhibitory and bactericidal concentrations (MIC and MBC) for all the bacterial strains were determined using a protocol established by the authors and described by Pires et al. (2018). Five Gram-negative bacteria and four Gram-positive bacteria were employed in this assay, in which the antibiotics ampicillin and imipenem were used as positive controls for the Gram-negatives, whereas ampicillin and vancomycin for the Gram-positives.

2.8. Statistical analysis

All obtained data were expressed as mean values and standard deviations (SD), as a result of the three repetitions of the samples and concentrations that were employed in all analysis. To determine significant differences, among two different samples (peel and pulp) with $\alpha = 0.05$, the Student's *t*-test was applied. Analyses were performed with the IBM SPSS Statistics for Windows, version 23.0. (IBM Corp., Armonk, New York, USA).

Table 1
Macronutrients (g/100 g fw) and energy value (kcal/100 g fw) of the *Ficus carica* pulp and peel parts.

	Peel	Pulp	*t*-Student test p-value
Moisture	67 ± 3	72 ± 1	0.132
Ash	1.01 ± 0.05	0.79 ± 0.01	< 0.001
Protein	2.2 ± 0.1	1.99 ± 0.03	0.021
Fat	1.64 ± 0.03	1.24 ± 0.03	< 0.001
Carbohydrates	27.8 ± 0.1	23.74 ± 0.01	< 0.001
Energy	134.7 ± 0.2	114.1 ± 0.1	< 0.001

A Student's *t*-test was used to determine the significant difference between two different samples, with $\alpha = 0.05$: $p < .001$ means a significant difference between the samples.

Table 2
Composition in free sugars (g/100 g fw), organic acids (mg/100 g fw), and tocopherols (mg/100 g fw) of the *Ficus carica* pulp and peel parts.

	Peel	Pulp	*t*-Student test p-value
Fructose	17.4 ± 0.1	13.16 ± 0.09	< 0.001
Glucose	21.0 ± 0.2	15.7 ± 0.1	< 0.001
Sucrose	4.83 ± 0.02	2.975 ± 0.002	< 0.001
Trehalose	0.21 ± 0.01	0.161 ± 0.001	0.001
Total sugars	43.4 ± 0.4	32.0 ± 0.2	< 0.001
Oxalic acid	143 ± 1	228 ± 3	< 0.001
Quinic acid	128 ± 5	72 ± 5	< 0.001
Malic acid	165 ± 4	91 ± 2	< 0.001
Citric acid	827 ± 37	259 ± 12	< 0.001
Succinic acid	317 ± 13	484 ± 4	< 0.001
Total organic acids	1580 ± 58	1134 ± 6	< 0.001
α-Tocopherol	2.75 ± 0.06	0.93 ± 0.03	< 0.001
β-Tocopherol	0.0157 ± 0.0004	0.0073 ± 0.0001	< 0.001
γ-Tocopherol	1.30 ± 0.02	2.68 ± 0.09	< 0.001
δ-Tocopherol	0.068 ± 0.002	0.109 ± 0.002	< 0.001
Total tocopherols	4.14 ± 0.04	3.7 ± 0.1	0.004

A Student's *t*-test was used to determine the significant difference between two different samples, with $\alpha = 0.05$: $p < .001$ means a significant difference between the samples.

3. Results and discussion

3.1. Nutritional and chemical composition

The composition of macronutrients, free sugars, organic acids, tocopherols, and fatty acids of our *F. carica* peel and pulp samples were determined, and the obtained results are displayed in Tables 1–3.

As shown in Table 1, our peel sample presented significantly higher contents of ash, fat and carbohydrates, and consequently higher energy value, than the corresponding pulp. There were no significant differences regarding their moisture and protein contents. Ajmal et al. (2016), in their characterization study of the distinct parts of a black variety of common fig, verified higher moisture contents (84.24 and 74.56 g/100 g, respectively for pulp and peel). They also verified a higher ash content (1.78 g/100 g) for their peel sample; however, their pulp's ash content was very similar to ours. Regarding their protein contents, the value reported for the peel (almost 3 g/100 g) was superior to ours, whereas the verified pulp's import (1 g/100 g) was half of our value. Furthermore, the authors reported much lower fat amounts for their peel and pulp samples, 0.38 and 0.2 g/100 g, respectively. Mamoudi et al. (2018) recently estimated the proximal components of fresh figs from nine cultivars grown in Algeria. They found a mean carbohydrate amount of 4.84 for the peel, which is a much lower than ours (27.8 ± 0.1 g/100 g fw), whereas an average content of 19.48 g/100 g fw for the pulp. The authors also verified that the mean protein concentration of the fig peel (1.06 g/100 g fw) were just slightly higher than that of the pulp (1.03 g/100 g fw).

Four free sugars were detected in our *F. carica* samples (Table 2).

Table 3
Fatty acid compositions of the *Ficus carica* peel and pulp, in relative percentage of each fatty acid.

	Peel	Pulp	*t*-Student test p-value
C6:0	0.583 ± 0.002	nd	–
C8:0	0.38 ± 0.02	0.093 ± 0.004	< 0.001
C10:0	0.970 ± 0.002	0.179 ± 0.001	< 0.001
C11:0	nd	0.233 ± 0.009	–
C12:0	0.96 ± 0.07	0.085 ± 0.004	< 0.001
C14:0	3.06 ± 0.06	0.50 ± 0.05	< 0.001
C14:1	0.099 ± 0.003	nd	–
C15:0	0.53 ± 0.05	0.30 ± 0.03	< 0.001
C16:0	23.9 ± 0.1	11.2 ± 0.3	< 0.001
C16:1	0.30 ± 0.02	0.121 ± 0.001	< 0.001
C17:0	0.53 ± 0.03	0.214 ± 0.005	< 0.001
C18:0	6.0 ± 0.1	3.91 ± 0.04	< 0.001
C18:1n9	12.2 ± 0.1	8.8 ± 0.1	< 0.001
C18:2n6	12.6 ± 0.2	19.9 ± 0.2	< 0.001
C18:3n3	28.0 ± 0.7	51.8 ± 0.4	< 0.001
C20:0	4.39 ± 0.09	0.84 ± 0.03	< 0.001
C20:1	0.129 ± 0.001	0.14 ± 0.01	< 0.001
C20:2	nd	0.153 ± 0.006	–
C21:0	0.15 ± 0.01	0.084 ± 0.006	0.077
C22:0	2.60 ± 0.05	0.82 ± 0.07	< 0.001
C22:2	0.267 ± 0.002	nd	–
C23:0	0.263 ± 0.001	0.139 ± 0.008	< 0.001
C24:0	2.184 ± 0.01	0.386 ± 0.004	< 0.001
Total SFA	46.5 ± 0.6	19.0 ± 0.5	< 0.001
Total MUFA	12.7 ± 0.2	9.1 ± 0.1	< 0.001
Total PUFA	40.8 ± 0.5	71.9 ± 0.6	< 0.001

Caproic acid (C6:0); Caprylic acid (C8:0); Capric acid (C10:0); Undecanoic acid (C11:0); Lauric acid (C12:0); Myristic acid (C14:0); Myristoleic acid (C14:1); Pentadecanoic acid (C15:0); Palmitic acid (C16:0); Palmitoleic acid (C16:1); Heptadecanoic acid (C17:0); Stearic acid (C18:0); Oleic acid (C18:1n9); Linoleic acid (C18:2n6); α-Linolenic acid (C18:3n3); Arachidic acid (C20:0); Eicosenoic acid (C20:1); *cis*-11,14-Eicosadienoic acid (C20:2); Heneicosanoic acid (C21:0); Behenic acid (C22:0); cis-13,16-Docosadienoic acid (C22:2); Tricosanoic acid (C23:0); Lignoceric acid (C24:0); Saturated fatty acids (SFA); Monounsaturated fatty acids (MUFA); Polyunsaturated fatty acids (PUFA). A Student's *t*-test was performed to determine the significant between two different samples, with $\alpha = 0.05$: $p < .001$ means a significant difference between the samples. nd - not detected.

Glucose was the principal sugar for both of them (21.0 ± 0.2 and 15.7 ± 0.2 g/100 g fw, for peel and pulp, respectively), followed by fructose and sucrose, in addition to threalose in very low amounts. Wojdyło et al. (2016), when investigating the composition of 10 fig varieties, also verified that fructose and glucose were the major sugars in all analyzed fruits, whilst sucrose was found in lower amounts. They reported total sugar contents ranging from 44.0 to 74.3 g/100 g dm. Our peel sample presented higher amounts of all detected sugars; therefore, its total free sugars content (43.4 ± 0.4 g/100 g fw) was 1.35-fold higher than the pulp's content.

Five organic acids were identified and quantified in our *F. carica* samples, namely oxalic, quinic, malic, citric, and succinic acids (Table 2). The citric acid was the most abundant component in the peel (827 ± 37 mg/100 g) whereas succinic acid was the most abundant in the pulp (484 ± 4 mg/100 g); these compounds accounted for 52% and 43% of samples total organic acids contents, respectively. The total organic acids content of our peel sample was almost 1.4-fold higher than the pulp's content. Pande and Akoh (2010) studied the composition of the 'Brown Turkey' variety whole fig fruit and peels, and reported the detection of malic, citric, ascorbic, succinic, and oxalic acids for both samples, which corroborates our verified profiles. The major organic acids in their fig peel sample were malic, citric and ascorbic acids, found in concentration values of 0.45, 0.18 and 0.10 mg/g fw, respectively.

Tocopherols were detected in all their four forms (α, β, δ and γ) in our samples (Table 2). α-Tocopherol was the major component in the peel (2.75 ± 0.06 mg/100 g fw), whereas the γ-tocopherol was the most abundant in the pulp (2.68 ± 0.09 mg/100 g fw). β-Tocopherol was found only in very low amounts in both samples. Pande and Akoh (2010) reported inferior concentrations of α-tocopherol (0.2 mg/100 g fw), γ-tocopherol (0.3 mg/100 g fw), and β-tocopherol (trace concentrations) when analyzing a *F. carica* whole-fruit sample; furthermore, they did not detect δ-tocopherol.

Twenty-three different fatty acids (FAs) were found in our *F. carica* extracts, with amounts given in relative percentage (Table 3). The α-linolenic acid (C18:3n3) was the most abundant component of both samples, accounting for > 50% of the pulp's total FA content and of almost 30% of the peel's content, followed by linoleic (C18:2n6), palmitic (C16:0), and oleic (C18:1n9) acids. Marrelli et al. (2012) verified similar FA profile when analyzing a *n*-hexane fraction of a hydroethanolic extract (70% ethanol) from fresh figs cultivated in Italy. The major FAs detected in their n-hexane fraction were linolenic (up to 35%), oleic and palmitic acids. Badgujar et al. (2014) also reported that linolenic acid was the main FA component (53%) of dried fig fruits, followed by linoleic acid (21%), palmitic acid (14%), and oleic acid (10%). However, Pande and Akoh (2010) found that linoleic acid (28%) was the predominant FA in the fig whole-fruit, followed by the palmitic, oleic and linonelic acids.

As expected, there were significant differences in the FA compositions of our peel and pulp extracts. The peel extract presented 21 FAs, as the undecanoic (C11:0) and the *cis*-11,14-eicosadienoic (C20:2) acids were not detected in this sample, although present in the pulp in very small amounts (< 1%). On the other hand, 20 FAs were detected in the pulp; caproic (C6:0), myristoleic (C14:1), and *cis*-13,16-docosadienoic (C22:2) acids were absent from this sample. Furthermore, the saturated fatty acids (SFA) percentage found in the peel were > 2-fold the content verified in the pulp, which on its turn had considerably superior polyunsaturated fatty acids (PUFA) tenor (> 1.76-fold higher).

3.2. Phenolic compounds profiles

The phenolic compositions of the hydroethanolic peel and pulp extracts of *F. carica* are presented in Table 4. Eighteen phenolic compounds were detected (Fig. 1), among which eight flavonoid derivatives, eight phenolic acids and derivatives, and two compounds which definite identification could not be assigned. To our best knowledge, there are no previous reports containing the in-depth phenolic characterization of a green fig variety from Portugal.

Regarding the phenolic acids found in fig samples, caffeic and vanillic acid derivatives were the predominant compounds. Peak 1 and 2, both presented the same pseudomolecular ion $[M-H]^-$ at *m/z* 341, with a characteristic MS^2 fragment at *m/z* 179 [caffeic acid - H]$^-$ (loss of 162 u, corresponding to an hexosyl moiety), being both tentatively identified as caffeic acid hexoside. Peak 3 was positively identified as 5-*O*-caffeoylquinic acid in comparison with the commercial standard. Peak 16 was assigned as cinnamoyl-amino acid conjugate, the tentative identification of this compound was possible comparing the chromatographic characteristics with the ones reported by Alonso-Salces, Guillou, and Berrueta (2009) for conjugated cinnamoyl-amino acids identified in green coffee beans. Peak 16 showed a UV spectra λ_{max} around 325 nm characteristic of hydroxycinnamic acids, and presented a pseudomolecular ion $[M-H]^-$ at *m/z* 527 followed by a major MS^2 fragment at *m/z* 365 (attributed to the loss of a hexose moiety, 162 u) and a fragment at *m/z* 203 coherent with the amino acid tryptophan, being tentatively identified as caffeoyl *N*-tryptophan hexoside. Peaks 5, 7, and 13 were assigned as vanillic acid derivatives, taking into account its UV–Vis spectra and MS fragmentation pattern. Peak 5 ($[M-H]^-$ at *m/z* 313) and 7 ($[M-H]^-$ at *m/z* 459) showed a UV spectra λ_{max} around 253,292 nm and MS^2 fragment at *m/z* 167 [vanillic acid - H]$^-$ (corresponding to one and two deoxyhexosyl moieties, respectively), being tentatively assigned as vanillic acid deoxyhexoside and vanillic acid dideoxyhexoside, respectively. Similarly, peak 13 ($[M-H]^-$ at *m/z* 545)

Table 4
Retention time (Rt), wavelengths of maximum absorption in the visible region (λ_{max}), mass spectrometric data, tentative identification, and quantification (mg/g extract) of the phenolic compounds composition of the *Ficus carica* hydroethanolic extracts, namely peel and pulp extracts.

Peak	Rt (min)	λ_{max} (nm)	$[M-H]^-$ (*m*/z)	Main MS^2 fragments (*m*/z)	Tentative identification	Peel	Pulp	p-Student *t*-Test
1	4.37	319	341	179(100),161(18),135(5)	Caffeic acid hexoside	0.0653 ± 0.003	0.207 ± 0.004	< 0.001
2	5.24	320	341	179(100),161(18),135(5)	Caffeic acid hexoside	0.0573 ± 0.0009	0.044 ± 0.002	< 0.001
3	6.02	285,320	465	303(100),285(7)	Taxifolin-*O*-hexoside	0.097 ± 0.002	nd	–
4	7.17	326	353	191(100),179(11),161(5),135(5)	5-*O*-Caffeoylquinic acid	0.285 ± 0.003	0.091 ± 0.004	< 0.001
5	7.92	253,290	313	167(100),152(10),123(5)	Vanillic acid deoxyhexoside	nd	0.058 ± 0.001	–
6	8.69	347	667	505(100),463(39),301(11)	Quercetin-*O*-hexoside-*O*-acetylhexoside	tr	nd	–
7	9.02	253,292	459	167(100),151(15),123(5)	Vanillic acid di-deoxyhexoside	0.062 ± 0.001	0.0430 ± 0.0006	
8	9.64	253,291	437	291(100)	Unknown	nq	nq	–
9	11.6	290,311	337	191(100),163(16),119(5)	5-*p*-Coumaroylquinic acid	0.068 ± 0.003	nd	–
10	14.13	330	563	473(58),443(100),383(15),353(20),311(5),297(5)	Apigenin-*C*-hexoside-*C*-pentoside	0.0541 ± 0.0004	tr	–
11	14.81	330	563	473(58),443(100),383(15),353(20),311(5),297(5)	Apigenin-*C*-hexoside-*C*-pentoside	0.0177 ± 0.0002	nd	–
12	15.31	283	367	205(100),161(0)	Unknown	nq	nq	–
13	16.54	253,283	545	501(100),459(13),313(5),167(98)	Vanillic acid malonyl di-deoxyhexoside	0.236 ± 0.004	0.100 ± 0.001	< 0.001
14	17.7	340	593	285(100)	Kaempherol-*O*-deoxyhexosyl-hexoside	nd	tr	–
15	17.93	354	609	301(100)	Quercetin-3-*O*-rutinoside	0.5134 ± 0.0007	tr	–
16	18.96	326	527	365(100),203(12)	Caffeoyl *N*-tryptophan hexoside	nd	tr	–
17	20.43	353	505	463(25),301(100)	Quercetin-*O*-acetylhexoside	0.038 ± 0.001	nd	–
18	22.28	330	619	499(5),457(100),413(2),341(4),311(5),293(14)	Apigenin-2″-*O*-rhamnose-*C*-acetylhexoside	0.026 ± 0.001	nd	–
					Total phenolic acids	0.77 ± 0.01	0.542 ± 0.001	< 0.001
					Total flavonoids	0.747 ± 0.005	tr	–
					Total phenolic compounds	1.52 ± 0.02	0.542 ± 0.001	< 0.001

Phenolic compound used for quantification: apigenin-6-glucoside (y = 107,025x + 61,531; R^2 = 0.999; LOD = 4.45 μg/mL; LOQ = 13.49 μg/mL); caffeic acid (y = 388,345x + 406,369; R^2 = 0.994; LOD = 8.57 μg/mL; LOQ = 25.97 μg/mL); chlorogenic acid (y = 168,823x – 161,172; R^2 = 0.999; LOD = 0.83 μg/mL; LOQ = 2.50 μg/mL); *p*-coumaric acid (y = 301,950x + 6966.7; R^2 = 0.999; LOD = 1.10 μg/mL; LOQ = 3.32 μg/mL); quercetin-3-*O*-rutinoside (y = 13,343x − 76,751; R^2 = 0.999; LOD = 14.71 μg/mL; LOQ = 44.59 μg/mL); taxifolin (y = 203,766x − 208,383; R^2 = 0.999; LOD = 0.67 μg/mL; LOQ = 2.02 μg/mL); vanillic acid (y = 29,751x − 28,661; R^2 = 0.999; LOD = 16.65 μg/mL; LOQ = 50.45 μg/mL). Linearity was performed with 11 levels 0.1–100 μg/m. nd = not detected; tr = trace amount; nq = not quantifiable. A Student's *t*-test was used to determine the significant difference between two different samples, with α = 0.05: $p < .001$ means a significant difference between the samples.

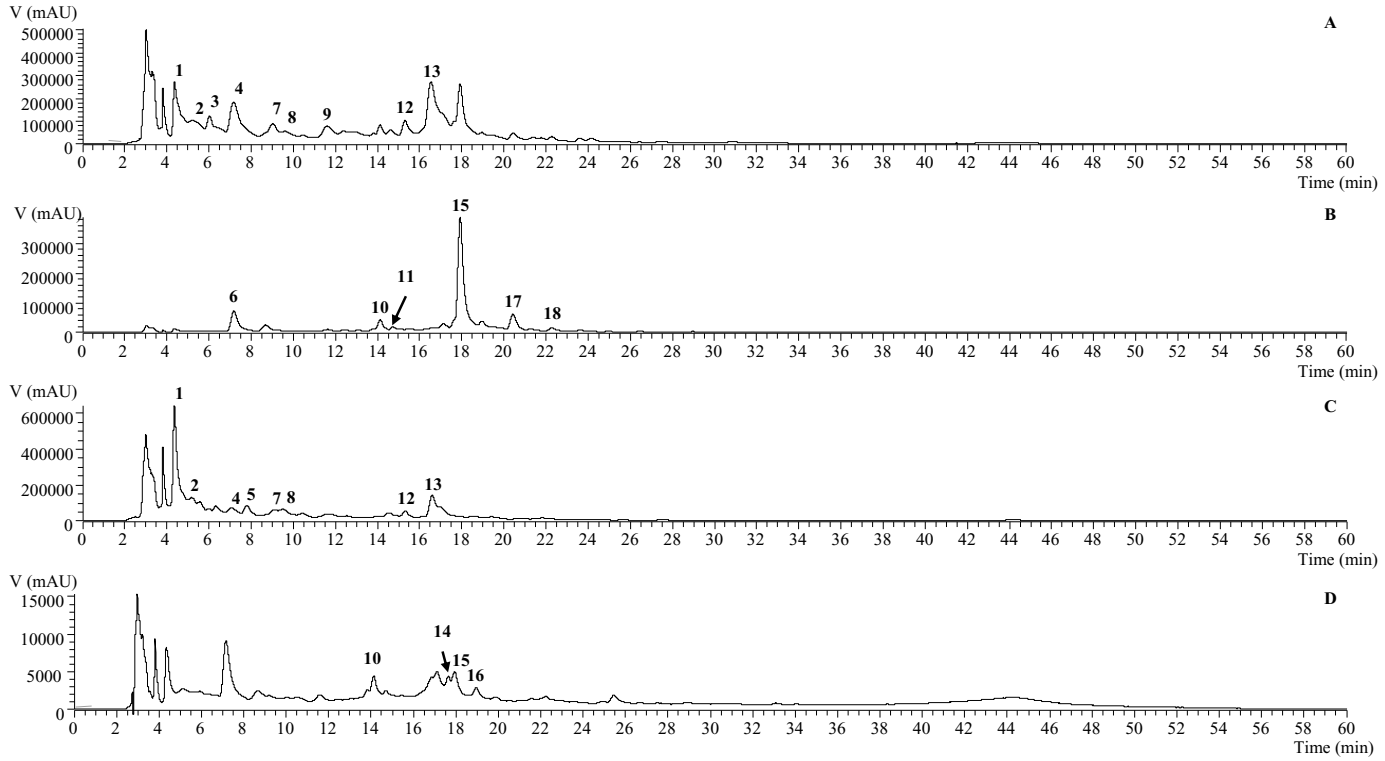

Fig. 1. Chromatographic profile of the peel (A and B) and pulp (C and D) parts of the fig recorded at 280 (A and C, respectively) and 370 nm (B and D, respectively).

presented MS^2 fragments at *m/z* 501 (44 u), 459 (42 u), 313 (146 u), and 167 (146 u), corresponding to the loss of a malonyl and two deoxyhexosyl moieties, being tentatively assigned as vanillic acid malonyl di-deoxyhexoside. Finally, peak 9 ([M-H]$^-$ at *m/z* 337) was assigned to 5-*p*-coumaroylquinic acid, using the hierarchical key system previously reported by Clifford, Johnston, Knight, and Kuhnert (2003).

Among the eight flavonoids glycoside derivatives found in fig samples, quercetin and *C*-glycosylated apigenin derivatives were the most representatives, followed by kaempherol and taxifolin derivatives. Peak 15 ([M-H]$^-$ at *m/z* 609) was assigned as quercetin-3-*O*-rutinoside (rutin), by comparing its retention time and λ_{max} with the available commercial standard. Peak 6 ([M-H]$^-$ at *m/z* 667) revealed three MS^2 fragments at *m/z* 505, 463, and 301 (quercetin aglycone), which corresponded to the losses of two hexosyl and acetyl moieties, being tentatively assigned as quercetin-*O*-hexoside-*O*-acetylhexoside. Similarly, peak 17 ([M-H]$^-$ at *m/z* 505) was assigned as quercetin-*O*-acetylhexoside. Peak 14 ([M-H]$^-$ at *m/z* 593) corresponded to a kaempherol derivative, due to its UV–vis characteristic with a λ_{max} at 263 and 340–348 nm. This peak revealed a unique MS^2 fragment at *m/z* 285, corresponding to the loss of 308 u (deoxyhexosyl-hexosyl moiety), thus presenting a lower retention time then kaempherol-3-*O*-rutinoside (commercial standard with a Rt = 21.3 min), being tentatively identified as kaempherol-*O*-deoxyhexosyl-hexoside. Peak 3 ([M-H]$^-$ at *m/z* 465) was assigned to a dihydroquercetin derivative ([taxifolin-H]$^-$), revealing a major MS^2 fragment at *m/z* 303, resulting from the loss of a hexosyl moiety (−162 u), thus being tentatively assigned as taxifolin-*O*-hexoside.

C-glycosylated flavonoids (apigenin derivatives), were also found in the fig samples. Peaks 10 and 11 ([M–H] at *m/z* 563) released MS^2 fragments corresponding to losses of 90 u (*m/z* at 473) and 120 u (*m/z* at 443), and at *m/z* 383 and 353 (apigenin aglycone plus residues, apigenin +113 u and apigenin +83 u, respectively), allowing their tentative identification as apigenin-*C*-hexoside-*C*-pentoside (Ferreres, Silva, Andrade, Seabra, & Ferreira, 2003). The last apigenin derivative (peak 18) was assigned as an *O*-glycosyl-*C*-glycosyl flavone according to the fragmentation patterns and abundances previously described (Ferreres et al., 2011; Ferreres, Gil-Izquierdo, Andrade, Valentao, & Tomás-Barberán, 2007). Peak 18 ([M–H] at *m/z* 619) presented a MS^2 fragment ion at *m/z* 499 ([M-120]), characteristic of *C*-hexosyl flavones, and at *m/z* 413 ([M-146–18]), characteristic of an *O*-glycosylation on the hydroxyl group at position 2 of the *C*-glycosylation sugar (Ferreres et al., 2007). The other MS^2 fragment ions at *m/z* 341, 311, and 293 are also characteristics of this type of compounds, corresponding to the apigenin aglycone plus residues, being tentatively assigned as apigenin-2″-*O*-rhamnose-*C*-acetylhexoside.

Fifteen different phenolic components were detected in the peels, whereas 12 were detected in the pulp. Quercetin-3-*O*-rutinoside (rutin) was the major compound present in the peel extract, accounting for 33.8% of its phenolic content, followed by 5-*O*-caffeoylquinic acid (5-CQA, chlorogenic acid; 18.8%), vanillic acid malonyl di-deoxyhexoside (15.5%), and in minor amounts taxifolin, apigenin, quercetin, caffeic, and other vanillic acid derivatives (Table 4). Caffeic acid derivatives, such as caffeic acid hexosides, were the major components of the pulp extract, followed by vanillic acid derivatives (vanillic acid malonyl di-deoxyhexoside, vanillic acid deoxyhexoside, and vanillic acid di-deoxyhexosideand), and 5-CQA. Rutin and apigenin derivatives were only found in trace amounts in this part of the sample.

Our results (Table 4) are in accordance with those present in literature data on the most important individual phenolic compounds detected in *F. carica* whole fruits (fresh and/or dried), as well as in their peel and pulp fractions. With respect to phenolic acids, gallic and syringic acids (hydroxylated derivatives of benzoic acid and chlorogenic acid), ferulic acid, caffeic and cinnamic acids (cinnamic acid derivatives) were the most often reported compounds. Regarding flavonoids, rutin (quercetin-3-*O*-rutinoside) and epicatechin were quantified in fresh fig samples in average concentrations of 0.68–0.38 mg/g, and 0.77 mg/g, respectively (Del Caro & Piga, 2008; Oliveira et al., 2009; Vallejo et al., 2012; Kamiloglu & Capanoglu, 2015; Pereira et al., 2017; Amessis-Ouchemoukh et al., 2017). Pereira et al. (2017) reported some phenolic compounds similar to ours when evaluating the composition

of peel and pulp parts of nine fig varieties from Spain via HPLC-DAD/ESI–MS. The authors detected phenolic acids like chlorogenic and ellagic acids, and flavonols such as rutin and quercetin-3-*O*-acetylglucoside. Regarding the amounts of phenolic acids, they reported chlorogenic acid contents of 0.6–2.1 mg/100 g fw for the peel samples and of 0.1–0.9 mg/100 g fw for the pulp samples, thus no comparison was achieved due to the different expressed units. Rutin ranged from 2.9 to 11.9 in the peel samples, and from 0.1 to 1.02 mg/100 g fw in the pulp samples. Several authors have also verified a superior concentration of phenolic compounds in *F. carica* fruit peel in comparison with the corresponding pulp (Del Caro & Piga, 2008; Oliveira et al., 2009; Vallejo et al., 2012; Kamiloglu & Capanoglu, 2015; Pereira et al., 2017; Amessis-Ouchemoukh et al., 2017), which corroborates our findings.

The total phenolic content (TPC) found for our peel extract (1.52 ± 0.02 mg/g) was almost 3-fold higher than the concentration verified for our pulp extract (Table 4). While our peel extract had a total flavonoid content (TFC) of almost 0.747 ± 0.005 mg/g, the corresponding pulp extract revealed trace amounts of this class of phenolic compounds; likewise, the peel's phenolic acids content (0.77 ± 0.01 mg/g) was significantly higher than the value verified for the pulp (0.542 ± 0.001 mg/g). Dozens of previous studies have evaluated the phenolic constitution of whole figs (fresh and/or dried, from very many varieties), and a great part of these papers comparatively assessed the fruits' peel and pulp fractions, using spectrophotometric and/or chromatographic approaches (Solomon et al., 2006; Del Caro & Piga, 2008; Oliveira et al., 2009; Russo et al., 2014; Kamiloglu & Capanoglu, 2015; Hoxha & Kongoli, 2016; Ajmal et al., 2016; Ammar et al., 2015; Harzallah et al., 2016; Vallejo et al., 2012; Wojdyło et al., 2016; Maghsoudlou et al., 2017; Pereira et al., 2017; Mahmoudi et al., 2018; Meziant et al. 2018; Mopuri et al., 2018). In many cases, the TPCs were given in gallic acid equivalents (GAE)/g fw, whereas the TFCs were expressed as mg (+)-catechin equivalent (CE)/g fw. Harzallah et al. (2016), for instance, studied the phenolic composition of the peel and pulp parts of a green fig variety (Bidhi) from Tunisia. The authors reported TPC values of 36 mg GAE/g fw for the peel and of 39 mg GAE/g fw for the pulp, and TFC values of 5 and 6 mg CE/g fw for the peel and pulp, respectively. Maghsoudlou et al. (2017) found considerably higher values of TPC and similar values of TFC when assessing Iranian green figs: 69 mg GAE/g fw for the peel and 45.44 GAE/g fw for the pulp, whereas 5.89 mg CE/g fw and 5.47 mg CE/g fw for peel and pulp, respectively.

Various monitoring and comparative works have evidenced that the phytochemical composition depends on the fig variety; however, it is also greatly influenced by other factors, e.g., coloration, the fraction analyzed (peel/pulp), maturity stage, edaphoclimatic conditions and eventual drying process (Kamiloglu & Capanoglu, 2015; Bachir Bey, Richard, Meziant, Fauconnier, & Louaileche, 2017; Harzallah et al., 2016; Pereira et al., 2017; Arvaniti et al., 2019).

3.3. Evaluation of bioactive properties

The antioxidant and antibacterial activities of the *F. carica* hydroethanolic extracts were assessed and the obtained results are displayed in Tables 5 and 6.

3.3.1. Antioxidant activity

Except for the study of Viuda-Martos et al. (2015), in which they analyzed figs by-products by the inhibition of the production of thiobarbituric acid reactive substances (TBARS) assay, we did not find reports on the use of cell-based approaches to assess the antioxidant capacity of *F. carica* extracts. Hence, to our best knowledge, the present work is the first report on the evaluation of *F. carica* extracts' antioxidant potential using such set of methods (DPPH, reducing power, β-carotene, TBARS, and OxHLIA assays).

Overall, our *F. carica* extracts presented promising antioxidant potentials in all tests; the peel extract displayed significantly lower IC_{50} values than the corresponding pulp extract, except for its β-carotene bleaching inhibition activity (Table 5). Our results corroborate literature data, as several previous studies have demonstrated that figs' peel extracts display more pronounced antioxidant capacities than their correspondent pulp extract (Solomon et al., 2006; Oliveira et al., 2009; Ammar et al., 2015; Ajmal et al., 2016; Harzallah et al., 2016; Hoxha & Kongoli, 2016; Maghsoudlou et al., 2017).

Table 5
Antioxidant activity of the *Ficus carica* peel and pulp extracts evaluated by a set of different chemical and cell-based assays, expressed in IC_{50} (mg/mL) and IC_{80} (mg/mL; for OxHLIA assay) values.

	Peel	Pulp	*t*-Student test p-value
DPPH scavenging activity	0.46 ± 0.01	1.13 ± 0.05	< 0.001
Reducing power	3.58 ± 0.03	4.34 ± 0.04	< 0.001
β-carotene bleaching inhibition	0.135 ± 0.005	0.048 ± 0.001	< 0.001
TBARS inhibition	1.14 ± 0.04	1.24 ± 0.04	< 0.001
OxHLIA, Δt = 60 min	0.85 ± 0.05	1.21 ± 0.06	0.003
OxHLIA, Δt = 120 min	2.67 ± 0.05	3.36 ± 0.05	< 0.001

Trolox EC_{50} values: 42 μg/mL (DPPH scavenging activity), 41 μg/mL (reducing power), 18 μg/mL (β-carotene bleaching inhibition) and 23 μg/mL (TBARS inhibition); Trolox IC_{80} values: 22 μg/mL (60 min) and 44.9 μg/mL (120 min). A Student's *t*-test was used to determine the significant difference between two different samples, with $\alpha = 0.05$: $p < .001$ means a significant difference between the samples.

Maghsoudlou et al. (2017) found less expressive results than ours when assessing the antioxidant capacities of peel and pulp extracts of a green fig variety grown in Iran via DPPH assay (IC_{50} values of 3.45 and 4.39 mg/mL for peel and pulp, respectively). However, when using the reducing power assay, the authors IC_{50} values were very similar to ours (4.62 and 4.44 mg/mL for peel and pulp, respectively). Harzallah et al. (2016) verified better antioxidant capacity values via reducing power method when analyzing different parts of a Tunisian green fig variety, with IC_{50} values of 0.5 and 2 mg/mL for peel and pulp, respectively. However, their antioxidant capacity values verified by the DPPH method were less expressive (IC_{50} = 26.7 mg/mL for the peel; IC_{50} = 10.59 mg/mL for the pulp). Bachir Bey et al. (2017) assessed the capacities of whole figs from three fig varieties from Algeria in preventing β-carotene oxidation and reported an average antioxidant activity of 24%.

Our antioxidant capacity values measured by the TBARS method were considerably better than the ones verified by Viuda-Martos et al. (2015) in their study on the antioxidant properties of fig peel and pulp powders obtained from discarded fruits. The authors found IC_{50} values of 7.19–11.45 mg/mL for the peel powders and of 17.13–19.42 for the pulp powders. For both assays (TBARS and OxHLIA), we used Trolox as the positive control; as expected, it displayed superior erythrocyte-protection capacity as well as inhibition of thiobarbituric acid reactive substances than the tested fig extracts.

The *F. carica* fruits' antioxidant capacities have been highly correlated with their amount of phenolic components (Arvaniti et al., 2019). Rutin (quercetin-3-*O*-rutinoside), the major individual phenolic in our peel sample, has demonstrated outstanding in vitro and in vivo antioxidant effects, among other bioativities (Gullón, Lú-Chau, Moreira, Lema, & Eibes, 2017). For instance, this flavonoid has proven antioxidative effect when applied in meat products (Tang et al., 2019). Nonetheless, phenolic compounds are not the only phytochemical agents expressing antioxidant effects in fig fruits; this bioactivity could also be a result of the action of other molecules, such as triterpenoids (Wojdyło et al., 2016).

Sundry researchers have reported that fruits and vegetables act as barrier against cancer due to the presence of bioactive phytochemicals (Corrêa, Barros, et al., 2018). Phenolic matrices comprise an extremely rich source of phytochemicals, which present a multitude of health

Table 6
Antibacterial potential of the *Ficus carica* peel and pulp hydroethanolic extracts.

	Peel		Pulp		Ampicillin (20 mg/mL)		Imipenem (1 mg/mL)		Vancomycin (1 mg/mL)	
	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
Gram-negative bacteria										
Escherichia coli	5	> 20	5	> 20	< 0.15	< 0.15	< 0.0078	< 0.0078	nt	nt
Klebsiella pneumoniae	20	> 20	20	> 20	10	20	< 0.0078	< 0.0078	nt	nt
Morganella morganii	5	> 20	5	> 20	20	> 20	< 0.0078	< 0.0078	nt	nt
Proteus mirabilis	20	> 20	20	> 20	< 0.15	< 0.15	< 0.0078	< 0.0078	nt	nt
Pseudomonas aeruginosa	> 20	> 20	20	> 20	> 20	> 20	0.5	1	nt	nt
Gram-positive bacteria										
Enterococcus faecalis	> 20	> 20	> 20	> 20	< 0.15	< 0.15	nt	nt	< 0.0078	< 0.0078
Listeria monocytogenes	> 20	> 20	> 20	> 20	< 0.15	< 0.15	< 0.0078	< 0.0078	nt	nt
MRSA	5	> 20	5	> 20	< 0.15	< 0.15	nt	nt	< 0.0078	< 0.0078
MSSA	2.5	> 20	2.5	> 20	< 0.15	< 0.15	nt	nt	0.25	0.5

MIC - minimum inhibitory concentration; MBC - minimum bactericidal concentrations.
MRSA - Methicillin-resistant *Staphylococcus aureus*; MSSA - Methicillin-sensitive *Staphylococcus aureus*.
n.t. – not tested.

benefits, including their ability to act as free radicals scavengers (Martins, Barros, & Ferreira, 2016). Furthermore, these bioactive molecules possess the ability to strengthen the potential of other phytochemicals, to block side effects of some constituents and also to acquire other biological properties (when combined in whole matrices). Thus, despite of their occurrence in vestigial amounts, phytochemicals play a crucial role in preventing and treating diseases (Martins et al., 2016; Corrêa, Barros, et al., 2018).

3.3.2. Antibacterial activity

The *F. carica* hydroethanolic extracts' minimum inhibitory concentration (MIC) values for five Gram-negative and four Gram-positive bacteria are displayed in Table 6. Our peel and pulp extracts showed practically identical antibacterial capacities, being both more effective contra Gram-positive bacteria, especially methicillin-sensitive *Staphylococcus aureus* (MSSA) (MIC values of 2.5 mg/mL). Likewise, both extracts inhibited the growth of methicillin-resistant *Staphylococcus aureus* (MRSA) as well as the Gram-negative bacteria *Escherichia coli* and *Morganella morganii* (all MIC values of 5 mg/mL). Jeong et al. (2009) found lower MIC (0.156–0.625 mg/mL) and MBC (0.313–0.625 mg/mL) values when evaluating the activity of a *F. carica* methanolic leaf extract against Gram-positive (*Streptococcus gordonii*, *Streptococcus anginosus*) and Gram-negative (*Prevotella intermedia*, *Porphyromonas gingivalis*) bacteria. Lazreg-Aref, Mars, Fekih, Aouni, and Said (2012) reported that the hexane extract of fig fruit latex had strong bactericidal effects against Gram-positive and Gram-negative bacteria, being very effective against *Staphylococcus aureus* ATCC 25923 (MIC = 19 μg/mL). However, Oliveira et al. (2009) assessed the inhibitory effects of a *F. carica* aqueous extracts against *Bacillus cereus*, *Staphylococcus epidermidis*, *S. aureus*, *E. coli*, and *Pseudomonas fluorescens* using disc diffusion method, and found no antimicrobial activity. Nonetheless, we have not found a previous comparative study on the antimicrobial potential of fig fruit's peel and pulp.

Recently, Shahbazi (2018) developed and characterized several nanocomposite biofilms based on chitosan and carboxymethylcellulose and added with the essencial oil of *Ziziphora clinopodioides* Lam and/or with a methonolic extract of *F. carica*. According to the authors, the most pronounced antibacterial (inhibition zones ranging from 14 to 27 mm) and antioxidant (DPPH scavenging activity of almost 40%) actions were found for the chitosan-nanomontmorillonite-based film containing 2% of essential oil and 1% of fig extract.

The antibacterial potentials verified for our *F. carica* extracts likely relate to their major phenolic constituents, which are all molecules with proven biological activities, as well as to the possible synergistic action of these phytocomponents. Al-Shabib et al. (2017) highlighted the promissory potential of rutin as a natural biofilm control agent for food industry, as it effectively inhibited biofilms formed by drug resistant MRSA and *E. coli*. Indeed, a bioactive rutin isolated from the peels of the sweet orange [*Citrus sinensis* (L.) Osbeck] displayed anti-biofilm activity against multidrug-resistant *P. aeruginosa* (Deepika et al., 2018). Furthermore, Bajko, Kalinowska, Borowski, Siergiejczyk, and Lewandowski (2016) assessed the inhibitory effects of the chlorogenic acid (5-CQA) against *E. coli*, *S. aureus*, *E. faecium*, and *P. aeruginosa*, and reported MIC values ranging from 5 to 10 mg/mL.

Our *F. carica* extracts displayed MIC values higher than 1.6 for all assessed bacteria (Table 6), which fits the classification of some authors for weak inhibitor profile (Corrêa, Peralta, et al., 2018); notwithstanding, the bacteria used in our assay are clinical isolated multi-resistant strains that present antibiotic resistance profiles quite higher to those of ATCC strains (Dias et al., 2016). Therefore, our data can be interpreted as evidence of important antibacterial potential.

4. Conclusion

Of millenary relevance, valued in our time as health and cultural foods, *F. carica* fruits are being prospected for scientists worldwide for the obtainment of high-added value bioproducts. Indeed, their peels present great potential as sources of natural food additives (antioxidants, preservatives, functionalizing ingredients) and nutraceuticals. To our best knowledge, this is the first study on the in-depth chemical characterization of the peel and pulp of a Portuguese green fig fruit cultivar, as well as on the evaluation of their antioxidant capacities using cell-based methods and antibacterial potentials. The information herein reported confirms that the fig peel is superior to the corresponding pulp as it relates to nutritional and phenolic profiles as well as biological activities, endorsing the urgency in valorising and exploiting this usually discarded agro industrial by-product.

Declaration of Competing Interest

None.

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