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Assessment of chemical, physico-chemical, techno-functional and antioxidant properties of fig (*Ficus carica* L.) powder co-products

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ABSTRACT

The aims of this study were determine (i) the chemical, physico-chemical and techno-functional properties (ii) the phenolic, flavonoid and anthocyanins profile, (iii) the organic acids and sugar content and (iv) the antioxidant properties of the fig powder co-products (FPC) obtained from the pulp and peel of two cultivar such as *colar* and *cuello de dama*. The main sugars were fructose and glucose with higher content in FPC obtained from pulp than FPC obtained from peel. In the same way, higher content of organic acids were found in FPC obtained from pulp than obtained from peel. The majority of the phenolic acids were found in FPC obtained from pulp; however, the flavonoids were predominant in FPC obtained from peel. As regards antioxidant activity, at all concentrations and with all methods, FPC obtained from peel present higher antioxidant activity than FPC obtained from pulp.

1. Introduction

The industrial transformation of vegetables and fruits generates large quantities of co-products rich in bioactive compounds that may well be suitable for other purposes (Viuda-Martos et al., 2009). However, the treatment of co-products is perceived as an expensive process, which implementation impacts negatively on the economic viability/sustainability of commercial enterprises.

One way of avoiding this problem would be, depending on the availability of an adequate technology, converted into commercial products either as raw materials for secondary processes (intermediate foods ingredients), as operating supplies or as ingredients for new products (Sánchez-Zapata et al., 2011) to take advantage of the large quantity of potentially beneficial compounds they contain, mainly fiber and polyphenolic compounds.

Food researchers are looking novel raw materials that meet these needs, with a particular focus on the co-products. Fibers extracted from some fruits co-products exhibit physiological and functional properties that make them promising ingredients for the food industry and for health applications (Ktari et al., 2014). In the same way, fruits co-products are rich in polyphenolic compounds which could be reused by food industries as natural ingredient for the formulation of functional foods (Schieber et al., 2001) due to the functional activities (antioxidant, antimicrobial, and so on) attributed to these compounds. Thus, the recovery of valuable compounds from natural resources is nowadays conducted using the so called "5-stage universal recovery processing". These stages are: (i) macroscopy pre-treatment, (ii) Macro- & micro molecules separation, (iii) Extraction, (iv) Isolation & purification and (v) Product formation (Galanakis, 2012). Additionally, as mentioned Galanakis (2013) the recovery of bioactive compounds from co-products could be improved using new trends, the so-called emerging technologies.

Fig (*Ficus carica* L.) is an important crop worldwide and one of the most abundant fruits in the Mediterranean diet for dry and fresh consumption. In Southeast of Spain, dry figs have been a common ingredient for the preparation of typical cakes in particular "fig cakes". This artisan product, of Arab origin, is elaborated with dried figs, almonds, cinnamon and cloves. Usually, this product is eaten at Christmas but their use is extending throughout the whole year. The fig industrialization produces a lot of co-products. These co-products come from fresh fig discarded because of inadequate ripening or over ripening, spoiled, size, texture or a low quality as table fruit, but they are safe for human consumption. The non-use of fig co-product constitutes a real economic loss since it is rich in nutrients and bioactive compounds which can be extracted and used as value-added materials. Figs and figs co-products are an excellent source of minerals, vitamins and dietary fiber; they are fat and cholesterol-free and contain a high number of amino acids

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(Solomon et al., 2006; Veberic et al., 2008a). Furthermore, some studies have described the presence of several phenolic compounds in this fruits (Vallejo et al., 2012; Bachir bey et al., 2014).

In many cases, there is a significant lack of research about the viability of fruit co-products exploitation and, as a result, its use is still under investigation (Babbar et al., 2011). To the best of our knowledge, there are no studies, as regards the fig co-products. Thus, it is necessary to study these co-products to identify alternatives for processing and reusing the co-products that are formed, overcoming environmental issues, and adding value to these products. The aims of this study were determine (i) the chemical, physico-chemical and techno-functional properties (ii) the phenolic, flavonoid and anthocyanins profile, (iii) the organic acids and sugar content and (iv) the antioxidant properties of the fig powder co-products (FPC) obtained from the pulp and peel to set their applications on the food industry as potential ingredient for food products.

2. Materials and methods

2.1. Plant material

Discarded fig fruits (*F. carica* L.) from two selected commercial varieties: cv. *colar* and *cuello de dama* were obtained from a fig industry located in Orihuela (Spain) who elaborates dry fig, fig jam and fig cakes.

2.2. Sample preparation

Discarded fig fruits of two cultivars (*colar and cuello de dama*) were transported to the pilot plant facilities of the IPOA Research Group at the Miguel Hernández University. The fig fruit were manually peeled and the skin separated from the pulp and separately, triturated for 40 s in a vertical cutter (Tekator 1094 Homogeneizer, Hoganas, Sweden) to obtain uniformly sized pieces and so increase the contact time during washing (1 L of water per kg of product).

The mixture was stirred constantly and the water temperature was kept at 60 °C during the 10 min that the washing process lasted. The whole co-product was pressed to drain liquid. Then, it was dried at 60 °C during 24 h in an air tunnel drier. A grinder mill and sieves were used to obtain a powder particle size of less than 0.417 mm. The four fractions obtained were fig power co-product (FPC) from peel cv. *collar*, FPC from pulp cv. *collar*, FPC from peel cv. *cuello de dama,* FPC from pulp cv. *cuello de dama* (FPC_{pucd}).

2.3. Chemical analysis

The proximate composition of fig powder extract samples, including moisture, protein, fat and ash contents was determined using the appropriate AOAC (2000). Moisture (g water/100 g dry matter (dm)) was determined by drying 3 g sample at 105 °C to constant weight. Protein content was determined by AOAC method 920.152. Ash content was determined by AOAC method 940.26 while fat was determined by AOAC method 963.15. Total dietary fiber (TDF) (g TDF/100 g dm) and insoluble dietary fiber (IDF) were determined following AOAC methods (AOAC, 2000). Soluble dietary fiber (SDF) was calculated by subtracting the IDF proportion from the TDF. Each assay was carried out in triplicate.

2.4. Physico-chemical analysis

The pH was measured in a suspension resulting from blending 1 g sample with 10 mL of deionized water for 2 min, using a pH meter (model pH/Ion 510, Eutech Instruments Pte Ltd., Singapore). The water activity (A_w) was determined in a Novasina Thermoconstanter Sprint TH-500 (Pfäffikon, Switzerland) at 25 °C. The color was studied in the CIEL*a*b* color space using a Minolta CM-2600d (Minolta Camera Co., Osaka, Japan), with illuminant D_{65}, 10° observer, SCI mode, 11 mm aperture of the instrument for illumination and 8 mm for measurement. Low reflectance glass (Minolta CR-A51/1829-752) was placed between the samples and the equipment. The following color coordinates were determined: lightness (L^*), redness (a^*, ±red–green), and yellowness (b^*, ±yellow–blue). From these coordinates, hue (H^*) and chroma (C^*) were calculated as follows:

$$\text{Hue} = \frac{\tan^{-1} b*}{a*} \text{Chroma} = (a*^2 + b*^2)^{1/2}$$

2.5. Techno-functional properties

The water-holding capacity (WHC) and oil holding capacity (OHC) were determined according to Robertson et al. (2000) with some modifications. Five milliliters of ultrapure water or commercial olive oil were added to 0.5 g of the different samples, vortex during 5 min and left at room temperature for 1 h. After centrifugation (3000 g; 5 min), the residue was weighed. The WHC was expressed as g of water held per g of sample while the OHC was expressed as g of oil held per g of sample. Each assay was carried out in triplicate.

Emulsifying activity (EA) and emulsion stability (ES) were also evaluated. One hundred milliliters of 2% (w/v) sample suspension in water was homogenized at 11 000 rpm for 30 s using an IKA T-25 homogenizer. One hundred milliliters of sunflower oil was then added and homogenized for another 1 min. The emulsions were centrifuged in 10 mL graduated centrifuge tubes at 1200 g for 5 min, and the volume of the emulsion left was measured. The EA was calculated as the volume of emulsified layer/volume of whole layer in the centrifuge tube × 100. To determine the ES, emulsions prepared by the above procedures were heated at 80 °C for 30 min, cooled to room temperature, and centrifuged at 1200 g for 5 min. The ES was calculated as the volume of remaining emulsified layer/original emulsion volume × 100. Each assay was carried out in triplicate.

2.6. Organic acid and sugar content

2.6.1. Extraction of organic acid and sugars

One gram of the different FPC samples was homogenized with 10 mL of acidified ultrapure water (0.1% phosphoric acid) in an Ultra-Turrax at 13 500 rpm for 20 s. Then, the samples were centrifuged at 5000 g for 10 min at 4 °C and the supernatants were filtered through 0.45 μm Millipore filter (Millipore Corporation, Bedford, USA). Triplicate extractions were obtained from each sample.

2.6.2. HPLC analysis

Organic acids and sugars were analyzed in a Hewlett–Packard HP-1100 instrument (Woldbronn, Germany) coupled with two detectors: UV–vis Diode Array Detector G1315A (set at 210 nm) and refractive index detector G-1362. Twenty microliters of sample were injected in a cation exchange column (Supelcogel C-610H, 300 × 7.8 mm, Supelco, Bellefonte) with a pre-column (Supelguard-H, 50 × 4.6 mm, Supelco), using phosphoric acid (0.1%) as mobile phase, operating flow rate of 0.5 mL/min. Samples were run at 30 °C and the run time was 30 min (Doughty, 1995). Standards of organic acids (L-ascorbic, malic, tartaric, citric, oxalic, acetic, malonic, lactic, fumaric and succinic acids) and monosaccharides (glucose, fructose and sucrose) were obtained from Sigma (Poole, Dorset, UK). Peaks were identified by comparison with retention time of the standards, and quantified by regression formula obtained with the standards.