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Extraction and Evaluation of Nutraceutical Molecules in Wastes of Fruit and Vegetables

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Abstract

Fruit and vegetables wastes not only have no commercial value, but also require expensive operations of removal and disposal, representing a significant cost for the manufacturers of plant products. However, this material may represent an important resource of commercially worth phyto-molecules endowed with various nutraceutical properties. In the present work, we have verified the possibility of using fruit and vegetable waste materials as a source of bioactive compounds. Several nutraceutical compounds of high economic interest were extracted and quantified from various waste plant materials deriving from the production phase ("first-gamma products") or discarded during the preparation of fresh ready-to-cook or ready-to-eat packaged products ("fourth-gamma products"). Obtained results showed that, despite the precarious and uncontrolled conditions which plant wastes products are subjected, the levels of the examined bioactive compounds are present in relevant amount, also in the parts of the plant that are discarded during the preparation of the ready-to-eat/cook products.

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Introduction

The harvest and the industrial manufacture of fruit and vegetables unavoidably leads to the production of large amount of bio-waste materials, represented by fresh not packaged products such as fallen or defective fruits (*I gamma*) or discarded during the preparation of fresh ready to cook or to eat packaged products (*IV gamma*). These plant wastes are not suitable to be commercialized and in addition represent a cost, requiring expensive operations of removal and disposal. However, both wastes may theoretically represent an important resource of precious phyto-molecules endowed with various nutraceutical properties such as for example Lycopene, Phloridzin, Ursolic acid, Kaempferol, Chlorogenic acid, Arbutin, Lutein, Sulforaphane, Lactucin and Lactucopicrin.

Lycopene is a carotenoid molecule responsible for the red colour in tomato fruits. It is widely used in food industry as additive and supplement and is the subject of a large number of studies of pharmaceutical/medical interest because of its well studied antioxidant and anticancer properties (Giovannucci et al. 1995, Stahlet al. 2003,Gannet al. 1999, Bramley et al. 2000, Tamini et al. 2009, Qu et al. 2011).

Phloridzin, one of the dihydrochalcones contained in apples, is a specific and competitive inhibitor of sodium/glucose cotransporters in intestine and kidney and for this reason it represents a potential candidate for the treatment or prevention of diabetes and obesity (Ehrenkranz et al. 2005, Najafian et al. 2012).

Ursolic acidis a triterpenoid ubiquitous in plant kingdom and its presence has been demonstrated in the cuticular wax

of many fruits, including apples and pears (Belding et al.1998, Andre et al. 2012, Li et al. 2014). It appears to increase skeletal muscle and brown fat and to possess anti-tumor and anti-inflammatory effects (Kunkel et al. 2012, Zang et al.2014). Moreover, it has been indicated as a potential agent against hyperglycaemia and obesity (Castro et al. 2015).

Kaempferol has been associated to a number of biological effects, inhibiting the angiogenesis process and the growth of cancer cell (Lee et al. 2010, Chen et al. 2013). In addition, it shows antioxidant and anti-inflammatory effects and inhibits *in vitro* bone resorption (Wattel et al. 2003).

Chlorogenic acid also shows anticancer properties and helps to protect from oxidative stress (Tanaka et al. 1993,Tsuchiya et al. 1996) as well as to inhibit the growth of preadipocytes (Hsu et al. 2006). Moreover, improving lipid metabolism, it has been proved to be more effective than Caffeic acid as anti-obesity agent in high fat diet induced obese mice (Cho et al. 2011). Furthermore, it contributes to enhance macrophage functions *in vivo* and *in vitro* and to influence the sleep-wake cycle (Wu et al. 2004, Shinomiya et al. 2004).

Arbutinis an important glycosylated hydroquinone compound detectable in pear fruit; it is endowed with antimicrobial properties and, due to its ability to inhibit tyrosinase, is used as a skin-lightening agent in cosmetics (Cui et al. 2005).

Lutein, a xanthophyll pigment present in the membranes of macula lutea of the primate vision apparatus, has been proven to be able to increase the macular pigment optical density, suggesting a prevention effect against damage caused by blue light as well as macular degeneration associated with aging (Landrum et al. 1997).

Sulforaphane, a naturally occurring isothiocyanate present in cruciferous vegetables, is well known to reduce risk of cancer by activation of phase II detoxification enzymes and by inducing apoptosis in cancer cells (Moreno et al., 1996). Moreover, it shows inhibitory activity against stomach cancer induced by benzo(a)pyrene and against the microbial pathogen *Helicobacter pylori* (Fahey et al. 2002).

Finally, Lactucin and Lactucopicrin, responsible of the characteristic bitter taste, largely present in *Lactuca* and *Cichorium* species, are endowed with antimalarial, anti-inflammatory and sedative properties (Bischoff et al. 2004,Wesolowska et al. 2006).

In the present work, the above citedmolecules were extracted and quantified from wastes obtained after harvesting or manufacturing plant products. This material was selected among those of main interest for the companies producing fruits and vegetables belonging to the AOP Unolombardia association (tomato, apple, pear, leek, chard, cabbage, broccoli, a variety of fruit and vegetables smoothies and a variety of chicory, radish, lettuce and endive).The possibility and the feasibility to transforming bio-wastes, representing a cost for the companies that produce them, in a source of nutraceutical molecules possessing a commercial value on the market of dietary supplements or of cosmetic products ingredients was then evaluated.

Materials and Methods

Materials

All the fresh vegetable and fruit wastes were harvested and collected from farms located in Lombardia region (Italy). As concerns plant wastes of packaged products, the materials were obtained from the company "La lineaverde", Manerbio (Brescia, Italy).

Standards and reagents

All solvents and reagents were purchased from Sigma Aldrich, Germany, as well as standards of Lycopene, Ursolic acid, Phloridzin, Kaempferol, Chlorogenic acid, Arbutin, Lutein and Sulforaphane.Standards ofLactucin and Lactucopicrin were purchased from Extrasynthese, France. Novozymes 50012 enzyme mixture was purchased from Novozymes, Denmark. The used water was purified by Milli-Q quality water system (Millipore Bedford, USA).

Extraction from waste material

Lycopene: Samples of tomato wastes (harvested in Alessandria, North Italy) were collected accurately separating pulp and peel. Other samples of mixed manufacturing waste of ripe tomato (pulp and peel)were harvested and collected in Collecchio. (Parma, Italy). Samples were ground with liquid nitrogen and homogenate sample (1g) was accurately weighed and stirred for 10 minutes with 25 ml of hexane / acetone / ethanol (50:25:25, v/v/v) at 0 °C. Samples were then transferred into a flask and shaken at 300 x g in the dark for 30 minutes at 4 °C. After the addition of 5 ml of water, the upper phase was collected and concentrated by using a rotavapor. The residue was resuspended in 1 ml of acetone, filtered and stored at -20 °C until HPLC analyses (Olives Barba 2006).

Phloridzin and Ursolic acid: Phloridzin was extracted from apple waste and Ursolic acid from apple, pear waste and from fruit smoothie preparations (mix of different fruits, table 1); Samples of apple and pear waste were accurately collected, separating pulp and peel. Both the compounds were extracted using the same method (modified) (Tsao et al. 2003). The samples were ground with liquid nitrogen, weighed (1.5 g) and placed in a test tube with 3 ml of ethanol; after they were mechanically stirred in a homogenizer for 3 minutes at 0 °C, they were placed in a ultrasonic bath for 5 minutes and left on a shaker at 300 x g, at 4 °C for 24 h. The extracts were then centrifuged and the obtained supernatant was filtered (0.45 µm) and stored at -20 °C until HPLC analysis.

Table 1. Compositions of wastes derived from fruit and vegetables smoothies.

	Percentage composition
	Ursolic acid (mg/g FW)
Mix 1	Sour black cherry 45%, pear 10%, grapes 45%
Mix 2	orange 15%, banana 17%, strawberry 40%, apple 14%, grapes 14%
Mix 3	orange 20%, banana 0.5%, strawberry 12%, apple 11%, blackberry 10%, laspberry 10%, lemon 0.5%, mulberry 10%, ribes 2%, grapes 24%
Mix 4	orange 16%, fennel 42%, banana 8%, lime 5%, lemon 0.2%, apple 20%, spinach 0.8%, grapes 8%
Mix 5	pineapple 24%, orange 11.7%, banana 0.1%, lemon 0.1%, lime 0.1%, mango 41%, apple 19%, passionfruit 4%

Arbutin: According to the method of Cui et al. (2005), with some modifications, pear waste samples were divided into three

parts: peel, pulp and core (seedless) and analyzed for the content of Arbutin. Each partwas ground with liquid nitrogen and 1 gram of sample was mashed for 5 minutes with 1 ml of ethanol 95% (precooled to -18 °C), containing 2% (v/v)phosphoric acid. The suspension was then transferred to a new flask, brought to 12 ml using 95% ethanol at -18 °C, placed in ultrasonic bath for 15 min and centrifuged at 3000 x g for 5 minutes. An aliquot (1 ml) of this sample was evaporated to dryness byspeedvacuum. The residue was resuspended in 1 ml of water, filtered and stored at -20°C until HPLC analysis.

Kaempferol and Chlorogenic acid: Kaempferol and Chlorogenic acid were extracted from leek wastes, dried at 40 °C for 48 h and then ground by using a Retsch MM301 grinder. The sample (2g) was then extracted with 20 ml of methanol by maceration at room temperature for 72 h. The extraction process was repeated until colorless residue was obtained. The samples were centrifuged at 3000 x g for 5 minutes and the recovered supernatant was then filtered. An aliquot of the sample (1 ml) was then dried by speed vacuum. The residue was resuspended in 0.25 ml of methanol and stored at -20 °C until carrying out HPLC analysis (Faera et al. 2013).

Lutein: Lutein was extracted from wastes of leek leaves, Catalognachicory and chard.All the materialswere ground using liquid nitrogen and 0.5 g of the samples were subsequently extracted with 1.5 ml of diethyl ether in a test tube in the dark for 1 h at 4 °C. After centrifugation at 3000 x g for 5 minutes, supernatant was collected and stored at – 20 °C. The residue was extracted two more times in diethyl ether before recovering combined supernatants and drying them by using speed vacuum. The residue was resuspended again in 1.5 ml of acetone, filtered and stored at -20 °C until HPLC analyses (Chang et al., 2013).

Sulforaphane extraction. Sulforaphane was extracted from cabbage and broccoli wastes; the materialswere dried at 60°C and then ground to powder. Sampleswere accurately weighed(150 mg) and suspended in 4 ml of 0.1 M HCl. The mixture was incubated at 45 °C for 2.5 h on a shaker in order to release Sulforaphane from the glucosinolate molecules.After that, the mixture was extracted with 20 ml of dichloromethane, mixed in a vortex for 1 minute and left at room temperature for 1 h. The organic extract was centrifuged at 3000 x g for 5 minutes in order to easily remove the residue. The clarified extract was dehydrated with anhydrous sodium sulfate, centrifuged again, and purified using an absorption column (SupelcleanTM LC-Si SPE 3 ml) previously equilibrated with 3 ml of dichloromethane. After the extract was loaded onto the cartridge, the column was washed by swishing 3 ml of ethyl acetate (discarded) and the sample was collected after elution of 3 ml of methanol. An aliquot (1 ml) of the collected sample was dried and the residue resuspended in 0.5 ml of acetonitrile + 0.21 ml of water, then filtered and stored at -20 °C before HPLC analyses (Campas-Baypoli et al., 2010).

Lactucin and Lactucopicrin: Lactucin and Lactucopicrin were extracted from wastes of Catalognacicory, baby lettuce, red radish, sugarloaf and two salad mixes (Table 2) were ground by liquid nitrogen. Each sample (4 g) were homogenized with 10 ml of 0.1M acetate buffer (containing calcium chloride 10 mM) + 0.4 ml of Novozymes 50012 hydrolytic enzymes mixture at pH 4.5, 50 °C for 4 h. The reaction mixture was centrifuged at 4000 rpm for 5 minutes and the supernatant was recovered and mixed with 10 ml hexane. After discarding the hexane phase, samples were extracted twice in a separating funnel with 4 ml of ethyl acetate. The ethyl acetate phases were combined and dried by using a speed vacuum centrifuge. The residue was extracted with a mixture of 0.075 ml of ethyl acetate and 0.075 ml of methanol, and subsequently with a mixture of 0.025 ml of chloroform and 0.025 ml of ethanol. The two collected mixtures were combined and evaporated. The residue was solubilized in 0.050 ml of acetone, centrifuged and the supernatant was recovered and dried again. The residue obtained was resuspended in 0.2 ml of methanol + 0.4 ml of hexane. The methanol phase was filtered and stored at -20 °C until HPLC analyses were carried out. All the above reported extractions were made in triplicate (Van Beek et al. 1990).

Table 2. Percentage compositions of the two salad mixes (leaves).

	Percentage composition
Mix A	Baby lettuce 45%, red lettuce 25%, mizuna 10%, tatsoi 10%, red chard 10%
Mix B	curled leaves endive 34%, scarole 33%, red radish 33%

HPL Canalysis

Unless otherwise specified, samples (20 µl) were injected into the HPLC system Kontron Instrument 420 system, equipped with a column Kinetex XB-C18, 250 mm x 4.6 mm, 5 µm. Peak identities were assessed by comparing the retention time of each peak in the analyzed specimen with that one of a standard sample. Quantitative analysis was obtained by calibration curves prepared over the expected analytical concentration range. After every run, the column was washed by methanol for 15 minutes and equilibrated with the initial mobile phase for 10 minutes before the next run. All analyses were carried out at room temperature.

Lycopene was determined as described by Olives Barbaet al. (2006). The isocratic mobile phase consisted methanol / acetonitrile (90:10, v/v) + TEA 9 µM. The flow rate was 1 ml/min. Detector wavelength was fixed at 470 nm. Under these conditions, retention time of Lycopene was found to be 24.4 min.

Phloridzin was determined as described by Tsaoet al. (2003) with modifications described below. The binary mobile phase consisted of a 2 mM sodium acetate buffer with 6% acetic acid, pH 2.55 (solvent A) and acetonitrile (solvent B); the gradient program was: 0-15 min, 0-15% B; 15-20 min, 15-30% B; 20-25 min, 30-50% B; 25-30 min, 0-100% B. The flow rate was 1.0 ml/min. Detector wavelength was fixed at 280 nm. Under these conditions, retention time of Phloridzin was found to be 22.6 min.

topadhyay (2012). The isocratic mobile phase consisted in acetonitrile/ methanol solution (80:20, v/v). The flow rate was 0.5 ml / min. Detector wavelength was fixed at 210 nm and the chromatographic run was performed at room temperature. Under these conditions, retention time of Ursolic acid was found to be 10.9 min.

Arbutin was determined as described by Cui et al. (2005), with modifications. Formic acid 0.04% was employed as mobile phase A and pure methanol as mobile phase B. The gradient procedure was 0-3 min, 2% B; 3-4 min, 2-25% B; 4-11 min, 25% B; 11-16 min, 25-50% B; 16-26 min, 50-80% B. The

flow rate was 1.0 ml/min. Detector wavelength was fixed at 280 nm. Under these conditions, retention time of Arbutin was 7.0 min.

Kaempferol and Chlorogenic acid were determined as described by Zuet al. (2006). The isocratic mobile phase consisted of methanol/ water/ acetonitrile (40:15:45, v/v/v) with 1% of acetic acid. The flow rate was 1 ml / min at room temperature. Detector wavelength was fixed at 368 nm for Kaempferol and 325 nm for Chlorogenic acid. Under these conditions, retention time of Kaempferol was 7.6 min, while retention time of Chlorogenic acid was 2.2 min.

Lutein was determined as described by Tukajet al. (2003) with some modifications described below. A methanol / 1 M ammonium acetate solution (80:20, v/v) was employed as mobile phase A and methanol/acetone (80:20, v/v) as mobile phase B. The gradient program was 100% A to 100% B in 10 min, followed by 5 min of 100% B. The flow rate was 1.0 ml/min. Detector wavelength was fixed at 450 nm. Under these conditions, retention time of Lutein was 12.3 min.

Sulforaphane was determined as described by Sivakumaret al. (2006). The HPLC system was equipped with a column C-30 Develosil RPAQEOUS-AR, 250mm x 4.6 mm, 5 µm. The isocratic mobile phase consisted of acetonitrile/water (70:30, v/v). The flow rate was 1.0 ml/min at room temperature and detector wavelength was fixed at 205 nm. Under these conditions, retention time of Sulforaphane was found to be 2.8 min.

Lactucin and Lactucopicrin were determined as described by van Beeket al. (1990). The HPLC system was equipped as described for Sulforaphane analysis. The isocratic mobile phase consisted of methanol/water (50:50, v/v) and the flow rate was 1.0 ml/min. Detector wavelength was fixed at 258 nm. Under these conditions, retention time of Lactucin was found to be 4.8 min, while about Lactucopicrin it was 23.8 min.

Results and Discussion

Reported data are presented as mg/g fresh weight (FW) or dry weight (DW), mean ± standard deviation (SD, n = 3) with the only exception of the data regarding Lycopene that are presented as mg/100 g FW.

As expected, Lycopene was concentrated mainly in the peel of ripe tomatoes. The amount of Lycopene present in mixed waste samples is slightly less than half that in the tomato peel (table 3). The results obtained donot differ much from those in the literature: values of Lycopene between 4.1 and 4.4 mg/100 g FW have been reported for two varieties of ripe tomato (Thompson et al. 2000); values of 4.8 - 14.1 mg / 100 g and 2.0 - 6.9 mg / 100 g FW have been reported, respectively, for the peel and the pulp of 12 varieties of ripe tomato (Georgeet al. 2004).

Table 3. Lycopene content in tomato wastes.

	Lycopene mg/100 g FW
tomato mix	0.20 ± 0.002
tomato peel	4.5 ± 0.005
tomato pulp	1.6 ± 0.002

Since Phloridzin is involved in processes of plant defense against pathogenic microorganisms, its presence is more abundant in the peel than in the pulp. In the literature, the highest concentrations of this dihydrochalcone have been reported for the leaves and bark of several species of *Malus*, followed by peel and finally pulp (Tsao et al. 2003; Escarpa et al. 1999), where it can be even undetectable in small amounts of analyzed sample. In the manuscript of Tsao, Phloridzin content in 8 varieties of apple peel in a range between 0.036 - 0.172 mg/g FW was reported. Our data, shown in table 4, are similar to these ones, except for the variety Granny in which Phloridzin levels are lower.

Table 4. Phloridzin content in wastes of the three analyzed apple cultivars.

	Peel	Pulp
Apple Golden	0.170 ± 0.005	0.101 ± 0.004
Apple Granny	0.159 ± 0.006	0.105 ± 0.002
Apple Stark	0.536 ± 0.030	0.110 ± 0.003
Pear	0.468 ± 0.005	0

	Phloridzin mg/g FW	
	Peel	**Pulp**
Stark	0.090 ± 0.005	0
Golden	0.080 ± 0.006	0
Granny	0.004 ± 0.001	0

The Ursolic acid values registered in apple and pear wastes are not too different from the results reported in literature for high quality fruits, i.e.: from 0.044 to 3.522 mg/g FW in apple peel (Andre et al. 2012); from 0.125 to 0.791 mg/g FW in pear peel (Lee et al. 2014). Ursolic acid is detectable in all the analyzed samples, except pear pulp. Table 5 shows that the apple Stark peel and the pear peel contain the highest values of Ursolic acid, followed by the smoothie wastes (mix6 and mix5).

Table 5. Ursolic acid content in wastes of the three apple cultivars and the pear (a), fruit and vegetable smoothies (Mix 1-6) (b).

	Ursolic acid (mg/g FW)
Mix 1	0.142 ± 0.003
Mix 2	0.207 ± 0.012
Mix 3	0.215 ± 0.016
Mix 4	0.243 ± 0.036
Mix 5	0.421 ± 0.017
Mix 6	0.424 ± 0.033

Arbutin levels in the peel and in the core were found higher compared to the pulp, (table 6), as expected on the basis of the information available in literature. The Arbutin content, while remaining not negligible, is much lower than that reported for immature pears, because it decreases rapidly during the fruit maturation process (Cui et al. 2005).

Table 6. Arbutin content in pear wastes.

	Arbutin mg/g FW
Pearpeel	0.148 ± 0.016
Pear pulp	0.015 ± 0.001
Pear core	0.223 ± 0.025

Regarding Kaempferol and Chlorogenic acid,results shown in table 7reveal that there is a relevant amount of both

Kaempferol and Chlorogenic acid in the analyzed samples. According to literature, in leek leavesKaempferol-3-O-glucosideis mainly present, while Kaempferolaglycones appear to be poorly present (0.001 mg/g DW) (Bernaert et al. 2013). However, the experimental conditions we have employed in the extraction method could promote the hydrolysis ofglycosidic bonds and the release of Kaempferol during the long drying process. Indeed, the amount of Kaempferol obtained (table 7) is similar to that (0.295 mg/g DW) registered by Hertoget al. (1992) for leek leaves after extraction in hydrolytic conditions. Values of both Kaempferol and Chlorogenic acid result respectively at least 5 and 7 times lower than the amounts reported by Faeraet al. (2013) (194.5 mg/100 g and 302 mg/100 g DW respectively), which is the only article we found in literature reporting such high levels of these compounds in Allium ampeloprasum leaves. The review by Manachet al.(2004) reports a value of 30 mg/kg FW for Kaempferol in leek, which is not far from results obtained in this work (0.330 mg/g DW ≈ 24.812 mg/kg FW, value obtained by measuring the ratio fresh weight / dry weight).

Table 7. Kaempferol and Chlorogenic acid content in leek wastes.

	Kaempferol mg/g DW	Chlorogenic acid mg/g DW
Leekleaves	0.330 ± 0.032	0.378 ± 0.023

The Lutein content found in leek leaves resulted much lower than that in chard and Catalognacicory (table 8), so this waste source should be regarded suitable to extract Chlorogenic acid and Kaempferol rather than Lutein. Catalognacicory seems to be a good source of Lutein (0.586 ± 0.103 mg/g DW). The obtained values are in line with data published by Žnidarčič et al. (2011) for two Chicoriaintybuscultivars (3.87 - 5.91 mg/100g DW), although these values are much higher than those obtained by Montefustoet al. (2015) (0.008 mg/g FW). This may be due to the difference in the analyzed experimental material: in our case, not all edible part of the Catalogna chicory was used; the white underside was discarded and only the leaves were extracted.

Table 8. Lutein content in chard, Catalognacicory and leek wastes.

	Lutein (mg/g DW)
Chardleaves	0.297 ± 0.050
Catalogna cicoryleaves	0.586 ± 0.103
Leekleaves	0.035 ± 0.002

The amount of Sulforaphane present in cabbage leaves (0.100 mg/g DW ≈ 0.003 mg/g FW) is in line with the data published by Liang et al. (0.001 - 0.005 mg/g FW) (Liang et al. 2006). In broccoli samples, the amount of Sulforaphane in the stems is higher than that in the florets (table 9). Although other cases of broccoli cultivars in which the stems have a quantity of Sulforaphane greater than the florets can be found (Nakagawa et al. 2006), the opposite case is more commonly presentin literature. Data reported in the present work point out that, among the analyzed samples, the stems, completely unusable as food, contain the highest amount of Sulforaphane, thus representing an excellent source of this important nutraceutical molecule originated by glucosinolates.

Table 9. Sulforaphane content in cabbage and broccoli wastes.

	Sulforaphane (mg/g DW)
Cabbageleaves	0.100 ± 0.002
Broccoli florets	0.168 ± 0.030
Broccoli stem	0.375 ± 0.055

Regarding the Lactucin and Lactucopicrin amount found in the waste, the mixB (see table 2) appears to be the best source for Lactucin among the analyzed samples and, together with sugarloaf, it contains also the highest amount of Lactucopicrin (table 10). These sesquiterpene lactones endowed with anti-malarial and digestive properties contribute to the bitter taste of many *Lactuca* and *Cichorium* species (Warashina et al. 2008). Indeed, in lettuce and in mix A smoothie (see table 2) samples, with almost no bitter taste, the Lactucin level is low, while Lactucopicrin is not detectable. In red radish samples, both sesquiterpenes lactones are more concentrated in the leaves than in stems.

Table 10. Lactucin and Lactucopicrin contents in Catalognacicory, baby lettuce, mixA, mixB, radish and sugarloaf wastes.

	Lactucin (mg/g FW)	Lactucopicrin (mg/g FW)
Catalognacicory leaves	0.013 ± 0.001	0.010 ± 0.001
Baby lettuceleaves	0.021 ± 0.001	0
MixA	0.049 ± 0.001	0
MixB	0.501 ± 0.038	0.160 ± 0.027
Redradishleaves	0.078 ± 0.002	0.013 ± 0.001
Redradishstems	0.050 ± 0.002	0.004 ± 0.0004
Sugarloafleaves	0.046 ± 0.003	0.200 ± 0.002

The data obtained in this work confirm the possibility of using fruit and vegetables waste materials, representing a cost and possessing no commercial value, making their recovery disadvantageous in comparison to not waste counterparts, as a source of nutraceutical substances of high economic interest. Indeed, despite the precarious and uncontrolled conditions which the plant wastes are subjected to, the level of the examined compounds doesn't seem to be substantially reduced. Moreover, most obtained data are in line with those available in literature for counterpart not-waste materials.

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