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Influence of drying process and particle size of persimmon fibre on its physicochemical, antioxidant, hydration and emulsifying properties

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ABSTRACT

Persimmon, given its current surplus production, could be an alternative source for the extraction of certain interesting ingredients for the food industry and human health, such as fibre. Thus, the aim of this study was to analyse the influence of hot air and freeze-drying, as well as the particle size of fibre extracted from persimmon peels or pulp on their physicochemical, antioxidant, hydration and emulsifying properties, compared to commercial fibres (from peach, lemon, orange and apple). The results showed that both freeze-dried persimmon pulp and freeze-dried peel had better hydration properties and oil holding capacity than other fibres analysed, although the swelling capacity was higher for lemon fibre. Freeze-dried persimmon peel fibre showed higher values of emulsion stability than commercial fibres. Finally, the antioxidant activity of the smallest sized persimmon peel fibre obtained by freeze-drying was higher than that for lemon, orange and peach fibre.

Keywords: Persimmon fibre; Antioxidant activity; Hydration properties; Freeze-drying; Hot air drying

1. INTRODUCTION

Persimmon crops are traditional in the Valencian Community (Spain), although persimmons come from China. This fruit tree belongs to the botanical family Ebanaceae, genus Diospyros, which has more than 300 species. However, only five species are of commercial importance, including Diospyros kaki L.f., which is cultivated around the world, and specifically in Spain (Hernándiz 1999).

From a commercial standpoint, Persimmon are divided into astringent (Rojo Brillante, Triumph, Tomatero, etc.) and non-astringent (Fuyu, Hana-Fuyu, Jiro, etc.) varieties. The fruits' astringency is linked to the content and solubility of tannins. In non-astringent varieties, tannins are insolubilized, allowing for consumption without carrying out any post-harvest treatment and without reaching physiological ripening. Astringent varieties have a high content of soluble tannins, which decreases as ripening is reached (Hernándiz 1999). "Rojo Brillante" is the most important variety both in terms of production and marketability, and it is the only variety recognized by the Designation of Origin Kaki Ribera del Xúquer. According to data from the Spanish Ministry of Agriculture (2013) there has been a remarkable increase in the land dedicated to persimmon, which has grown from 2,281 hectares to nearly ten thousand. In the last year, there was a 20% increase, from 7,995 to 9,580 hectares, according to official statistics (INE, 2014). In early 2000, when consumption began to expand, production of this fruit did not exceed 20,000 tons. Today, production reaches 150,000 tons and in the next two years, it is expected to reach 500,000 tons (Alós 2014).

Fibre intake is associated with the prevention and treatment of some diseases related to oxidative stress (Rajendran et al. 2014) and others such as constipation (improvement of intestinal transit), colon cancer, coronary heart disease (lowering of cholesterol) and diabetes (Abdul-Hamid and Luan 2000). It is believed that not only the fibre but also bioactive compounds (antioxidants) may be retained after extraction and stabilization of the fibre. These would also be partially responsible for the health benefits associated with the consumption of fibre. In this

regard, it is increasingly common to incorporate fibre in formulations in order to guarantee the minimum recommended daily intake, which is 35 g/day (Storey and Anderson 2014). More specifically, and bearing in mind the bioactive compounds of the persimmon fruit, a study conducted on rats showed that the consumption of persimmon helped to limit fat absorption, probably due to the high fibre content of the fruit (Gorinstein et al. 2000). Additionally, studies have recently been carried out to stabilize fat food products by using dietary fibres with antioxidant properties to improve their stability to oxidation and extend their shelf life (Zha et al. 2009)

Nowadays, the main sources of fibre are fruits and cereals. Hence, fibres from apple, pea, sugar beet, soybean, orange or lemon can be found in the market, but not fibres from persimmon. In addition to the health benefits associated with human consumption of fibre, its addition to food also leads to technological advantages such as improvements in viscosity, texture, sensory characteristics, as well as an increase in shelf life. Currently, fibre is included as an ingredient in many kinds of foods such as cakes, cooked meat products, cereals, beverages, pasta and soups (Thebaudin et al. 1997).

The aim of this study was to analyse the influence of the drying method (hot air and freeze-drying) on the stabilization of the fibre extracted from the persimmon peel and pulp, and to assess the influence of the particle size of the fibre on the physico-chemical, antioxidant, moisturizing and emulsifying properties of the different fractions obtained. These properties were compared with those of four commercial fibres (orange, lemon, peach and apple) to determine the possible uses of this persimmon fibre as an ingredient in food formulation.

2. MATERIALS AND METHODS

2.1 Raw material

Persimmon (Diospyros kaki Thumb. cv. Rojo Brillante) fruits were harvested in Alginet (Spain) and then treated to remove astringency in closed containers with 95% CO_2 for 24 h at 20 °C and 90% of relative humidity (Arnal and Del Río 2003).

The fresh persimmon fruits were cleaned and peeled. Pulp and peel were homogenized separately by using a stirrer (IKA T 18 basic ULTRA-TURRAX®). Each sample was put into contact with boiling ethanol (96% v/v) and stirred (600 rpm) for 15 min in a ratio 1:2 (w/v). Finally, ethanol was separated from fibre by means of a sieve and the resulting solid fraction was divided in two even parts. One of them was dried at 40 °C till constant weight (approximately 7 h), obtaining the products denominated PULP-A (obtained from persimmon pulp) and PEEL-A (obtained from persimmon peel). The other one was frozen at -40 °C for 24 h and then it was freeze-dried (vacuum pressure of 10^{-1} mbar for 24 hours). In this case, the products were named PULP-F and PEEL-F when they came from persimmon pulp and peel, respectively. Then, each fraction was separated into three sub-fractions based on the particle size using three sieves (NWK, model 3-102), with different aperture sizes (125 μm, 250 μm and 500 μm). As a result, persimmon fibre was subdivided into three particle size ranges: 500-250 μm, 250-125 μm and <125 μm. Samples were stored at -40 °C until analysis.

Furthermore, four commercial fibres (lemon, orange, peach and apple) (Indulleida, particle size <125 μm) were characterized in order to compare the properties of these fibres with the persimmon fibres obtained.

Below is a description of the analytical determinations made, each of which was carried out in triplicate for all the fibres studied.

2.2 Physical and chemical characterization of fibre powders

Moisture content (g water/100 g sample) was determined by drying the fibre to constant weight at 60 °C in a vacuum oven at 10 kPa (adaptation of method 934.06 AOAC, 2000).

Protein (g protein/100 g sample) was analysed using the Kjeldahl method (AOAC, Method 920.152, 1990). Factor 6.25 was used for conversion of nitrogen to crude protein.

Fat (g fat/100 g sample) was calculated by weight loss after a six-cycle extraction with petroleum ether (40-60 °C boiling range) in a Soxhlet extractor.

The colour of fibres was measured using a Minolta spectrocolorimeter (Minolta CM-3600 d, Tokyo, Japan). CIEL*a*b* coordinates were obtained using D65 illuminant and 10° observer as the reference system.

Water activity (a_w) was determined at 25 °C with a hygrometer (Aqualab, USA).

Specific volume, defined as the inverse of apparent density, was determined by measuring the volume occupied by a sample (5 g) using a 10 mL-graduated and calibrated cylinder. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further decrease of the sample level (Chau et al. 2007).

2.3 Hydration properties

2.3.1 Swelling capacity (SC)

A sample (≈0.2 g) of persimmon fibre was weighed and placed in a graduated conical tube and 10 mL of water was added. It was hydrated for 18 h at 25 °C. After this time, the final volume attained by the fibre powder was measured (Raghavendra et al. 2004; Robertson et al. 2000) and SC was calculated as:

$$SC[mL/g] = \frac{volumeoccupiedbysample}{originalsampleweight} \quad \text{(Equation I)}$$

2.3.2 Water holding capacity (WHC)

A sample (≈0.2 g) of persimmon fibre was weighed and placed in a graduated conical tube and 10 mL of water was added. It was hydrated for 18 h at 25 °C. The supernatant was removed and the decanted residue was weighed. The weight of the hydrated residue was recorded (HR). After

freeze-drying, the weight of the dried residue was also recorded (DR). This assay was performed in triplicate and WHC was calculated as:

$$WHC[g/g] = \frac{HR-DR}{DR} \quad \text{(Equation II)}$$

2.3.3 Water retention capacity (WRC)

A sample (≈1 g) of persimmon fibre was weighed and placed in a graduated conical tube and 10 mL of water was added. It was hydrated for 18 h at 25 °C. Centrifugation for 30 min at 2000 rpm was then performed in the same tube. The supernatant was separated and the residue was weighed. The remaining wet fibre was weighed (R + W_2), as well as the freeze-dried residue (R) (Raghavendra et al. 2004; de Escalada Pla et al. 2012) and WRC was calculated as:

$$WRC[g\ water/g\ driedresidue] = \frac{W_2}{R} \quad \text{(Equation III)}$$

where R is the dried residue and W_2 is the retained water.

2.4. Oil holding capacity (OHC)

OHC was measured according to Garau et al. (2007). Samples (≈0.2 g) were mixed with sunflower oil (≈1.5 g), left overnight at room temperature and then centrifuged (1500xg; 5 min). The supernatant was decanted and the sample was weighed. OHC was evaluated based on the increase in weight and expressed as g of oil absorbed/g dry sample.

2.5 Emulsifying properties

2.5.1 Emulsifying activity (EA)

Emulsifying activity was measured using the method of Yasumatsu et al. (1972). 7 mL of 2% aqueous dispersion of the fibre (w/v) was mixed with 7 mL of sunflower oil and stirred for 5 min at high speed (Vortex, Heidolph). An aliquot was then centrifuged at 10,000 rpm for 5 min and the emulsion volume formed was then measured using the following equation:

$$\%EA = \frac{VEL}{V} \cdot 100 \quad \text{(Equation IV)},$$

where VEL refers to the volume of the emulsified layer (mL) and V is the total volume of fluid (mL).

2.5.2 Emulsion stability (ES)

The emulsion stability was determined using the method of Yasumatsu et al. (1972) adapted as follows: 7 mL of 2% aqueous dispersion of the fibre (w/v) was mixed with 7 mL of sunflower oil and stirred for 5 min at high speed (Vortex, Heidolph). The emulsions were heated to 80 °C for 30 minutes, cooled for 15 minutes in running water and centrifuged at 2000 rpm for 5 minutes. The stability of the emulsion was calculated using the equation:

$$\%ES = \frac{VREL}{V} \cdot 100 \quad \text{(Equation V)},$$

where VREL refers to the volume of the remaining emulsion layer (mL) and V is the total volume of fluid (mL).

2.6 Total Phenolic Content and Antioxidant Activity

Samples were analysed spectrophotometrically, using a modified Folin-Ciocalteu method (Sakanaka et al. 2005), in order to determine the total phenolic content (TPC). The TPC were extracted with methanol (3 grams of crushed fruit/5 mL of methanol) and then kept stirring at 200 rpm for one hour (horizontal shaker COMECTA WY-100). The test tubes were centrifuged for 10 minutes at 10,000 rpm (Medifriger BL-S, P-Selecta). 0.5 mL of distilled water and 0.125 mL of the supernatant of the extract were added to a cuvette followed by the addition of 0.125 mL of Folin-Ciocalteu reagent. The mixture was shaken and 1.25 mL of a 7% sodium carbonate solution and 1 mL of distilled water were added after 6 min. The colour was left to develop for 90 min and the absorbance was measured at 760 nm using a spectrophotometer (JASCO V-630). The measurement was compared to a standard curve of gallic acid solutions and expressed as

mg of gallic acid equivalents per gram (mg GA/g dry matter). A blank was prepared in the same way but without any sample.

The antioxidant activity (AA) of the persimmon fruit was measured on the basis of the scavenging activities of the stable 2,2-diphenyl-1-picrylhydrazyl free radical as described by Shahidi et al. (2006) with some modifications. According to this method, the purple colour intensity of 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution decays in the presence of an antioxidant, and this absorbance change is measured spectrophotometrically at 515 nm.

3 grams of the crushed sample were diluted in 5 mL of methanol and were subjected to stirring for 5 minutes. Then, the test tubes with the sample-methanol mixture were centrifuged at 10,000 rpm for 10 minutes (Medifriger BL-S, P-Selecta). 0.1 mL of the supernatant was added to 3.9 mL of a methanolic solution of DPPH (80:20; methanol:water) (0.025 mg/mL). The solution was shaken and after 30 min the absorbance of the sample was measured at 515 nm using methanol as a blank. The antioxidant activity (%) of the samples was calculated using the equation I:

$$AA(\quad) = \frac{A_{t=0} - A_{t=30}}{A_{t=0}} \cdot 100 \qquad \text{(Equation VI)},$$

where $A_{t=0}$ is the initial absorbance of the DPPH (without sample) and $A_{t=30}$ is the absorbance of the sample after 30 min. The measurement was compared to a standard curve of Trolox (6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) solutions and expressed as mg of Trolox per gram.

2.7 Statistical analysis

All experiments were carried out in triplicate. Results are expressed as mean values ± standard deviation. Data were subjected to analyses of variance (ANOVA), and multiple comparisons between means were determined using the LSD test ($P \leq 0.05$) by means of the Statgraphics Plus 5.1 software application (Manugistics, Inc., Rockville, MD, USA).

3. RESULTS AND DISCUSSION

3.1 Influence of drying method and particle size on the optical and physicochemical properties of pulp and peel fibre from persimmon

The organoleptic characteristics of a food system may be affected after the incorporation of different ingredients such as fibre. In fact, their addition typically leads to an undesirable change in the colour and texture of the products (de Escalada Pla et al. 2012), which represents a challenge for the food industry. In this regard, analysing the colorimetric properties of new ingredients, such as persimmon fibre, is essential.

In Figure 1, the chromatic planes L*-a* and b*-a*coordinates of the different persimmon fibres studied (freeze-dried and hot air dried fibres, classified by particle size) along with the results for the commercial fibres are presented. The hot air dried fibres showed lower lightness (L*=52±8) than those stabilized by freeze-drying (L*=69±4), except for the hot air dried pulp fibre with a particle size lower than 125 µm (PULP-A <125) (L*=66.1±0.4). Freeze-dried fibres also showed similar L* values to commercial analysed fibres. Statistical analysis (ANOVA) showed the existence of significant differences in this parameter depending on the drying method and particle size in all cases except for the pulp fibre with a particle size between 500-250 and 250-125µm. Regarding the a* and b* coordinates, the hot air drying resulted in more brownish-orange fibres (a*=18±4 and b*=31±6) than freeze-dried fibres (a*=11±2 and b*=25±3), which presented tones that were more orange with a tendency towards yellow shades. This is a consequence of an increase mainly in the a* coordinate as a result of Maillard reactions occurring during the hot air drying (Perez-Jimenez et al. 2014). However, the hot air dried fibres resulted in tonalities which were more orange with higher chroma than freeze-drying. This was more significant in the case of persimmon pulp fibre. As for the particle size, and regardless of the origin of the fibre or technique applied for stabilization, the results showed a gradual increase in the a* coordinate as the particle size increased. This effect was very clear in the case

of hot air dried pulp and freeze-dried peel fibres. In general, the b* parameter was instead unaffected by particle size.

Table 1 shows the physicochemical characteristics of pulp and peel fibres from persimmon dried by freeze-drying (F) or hot air drying (A) and the values of these properties obtained for the commercial fibres. The difference in the specific volume suggests differences in the capillary structure: the more porous the system, the higher water content it can absorb, assuming the chemical composition is constant. According to Vetter and Kunzek (2003), the drying method affects the porosity of the product, hence persimmon fibres dried with hot air showed a specific volume similar to those of commercial fibres analysed commonly obtained using this method. However, freeze-dried fibres presented significantly higher values (around 2.85 cm^3/g), which is probably related to the sublimation water process, which leads to a different capillary structure, which is more open and porous (Basanta et al. 2012). Most fibres presented moisture contents ranging from 2% to 11% (Femenia et al. 1999) and although the moisture content of persimmon fibre is found to be in this interval, the main difference observed between commercial and extracted fibres relates precisely to moisture content, which is significantly higher in persimmon fibres and especially in freeze-dried ones. This result evidences a higher hygroscopicity of persimmon fibres and this could also justify the higher specific volume recorded in this type of fibre. However, these higher levels do not result in significantly higher values of water activity, which indicates that the interactions of persimmon fibre with water are stronger, ensuring the product stability against lipid oxidation reactions, hydrolytic reactions, non-enzymatic browning and microbial spoilage (Adams and Moss 1997). Protein levels in persimmon fibres were similar to those in apple and peach fibres and lower than in other commercial fibres, and fat content was lower than in all commercial fibres analysed, although both parameters are within the range of values found in literature for other types of fibre fruits (de Moraes Crizel et al. 2013).

3.2 Functional properties: hydration, oil retention and emulsification

Hydration properties are related to the quantity and characteristics of polysaccharides contained and are influenced by porosity and particle size (Femenia et al. 1997). The swelling capacity (SC) of fibre is a property that is usually evaluated in this type of products due to the implications it has not only in the food matrix (in which this ingredient is included), but also the satiating effect that it can provide due to swelling during the digestive process in the stomach. In this regard, Figure 2 shows the swelling capacity (SC), the water holding capacity (WHC) and the water retention capacity (WRC) of persimmon fibres depending on the type of drying (freeze or hot air) and particle size. Additionally, Table 2 shows the results of these hydration properties (SC, WHC, WRC and oil holding capacity: OHC) along with the emulsifying properties (emulsifying activity: EA and emulsion stability: ES) and the antioxidant properties (antioxidant activity: AA and total phenolic content: TPC) of the four commercial fibres.

The swelling capacity (SC) of the different fractions of persimmon fibre was very similar for pulp and peel and also comparable to the commercial fibres from orange, peach and apple. Besides, Figuerola et al. (2005) reported similar values of SC for fibres obtained from citrus fruit peels (6.11 to 8.27 mL water/g of dry matter) in the case of hot air-dried persimmon fibres while freeze-dried persimmon fibres showed higher SC.

When fibre was stabilized by freeze-drying, the water holding capacity (WHC) and the water retention capacity (WRC) were similar for persimmon fibre from peel and pulp. However, hot air drying noticeably decreased the WHC and WRC of pulp fibre, but had no influence on peel fibres, which had the same values as freeze-dried persimmon fibres. Comparing these results to those obtained for commercial fibres, WHC of persimmon fibres were in the same range as those for commercial fibres, whereas WRC were higher for persimmon fibres, except for the pulp fibre obtained by hot air drying which showed similar values to the commercial fibres.

With regard to the influence of the particle size, an improvement of hydration properties (SC, WHC and WRC) was recorded as the particle size decreased. This fact differs from the results

obtained by Kethireddipalli et al. (2002) who stated that an intense milling negatively affects fibre functionality, and specially its hydration properties.

In addition to hydration properties, fibre has the ability to trap fat, and therefore the oil holding capacity (OHC) is another essential parameter in the characterization of dietary fibres. This parameter is affected by the type, size, shape and superficial area of the particles of fibre, but also by its chemical composition (López et al. 1996). Figure 3 shows the OHC results for the persimmon fibres studied, depending on the type of drying and the particle size. As can be observed, the type of drying significantly affected the OHC of the fibre, being lower for hot air drying than for freeze-drying. In general, hot air dried pulp registered significantly less OHC than hot air dried peel. As for particle size, there was a noteworthy decrease in the OHC for peel in the case of increased particle size in fibres obtained by hot air drying. However, no remarkable differences were found in the other cases. Moreover, freeze-dried persimmon fibres reached values of OHC similar to all the commercial fibres. This behaviour could be related to the changes in the microstructure of the fibres, which is affected not only by the type of drying but also by the composition of the tissue. In freeze-drying, all types of tissues are less collapsed than in hot air drying, giving place to wider cavities that can retain more fat. In the case of hot air drying, there was a higher collapse in pulp than in peel.

As for emulsion properties, Figure 4 presents the percentages of emulsifying activity (EA) and the emulsion stability (ES) for persimmon fibres of 125 ?m. These properties are related to the protein solubility in water, which contributes to the decrease in the interfacial tension among the hydrophobic and hydrophilic compounds, giving place to a greater disposition of molecules to act in the interphase (Singh 2001). The EA of persimmon fibres was comparable to commercial fibres and no significant differences were found due to the drying method in pulp, while only a slight reduction in AE was recorded when fibre was obtained by hot air drying from peels. As for emulsion stability (ES), it is noteworthy that emulsions formed by fibres from peel were more

stable than those obtained from pulp and in both cases the highest stability was reached by freeze-drying.

3.3 Antioxidant properties

Persimmon fruit is a rich source of fibre, also containing vitamin C and phenols that confer antioxidant properties (George and Redpath 2008). Its antioxidant capacity is higher than for tomato, strawberry, apple and grape (Chen et al. 2008) and according to Gorinstein et al. (1998) it is one of the fruits that are richest in bioactive compounds. Figure 5 shows the values of antioxidant activity (AA) and total phenolic content (TPC) of persimmon fibres obtained in this study. Antioxidant compounds in fruits usually present higher concentrations in the peel as is the case of persimmon, whose peel is rich in carotenoids, which is the reason for its characteristic colour. However, due to the instability of these compounds, the drying process used for stabilization significantly affected their final content; and consequently, peel fibre obtained by hot air drying showed antioxidant properties which were similar to those of pulp fibre. Conversely, freeze-drying led to the highest values of AA and TPC in peel, but no significant differences were found in AA in the pulp based on the drying method used. Based on these results, the drying method has a notable influence on the stability of carotenoids, the freeze-drying being the most suitable technique for stabilizing peel fibre. Also noteworthy was that the particle size had a significant influence on the AA and the TPC in both fractions (peel and pulp), the fibres with the lowest size having the highest values in terms of antioxidant properties. If we compare the results of AA and TPC of the persimmon fibres from peel with the smallest particle size to the values obtained for the four commercial fibres (Table 2), it can be seen that the antioxidant activity was higher for persimmon fibre in all cases, except for in the case of apple fibre. However, the TPC of persimmon fibre was only similar to lemon and peach fibres, being much lower than for orange and apple fibres.

4. CONCLUSIONS

According to these results, persimmon fibre can be considered an ingredient with technological and antioxidant properties comparable to commercial fibres used in food industry. In particular, freeze-dried persimmon fibres show similar levels of SC, WHC, AE and total phenols and antioxidant capacity as those of the commercial fibres analysed and even higher WRC, OHC and EE. Moreover, this study evidences that a grinding process producing a particle size equal to or lower than 125 μm enhanced fibre functionality. As a consequence, fibre extraction from persimmon by-products might be considered an added-value activity for persimmon crops.

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Table 1. Physicochemical characteristics of persimmon pulp and skin fibres obtained by freeze-drying (F) or hot air drying (A) and different commercial fibres (lemon, orange, peach and apple).

	Lemon fibre	Orange fibre	Peach fibre	Apple fibre	Persimmon pulp fibre		Persimmon peel fibre	
					F	A	F	A
Specific volume*	$1.84 \pm 0.04^{(a)}$	$1.53 \pm 0.02^{(a)}$	$1.52 \pm 0.01^{(a)}$	$1.598 \pm 0.008^{(a)}$	$2.8 \pm 0.4^{(b)}$	$1.60 \pm 0.01^{(a)}$	$2.9 \pm 0.4^{(b)}$	$1.6 \pm 0.2^{(a)}$
Apparent density**	$0.54 \pm 0.01^{(b)}$	$0.652 \pm 0.008^{(c)}$	$0.656 \pm 0.004^{(c)}$	$0.626 \pm 0.003^{(c)}$	$0.37 \pm 0.05^{(a)}$	$0.624 \pm 0.007^{(c)}$	$0.35 \pm 0.04^{(a)}$	$0.64 \pm 0.07^{(c)}$
Water activity	$0.46 \pm 0.01^{(e)}$	$0.35 \pm 0.01^{(b)}$	$0.29 \pm 0.02^{(a)}$	$0.37 \pm 0.008^{(b)}$	$0.47 \pm 0.02^{(e)}$	$0.42 \pm 0.03^{(cd)}$	$0.44 \pm 0.04^{(de)}$	$0.41 \pm 0.01^{(c)}$
Moisture***	$3.5 \pm 0.1^{(b)}$	$2.6 \pm 0.1^{(b)}$	$1.0 \pm 0.1^{(a)}$	$3.70 \pm 0.07^{(b)}$	$7.8 \pm 0.3^{(d)}$	$6 \pm 1^{(c)}$	$8 \pm 1^{(d)}$	$6.9 \pm 0.5^{(c)}$
Protein***	≥7%	≥7%	≥4%	≥4%	≥4%	≥4%	≥4%	≥4%
Fat***	<2%	<2.5%	<3%	<3%	<2%	<2%	<2%	<2%

(cm^3/g); *(g/cm^3); ***** (g/100g)**

Table 2. Hydration properties, antioxidant activity and total phenols content of commercial fibres

	Lemon fibre	Orange fibre	Peach fibre	Apple fibre
Swelling capacity (SC)	$12.1 \pm 0.8^{(d)}$	$7.6 \pm 0.2^{(a)}$	$10.5 \pm 0.3^{(c)}$	$8.9 \pm 0.7^{(b)}$
Water holding capacity (WHC)	$14.4 \pm 0.4^{(b)}$	$9.9 \pm 0.2^{(a)}$	$14 \pm 1^{(b)}$	$15.4 \pm 0.7^{(c)}$
Water Retention Capacity (WRC)	$12.0 \pm 0.4^{(bc)}$	$9.3 \pm 0.3^{(a)}$	$11.0 \pm 0.5^{(ab)}$	$12.9 \pm 0.8^{(c)}$
Oil holding capacity (OHC)	$2.9 \pm 0.3^{(b)}$	$2.67 \pm 0.08^{(b)}$	$2.7 \pm 0.2^{(b)}$	$2.486 \pm 0.009^{(ab)}$
Emulsifying activity (AE)	$11.9 \pm 0.4^{(b)}$	$8 \pm 2^{(a)}$	$11 \pm 2^{(b)}$	$8 \pm 1^{(a)}$
Emulsifying stability (EE)	$36 \pm 3^{(b)}$	$41 \pm 3^{(c)}$	$38 \pm 1^{(bc)}$	$42 \pm 2^{(c)}$
Antioxidant activity (mg Trolox/g dry matter)	$2.3 \pm 0.3^{(a)}$	$4.1 \pm 0.3^{(c)}$	$3.8 \pm 0.3^{(c)}$	$7.8 \pm 0.2^{(e)}$
Total phenols content (mg GA/g dry matter)	$3.7 \pm 0.7^{(c)}$	$15.7 \pm 0.7^{(f)}$	$4.4 \pm 0.4^{(d)}$	$9.0 \pm 0.2^{(e)}$

Figure captions:

Figure 1. L*-a* and b*-a* colour planes of commercial fibres (lemon, orange, peach and apple) and persimmon fibres (from pulp or peel) obtained by different techniques (hot air drying: A or freeze-drying: L) and particle size (500: 500-250 μm; 250: 250-125 μm and <125 μm). Three replicates were carried out.

Figure 2. Swelling capacity (SC), water holding capacity (WHC) and water retention capacity (WRC) of persimmon fibres (from pulp or peel) obtained by different techniques (hot air drying: bars with points or freeze-drying: bars without points) and particle size (500: 500-250 μm; 250: 250-125 μm and <125 μm). Equal letters mean homogenous groups for each parameter. Three replicates were carried out.

Figure 3. Oil holding capacity (OHC) of persimmon fibres (from pulp or peel) obtained by different techniques (hot air drying: A or freeze-drying: F) and particle size (500: 500-250 μm; 250: 250-125 μm and <125 μm). Equal letters mean homogenous groups for each parameter. Three replicates were carried out.

Figure 4. Emulsifying activity (AE) and emulsifying stability (EE) of persimmon fibres (from pulp or peel) obtained by different techniques (hot air drying: A or freeze-drying: F). Equal letters mean homogenous groups for each parameter. Three replicates were carried out.

Figure 5. Antioxidant activity (AA) and total phenols content (TPC) of persimmon fibres (from pulp or peel) obtained by different techniques (hot air drying: A or freeze-drying: F) and particle size (500: 500-250 μm; 250: 250-125 μm and <125 μm). Equal letters mean homogenous groups for each parameter. Three replicates were carried out.

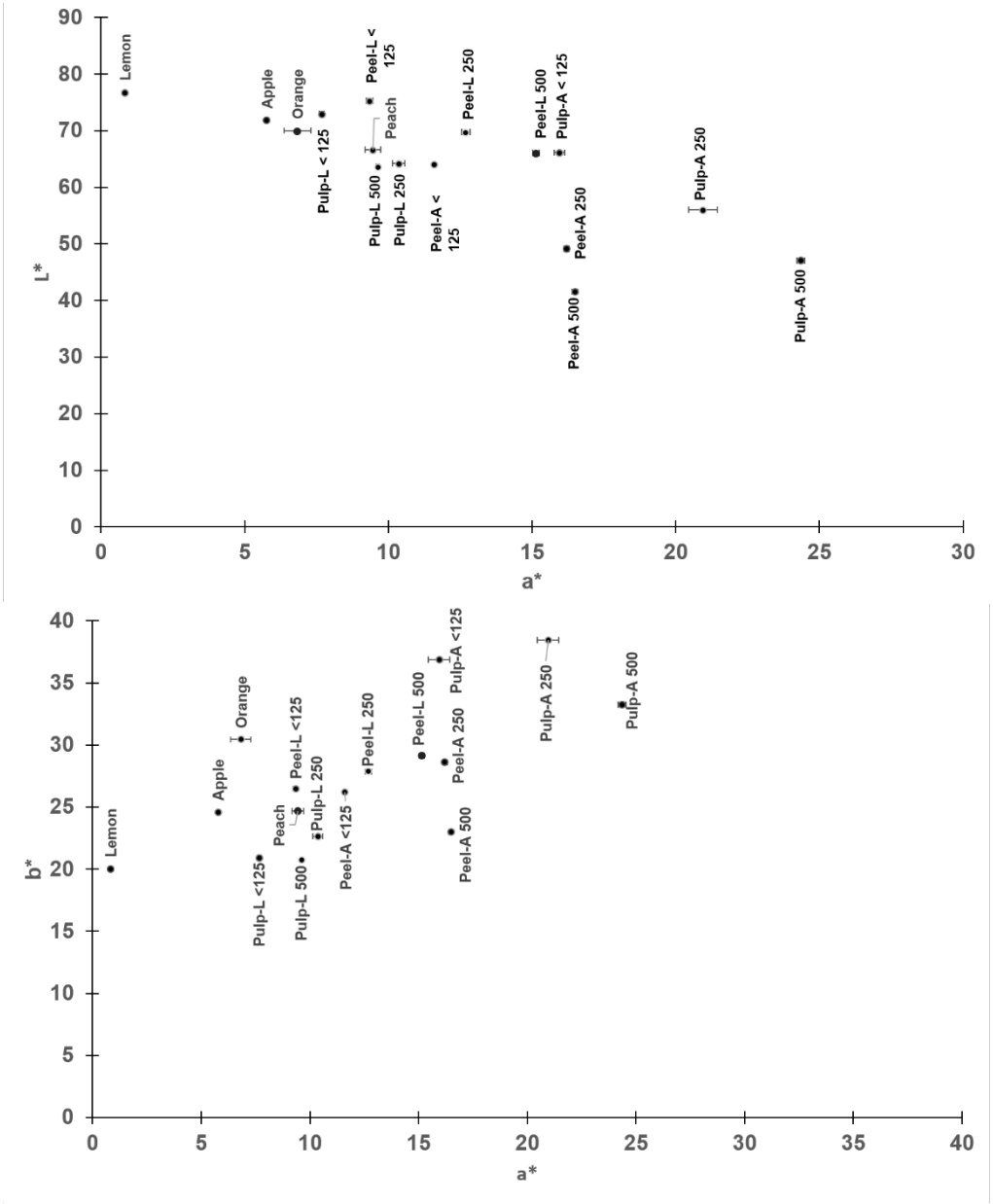
L*
a*
Lemon
Apple
Orange
Pulp-L < 125
Pulp-L 500
Peel-L < 125
Peach
Pulp-L 250
Peel-A < 125
Peel-L 250
Peel-L 500
Pulp-A < 125
Peel-A 250
Peel-A 500
Pulp-A 250
Pulp-A 500
b*
a*
Lemon
Apple
Orange
Pulp-L <125
Peach
Pulp-L 500
Peel-L <125
Pulp-L 250
Peel-A <125
Peel-L 250
Peel-L 500
Pulp-A <125
Peel-A 250
Peel-A 500
Pulp-A 250
Pulp-A 500

Figure 1.

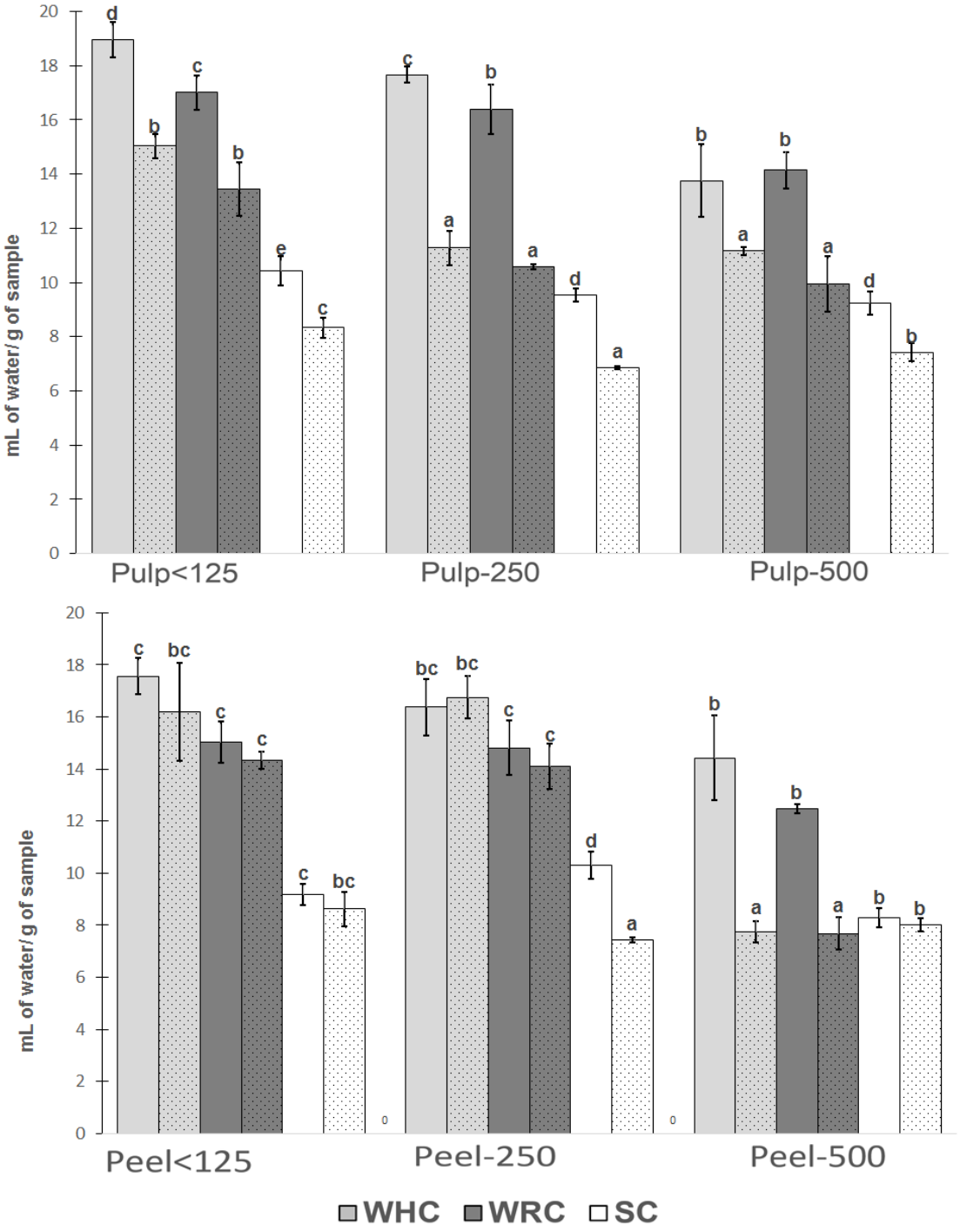
mL of water/ g of sample
Pulp<125
Pulp-250
Pulp-500
Peel<125
Peel-250
Peel-500
WHC
WRC
SC

Figure 2.

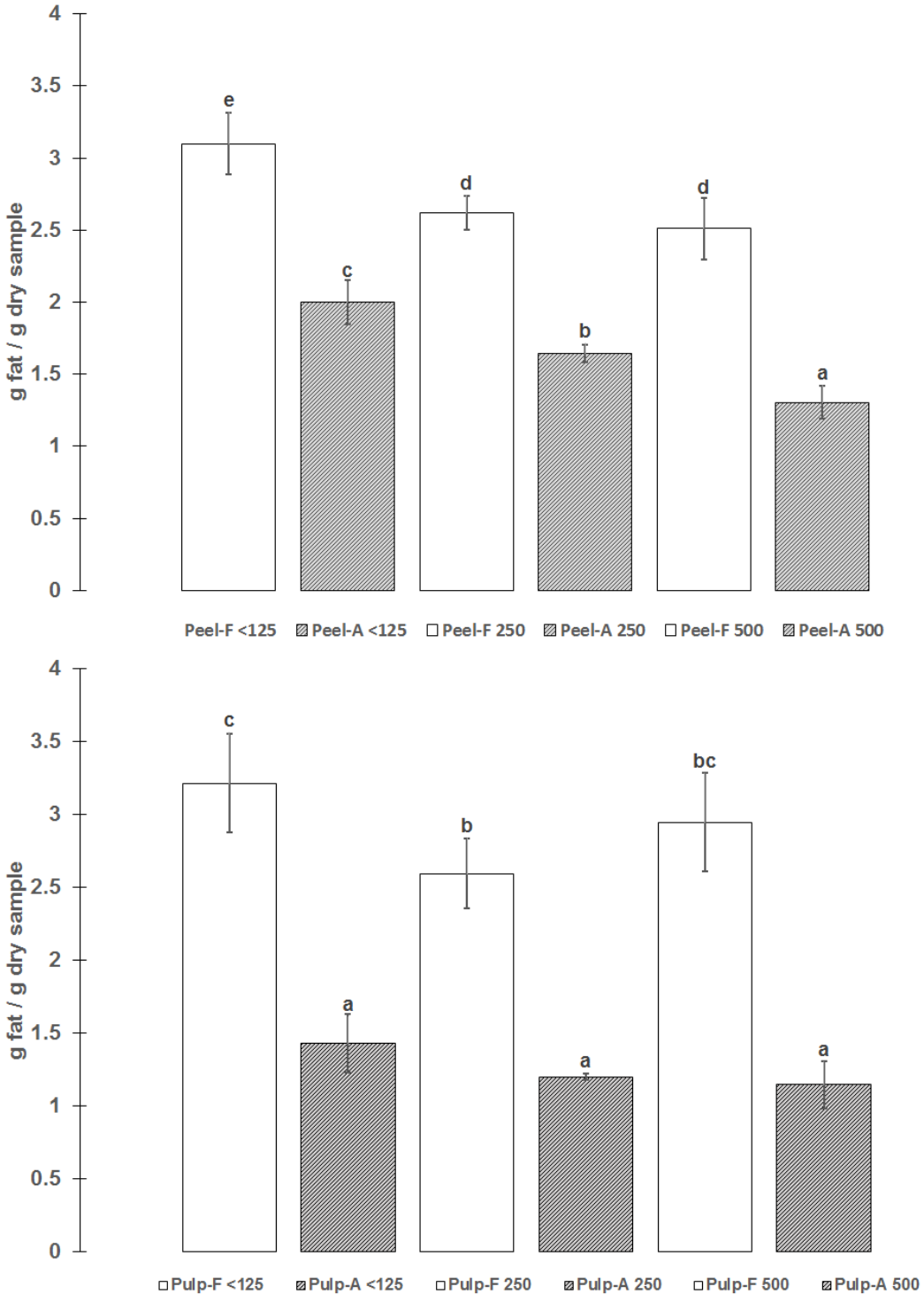
g fat / g dry sample
4
3.5
3
2.5
2
1.5
1
0.5
0
e
c
d
b
d
a
Peel-F <125
Peel-A <125
Peel-F 250
Peel-A 250
Peel-F 500
Peel-A 500
g fat / g dry sample
c
a
b
a
bc
a
Pulp-F <125
Pulp-A <125
Pulp-F 250
Pulp-A 250
Pulp-F 500
Pulp-A 500

Figure 3.

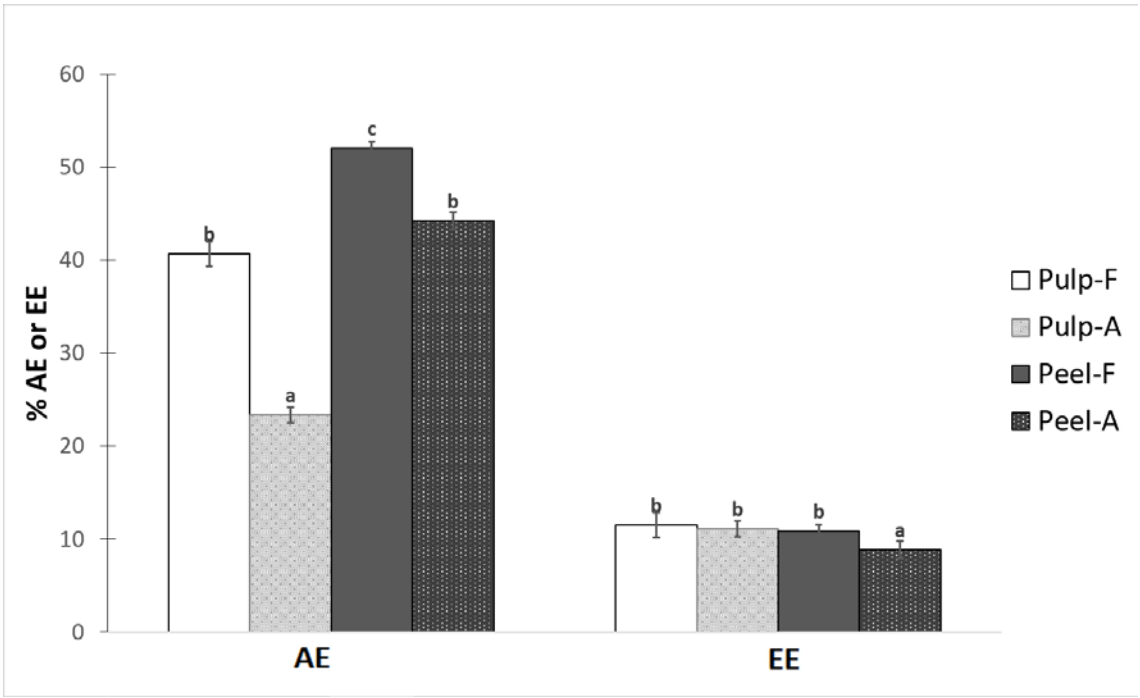
60
50
40
30
20
10
0
% AE or EE
b
a
c
b
b
b
b
a
AE
EE
Pulp-F
Pulp-A
Peel-F
Peel-A

Figure 4.

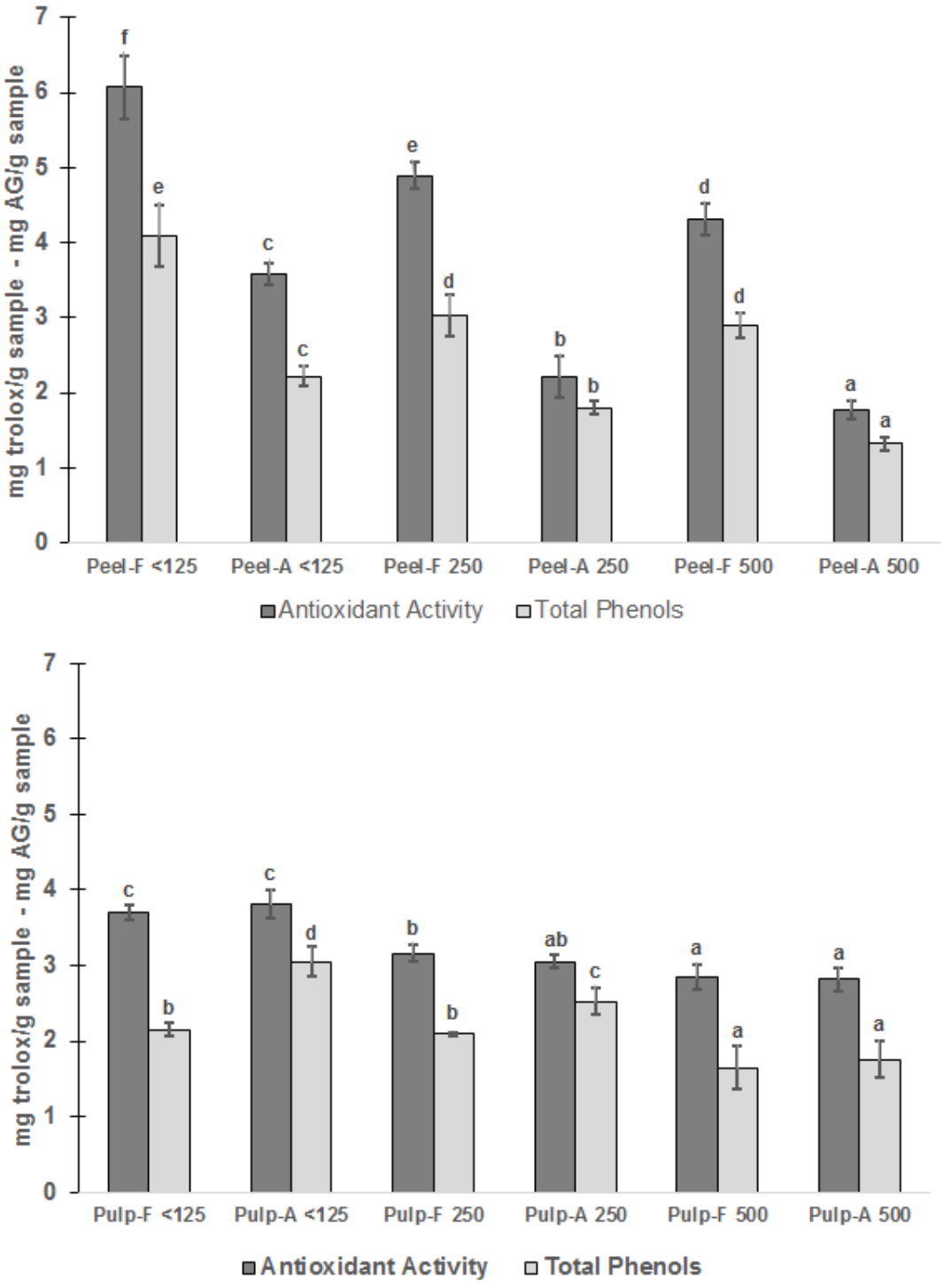
mg trolox/g sample - mg AG/g sample
0
1
2
3
4
5
6
7
f
e
c
c
e
d
b
b
d
d
a
a
Peel-F <125
Peel-A <125
Peel-F 250
Peel-A 250
Peel-F 500
Peel-A 500
Antioxidant Activity
Total Phenols
mg trolox/g sample - mg AG/g sample
0
1
2
3
4
5
6
7
c
b
c
d
b
b
ab
c
a
a
a
a
Pulp-F <125
Pulp-A <125
Pulp-F 250
Pulp-A 250
Pulp-F 500
Pulp-A 500
Antioxidant Activity
Total Phenols

Figure 5.