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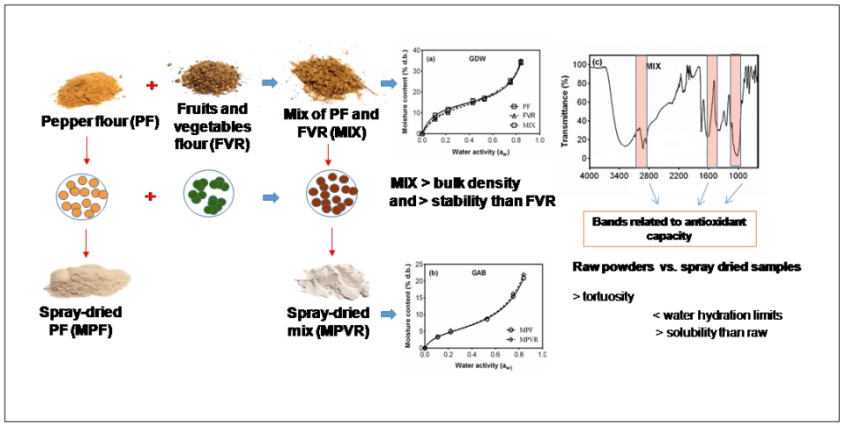

Graphical abstract

338x190mm (96 x 96 DPI)

Flour from fruits and vegetables waste with addition of a South-American pepper (*Capsicum baccatum*) proposed as food ingredient

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Abstract

The objective of this work was to evaluate the physicochemical properties of previously characterized flours obtained by milling the solid waste from the manufacture of an isotonic drink produced with various fruits and vegetables (FVR) to which powdered pepper fruits (PF) were added. Aqueous extracts were also prepared and encapsulated for protecting their functional compounds and improving their solubility. The encapsulation yields of the spray-drying processes were 90% and 64% for PF and FVR-PF, respectively. The addition of PF to FVR improved antioxidant capacity, stability and appearance, providing reddish color. FT-IR spectra reflected the addition of PF by changes in the absorbances at wave-numbers typical of carotenoids, acylglycerols, chlorophylls and those related to antioxidant capacity. The encapsulated extracts could be applied when solubility is needed in hydrophilic media. The obtained flours with PF addition are suitably cheap, stable functional food ingredients for industrial uses, such as breading or seasoning ingredients.

Keywords: Pepper; beverage waste; encapsulation; isotherms; powder stability; antioxidant activity

Highlights

- Addition of pepper increased bulk density, improving the stability of the MIX.
- The models that best fitted isotherms were GDW (raw) and GAB (encapsulated).
- The addition of pepper increased antioxidant capacity and provided reddish color
- The main differences in the FT-IR spectra reflected compositional aspects

1. Introduction

Agroindustrial activity generates a dramatic amount of waste and their disposal (landfilling, incineration) was defined as the worst environmental option. Agri-food waste prevention is a better option and its utilization to yield value-added products is considered an interesting waste minimization strategy (Galanakis et al., 2018).

Recently, the residues from an isotonic beverage composed of fruits and vegetables (FVR), processed as flour, have been successfully used in the formulation of cereal bars and biscuits to increase microbiological stability, water retention capacity, mineral and fiber content (Neacsu et al., 2015). These novel ingredients demonstrated the ability to overcome constipation and can be used for the development of functional foods (Gonçalves et al., 2018; Andrade et. al, 2014).

Pepper fruits (from *Capsicum* genus), commercialized worldwide, may complement the flour from fruits and vegetables, providing flavor and color characteristics, improved nutritional value and antioxidant properties (Perla et al., 2016). A typical South-American pepper (*Capsicum baccatum*) is the most consumed in Brazil, and highly relevant in regional gastronomy as flavoring and colorant agent. Besides antioxidant properties, *C. baccatum* extracts display anti-inflammatory activities, may combat antibiotic-resistant bacteria, prevent bacterial adhesion and biofilm formation (von Borowski et al., 2019).

Although FVR composition, antioxidant capacity, colorimetric and rheological properties related to the film forming capacity was reported (Brito et al., 2019), the characterization of the product obtained by its combination with pepper has not been yet performed. Thus, the objective of this work was to evaluate the applicability of combined flours from fruits and vegetables waste (FVR) with pepper flour (PF), or of their spray-dried aqueous extracts, for the development of functional food ingredients.

2. Materials and Methods

2.1. Preparation of samples

2.1.1. Pepper Flour (PF) was obtained from fully ripe pepper fruits "dedo-de-moça" (*Capsicum baccatum L. var. Pendulum*) purchased at Hortifrutti, a local market in Rio de Janeiro, Brazil, in May 2016. The peppers were authenticated by a Food Agricultural Engineers staff member, and processed according to the methodology applied by Ferreira et al. (2015), consisting in convective drying at 75 ºC for 5 hours, then at 90 ºC for 1 hour, milled, homogenized and stored at 25 ºC. One lot of 1000g fresh pepper was processed, from which 141g of PF were obtained.

2.1.2. Fruits and vegetables flour (FVR) was prepared with residues from the manufacture of an isotonic beverage, as previously described by Ferreira et al. (2015). The beverage has been formulated with a stablished composition and proposed as a potential functional product applied in the improvement of gastrointestinal disorders (Andrade et al., 2014).

The beverage was composed of the following species: 11% of sweet orange (*Citrus sinensis*) 19% of passion fruit (*Passiflora edulis*), 22% of watermelon (*Citrullus lanatus*), 8.5% of cucumber (*Cucumis sativus*) and courgette (*Cucurbita pepo*), 2% of rocket (*Eruca sativa*) and mint (*Mentha sp*),13% of carrot (*Daucus carota*) and 5.5% of lettuce (*Lactuca sativa*), spinach (*Spinacea oleracea*) and taro (*Colocasia esculenta*), entirely processed for the drink preparation, including non-conventional edible parts such as pulp, stalks, peels, seeds and stems (Ferreira et al., 2015). The remaining solid residues were processed as flour and previously characterized, containing dietary fiber (48%, 80% of which was insoluble), carbohydrates (26%), proteins (9.5%) and lipids (5%). Analysis of different lots in different years allows standardization for assuring the composition constancy of the waste (Brito et al., 2019).

2.1.3. Mix of PF and FVR (MIX): PF and FVR flours were mixed in the proportion of 1:1 (w/w) and homogenized manually in a mortar, using liquid nitrogen to avoid the material stickiness due to exposure to ambient humidity.

2.1.4. Microencapsulated extracts: PF or FVR were suspended in aqueous solutions of 30% (w/w) maltodextrin (MD, DE 15) from Saporiti S.A. (Buenos Aires, Argentina) to obtain a final concentration of 6.4%. For the microencapsulated mix (MPVR), PF and FVR were added in order

to obtain 3.2% of each one. The suspensions were homogenized at 500 rpm for 10 min with Ultra Turrax T18 (IKA, Konigswinter, Germany) and 15,000 rpm for 2 min. Subsequently the systems were submitted to the Ultrasonic Processor UP 100H (Ultrasound Technology) for 5 min. After centrifugation at 10,000 rpm for 15 min at 10 °C, the supernatant was collected and filtered twice in a Buchner system using paper filters (Whatman 1.20-μ pore). The filtrate was spray dried (in a Buchi B290, Flawil, Switzerland drier) at a flow rate 8 mL/min, air pressure 3.2 kPa, nozzle diameter 1.5 mm, inlet temperature 174 °C and outlet temperature 95 °C. The product yields of samples after spray drying were calculated according to the following formula:

$$\%\ Yield = \frac{Mass\ of\ powder\ obtained\ after\ the\ spray-drying\ process}{Mass\ of\ initial\ soluble\ solids\ (form\ flour + maltodextrin)} \times 100$$

2.2. Physicochemical characterization

2.2.1. Bulk density

Bulk density (g/mL) was determined according to Santhalakshmy et al. (2015) by measuring the volume of 1.00 g of powder gently introduced into a 10.00 mL graduated cylinder, at 25°C.

2.2.2. Water activity (a_w)

a_w values were measured using an electronic a_w meter Aqualab Series 3 (Decagon Devices, Pullman, WA, USA), based on the dew point determination by water condensation on a mirror as temperature decreased.

2.2.3. Hygroscopicity

Hygroscopicity evaluation was performed as described by Santhalakshmy et al. (2015) with modifications. One gram of the sample was placed in a container at 25 °C with a saturated NaCl solution (75% RH). Samples were weighed every 30 min for 285 min and during 2 days until

constant weight. Hygroscopicity was expressed in grams of water adsorbed per 100 grams of dry matter (g/100 g d.b.).

2.2.4. Solubility

Solubility was determined according to the procedure described by Cano-Chauca et al. (2005) with modifications. Briefly, 1 g of dry powder was carefully added to 50 mL of distilled water into a plastic tube, and stirred at high velocity for 5 min. The solution was centrifuged at 3000g during 5 min. An aliquot of 20 mL of the supernatant was transferred to pre-weighed Petri dishes and immediately oven-dried at 105 ºC for 5 h. Then the solubility (%) was calculated by weight difference.

2.2.5. Colorimetric determinations

A Minolta CM-508-d tristimulus photocolorimeter (Minolta Corp., Ramsey, NJ, USA), with integrating sphere was employed to analyze the color attributes of the samples. Transparent recipients of 2 cm diameter and 0.5 cm height were employed. The chromatic coordinates in the CIELAB space were obtained, which represent the color attributes: L^* (lightness, representing the psychophysical quality of clarity with values 0 for black up to 100 for white), a^* (red-green axis) and b^*(yellow-blue axis). The color coordinates were calculated for the CIE D65 illuminant and 2° observer angle.

2.2.6. Water adsorption isotherms

The isopiestic method was employed for obtaining adsorption isotherms, by exposing the samples at saturated salt solutions at water activities (a_w) values 0.22, 0.43, 0.53, 0.75 and 0.84 at 25 ± 1 °C (Greenspan,1977). The adsorption isotherms were adjusted with BET, GAB and GDW (D'Arcy -Watt) models, using GraphPad Prism 6 software. The coefficient of determination (R^2), relative mean deviation (%E), equation (1) and mean square error (RMS), equation (2), were calculated

to verify the degree of fit of the studied models (Téllez-Pérez et al., 2014).

$$\%E = \frac{1}{N}\sum_{i=1}^{N}\frac{|m_i - m_{pi}|}{m_i} \quad (1) \qquad \%RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{m_i - m_{pi}}{m_i}\right)^2} \quad (2)$$

where m_i and m_{pi} are the actual and predicted moisture content values, respectively, and N is the number of observations.

2.2.7. FT-IR spectroscopy

The analysis of compositional aspects and component interactions in the samples was performed by FT-IR spectra obtained with a Spectrum 400 spectrometer (Perkin Elmer, Inc., Shelton, CT, USA) with an attenuated total reflection (ATR) device, by averaging 96 scans over the spectral range of 600 to 4000 cm^{-1}. Data analysis of each sample was performed with OriginPro 2017 program (OriginLab, Northampton, MA, U.S.A.). The average of triplicates for each system was reported. Baseline was corrected and the spectra were normalized.

2.3. Antioxidant activity

The extracts were obtained from 5% of dry solids in water or in 1:1 ethanol:water solution, vortexed for 30 min and centrifuged during 10 minutes at 10.000 rpm. The supernatant was recovered for analysis of total phenolic compounds and antioxidant activity.

2.3.1. Total polyphenols contents by Folin-Ciocalteu method

Total phenolic contents (TPC) of the extracts were determined by the Folin–Ciocalteu method, with some modifications (Busch et al., 2017). Briefly, 125 mL of a solution of Na_2CO_3 (20% w/w), 800 mL of distilled water and 50 µL of sample were added to 125 µL of the Folin-Ciocalteau reagent (Biopack®, Zarate, Buenos Aires, Argentina). The absorbance at 765 nm was measured

in a UV-Vis spectrophotometer (JASCO Inc., Maryland, USA) after 30 min at 25 ºC in the dark. Total polyphenols (TP) were expressed as mg gallic acid per 100 g of dry matter (mg GAE/100 g of d.b.), through a calibration curve.

2.3.2. Free radical scavenging by DPPH•

The radical scavenging activity (RSA) was calculated as a percentage of the free radical DPPH• (2,2-diphenyl-1-picryl-hydrazyl) discoloration in 30 minutes, using Equation (3):

$$\%\mathrm{RSA} = \frac{(\mathrm{A_{DPPH\bullet}} - \mathrm{A_{EXT}})}{\mathrm{A_{DPPH\bullet}}} \mathrm{x}\ 100 \qquad (3)$$

where $A_{DPPH•}$ is the absorbance value of the DPPH• test solution and A_{EXT} is the difference between the absorbance values of the test solution with the extract and of its blank at 30 min (Busch et al., 2017).

3. Results and Discussion

3.1. Physicochemical characterization

The parameters color coordinates, bulk density, hygroscopicity and solubility, as so as the a_w values of the samples, are shown in Table 1.

All the samples were of intermediate lightness, since *L** values (representing luminosity) were close to 50. The visual appearance of FVR was of a greenish-brown coloration, and reflected in the color coordinates, since the a^* value was positive but close to 0 (slightly in the red region) and *b** was >0, well in the yellow zone. The PF sample was visually reddish-yellow, with higher *a** and *b** values. As a consequence, the color coordinates of MIX had intermediate chroma values, providing a reddish-brown color, with positive and intermediate a^* and b^* values. In the spray-dried powders the visual appearance was governed by the presence of maltodextrin, the samples were almost achromatic, with very high luminosity (*L** value close to 85), being MPF slightly pink.

The encapsulation efficiencies for PF and MIX were 90% and 64% w/w, respectively. The different yields can be related to the nature of the raw material, since the spray-drying conditions were maintained as a constant (Tontul and Topuz, 2017).

PF and MIX powders presented higher bulk density than FVR. As higher is the bulk density, less air is occluded within the powder particles. Considering that the heavier material can be more easily accommodated in the spaces between particles (Santhalakshmy et al. 2015), there is less possibility of product oxidation and thus storage stability is increased due to less contact with atmospheric oxygen. High bulk density is also favorable for transportation and packaging (Tontul and Topuz, 2017). Consequently, the addition of PF to FVR potentially favors the functional components stability. No differences in bulk density were observed among the microencapsulated samples, since it was predominantly governed by the maltodextrin matrix.

a_w and hygroscopicity play important roles for storage stability, while solubility is related to the powders reconstitution (Rezende et al., 2018). The a_w of the samples were between 0.09 and 0.3, indicating stability against chemical or enzymatic reactions. Spray-drying with maltodextrin as wall materials resulted in the lowest a_w values, important for packaging specifications. The samples presented hygroscopicity values from 13.26 to 16.63% (d.b.), which are considered adequate, since values lower than 20% indicate a low tendency to absorb water (Tontul and Topuz, 2017). In agreement with other researchers, encapsulation by spray-drying with maltodextrin as wall material, which decreased degradation of bioactive compounds (Busch et al., 2017; Rezende et al., 2018), increased the solubility and water absorption of the powders in aqueous media.

3.2. Water adsorption isotherms

Water sorption isotherms at 25 °C presented sigmoidal shape, characteristic of type II isotherms (Fig. S1), indicating the existence of multilayers in the inner surface of the material (Fonteles et al., 2016).

The BET, GAB and GDW models employed provided adequate description of the experimental data (Table 2), with determination coefficients (R^2) higher than 0.99, and %E less than 10% (Téllez-Pérez et al., 2014), being the BET model limited to a_w values lower than 0.5 (Furmaniak et al., 2009).

The hydration limits (X_m, or "monolayer values") obtained by the GAB equation for PF was in the range of those obtained for different pepper varieties (Seid and Hense, 2012). As higher is the GAB constant *C*, greater is the water binding force at the monolayer (Téllez-Pérez et al., 2014). For the analyzed systems GAB constants values, $k < 1$ and $C > 2$ were obtained for all studied samples (Table 2), which is also typical of type II isotherms.

The GDW model, previously used to describe water sorption isotherms of different food products (Furmaniak et al., 2009), maintains all the considerations for the GAB model, but assumes that only a proportion of water molecules bound to primary adsorption centers can act as secondary centers and *w* is lower than a value of 1. When each one of the water molecules adsorbed in primary sites is converted to a secondary sorption site, the parameter *w* equals 1 and the GDW model is reduced to GAB model. In some cases, one primary center can adsorb more than one water molecule (Furmaniak et al., 2009), and in this case $w > 1$. As shown in Table 2, *w* was quite lower than 1 for the un-encapsulated systems and quite close to 1 for the encapsulated systems. This indicates that the raw milled samples had a denser or tortuous microstructure while the spray-dried samples presented a more open and less compact structure, which allowed the full conversion of primary sites into secondary sites for water adsorption. This fact explains why the spray-dried samples were well represented by the GAB equation while GDW provided a better description for the water sorption in raw powders.

As previously observed (Furmaniak et al., 2009), M_e values of the GDW model were higher than those obtained for X_m of the GAB model. Sorption kinetic constants for the primary sites (*K*) presented values higher than one, corresponding to type II isotherms. The *K* values indicate that the FVR and MIX milled systems have slower water sorption than the FP and encapsulated

extracts. The sorption kinetic constants for the secondary sites (*k*) were slightly higher than 1 for the milled systems and slightly lower than 1 for the encapsulated extracts.

3.3. Antioxidant activity assay

The total phenolic contents were higher for the aqueous extracts than for the ethanolic extracts (Table 3). The addition of PF to the FVR increased the phenolic content. Recently, 42 phenolic compounds were identified by UPLC-ESI-Q-TOF-MS/MS in PF, of which quercetin 3-O-rhamnoside, luteolin 7-O-glycoside and naringenin were the most abundant (Mendes et al., 2019). On the other hand, 88 compounds were tentatively identified in the FVR: phenolic acids (28), flavonoids (32) and other polyphenols (28), being hesperidin the main compound extracted (Gonçalves et al., 2018).

As shown in Table 3, the ethanol extract of PF showed higher free radical scavenging activity than FVR and the MIX. Non-spray-encapsulated samples, showed similar anti-radical capacity in aqueous and ethanol media. The lowest antioxidant activity of the samples was observed for the spray dried samples (MPF followed by the MPVR, Table 3), due to their dilution in the maltodextrin matrix. The antiradical capacity was higher for the samples extracted with water, in parallel with their higher total polyphenols content.

3.3. FT-IR spectroscopy

The main differences in the FT-IR spectra of PF, FVR and MIX are indicated in Figure 1 a, b and c, respectively. The normalized absorbance values of those signals are presented in Figure 2 as a function of the proportion of PF (Fig. 2a), or of total polyphenols content (Fig. 2b). The absorbance values at frequencies typical of the hydrocarbonated skeleton of carotenoids (which are those at 2922 cm^{-1} and 2853 cm^{-1} related to CH_3 and CH_2 vibrations, around 1450 cm^{-1}, due to the bending vibration of methylene $–CH_2$, and those around 1367 cm^{-1}, caused by scissoring and bending bonds of alkanes (Kushwaha et al., 2014), followed the order FVR < MIX < PF

(Figure 2a). The absorbances of the band at 1743 cm^{-1}, attributed to the ester carbonyl group of acylglycerols, were in the same order (Figure 2a), due to the higher proportion of lipids in PF.

As shown in Figure 2b, the absorbance values at 1580, 1410 and at 1020 cm^{-1}, which have been associated with the antioxidant activity of fruit extracts (Lu and Rasco, 2012), and the absorbances at 1650 cm^{-1}, caused by chlorophylls and proteins (Kushwaha et al., 2014) increased with higher total polyphenolic contents and with the PF content.

The ratio of absorbances at 1625 cm^{-1} (related to chlorophylls) and 1743 cm^{-1} (lipids + chlorophylls) was very sensitive to the compositional changes (Figure 2b).

The FT-IR bands in the ranges 3270-3320 cm^{-1}, 1629-1663 cm^{-1} and 1014-1019 cm^{-1} have been associated to polyphenol contents of tea extracts (Senthilkumar et al., 2017). However, for the analyzed samples, only the absorbances at 1020 cm^{-1} were related to increasing PF proportion and with the antioxidant capacity (Figure 2b).

No frequency displacements in the range 3470 to 3230 cm^{-1} (which corresponds to –OH interactions) were detected by PF addition, reflecting that potential molecular interactions of polyphenols with other components (Fig. 1, a-c), would not affect the antioxidant capacity, in agreement with the data shown in Table 3.

4. Conclusions

Dried fruits and vegetables by-products combined with pepper flour represent an interesting alternative for the production of functional ingredients. The addition of pepper flour to the fruits and vegetables flour increased the red coloration, modified the bulk density, improving its stability, and functional properties, also increasing polyphenols content and antioxidant capacity. The absorbance of selected FT-IR bands, mainly those related to carotenoids, phenolics and chlorophylls, reflected the addition of PF to the fruit and vegetable extract.

FVR, PF and MIX could be used after a very easy drying and milling procedure when there are no solubility requirements, as in the case of snacks and seasonings for breaded preparations. On

the other side, flours extracts encapsulation by spray-drying may be the choice when the water solubility of the powders is needed. Spray dried powders are characterized by their reduced water content, without a significant change in hygroscopicity. By the encapsulation process, the ingredients obtained developed an improved stability and are suitable for applications in hydrophilic media. The proposed ingredients represent an attractive alternative for the development of innovative products, as well as a viable solution for the valorization of food processing by-products, agroindustrial waste and regional resources, adding value to unappreciated materials.

Conflict of Interest

All authors declare that there is no conflict of interest.

Ethical Guidelines

Ethics approve was not required for this research.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Legends for figures

Figure 1. Fourier transform infrared (FT-IR) spectra in the range 4000-700 cm^{-1} for fruit and vegetable flour (FVR), pepper flour (PF) and MIX (PF/FVR)**.** The circles indicate the main differences of the spectral bands. Bands located in the ranges 3270-3320 cm^{-1} and 1743-1663 cm^{-1} are typical of polyphenols. Peaks in the region around 1625 cm^{-1} are attributed to chlorophylls and proteins, contributions of carotenoids are located at 1450 and 1250 cm^{-1}.

Figure 2. Absorbances in the IR regions at which differences were observed when changing the proportion pepper flour (PF) and fruit and vegetable flour (FVR).

a) Absorbance values at 1450, 1367, 2922 and 2853 cm^{-1} (attributed to carotenoids), at 1743 cm^{-1} (mainly attributed to lipids), as a function of the mass fraction of PF.

b) Absorbance values at 1020, 1410, 1580 and 1650 cm^{-1} and the absorbances ratio between 1743 and 1625 cm^{-1} as a function of total polyphenols in the aqueous extracts.

Table 1. Physicochemical characterization of pepper flour (PF), fruits and vegetables flour (FVR), mix of PF and FVR (MIX) and dry powders obtained by spray drying: PF Microcapsules (MPF); PF and FVR Microcapsules (MPVR).

	PF	FVR	MIX	MPF	MPVR
Bulk Density (g/mL)	0.54 ± 0.04	0.42 ± 0.01	0.55 ± 0.02	0.49 ± 0.01	0.50 ± 0.01
a_w	0.37 ± 0.02	0.34 ± 0.04	0.39 ± 0.02	0.09 ± 0.01	0.09 ± 0.01
Hygroscopicity (g.a.w/100 g)	13.0 ± 0.1	16 ± 2	14.8 ± 0.3	13.3 ± 0.8	15.72 ± 0.01
Solubility (%)	43 ± 2	42 ± 1	38.01 ± 0.03	99 ± 1	100.00 ± 0.01
L*	52.8 ± 0.5	55.8 ± 0.3	50.7 ± 0.4	84.7 ± 0.6	92.1 ± 0.7
a*	21.4 ± 0.2	2.6 ± 0.1	13.7 ± 0.2	16.1 ± 0.1	7.3 ± 0.2
b*	37.8 ± 0.2	20.0 ± 0.3	31.9 ± 0.3	18.1 ± 0.3	14.9 ± 0.1

g.a.w: g of absorbed water. All results are the means ± SD (*n* = 3).

Table 2. Parameters of the proposed models for moisture sorption isotherms at 25 °C.

Model	Constants	PF	FVR	MIX	MPF	MPVR
BET	X_m	9.359	9.175	9.516	4.674	5.118
	C	51.69	19.45	23.08	14.45	11.39
	R^2	0.997	0.998	0.998	1.000	0.998
	%E	1.886	1.498	1.768	0.306	1.909
	%RMS	3.772	2.997	3.536	0.613	3.819
GAB	X_m	10.13	9.916	10.02	4.895	4.985
	C	44.38	19.36	25.91	14.15	13.64
	K	0.839	0.859	0.849	0.918	0.926
	R^2	0.998	0.999	0.997	0.999	0.998
	%E	2.345	1.985	3.172	0.799	3.069
	%RMS	5.744	4.863	7.771	1.959	7.519
GDW	M	16.29	17.50	18.03	5.042	5.606
	K	10.06	5.798	6.300	13.49	10.97
	k	1.025	1.027	1.006	0.906	0.919
	w	0.215	0.2248	0.2337	1.102	0.985
	R^2	0.999	0.999	0.999	0.999	0.998
	%E	0.922	0.855	0.744	1.070	3.338
	%RMS	2.438	2.262	1.798	2.823	8.831

X_m, M: water hydration limit ("monolayer value", % dry basis); C, K, k, w, A, B: model parameters; R^2: determinant coefficient; %E: mean relative percentage deviation; %RMS: root mean square.

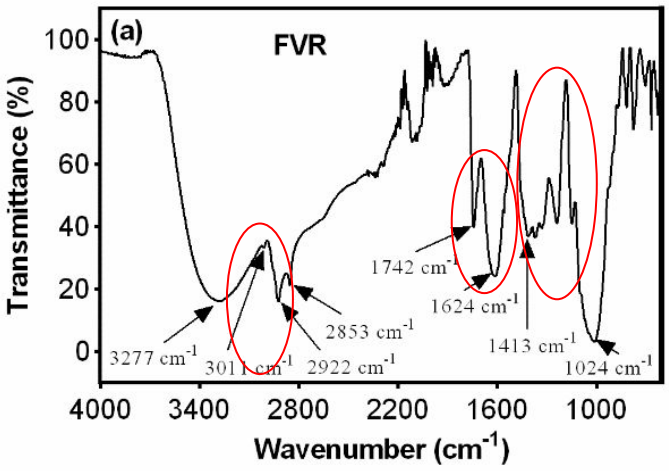
Table 3. Total phenolic contents and antioxidant activity of PF, FVR, MIX, MPF and MPVR.

Samples	Total phenolic contents (mg GAE/g extract)		DPPH• (%of DPPH• discoloration, 30')	
	H_2O	ETHANOL 50 %	H_2O	ETHANOL 50 %
PF	387 ± 2 $^{a, A}$	300 ± 22 $^{a, B}$	73.7 ± 0.5 $^{a, A}$	84 ± 1 $^{a, A}$
FVR	314 ± 15 $^{b, A}$	271 ± 13 $^{a, A}$	70 ± 2 $^{a. A}$	69 ± 3 $^{b, A}$
MIX	361 ± 13 $^{a, A}$	308 ± 1 $^{a, A}$	74 ± 6 $^{a, A}$	70 ± 2 $^{b, A}$
MPF	151 ± 9 $^{c, A}$	118 ± 13 $^{b, A}$	13 ± 3 $^{b, A}$	2.9 ± 0.5 $^{c, B}$
MPVR	159 ± 3 $^{c, A}$	82 ± 4 $^{b, B}$	19 ± 6 $^{b, A}$	3 ± 0.2 $^{c, B}$

All results are the means ± SD (n = 3). Different lowercase letters in the same column indicate significant differences between samples using Tukey's multiple range test (p <*0.05*). Different uppercase letters in the same line indicate significant differences between samples using Tukey's multiple range test (p <*0.05).*

417

418 **Figure 1.**


(a)
FVR
Transmittance (%)
Wavenumber (cm-1)
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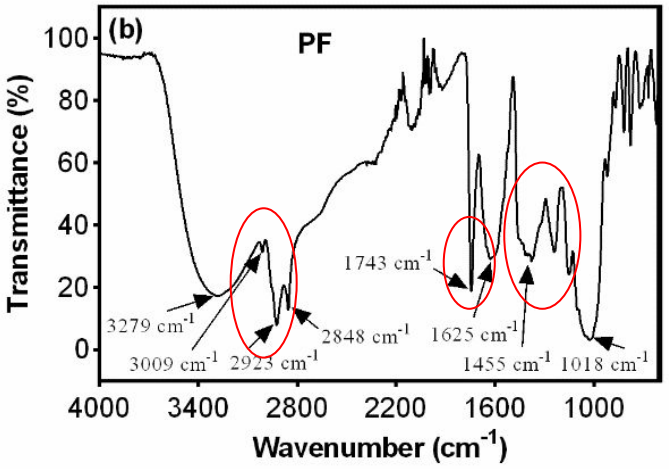
3011 cm-1
2922 cm-1
2853 cm-1
1742 cm-1
1624 cm-1
1413 cm-1
1024 cm-1


(b)
PF
Transmittance (%)
Wavenumber (cm-1)
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2923 cm-1
2848 cm-1
1743 cm-1
1625 cm-1
1455 cm-1
1018 cm-1

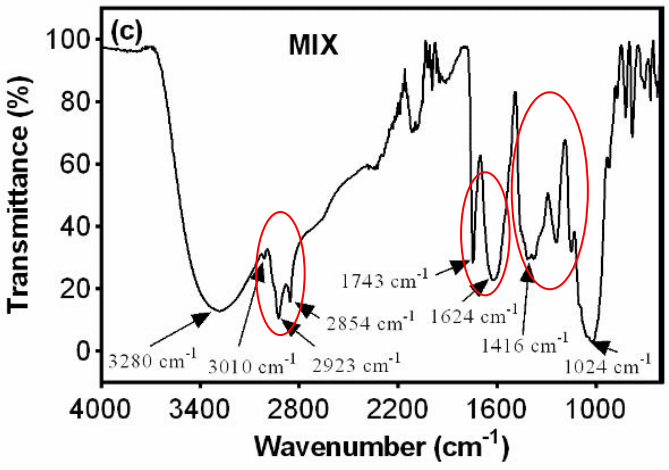

(c)
MIX
Transmittance (%)
Wavenumber (cm-1)
3280 cm-1
3010 cm-1
2923 cm-1
2854 cm-1
1743 cm-1
1624 cm-1
1416 cm-1
1024 cm-1

Figure 2.

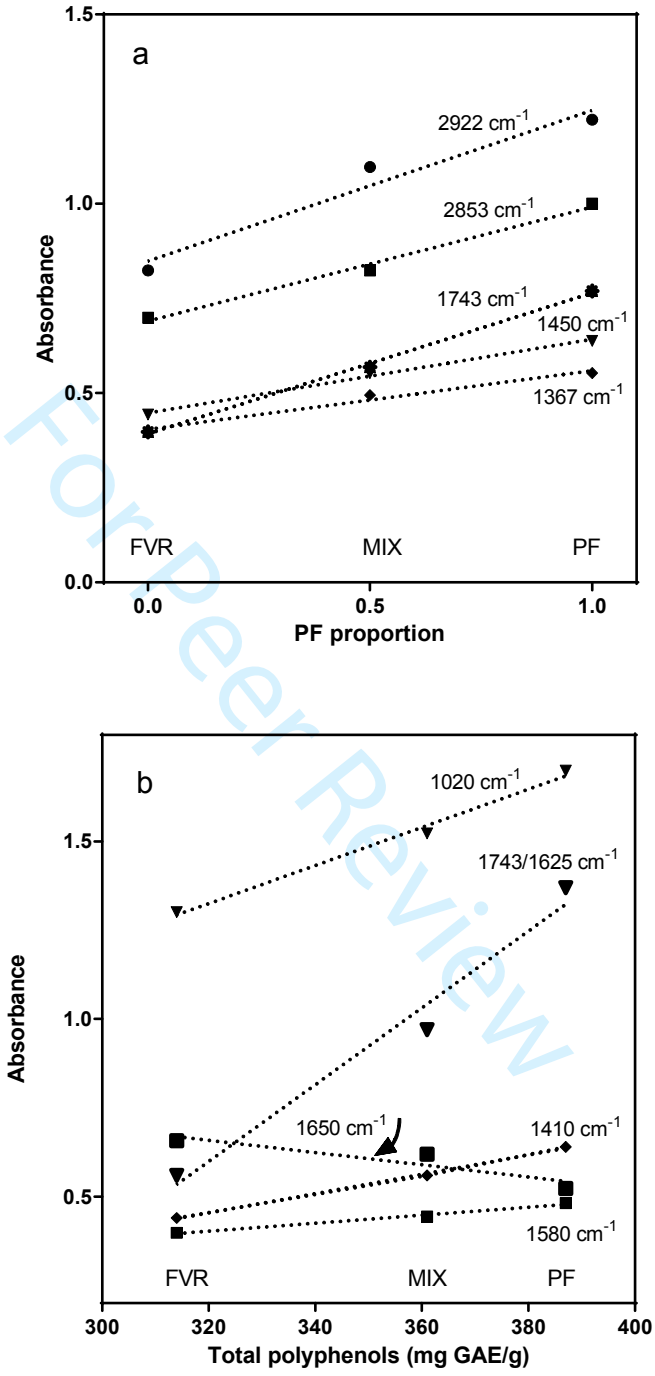
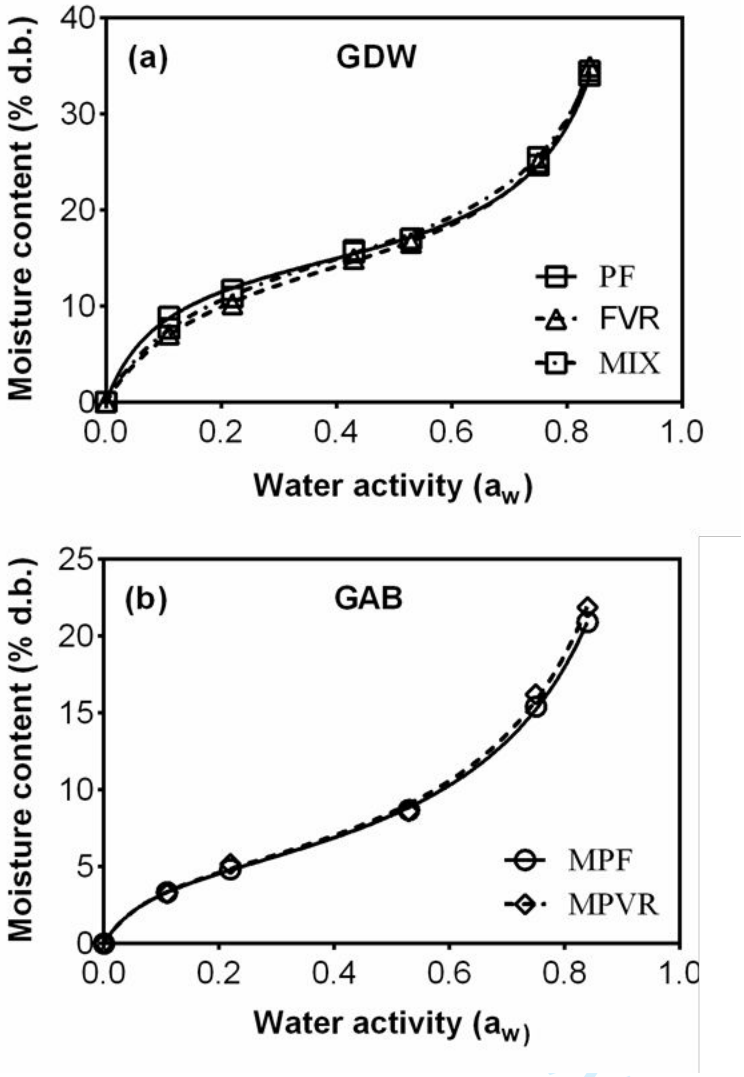
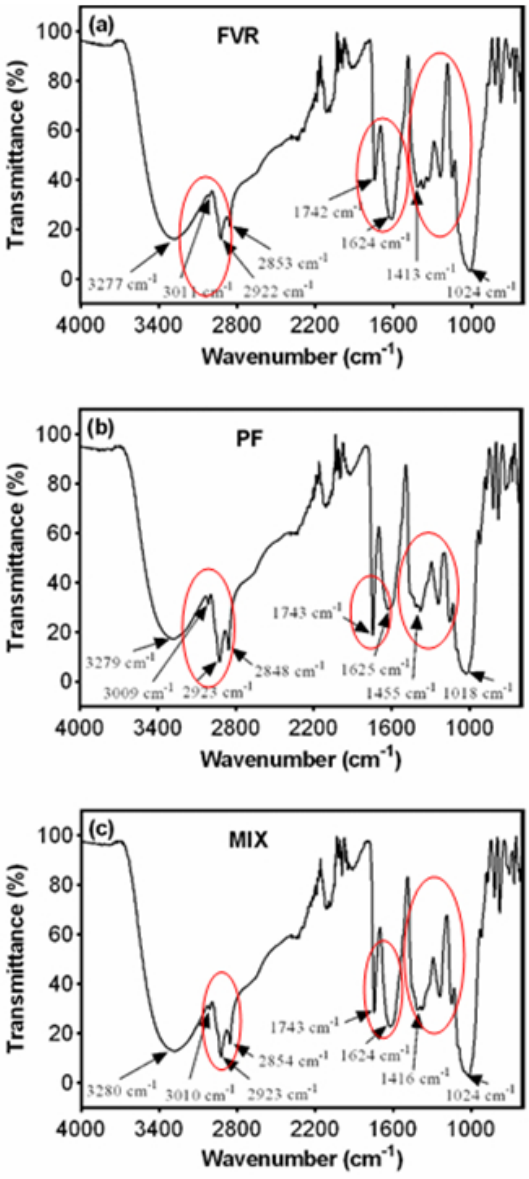


FIG S1



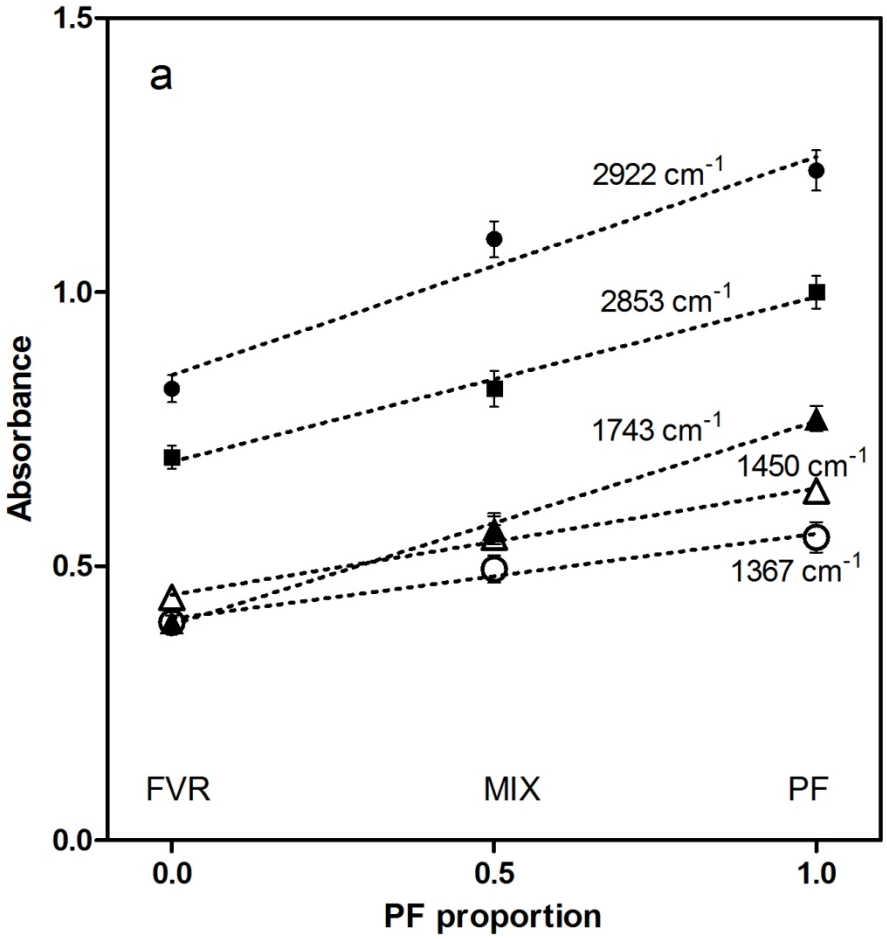
Supplementary Figure 1. Adsorption isotherms at 25 °C for un-encapsulated samples, with the curves obtained by applying the generalized D'Arcy and Watt –GDW- model **(a)** and for encapsulated samples, with the curves obtained by applying the GAB model **(b)**.

Symbols represent the experimental points. PF: pepper flour; FVR: Fruit and vegetable residues; MIX: PF mixed with FVR (1:1); MPF: spray-dried extract of pepper flour; MPVR: spray-dried extract of fruit and vegetable residues. The mean relative percentage deviation was below 5% and error bars lay below the symbols.



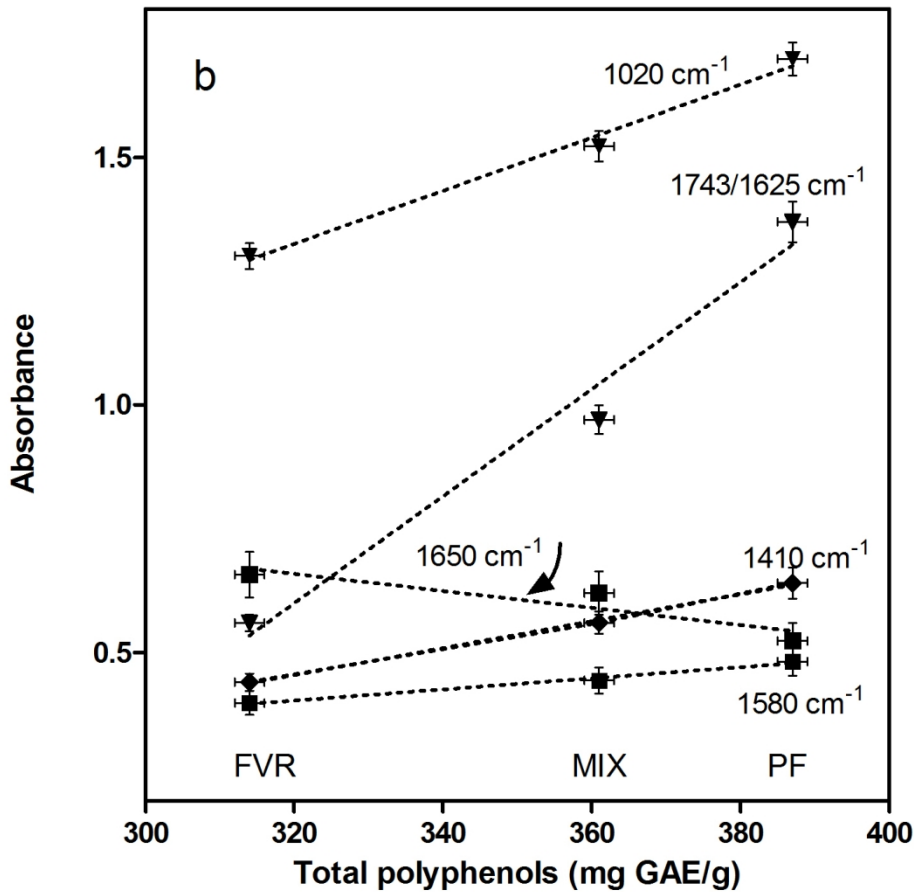
Fourier transform infrared (FT-IR) spectra in the range 4000-700 cm^{-1} for fruit and vegetable flour (FVR), pepper flour (PF) and MIX (PF/FVR). The the main differences of the spectral bands are indicated.

162x191mm (96 x 96 DPI)



Absorbances in the IR regions at which differences were observed when changing the proportion pepper flour (PF) and fruit and vegetable flour (FVR). Error bars represent standard deviation and some of them lay below the symbols.
a) Absorbance values at 1450, 1367, 2922 and 2853 cm-1 (attributed to carotenoids), at 1743 cm-1 (mainly attributed to lipids), as a function of the mass fraction of PF.

128x128mm (300 x 300 DPI)



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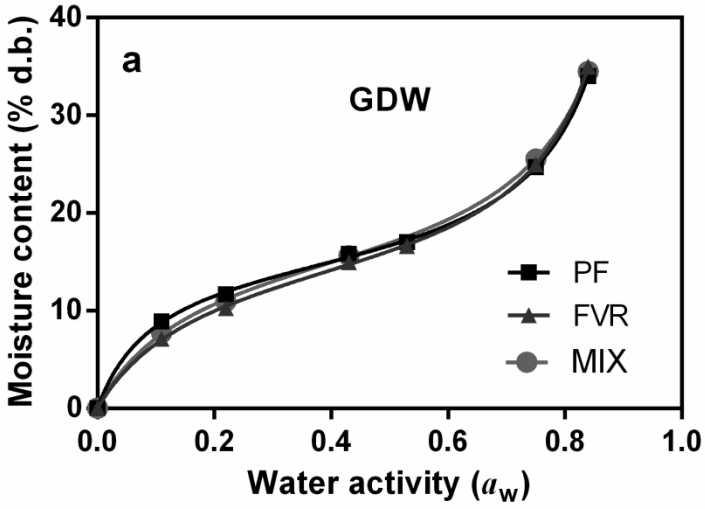

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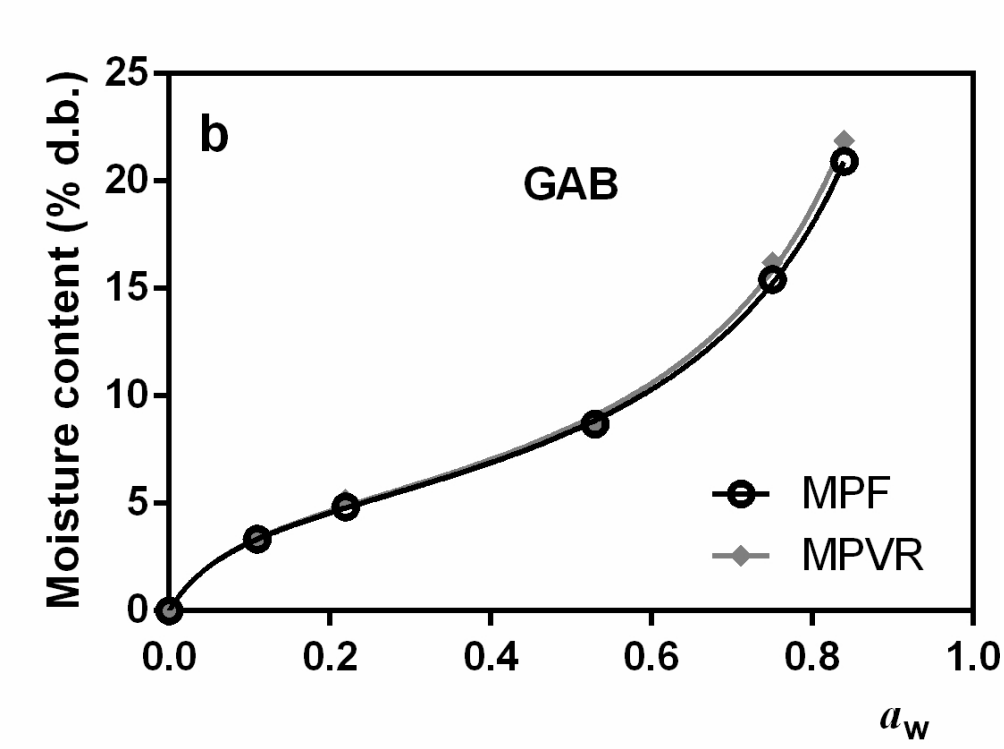

94x74mm (300 x 300 DPI)

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