

# Physicochemical characteristics, bioactive compounds and antioxidant activity in juice, pulp, peel and seeds of *Cantaloupe* melon

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Received: 14 July 2017 / Accepted: 15 September 2017 / Published online: 22 September 2017  
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**Abstract** Although it is known that fruit products are rich sources of natural bioactive compounds, information on the nutritional value of their waste parts is scarce. The objective was to characterize the edible (juice and pulp) and waste (peel and seeds) parts of *Cantaloupe* melon (*Cucumis melon* L. var. *reticulatus*) in terms of some physicochemical characteristics, bioactive compounds and total antioxidant activity. Juice, pulp, peel and seeds represent 42, 23, 25 and 7% of total weight, respectively. Juice and pulp presented identical profiles in terms of physicochemical characteristics, bioactive compounds and antioxidant activity. They contributed to the majority of the overall content of carotenoids (80%) and vitamin C (84%) in *Cantaloupe*. Peel and seeds had the highest concentrations of potassium, being seeds the richest portion ( $7.08 \pm 0.16$  mg/g). Seeds had also the significantly highest total phenolics concentration ( $229.13 \pm 20.92$  µg/g), antioxidant activity ( $653.67 \pm 169.20$  µg/g), and soluble solids content ( $11.79 \pm 0.90$  °Brix). Peel stood out by the presence of chlorophylls. Since waste parts of *Cantaloupe* melon represent around 32% of total weight, their valorization is a challenge and strategies to improve ways of re-using them should be developed.

**Keywords** Melon · Bioactive compounds · Antioxidant activity · Juice · Pulp · Wastes

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## Introduction

Melon (*Cucumis melon* L.) is a valuable source of minerals and antioxidant compounds. This fruit is cultivated in temperate climate regions of the world, with good adaption to soil diversity [1]. Particularly, *Cucumis melon* var. *reticulatus* belonging to the *Cucurbitaceae* family is highly appreciated and consumed due to its nutritional and organoleptic attributes. This type of melon is a relevant source of vitamin C, β-carotene, polyphenol antioxidants and potassium content [2]. These compounds provide important health benefits, being associated with a lower risk of chronic diseases [3]. Usually, melon is consumed fresh or transformed into juices, nectars, compotes or jams, resulting in great amounts of peel and seeds as by-products and waste parts.

There are several studies that evaluated bioactive compounds in fresh-cut melon tissue [2, 4–7]. According to many authors the content in bioactive compounds on fruit waste parts is very significant [8, 9].

Some studies focusing on fruit waste parts have been carried out. However, research related to melon peel and seeds is still scarce [10–12]. Jiménez-Aguilar et al. [9] reported some results for cactus pear, concluding that peel is the most important fraction of this fruit, because it contains the highest levels of soluble dietary fiber, phenolic compounds, flavonoids and antioxidant activity. Another work developed by Contreras-Calderón et al. [8] on exotic fruits from Colombia revealed that peel and seeds have a high antioxidant potential. The chemical composition and bioactive components in peel and seeds of three species of pumpkin were assessed by Kim et al. [11]. Mohapatra et al. [10] evaluated the potential of banana peel in terms of relevant constituents, while Crizel et al. [12] investigated fibers from orange wastes and studied their application as a fat replacer in ice cream. Duda-Chodak and Tarko [13] assessed the antioxidant properties of seeds

and peels of different fruits such as watermelon, lemon, grapefruit, kiwi fruit, melon, grapes and oranges. Tomato peel was also studied by Navarro-Gonzalez et al. [14] in terms of functional properties, total antioxidant activity and content of antioxidant bioactive compounds.

The increasing demand for healthy foods has been growing in recent years and for that reason the food industry is constantly looking for new sources of nutritional and healthful components [15]. Therefore, it would be advantageous if waste parts of fruits would be characterized in terms of healthy compounds in order to be used as a source of natural food additives and ingredients. With respect to food industries, the complete utilization of the whole fruit would allow the minimization of wastes during processing, reduction of the environmental impact and profit increasing. From the consumer perspective, the availability of healthy alternative ingredients will certainly be a lever for products' choice. In this context, the characterization of waste parts of melon, which is a fruit with considerable weight of waste material, is still an unexploited area.

The main goal of this work was to assess some physicochemical characteristics (soluble solids content, titratable acidity, pH, color, water activity and potassium content), bioactive compounds (total phenolics and carotenoids, chlorophylls, and vitamin C) and total antioxidant activity present in edible (juice and pulp) and non-edible (peel and seeds) parts of *Cantaloupe* melon. Results will allow to exploit the potentiality of fruit waste parts as sources of healthy compounds.

## Materials and methods

### Samples preparation

Nine *Cantaloupe* melons (*Cucumis melo* L. var. *reticulatus*) were obtained at a local supermarket, at commercial maturity stage and stored overnight at 4 °C. Fruits were carefully inspected for bruising and compression damage and only those without visual defects and uniform in shape and size were selected for analyses. For each replicate, three melons were randomly selected for calculation of average weight of each fruit, using an analytical balance. Peel was manually removed with a sharp stainless steel knife and seeds were separated. Peel and seeds were triturated for 3 min with a domestic blender (Moulinex DD831810 Optitouch, France); juice and pulp were obtained by a domestic centrifuge (Centrifugal Juicer Excel JE850, UK).

For carotenoids and vitamin C determinations, samples were frozen with liquid nitrogen, immediately after trituration/centrifugation of the fruit parts.

Three true replicates were carried out for all determinations.

## Physicochemical analyses

### Soluble solids content, titratable acidity and pH

For each melon, homogenized samples of pulp, peel and seeds were filtered through cheesecloth and used to measure soluble solids content (SSC, °Brix), titratable acidity (TA) and pH, while juice was directly analyzed. Soluble solids content was measured with a Palette PR-32 digital refractometer (Atago, Tokyo, Japan). Titration was conducted with a 0.10 M NaOH to pH 8.1, and TA was expressed as mmol H<sup>+</sup> L<sup>-1</sup> of sample. The values of pH were measured using a pH meter (GLP 22, Crison Instruments, Spain).

The maturity state of the melon was assessed using the following equation:

$$\text{Maturity index (MI\%)} = \frac{\text{Soluble solids content}}{\text{Titratable acidity}} \times 100 \quad (1)$$

### Color

The color parameters ( $L^*$   $a^*$   $b^*$ ) of the melon parts were measured using a Minolta CR-400 colorimeter (Konica-Minolta, Osaka, Japan). The color brightness coordinate  $L^*$  measures the whiteness value of a color, and ranges from black at 0 to white at 100. The chromaticity coordinate  $a^*$  measures red when positive and green when negative, and the chromaticity coordinate  $b^*$  measures yellow when positive and blue when negative.

Chroma (or saturation index) and hue angle were also determined according to equations 2 and 3, respectively:

$$\text{Chroma} = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$\text{Hue angle} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (3)$$

The preceding parameters provide a more accurate spatial distribution of colors than direct values of tristimulus measurements [16]. Chroma is related to color intensity (higher values correspond to higher intensity observed), and hue angle defines color as follows: red at 0°, yellow at 90°, green at 180° and blue at 270° [17].

For each replicate, samples were analyzed in duplicate and three readings were carried out.

### Water activity

Water activity determinations were performed with a dew point hygrometer (Aqualab-Series 3, Decagon Devices Inc., USA) at 22 ± 1 °C. For each sample, measurements were performed in triplicate.

## Potassium

To each sample rigorously weighed (ca. 1 g), 50.0 mL of ionic strength adjustment solution was added. The mixture was homogenized during 2 min with an ultra-turrax (Ika digital T25, IKA®-Werke GmbH & Co. KG, Staufen, Germany), before analysis. Subsequently, each sample was analyzed towards potassium using potentiometric detection system. The potentiometric system included a decimillivoltmeter (microH 2002, Crison), the potassium selective electrode and an AgCl/Ag reference electrode (model 90-02, ThermoOrion). The potassium sensor was prepared as described elsewhere [18]. The electrode was constructed following the procedure described by Alegret et al. [19]. Quantification of potassium was attained following the external standard calibration curve using KNO<sub>3</sub> standard solutions of appropriate concentration.

## Bioactive compounds

### Total phenolics

Extractions were performed by homogenizing 25.0 g of pulp, juice, peel or seeds in 50.0 mL of 100% methanol (Merck) with an ultra-turrax homogenizer (Ika digital T25, IKA®-Werke GmbH & Co. KG, Staufen, Germany). The mixture was centrifuged at 5000×g for 10 min at 4 °C and the extract was filtered with filter paper. The chromophore development reaction is based on oxidation of polyphenols via Folin–Ciocalteu reagent, which is a mixture of phosphomolybdic and phosphotungstic acids, in a basic medium; the blue complex thus formed is assayed for absorbance at 750 nm, which is directly proportional to the total amount of polyphenols in the medium.

The standard stock solution was prepared by dissolving 0.010 g of gallic acid monohydrate in 1.0 mL of 100% methanol in an eppendorf 2.0 mL tube. A solution containing 1.0 mg mL<sup>-1</sup> of gallic acid was prepared by mixing 100 μL of the standard stock solution with 900 μL of 100% methanol. Standard solutions for the calibration curve were prepared by adding 0, 20, 40, 60 and 80 μL of the previous solution and 200, 180, 160, 140 and 120 μL of Milli-Q water to eppendorf 2.0 mL tubes.

The reaction was attained by adding 50.0 μL of standard or sample to 50.0 μL of Folin–Ciocalteu's phenol reagent, 1.0 mL of Na<sub>2</sub>CO<sub>3</sub> 75.0 g L<sup>-1</sup> and 1.4 mL of distilled water to spectrophotometer cuvettes. After incubating for 1 h in the dark at room temperature, the absorbance was read at 750 nm using an UV/VIS spectrophotometer (Model 5625, ATI Unicam, UK). Two extractions were carried out for each melon part and absorbance values were measured in triplicate for each extraction. The total phenolics content in the samples (reported as gallic acid equivalent per gram of

sample; μg/g) were calculated from interpolating the respective absorbance values in the calibration curve.

### Chlorophylls

Extractions were performed by homogenizing 7.0 g of pulp, juice, peel and seeds in 50.0 mL of 100% methanol with an ultra-turrax homogenizer. The mixture was centrifuged at 5000×g for 10 min at 4 °C, and the extract was filtered with filter paper. Quantitative chlorophyll determinations were carried out by reading absorbance at 665.2 and 652.4 nm in the UV/VIS spectrophotometer. Two extractions were performed for each melon part and absorbance values were measured in triplicate for each extraction. Contents of chlorophylls *a* and *b* were calculated using equations 4 and 5 (μg/mL) [20] and were expressed in μg per gram of sample. Total chlorophyll content was calculated from the sum of chlorophyll *a* and chlorophyll *b*.

$$\text{Chlorophyll } a = 16.72 A_{665.2nm} - 9.16 A_{652.4nm} \quad (4)$$

$$\text{Chlorophyll } b = 34.09 A_{652.4nm} - 15.28 A_{665.2nm} \quad (5)$$

### Total carotenoids

Extractions were performed by homogenizing 2.5 g of pulp, juice, peel and seeds in 10.0 mL of 100% cooled ethanol with an ultra-turrax. A volume of 10.0 mL of *n*-hexane was added and the mixture was centrifuged at 5000×g for 10 min at 4 °C. Saturated sodium chloride solution (2.5 mL) and *n*-hexane (12.0 mL) were added, and the mixture was centrifuged again as described previously. The extract was filtered with filter paper. For the saponification, 15.0 mL of 10% (w/v) methanolic potassium hydroxide was added to the extract and the mixture was sealed and wrapped in aluminum foil to protect from light. The reaction was carried out at room temperature for 16 h, with gentle shaking [21]. The mixture was then transferred to a separatory funnel and washed to remove potassium hydroxide, first with 50 mL of 10% (w/v) NaCl and then with deionized water until a neutral pH of the rinse. Total volume of extract was determined and β-carotene was quantified by measuring absorbance at 454 nm. The calibration curve was built with a pure β-carotene standard (Sigma-Aldrich, St. Louis, MO).

### Vitamin C

The quantification of vitamin C [ascorbic acid (AA) plus dehydroascorbic acid (DAA)] in *Cantaloupe* pulp, juice, peel and seeds was carried out using the method described by Zapata and Dufour [22] and used by Oliveira et al. [23]. AA and DAA contents were determined by high-performance liquid chromatography (HPLC) analysis, using isoascorbic acid (IAA) as internal standard. The flow rate of the mobile

phase was  $1.8 \text{ mL min}^{-1}$  and detector wavelengths were 348 and 261 nm for DAA and AA detections, respectively. DAA was detected as fluorophore 3-(1,2-dihydroxyethyl) furo(3,4-b)quinoxaline-1-one (DFQ) after derivatization with 1,2-phenylenediamine dihydrochloride (OPDA). Separation was performed in a reverse phase C18-silica analytical column (Waters Spherisorb ODS2  $5 \mu\text{m } 4.6 \times 250 \text{ mm}$ ).

The mobile phase was prepared by dissolving 13.6 g of potassium dihydrogen phosphate (Fluka) and 3.6 g of hexadecyltrimethylammonium bromide (cetrimide; Fluka) in 2.0 L of 5% (v/v) methanol. The solution was then filtered by vacuum through a 0.45-mm cellulose acetate membrane filter (Whatman) and finally degassed by ultrasound. The standard stock solution was prepared by dissolving 0.05 g of AA (Merck) and 0.05 g of DAA (Sigma-Aldrich) in methanol solution (5% v/v), adjusting the volume to 50.0 mL. Seven standard solutions were prepared by adding 1.0 mL of IAA (0.03 g in 50.0 mL of 5% v/v methanol) to 0.0625, 0.125, 0.25, 0.5, 1.0, 2.0 and 4.0 mL of the stock standard solution. 5% (v/v) methanol was added to each standard solution to attain approximately (but lower than) 20 mL. After adjusting pH of solutions to 2.5 with hydrochloric acid ( $1.0 \text{ mol L}^{-1}$ ), the volume was then completed up to 20.0 mL also with 5% (v/v) methanol.

A volume of 3.0 mL of each standard solution was added to 1.0 mL of OPDA, prepared by dissolving 0.03 g of ortho-phenylenediamine dihydrochloride (Sigma-Aldrich) in 50.0 mL of 5% (v/v) methanol. The resulting solutions were stored in the dark at room temperature for 40 min. Thereafter, they were filtered to vials with a syringe attached to a 0.22- $\mu\text{m}$  filter. The vials were placed on the HPLC to be analyzed in duplicate.

For the analyses of melon samples, 10.0 g of pulp, peel or seeds and 8.0 g of juice were extracted with 10.0 mL of 5% (v/v) methanol and homogenized with an ultra-turrax. The resultant suspensions were filtered with cheesecloth, and 5% (v/v) methanol was added to each sample to attain approximately (but lower than) 20.0 mL. After adjusting pH of samples to 2.5 with hydrochloric acid ( $1.0 \text{ mol L}^{-1}$ ), the volume was then completed up to 20.0 mL also with 5% (v/v) methanol.

Samples were centrifuged at  $5000 \times g$  for 10 min at  $4 \text{ }^\circ\text{C}$  and further reaction with OPDA was performed as described for the standard solutions. Results were expressed in mg of vitamin C per 100 g of sample.

### Total antioxidant activity

Extractions were performed as described for total phenolics determination and the remaining procedure was adapted from the one described by Oliveira et al. [23]. Direct production of the (blue/green) ABTS•+ chromophore was achieved via reaction between ABTS and potassium persulfate. This

method is able to quantify both water and lipid-soluble antioxidants as pure compounds or in crude extracts containing them. Solution of ABTS  $7 \text{ mmol L}^{-1}$  was prepared by dissolving 38.4 mg of 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt in 10.0 mL of Milli-Q water. Potassium persulfate  $2.5 \text{ mmol L}^{-1}$  was prepared by dissolving 6.6 mg of the solid substance in 10.0 mL of Milli-Q water. ABTS•+ solution was prepared by adding the previous solutions to a test tube protected from light with aluminum paper, which was kept in the dark for 16 h at room temperature and after that stored at  $4 \text{ }^\circ\text{C}$  for further experiments. To obtain the diluted ABTS solution, approximately 2.0 mL of the ABTS•+ solution (filtered with filter-syringe) were added to ultra-pure water, adjusting the absorbance ( $\lambda = 734 \text{ nm}$ ) to  $0.700 \pm 0.020$ .

Ascorbic acid stock solution ( $10.0 \text{ mg mL}^{-1}$ ) was prepared by dissolving 10.0 mg of ascorbic acid in 1.0 mL of 100% methanol. Ascorbic acid solution ( $0.25 \text{ mg mL}^{-1}$ ) was prepared by mixing 25.0  $\mu\text{L}$  of the stock solution with 975.0  $\mu\text{L}$  of 100% methanol. Ascorbic acid standards were prepared by appropriate dilution of the previous solution and adjusting the volume to 200.0  $\mu\text{L}$  with Milli-Q water, resulting in ascorbic acid concentrations of 0, 0.04, 0.06, 0.08, 0.10, 0.15, 0.20 and  $0.25 \text{ mg mL}^{-1}$ . The reaction was attained by adding 10.0  $\mu\text{L}$  of the standard solution or sample to 1000  $\mu\text{L}$  of the ABTS diluted solution. After waiting 6 min in the dark, absorbance values were measured at 734 nm. Two extractions were prepared for each melon part and absorbance values were measured in triplicate. Quantitative results (in  $\text{g L}^{-1}$  of ascorbic acid equivalent) were calculated through interpolation of the samples absorbance values in the calibration curve obtained with the standard solutions. Results were expressed as  $\mu\text{g}$  of ascorbic acid per gram of sample.

### Data analyses

Differences between the four parts of the *Cantaloupe* melon and concerning all characteristics analyzed were detected by analysis of variance, using one-way ANOVA. For post-hoc pairwise differences of means, the Tukey's test was performed. Normality and homoscedasticity of data was assessed using Shapiro-Wilk and Levene's tests, respectively.

Alternatively to one-way ANOVA, the Kurskal-Wallis test was carried out when normality of data was not verified. In such situations, the nonparametric Mann-Whitney test was posteriorly performed to detect paired differences. The significance level assumed was 5% in all analyses performed.

Results were expressed as mean  $\pm$  margin of confidence interval at 95%.

Data analyses were performed using IBM SPSS Statistics 24 for Windows® (SPSS Inc., Chicago, USA).

## Results and discussion

### Physicochemical characteristics

Soluble solids content (SSC, measured in °Brix) represents the balance of sugars and acids present in a matrix, which has a main impact on fruit flavor [24]. Results of SSC determined in all parts of *Cantaloupe* melon are in Fig. 1. Juice and pulp were equivalent in terms of SSC ( $9.73 \pm 0.51$  and  $10.35 \pm 0.54$  °Brix, respectively). Amaro et al. [4] reported 13.0 °Brix for fresh-cut cantaloupe of the same variety. Peel had the lowest value ( $5.67 \pm 0.21$  °Brix) and seeds the highest one ( $11.79 \pm 0.90$  °Brix), which means that this part of melon is the richest in sugars.

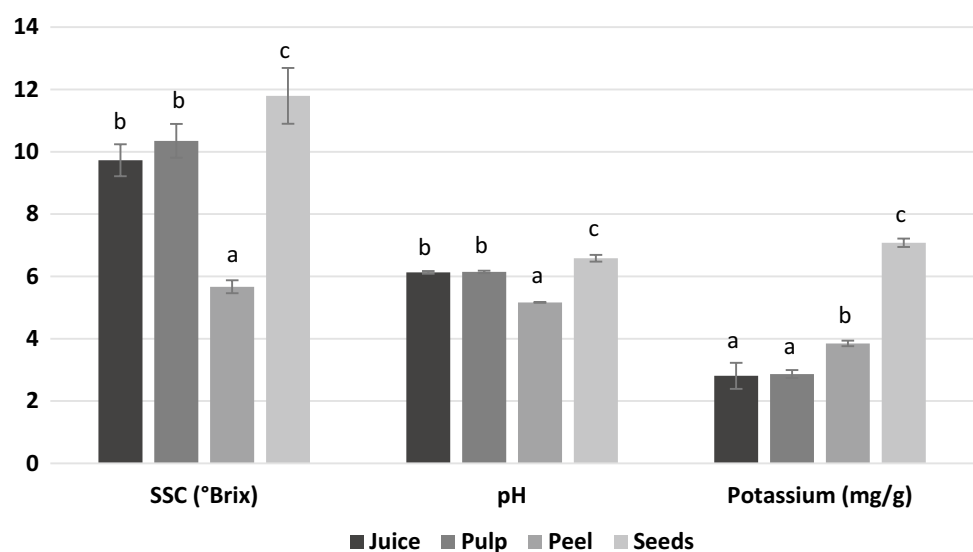
In relation to pH, edible parts (juice and pulp) had equivalent pH values ( $6.14 \pm 0.03$ ). Maietti et al. [2] reported a slightly higher value (around 6.65), yet it was for different cultivars. Peel and seeds had significant different pH values,  $5.17 \pm 0.01$  and  $6.58 \pm 0.11$ , respectively (Fig. 1).

Titrateable acidity (TA) results are in Table 1. This parameter is related to the total concentration of free protons that can be neutralized by a strong base. In the case

of fruit, the acidity is due to the content of several organic acids such as citric, malic, fumaric, acetic, ascorbic or galacturonic [25–27]. Results revealed that *Cantaloupe* edible parts had similar TA values, being  $10.3 \pm 1.6$  and  $9.4 \pm 1.5$  mmol H<sup>+</sup> L<sup>-1</sup> for juice and pulp, respectively. Waste parts presented different and significantly higher values ( $19.8 \pm 0.8$  and  $29.3 \pm 9.9$  mmol H<sup>+</sup> L<sup>-1</sup> for peel and seeds, respectively), probably because they have an higher amount of organic acids. The lower pH value obtained for peel than for seeds maybe explained by the presence of stronger organic acids in peel.

The maturity index (MI) was calculated for melon edible parts and is also included in Table 1. This parameter is the balance between the soluble solids content and the titrateable acidity and it is an useful way to determine the internal fruit maturation, since during ripening titrateable acidity decreases (due to catabolism of organic acids) and the sugar content increases [28]. The maturity indexes calculated for juice and pulp of *Cantaloupe* are within the range reported by Obando et al. [29] and Kohn et al. [30] for other melon varieties (127.2 and 98.57%).

**Fig. 1** Soluble solids content, potassium concentration and pH of the juice, pulp, peel and seeds of *Cantaloupe* melon. Data are mean values and the limits of the bars are confidence intervals at 95% (for a given characteristic, values with different letters differ significantly;  $p < 0.05$ )



**Table 1** Color parameters, titrateable acidity and maturity index (MI) of juice, pulp, peel and seeds of *Cantaloupe* melon

	Color parameters					Titrateable acidity (mmol H <sup>+</sup> L <sup>-1</sup> )	MI (%)
	L*	a*	b*	Chroma	Hue angle (°)		
Juice	45.36 ± 8.24 <sup>ab</sup>	13.61 ± 9.68 <sup>b</sup>	24.38 ± 4.48 <sup>ab</sup>	29.88 ± 9.18 <sup>ab</sup>	65.97 ± 6.54 <sup>a</sup>	10.3 ± 1.6 <sup>a</sup>	94.1
Pulp	51.16 ± 2.65 <sup>b</sup>	9.10 ± 0.39 <sup>b</sup>	30.27 ± 4.01 <sup>b</sup>	31.88 ± 3.41 <sup>b</sup>	70.66 ± 7.12 <sup>a</sup>	9.4 ± 1.5 <sup>a</sup>	110.1
Peel	37.80 ± 1.88 <sup>a</sup>	-8.91 ± 0.49 <sup>a</sup>	25.74 ± 0.96 <sup>a</sup>	27.26 ± 0.94 <sup>a</sup>	109.14 ± 1.14 <sup>b</sup>	19.8 ± 0.8 <sup>b</sup>	–
Seeds	57.12 ± 8.63 <sup>b</sup>	9.46 ± 2.33 <sup>b</sup>	27.55 ± 6.45 <sup>ab</sup>	29.14 ± 6.85 <sup>ab</sup>	71.57 ± 1.07 <sup>a</sup>	29.3 ± 9.9 <sup>c</sup>	–

The values are mean ± margin of confidence interval at 95%

Margin of confidence interval at 95% = confidence interval at 95%/2

For a given characteristic, values with different letters differ significantly ( $p < 0.05$ )

Color parameters  $L^*$  (brightness),  $a^*$  (greenness),  $b^*$  (yellowness), chroma and hue angle are in Table 1. The  $L^*$  values revealed that peel was less bright than pulp and seeds. The  $a^*$  and  $b^*$  coordinates were equivalent in juice, pulp and seeds. The lowest  $a^*$  value was determined in peel due to greener color of this part. In terms of color intensity evaluated by the magnitude of chroma, results showed that peel color was less intense than the pulp color. Hue angle was significantly higher in peel than in the remaining fruit parts. Juice, pulp and seeds had similar values of hue angle, situated between red and yellow, indicating an orange color probably due to carotenoids content. The hue angle for peel fell between yellow and green color, which may be related to the presence of chlorophylls [17].

The water activity values were  $1.001 \pm 0.005$  in juice,  $0.999 \pm 0.002$  in pulp,  $1.000 \pm 0.002$  in peel and  $0.997 \pm 0.003$  in seeds, being these values statistically equivalent. Water activity is a measurement of free or available water in a product that supports microbial growth, chemical and enzymatic reactions, and consequently spoilage processes. Products that have water activity values above 0.6 require refrigeration or another preservation process in order to control the growth of pathogens and other spoilage organisms [31]. Since pH interplays with microbial stability [32], peel can be considered the most stable part of *Cantaloupe* with the lower pH observed.

Potassium was detected in both edible and non-edible parts of *Cantaloupe* (Fig. 1), with no significant differences between juice and pulp ( $2.81 \pm 0.47$  and  $2.87 \pm 0.15$  mg/g, respectively). This is in agreement with U.S. Department of Agriculture [33] data that reported a value of 2.67 mg of potassium content per g of cantaloupe edible tissue. However, peel and seeds had higher concentrations of this macro-nutrient, being seeds the richest portion ( $7.08 \pm 0.16$  mg/g).

### Bioactive compounds

The bioactive characterization of all melon parts were carried out by the evaluation of total phenolics, chlorophylls, total carotenoids and vitamin C concentrations (Fig. 2; Table 2).

Phenolic compounds are secondary metabolites produced in fruits through the phenylpropanoid pathway and are not uniformly distributed within the fruits tissue [34]. Our results illustrate this. Juice and pulp had similar concentrations of total phenolics ( $95.35 \pm 9.23$  and  $101.90 \pm 14.99$   $\mu\text{g/g}$ , respectively). These values are within the range reported by Antonious et al. [35] for fresh-cut *Cucumis melo* cv. Athena ( $\approx 100$   $\mu\text{g/g}$ ). Peel had a significantly higher value,  $141.89 \pm 13.61$   $\mu\text{g/g}$ , and seeds stood out with the highest concentration,  $229.13 \pm 20.92$   $\mu\text{g/g}$ . Kolniak-Ostek and Oszmiański [36] arrived at similar conclusions when studying phenolics content in pear. These

**Table 2** Chlorophylls and total carotenoids concentration in juice, pulp, peel and seeds of *Cantaloupe* melon

	Chlorophylls ( $\mu\text{g/g}$ )			Carotenoids (mg/g)
	a	b	Total	
Juice	nd	nd	nd	$49.90 \pm 23.29^{\text{bc}}$
Pulp	nd	nd	nd	$68.92 \pm 12.48^{\text{c}}$
Peel	$45.82 \pm 5.13$	$32.95 \pm 2.99$	$78.77 \pm 7.90$	$23.46 \pm 7.68^{\text{a}}$
Seeds	nd	nd	nd	$30.51 \pm 4.50^{\text{ab}}$

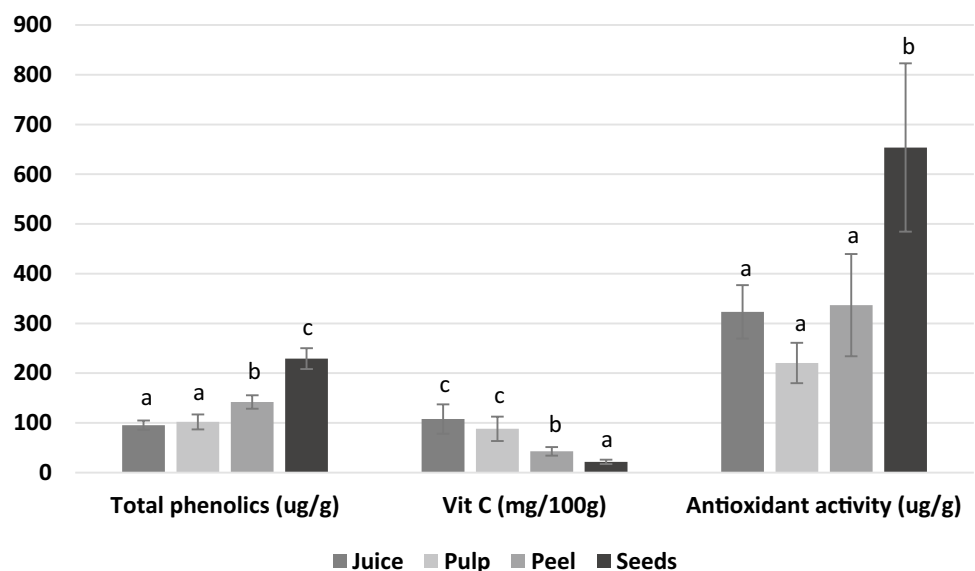
The values are mean  $\pm$  margin of confidence interval at 95%

Margin of confidence interval at 95% = confidence interval at 95%/2

For a given characteristic, values with different letters differ significantly ( $p < 0.05$ )

nd below the detection limit

**Fig. 2** Total phenolics, vitamin C and total antioxidant activity of the juice, pulp, peel and seeds of *Cantaloupe* melon. Data are mean values and the limits of the bars are confidence intervals at 95% (for a given characteristic, values with different letters differ significantly;  $p < 0.05$ )



authors reported that the highest diversity of phenolics was found in pear seeds, while in the pulp the lowest number of phenolic compounds was identified.

Chlorophylls were quantified in *Cantaloupe* peel, being strongly related to green color characteristic, and antioxidant and antimutagenic activities [37]. The concentration of total chlorophylls in peel was  $78.77 \pm 7.90 \mu\text{g/g}$ , distributed by chlorophylls *a* ( $45.82 \pm 5.13 \mu\text{g/g}$ ) and *b* ( $32.95 \pm 2.99 \mu\text{g/g}$ ). These are the most important forms found in fruit peels [38, 39]. Tadmor et al. [40] determined total chlorophylls content in different melon varieties and obtained values ranging from 50 to 750  $\mu\text{g/g}$  for *Noy-Amid* and *Tendral Verde Tardio*, respectively. Menezes et al. [41] quantified total chlorophylls in *Galia* melon peel and obtained slightly lower values ( $47.92 \mu\text{g/g}$ ). This can be explained by the differences in genus, species, cultivar and also environmental factors [42].

In *Cantaloupe* juice, pulp and seeds only traces of chlorophylls were detected, being below the detection limit.

Carotenoids are considered important bioactive compounds whose consumption are associated with health benefits [5]. For melon fruit, high concentration of  $\beta$ -carotene is linked with its nutritional quality [2]. Orange-fleshed muskmelons, as *Cantaloupe*, are excellent sources of  $\beta$ -carotene [6]. Total carotenoids concentration in juice, pulp, peel and seeds of *Cantaloupe* melon is included in Table 2. Results demonstrated that *Cantaloupe* edible parts were equivalent in terms of total carotenoids concentration and had the highest values,  $49.90 \pm 23.29 \text{ mg/g}$  in juice and  $68.92 \pm 12.48 \text{ mg/g}$  in pulp. However, seeds were not significantly different from juice, with a concentration of  $30.51 \pm 4.50 \text{ mg/g}$ . Carotenoids concentration in peel was  $23.46 \pm 7.68 \text{ mg/g}$ , which was significantly lower than the ones in juice and pulp. Since peel is rich in chlorophylls, it may present a greater susceptibility to carotenoid losses due to saponification [5]. Moreira et al. [7] reported a value of  $40.0 \text{ mg/g}$  of total carotenoids in fresh-cut *Cantaloupe* melon, when studying the effect of packaging on the fruit.

Vitamin C concentrations in all parts of *Cantaloupe* are presented in Fig. 2. Juice and pulp did not differ in vitamin C concentration and had the highest values ( $107.59 \pm 29.62$  and  $88.08 \pm 24.55 \text{ mg/100 g}$ , respectively). Peel had  $42.76 \pm 8.62 \text{ mg/100 g}$  and seeds presented the lowest value ( $21.50 \pm 4.25 \text{ mg/100 g}$ ). Moreira et al. [7] reported a concentration of around  $70 \text{ mg/100 g}$  for fresh-cut *Cantaloupe* melon. Jiménez-Aguilar et al. [9] evaluated vitamin C content in juice, pulp, peel and seeds of four different varieties of cactus pear. Both cactus pear juice and pulp had the highest concentration of vitamin C. In peel only traces were detected and in seeds vitamin C was not detected at all. The study of this element is of utmost importance, because it is considered an indicator of food quality due to its antioxidant properties.

## Total antioxidant activity

The antioxidant activity is associated to the presence of vitamins and polyphenols, and plays an important role in the prevention of oxidative stress responsible for chronic diseases [43]. The results of total antioxidant activity of all parts of *Cantaloupe* melon are in Fig. 2. Juice, pulp and peel had equivalent values ( $323.21 \pm 53.80$ ,  $220.38 \pm 40.50$  and  $336.78 \pm 102.86 \mu\text{g/g}$ , respectively). Amaro et al. [4] reported a lower value of  $153.3 \pm 18.0 \mu\text{g/g}$  in *Cantaloupe* fresh-cut tissue. However, seeds had the significantly highest value of  $653.67 \pm 169.20 \mu\text{g/g}$ . This is in agreement with the work developed by Contreras-Calderón et al. [8] that pointed seeds as an important source of natural antioxidants. These antioxidant properties are related to the presence of polyphenol components, mainly phenolic acids and flavonoids [13].

## Distribution of potassium, vitamin C, total carotenoids, total phenolics and antioxidant activity by *Cantaloupe* parts

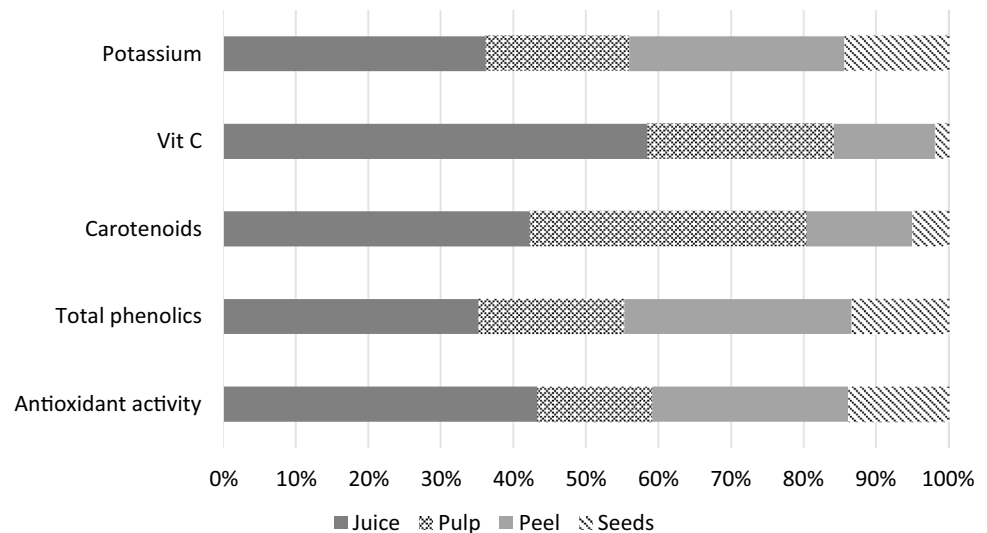
Edible parts (juice and pulp) represented around 65% of the total weight of the *Cantaloupe* melon, being 42% attributed to juice and 23% to pulp. Waste parts (peel and seeds) constituted 32% of the total weight, with peel representing 25% and seeds 7%. The remaining 3% were weight losses related to samples preparation. Seeking understanding of the potential of non-edible portions, some of the most important quality parameters analyzed, *i.e.* potassium, vitamin C, total carotenoids and phenolics and antioxidant activity, were quantified as weight percentages distributed by *Cantaloupe* melon parts (Fig. 3).

Juice contained 36% of all potassium content, followed by peel (30%), pulp (20%) and seeds (14%). In terms of vitamin C, juice is the soundest contributor (58%) and seeds accounts for only 2%. Total carotenoids are mainly present in juice and pulp (42 and 38%); peel had 15% and seeds 5%. The distribution of total phenolics is 35% in juice, 32% in peel, 20% in pulp and 13% in seeds. In relation to total antioxidant activity, juice contained 43%, peel 27%, pulp 16% and seeds 14%.

Waste parts (peel and seeds) contain 44% of all potassium content, 45% of total phenolics and 41% of total antioxidant activity, which are important contributions. Although seeds presented the highest potassium concentration (Fig. 1) and the highest antioxidant activity (Fig. 2), they represent the smallest portion of the fruit accounting for only 14% of the total amount of potassium and also 14% of antioxidant activity.

Edible parts (juice and pulp) contribute to 80% of total carotenoids content and 84% of vitamin C.

**Fig. 3** Distribution of weight percentage of potassium, vitamin C, total carotenoids and phenolics, and antioxidant activity by *Cantaloupe* melon parts



## Conclusions

Seeds of *Cantaloupe* melon are important sources of potassium, total phenolics, and antioxidant activity, with the highest soluble solids content. Peel stood out by the presence of chlorophylls.

In terms of all physicochemical characteristics analyzed, bioactive compounds and antioxidant activity, juice and pulp had similar profiles. However, they presented the highest carotenoids and vitamin C concentrations when compared to non-edible parts, contributing to the majority of the overall content of *Cantaloupe* in such biocompounds.

It should be emphasized that peel contributes to 31% of total phenolics content assessed in *Cantaloupe*, which is only slightly lower than the content determined in the juice (35%). In terms of total antioxidant activity, seeds contribute to 14% while pulp contributes to 16%, which are also comparable.

These results allowed concluding that not only *Cantaloupe* edible parts are important sources of healthy compounds. Waste parts deserve valorization that may be attained by developing strategies to transform them into more convenient forms that can be used as food ingredients.

**Acknowledgements** Joana F. Fundo, Fátima A. Miller and Teresa R.S. Brandão gratefully acknowledge, respectively, their Post-Doctoral Grants SFRH/BPD/109519/2015, SFRH/BPD/65041/2009 and SFRH/BPD/101179/2014 to Fundação para a Ciência e a Tecnologia (FCT). This work was supported by National Funds from FCT - Fundação para a Ciência e a Tecnologia through project UID/Multi/50016/2013.

## Compliance with ethical standards

**Conflict of interest** There are no conflicts of interest regarding this paper.

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