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# Physicochemical and Bioactive Characterisation of Edible and Waste Parts of “*Piel de Sapo*” Melon

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Received: 6 August 2020; Accepted: 25 September 2020; Published: 1 October 2020



**Abstract:** Several scientific studies point fruits as rich sources of antioxidants but mainly focus on their edible part. However, fruits wastes are abundant sources of bioactive compounds and nutrients, which are considered to be health beneficial. The main purpose was to characterise juice, pulp, peel and seeds of *Piel de Sapo* melon, in terms of several physicochemical characteristics (soluble solids content, titratable acidity, pH, potassium, colour and water activity), some bioactive compounds (total phenolics, vitamin C, chlorophylls and total carotenoids) and total antioxidant activity. Juice, pulp, peel and seeds represent 47, 19, 27 and 5% of melon total weight, respectively. Peel and seeds stood out by their higher concentration of total phenolics compounds and antioxidant activity when compared to edible parts. The highest potassium concentration was found in seeds. Chlorophylls were only detected in peel, while carotenoids were not detected in any part of the melon analysed. Juice and pulp contributed to 69% of vitamin C amount of the whole fruit. However, its concentration in peel was equivalent to the ones observed in juice and pulp. These results pointed out the importance of fruit wastes valorisation and the development of strategies for their re-utilisation.

**Keywords:** antioxidant activity; fruit; juice; quality; wastes

## 1. Introduction

The increasing demand for natural antioxidants potencies the search for new sources of these compounds. Besides numerous scientific works point fruits and vegetables as rich sources of antioxidants, only a few of them involve waste parts of the products, i.e., seeds and peels. Significant amounts of waste and by-products of fruits and vegetables are discarded during processing at industrial scale. This represents a severe problem with negative impacts on the environment. The valorisation of biocomponents present in by-products from fruit and vegetable industries is a challenge, as well as the development of strategies to valorise and re-use wastes [1].

Investigations on the waste fractions have already been carried out for a high number of different fruits. Duda-Chodak & Tarko [2] evaluated the antioxidant properties of seeds and peels of grapes, orange, melon, watermelon, lemon, kiwi and grapefruit. In contrast, Crizel et al. [1] characterised fibres from orange wastes and used them as a fat replacer in ice cream. Kim et al. [3] studied the chemical composition and bioactive components in peel and seeds of pumpkins. Navarro-Gonzalez et al. [4] analysed the functional properties, total antioxidant activity, and the content of bioactive antioxidant compounds of commercial tomato peel. Relevant constituents of banana peel were

also investigated [5,6]. Other studies focus mainly on extraction methods [7,8] and optimisation of conditions.

Bioactive components of waste parts of several fruits were also quantified and compared with their edible parts. Results showed that waste materials are potential sources of antioxidants (carotenoids and polyphenols) and nutrients (proteins, fatty acids, fibres, minerals and vitamins). A study on Mexican cactus pear allowed concluding that the peel contains the highest levels of soluble dietary fibre, phenolic compounds, flavonoids and antioxidant activity [9]. Kolniak-Ostek & Oszmiański [10] characterised the phenolic compounds in seeds, peel, pulp and leaves of pear and concluded that the seeds and leaves had the highest diversity of phenolics; in contrast, pulp had the lowest number of those compounds. Liu et al. [11] reported high concentrations of phenolic compounds in peach peel, which was associated to protection against pathogens and environmental stresses.

Melon (*Cucumis melo* L.) is a broadly cultivated and consumed fruit. In Portugal, *Piel de Sapo* is a popular cultivar, which belongs to the inodorous group. Consumers highly appreciate this melon variety due to its sensory attributes and nutrients content. It is considered a good source of minerals, vitamins and phytochemicals, which are recognized to have a health protective action [12].

Few studies have investigated the main characteristics of melon fruit and there is little information available on the nutritive profile and bioactive compounds, focusing mainly on cantaloupe melon. Indeed, the same authors already analysed some of these quality characteristics for cantaloupe melon in a previous study [13].

In this work, the objective was to evaluate some quality features of different edible and waste parts of *Piel de Sapo* melon. The aim was to assess several physicochemical characteristics (soluble solids, titratable acidity, pH, potassium, colour and water activity), some bioactive compounds (total phenolics, vitamin C, chlorophylls and total carotenoids) and antioxidant activity in melon juice, pulp, peel and seeds.

## 2. Materials and Methods

### 2.1. Fruit Samples

*Piel de Sapo* melons (*Cucumis melo* var. *inodorus* H. Jacq.) were acquired in a local market at a stage of maturity accepted for consumption, and all sample parts were separated and prepared as explained in Fundo et al. [13].

Three replicates were performed in all experimental assays.

### 2.2. Physicochemical Analyses

#### 2.2.1. Soluble Solids Content, Titratable Acidity and pH

Soluble solids content (SSC, °Brix) were determined in homogenised pulp and triturated peel and seeds using a Palette PR-32 digital refractometer (Atago, Tokyo, Japan) after filtration of the samples through a cheesecloth. Titratable acidity (TA) was measured by titration with a standard base (0.1 M NaOH to pH 8.1) and expressed as meq L<sup>-1</sup>. pH measurements were made using a pH meter (GLP 22, Crison Instruments, Spain).

The fruit initial maturity state was assessed using the following equation:

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

#### 2.2.2. Colour

Colour coordinates ( $L^* a^* b^*$ ) of melon pulp, juice, peel and seeds were evaluated using a Minolta CR-400 colourimeter (Konica-Minolta, Osaka, Japan). The colourimeter was properly calibrated with a standard white reference tile. The colour brightness parameter  $L^*$  measures whiteness and ranges from

0 (black) to 100 (white). The chromaticity coordinates  $a^*$  measures green when negative and red when positive, and  $b^*$  measures blue when negative and yellow when positive.

The saturation index or chroma Equation (2) and hue angle Equation (3) were calculated from  $a^*$  and  $b^*$  values:

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

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

Samples were analysed in duplicate, each with three readings.

### 2.2.3. Water Activity

Water activity was measured, in triplicate, using a dew-point hygrometer (Aqualab—Series 3, Decagon Devices Inc., Pullman, WA, USA) at  $(22 \pm 1)^\circ\text{C}$ .

### 2.2.4. Potassium Content

Quantification of potassium in all samples was attained using a potentiometric detection system described in Fundo et al. [13].

## 2.3. Bioactive Compounds Content

### 2.3.1. Folin–Ciocalteu Reagent (FCR) Reducing Capacity

FCR reducing capacity (approximately total phenolic content) was determined using the Folin–Ciocalteu method [13]. Values were displayed as  $\mu\text{g}$  gallic acid equivalent per g of sample.

### 2.3.2. Chlorophylls

Chlorophylls  $a$  and  $b$  were extracted and determined in each melon part according to Fundo et al. [13].

Chlorophylls  $a$  and  $b$  were determined spectrophotometrically and quantified using Equations (4) and (5) ( $\mu\text{g mL}^{-1}$ ; [14]).

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

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

The sum of chlorophyll  $a$  and chlorophyll  $b$  gives the total chlorophyll content. Values were displayed as  $\mu\text{g}$  per gram of sample.

### 2.3.3. Total Carotenoids

The experimental procedure for total carotenoids extraction and determination was based on methodology described by Fundo et al. [13].

### 2.3.4. Vitamin C

Vitamin C (ascorbic acid [AA] plus dehydroascorbic acid [DAA]) was quantified by high-performance liquid chromatography (HPLC) coupled with a reverse phase C18-silica analytical column (Waters Spherisorb ODS2  $5 \mu\text{m}$   $4.6 \times 250 \text{ mm}$ ) according to Zapata & Dufour [15]. Standard solutions, mobile phase, and samples were prepared as explained by Fundo et al. [13].

Values were displayed as mg of vitamin C per 100 g of sample.

## 2.4. Total Antioxidant Activity

The content of antioxidants was assessed using ABTS method as described by Fundo et al. [13]. Results were displayed as  $\mu\text{g}$  of AA per gram of sample.

### 2.5. Data Analyses

Normal distribution of data was evaluated using the Shapiro-Wilk test. When normality was verified, a one-way ANOVA was used to detect significant differences between the four melon parts concerning all characteristics analysed. Posteriorly, Tukey's test was applied for pairwise comparisons of means. When data were not normally distributed the following non-parametric tests were used: Kruskal-Wallis test (alternatively to one-way ANOVA) and the Mann-Whitney test for post-hoc comparisons. The significance level was set at 5% in all tests performed.

Results were displayed as *mean ± margin of confidence interval at 95%*.

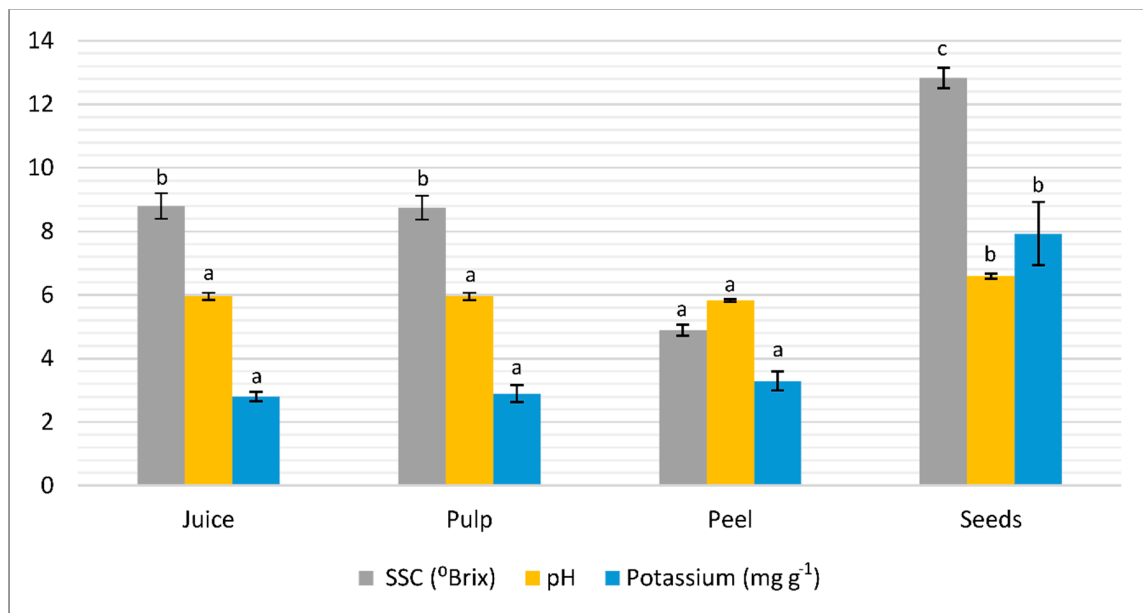
IBM SPSS Statistics 23 for Windows® (SPSS Inc., Chicago, IL, USA) was used for all data analyses.

## 3. Results and Discussion

The weight of a whole melon averaged ( $2657.3 \pm 404.2$ ) g. Edible parts represented around 66% of the whole fruit weight, being 47% juice and 19% pulp. Waste parts are 32% of melon weight, with a fraction of 27% for peel and 5% for seeds. The remaining 2% were related with losses that occurred during samples preparation.

### 3.1. Physicochemical Characteristics

The soluble solids content of the four melon parts is in Figure 1. SSC is related to the portion of sugars and acids, and it has a significant impact on the flavour of the fruit [16]. Peel presented the lowest SSC, ( $4.9 \pm 0.2$ ) °Brix, which means that it has low sugar content. On the opposite, the highest value was observed in seeds, ( $12.8 \pm 0.3$ ) °Brix, possibly because they are a source of supporting sugars for the initial development of the plant. In juice and pulp, SSC was not significantly different, ( $8.8 \pm 0.4$ ) °Brix. This is in line with the values published by Fundo et al. [17] for edible parts of melon of the same variety.



**Figure 1.** Soluble solids content, pH and potassium concentration of melon parts. Bars are 95% confidence intervals for the mean; for a specific characteristic, values with different letters are significantly different ( $p < 0.05$ ).

Titrateable acidity values are included in Table 1. For juice and pulp, the values were not significantly different, being ( $13.1 \pm 1.8$ ) meq L<sup>-1</sup> and ( $13.2 \pm 2.3$ ) meq L<sup>-1</sup>, respectively. The highest value was observed for seeds, ( $36.9 \pm 3.5$ ) meq L<sup>-1</sup>. Since we are dealing with fruit parts, the acidity is due to the presence of some organic acids content (i.e., acetic, ascorbic, citric, fumaric, galacturonic, and malic).

Therefore, titratable acidity is well correlated with melon flavour, and it is relevant to preserve the organoleptic nature and to circumvent fermentation processes [18,19].

**Table 1.** Colour parameters, titratable acidity and maturity index (MI) of edible and non-edible melon parts. Results are displayed as mean  $\pm$  margin of 95% confidence interval †.

	Colour Parameters					Titratable Acidity (meq L <sup>-1</sup> )	MI (%)
	L*	a*	b*	Chroma	Hue Angle (°)		
Juice	38.79 $\pm$ 2.10 <sup>a</sup>	-1.18 $\pm$ 0.34 <sup>c</sup>	7.57 $\pm$ 3.74 <sup>a</sup>	7.69 $\pm$ 3.74 <sup>a</sup>	104.18 $\pm$ 3.43 <sup>b</sup>	13.1 $\pm$ 1.8 <sup>a</sup>	67.2
Pulp	60.20 $\pm$ 2.36 <sup>c</sup>	-3.20 $\pm$ 0.18 <sup>b</sup>	10.08 $\pm$ 0.66 <sup>a</sup>	10.60 $\pm$ 0.67 <sup>a</sup>	107.98 $\pm$ 0.60 <sup>c</sup>	13.2 $\pm$ 2.3 <sup>a</sup>	66.3
Peel	49.68 $\pm$ 2.19 <sup>b</sup>	-10.78 $\pm$ 0.74 <sup>a</sup>	29.54 $\pm$ 1.87 <sup>b</sup>	31.46 $\pm$ 1.97 <sup>c</sup>	110.07 $\pm$ 0.68 <sup>c</sup>	19.4 $\pm$ 7.0 <sup>b</sup>	-
Seeds	75.88 $\pm$ 1.69 <sup>d</sup>	4.51 $\pm$ 0.66 <sup>d</sup>	25.85 $\pm$ 1.69 <sup>b</sup>	26.25 $\pm$ 1.77 <sup>b</sup>	80.28 $\pm$ 0.83 <sup>a</sup>	36.9 $\pm$ 3.5 <sup>c</sup>	-

† Margin of 95% confidence interval = (confidence intervals at 95%)/2. For a specific characteristic, values with different letters are significantly different ( $p < 0.05$ ).

The pH values of different melon parts were similar (Figure 1), except for seeds that had a significantly higher value ( $6.6 \pm 0.1$ ).

The similar pH and titratable acidity values observed in juice, pulp and peel may be explained by the presence of an equivalent amount of organic acids with similar strength. In contrast, the higher titratable acidity value observed in seeds may be explained by a higher content of organic acids. Once seeds pH is also higher, their organic acids should be weaker than the ones in the juice, pulp and peel.

The maturity index is related to the sugar/acid ratio, which is an indicator of the ripening stage. During ripening, the fruit acids are degraded, the sugar content increases and the sugar/acid ratio achieves a higher value [20]. Overripe fruits have shallow levels of acidity and therefore lack characteristic flavour. Maturity indexes were determined for melon pulp and juice (Table 1). As expected, the values were similar in those parts. When compared to published results [21,22], those values are slightly lower, due to different cultivars and harvest conditions.

Table 1 includes mean values of the colour coordinates L\* (brightness), a\* (greenness) and b\* (yellowness) obtained for all fruit parts, as well as chroma and hue angle. L\* values were significantly different in all melon parts. The highest values were obtained for seeds and pulp, indicating a lighter colour of these parts.

The lowest a\* value was observed for peel since this was the greener part of the melon. The b\* coordinate was equal in juice and pulp and lower than the ones determined in peel and seeds, which is indicative of yellowness of the non-edible parts.

Chroma and hue angle allow a more accurate assessment of spatial colour distribution than direct tristimulus measurements [23]. Concerning the chroma parameter, higher values were obtained for seeds and peel, which reveals a higher colour intensity; in juice and pulp chroma was equivalent. Peel also presented the highest hue angle, indicating a greener colour probably related to chlorophyll content [22].

Water activity in juice, pulp, peel, and seeds was  $0.996 \pm 0.002$ ,  $0.997 \pm 0.001$ ,  $0.998 \pm 0.001$  and  $0.994 \pm 0.002$ , respectively.

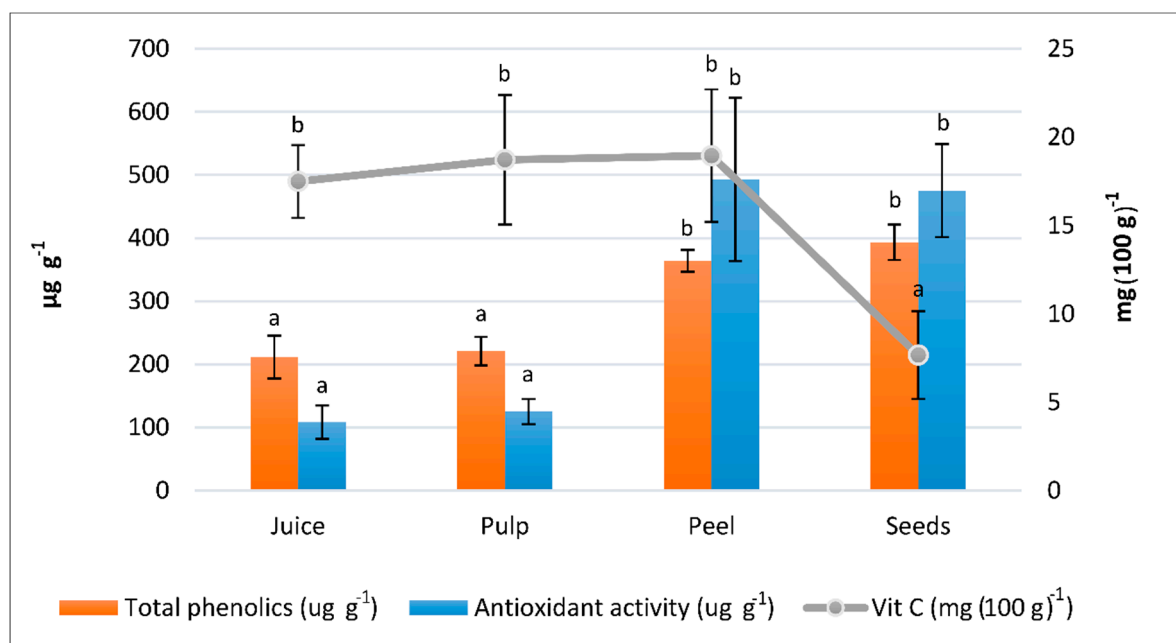
About potassium concentration (Figure 1), seeds showed the highest value, ( $7.93 \pm 0.10$ ) mg g<sup>-1</sup>. In the remaining parts, the concentration was not significantly different ( $2.80 \pm 0.15$ ,  $2.90 \pm 0.27$  and  $3.29 \pm 0.30$  mg g<sup>-1</sup>, respectively in juice, pulp and peel).

United States Department of Agriculture [24] reported potassium concentrations in different varieties of melon, namely cantaloupe, casaba, horned and honeydew, with values ranging from 1.23 mg g<sup>-1</sup> to 2.67 mg g<sup>-1</sup> in edible fruit parts. These values are slightly lower than the ones determined in the edible part of *Piel de Sapo* melon. Sabino et al. [25] observed that flour prepared with melon peel stood out because of the high potassium concentration present ( $5.23$  mg g<sup>-1</sup>), which was higher than the value found in *Piel de Sapo* peel. Potassium is a mineral that is crucial for a healthy diet [26].

Eating potassium-rich foods can lower the risk of high blood pressure and reduces cardiovascular diseases [27].

### 3.2. Bioactive Compounds

Results of FCR reducing capacity (phenolics) and vitamin C content are in Figure 2.



**Figure 2.** Total phenolics, antioxidant activity and vitamin C of melon parts. Bars are 95% confidence intervals for the mean; for a specific characteristic, values with different letters are significantly different ( $p < 0.05$ ).

Peel and seeds were equivalent in terms of phenolics content and presented the highest values, ( $364.01 \pm 17.29$ )  $\mu\text{g g}^{-1}$  and ( $393.62 \pm 28.24$ )  $\mu\text{g g}^{-1}$ , respectively. In juice and pulp, the concentrations were lower but similar, ( $211.55 \pm 33.84$ )  $\mu\text{g g}^{-1}$  and ( $221.04 \pm 22.59$ )  $\mu\text{g g}^{-1}$ , respectively. This is in agreement with the findings of Kolniak-Ostek & Oszmiński [10] who reported for pear the highest diversity of phenolics in the seeds and the lowest number of these compounds in the pulp.

Liu et al. [11] determined the concentration of total phenolics in peels and pulps of peaches from different cultivars. They concluded that peels always had a higher concentration of total phenolics when compared to the corresponding pulps. The same conclusion was reported by Manzoor et al. [28] for two pear varieties. Phenolic compounds are secondary metabolites produced in fruits which are not uniformly distributed within the fruit tissues. Higher concentrations of phenolic compounds in external tissues are associated with peels primary natural function: protection against pathogens and environmental stresses [11]. Therefore, phenolics have a biological activity and have protective effects against viruses, bacteria, and even some toxins.

Vitamin C is an essential nutrient for humans and many animal species, constituting a co-factor in enzymatic metabolic reactions. Moreover, it is also known for its antioxidant properties, protecting the organism from oxidative stress and being considered for this reason, an indicator of food quality [29]. Juice, pulp and peel of *Piel de Sapo* melon had no significant differences in vitamin C concentrations: ( $14.49 \pm 2.06$ )  $\text{mg (100 g)}^{-1}$  in juice, ( $18.73 \pm 3.67$ )  $\text{mg (100 g)}^{-1}$  in pulp and ( $18.95 \pm 3.75$ )  $\text{mg (100 g)}^{-1}$  in the peel. Seeds presented ( $7.67 \pm 2.48$ )  $\text{mg (100 g)}^{-1}$ , which was significantly lower. Plaza et al. [30] reported a value of approximately 10  $\text{mg (100 g)}^{-1}$  for fresh-cut tissue of *Piel de Sapo* melon, which is lower than the values determined for juice, pulp and peel in our study. Jiménez-Aguilar et al. [9] carried out a study on phytochemical characterisation of four cactus pear varieties, analysing the

vitamin C content in edible and waste parts. Although high vitamin C contents were observed in juice and pulp, seeds did not present any vitamin C.

Chlorophylls are pigments abundant in many fruit peels, strongly related with their colour. Thus, they are also related to the aspect of the fruit, playing a crucial role in the overall consumer's acceptability. The most important forms are chlorophyll *a* and chlorophyll *b*, occurring in a proportion of 3:1 [31]. The difference in the composition of the sidechain (for chlorophyll *a* –CH<sub>3</sub> and chlorophyll *b* –CH=O) implies that each type of chlorophyll absorbs light at slightly different wavelengths [32].

Melon peel presented the highest content of total chlorophylls, ( $87.85 \pm 10.47$ )  $\mu\text{g g}^{-1}$ , distributed by ( $57.50 \pm 6.27$ )  $\mu\text{g g}^{-1}$  of chlorophyll *a* and ( $30.36 \pm 4.32$ )  $\mu\text{g g}^{-1}$  of chlorophyll *b*. In the remaining parts, only traces of total chlorophylls were detected: ( $1.85 \pm 0.60$ )  $\mu\text{g g}^{-1}$  in juice, ( $1.61 \pm 0.78$ )  $\mu\text{g g}^{-1}$  in pulp and ( $4.80 \pm 4.46$ )  $\mu\text{g g}^{-1}$  in seeds.

The concentration of total chlorophylls in *Piel de Sapo* peel is within the range reported by Tadmor et al. [33] for different melon varieties or by the present authors for Cantaloupe melon [13]. The estimated ratio of chlorophylls *a,b* in peel was approximately 2:1, which is lower than the one reported in the literature. This discrepancy may be due to differences in genus, species, cultivar or even environmental factors [34].

The high concentration of chlorophyll pigments in peel matrixes, with proven biological properties such as antioxidant and antimutagenic ones [35–37], highlights the importance of the valorisation of melon waste parts.

Carotenoids were evaluated in all parts of *Piel de Sapo* melon. However, this compound was not detected in any fruit part.

### 3.3. Total Antioxidant Activity

Antioxidant compounds play an essential role in the prevention of oxidative stress responsible for several diseases [38]. The antioxidant activity is mainly related to the presence of vitamins, phenolic acids, and flavonoids [2] and it is often considered an important indicator for fruits quality.

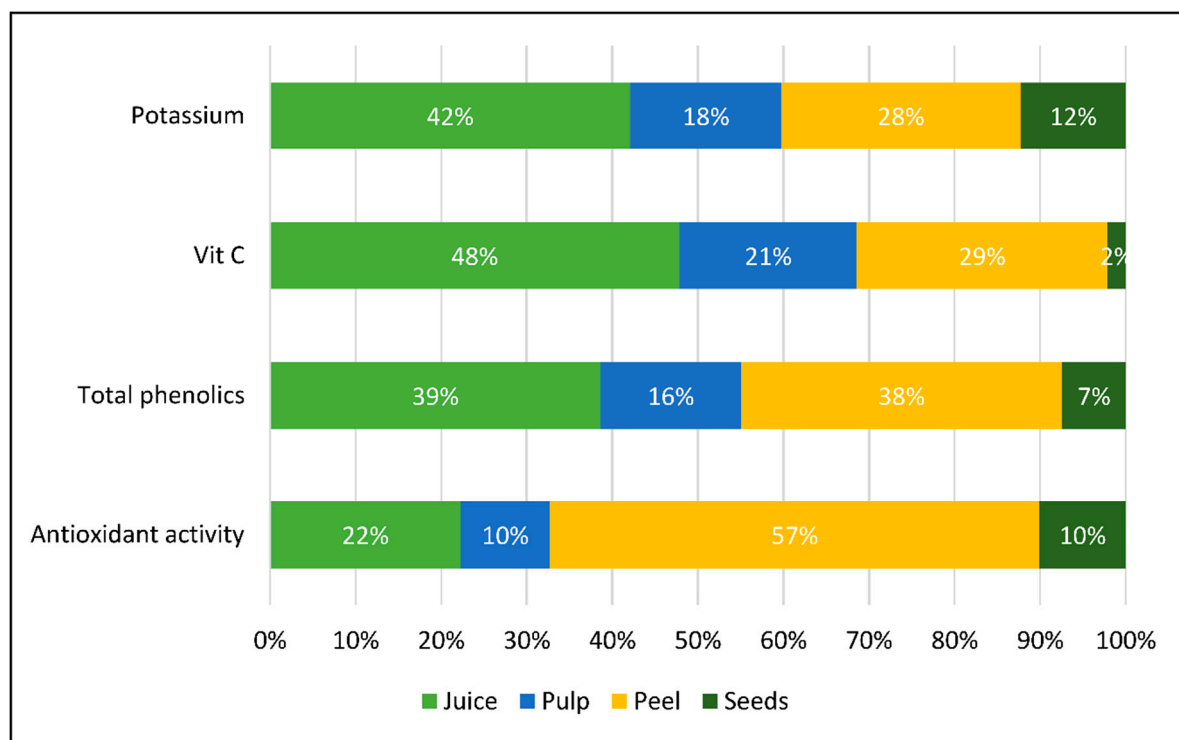
Results obtained for the total antioxidant activity of all melon parts are in Figure 2. The values for juice and pulp were similar, ( $108.37 \pm 26.68$ )  $\mu\text{g g}^{-1}$  and ( $125.10 \pm 20.06$ )  $\mu\text{g g}^{-1}$ , respectively, but significantly lower than the ones obtained for peel ( $493.01 \pm 129.25$ )  $\mu\text{g g}^{-1}$  and seeds ( $475.40 \pm 73.79$ )  $\mu\text{g g}^{-1}$ . Plaza et al. [30] obtained similar results for fresh-cut tissue of *Piel de Sapo* edible parts, reporting an antioxidant capacity ranging from 115  $\mu\text{g g}^{-1}$  to 133  $\mu\text{g g}^{-1}$ .

Results pointed out that melon seeds and peel are rich sources of natural antioxidant components. Contreras-Calderón et al. [39] arrived at similar conclusions when they studied the antioxidant capacity in pulp, peel and seeds from 24 exotic fruits from Colombia.

### 3.4. Weight Distribution of Some Characteristics by Melon Parts

Information on the characterisation of waste parts of melon is limited, despite they represent up to 32% of the total fruit weight. To clarify the potential of these portions, several quality characteristics (potassium, bioactive compounds, and antioxidant activity) were quantified as a percentage of total fruit weight. These results are shown in Figure 3.

Peel and seeds contribute with 67% of antioxidant activity and contain 45% of total phenolics, 31% of vitamin C, and 40% of all potassium content. Although seeds had the highest potassium content (Figure 1), they account for only 12% of the total amount of mineral included in the whole fruit. Concerning vitamin C, juice and pulp have the highest value, being 48% in juice and 21% in pulp; seeds have a poorer contribution (around 2%). Total phenolics were similar in edible and non-edible parts. Juice and peel are the primary sources contributing to 39% and 38%, respectively. Peel stood out for representing 57% of the total antioxidant activity, which was the highest value observed.



**Figure 3.** Weight distribution of antioxidant activity, total phenolics, vitamin C and potassium by melon parts.

#### 4. Conclusions

Non-edible parts of *Piel de Sapo* melon are potential sources of healthy compounds, namely total phenolics content and antioxidant activity. Peel had the highest antioxidant activity, contributing to 57% of the total assessed in the whole melon. It was also a good source of vitamin C, with comparable concentrations to the ones observed in juice and pulp. Seeds stood out by their total phenolics content, which was equivalent to the one observed in the juice. When compared to the remaining parts analysed, seeds also presented the highest potassium concentration, soluble solids content and organic acids concentration assessed by titratable acidity measurements.

Juice and pulp presented a similar profile in all physicochemical characteristics, except for colour parameters. They also had comparable results in terms of bioactive compounds and total antioxidant activity. Juice is the main source of total vitamin C assessed in melon.

Once waste parts of *Piel de Sapo* melon are potential contributors of bioactive compounds and antioxidant activity, their valorisation may be accomplished by emerging approaches to transform them into edible forms.

**Author Contributions:** Conceptualization, F.A.M. and T.R.S.B; methodology, E.G. and J.R.S.; statistical analysis, T.R.S.B.; resources, C.L.M.S.; writing—original draft preparation, F.A.M. and J.F.F.; writing—review and editing, T.R.S.B.; supervision, C.L.M.S. and T.R.S.B.; All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by National Funds from FCT—Fundação para a Ciência e a Tecnologia through project UID/Multi/50016/2019.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.



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