SEMEAR: REVISTA DE ALIMENTAÇÃO, NUTRIÇÃO E SAÚDE

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Bioactive profile of a spray-dried supplement of fruits and vegetables and its residues: a full and sustainable exploitation

Mônica Cristine Pereira dos Santos [1]; Suellen Gome [2]; Mariana Pumar[3]; Sidney Pacheco [4]; Ronoel Luiz de O. Godoy [4]; Édira Castello Branco de Andrade Gonçalves [1]*

RESUMO

As perdas e desperdícios de alimentos ao longo da cadeia alimentar representam um grande problema para a maioria dos países. Na América Latina, frutas e vegetais são a segunda maior comodity produzida, com quase 50% de todos os produtos desperdiçados antes de chegar ao consumidor. A maioria das partes não comestíveis de frutas e vegetais são fontes importantes de compostos bioativos. Assim, a exploração integral de frutas e vegetais tem sido incentivada nos últimos anos para promover uma cadeia alimentar mais sustentável. O objetivo deste estudo foi determinar o teor de compostos fenólicos totais por Folin-Ciocalteau, e identificar e quantificar os compostos fenólicos os carotenoides por HPLC-DAD, de um suplemento de frutas e vegetais (FVS), um produto alimentício atomizado por spray-drier e seu resíduo (FVR), destacando a possibilidade de exploração integral dos alimentos. Os resultados demonstraram que a FVS e a FVR apresentam principalmente ácidos fenólicos e uma atividade antioxidante significativa. Os principais fenólicos presentes na FVS foram o ácido *p*-coumarico (1342,74 mg.Kg^{-1}) e o ácido sinapínico (1183,85 mg.Kg^{-1}). O *p*-coumaric também foi o principal fenólico encontrado na FVR (1348,57 mg.Kg^{-1}), seguido pelo ácido 4-hidroxibenzóico (858,02 mg.Kg^{-1}) e ácido vanílico (606,76 mg.Kg-^{1}). Verificou-se que o *β*-caroteno estava presente predominantemente no suplemento (486 ± 19,09 µg.100g^{-1}) e no resíduo (1317 ± 207 µg.100g^{-1}). Quantidades menores de outros carotenoides e compostos fenólicos também foram observadas, indicando que esse resíduo poderia ser uma fonte valiosa de fitoquímicos. Concluiu-se que tanto o FVS quanto o FVR são fontes importantes de uma ampla gama de compostos fenólicos e de uma quantidade significativa de carotenoides.

Palavras-chave: compostos bioativos, spray-dryer; CLAE-DAD; suplemento natural; resíduo.

Institution: Universidade Federal do Estado do Rio de Janeiro – UNIRIO, Rio de Janeiro, RJ, Brazil

[*] **Corresponding author:**

Édira Castello Branco de Andrade Gonçalves - e-mail: ediracba.analisedealimentos@unirio.br

Universidade Federal do Estado do Rio de Janeiro - UNIRIO

PPGAN - Laboratory of Bioactive Compounds

Address: Av. Pasteur 296 — 2º floor, Urca, Rio de Janeiro/RJ – ZIP CODE: 22290-240

Phone number: (+55) 021 2542 7418

ABSTRACT

Food losses and waste along the food chain represents a major problem for most countries. In Latin America, fruits and vegetables are the second largest commodity produced, with almost 50% of all products wasted before reaching the consumer. Most non-edible parts of fruits and vegetables are important sources of bioactive compounds. Thus, the integral exploitation of fruits and vegetables has been encouraged for the past few years to promote a more sustainable food chain. The aim of this study was to assess the total phenolic compounds by Folin-Ciocalteau, and to identfy and quantify the phenolic compounds by HPLC-DAD and carotenoids by HPLC-DAD, of a fruit and vegetable supplement (FVS), a spray-dried food product, and its residue (FVR), highlighting the possibility of integral exploitation of food. The results demonstrated that FVS and FVR present mainly phenolic acids. And, the major phenolics present were p-Coumaric acid (1342.74 mg.Kg^{-1} and 1348.57 mg.Kg^{-1} for FVS and FVR respectively) and Sinapinic acid (1183.85 mg.Kg^{-1}) in FVS. For FVR 4-Hydroxybenzoic acid (858.02 mg.Kg^{-1}), and Vanillic acid (606.76 mg.Kg^{-1}) were also significant. β-carotene was found to be predominantly present in the FVS (486 ± 19.09 µg.100g^{-1}) and FVR (1317 ± 207 µg.100g^{-1}). Lower amounts of other carotenoids and phenolic compounds were also observed indicating that this residue could be a valuable source of phytochemicals. It was concluded that both the FVS and the FVR are important sources of a wide range of phenolic compounds and a significant amount of carotenoids.

Keywords: *bioactive compounds; Spray-drying; HPLC-DAD; Natural supplement; residue.*

1. INTRODUÇÃO

In 2011 Food and Agricultural Organization of the United Nations (FAO), outlined that about 1.3 billion tons per year of food is lost or wasted, leading to a huge waste of natural resources, nutrients, and non-nutrients (e.g. phenolic compounds and carotenoids)[1].

According to the latest FAO report [40], Latin America and the Caribbean are responsible for nearly 20% of the global amount of food lost from post-harvest up to retail, even though the region had, in 2018, 47 million people suffering from hunger.

Fruits and vegetables are the 2nd largest commodity produced in Latin America, only behind cereals crops, with over 50% of all products lost or wasted along food chain. That represents nearly 90 million tons of fruits and vegetables lost every year[2], due to problems in harvesting, packing, transport, infrastructure or market/price, and also as a result of consumers behavior[1,2].

For that reason, knowing the most important stages where the problem happens is the best way to minimize this enormous waste of food, and a pathway to propose a sustainable process for the food supply chain, where the integral exploitation of food could contribute as an alternative solution for waste problems in many industries[39].

Researchers have demonstrated the nutritional and technological potential of the residue obtained from the processing of fruits, vegetables, and their applications in industries, such as new sources of bioactive compounds and natural colorants[4].

Among the primary compounds with functional activity found in human diets, phenolics and carotenoids can be highlighted as the highest occurrence in the usual diets. This fact can be explained by the variety and distribution of these compounds in nearly all vegetables [5,6].

The functional potential of plant-based foods is the result of a cumulative, synergistic action of a variety of compounds such as vitamins, phenolic compounds, carotenoids, minerals, and fiber, among others[41-43]. Their biological effects depend upon their bioavailability and bioaccessibility, which can also be affected by the presence of different food components in the same matrix [7,44].

The amount of bioactive compounds and their activity are directly linked to the variety, the degree of ripening, storage conditions and processing. In this sense, the manufacturing of powder supplements from fruits and vegetables (FVS) is an alternative to preserve the bioactive components of the food matrix and

ensure product availability and stability during storage[8]. However, without proper handling, processing of fruits and vegetables generates too much waste[2].

In a previous pilot study, a fruit and vegetable drink developed by this research group, showed a positive effect on the hydration and oxidative stress recovery of athletes from different sports in comparison to water intake[45]. Thus, this same drink was atomized by spray-drier to obtain the Fruits and Vegetable Supplement (FVS), in order to characterize its bioactive compounds.

Also, the residue obtained from the manufacturing of the fruit and vegetable drink was formerly characterized as a fiber source to new products, potentially suitable for use in food applications[8]. Remarkably, the Fruits and Vegetable residue (FVR) showed a high potential as functional product applied in the improvement of gastrointestinal disorders due to its high dietary fiber content, promoting an immediate increase in the number of bowel movements in adult women volunteers[9]. Also, a significant antioxidant activity in alcoholic: aqueous (v/v) extractors has been previously reported by Santos and Gonçalves[10].

Thus, this study aimed to assess the phenolic compounds and, carotenoids of a powder supplement obtained from a concentrated juice of 8 vegetables and 3 fruits and, the residue obtained at the end of the manufacturing process.

2. METHOD

2.1. Chemicals and reagents

All chemicals and solvents were of HPLC or analytical grade. Folin-Ciocalteu's, glacial acetic acid, methanol, ethanol, sodium carbonate, acetonitrile and formic acid were purchased from Sigma-Aldrich Chemical Company (MO, USA). The following standards (purity > 95%) were used for identification and quantification purposes with HPLC-DAD: 3.4-dihydroxyphenyacetic acid, catechin, 4-hydroxybenzoic acid, epicatechin, *trans*-caffeic acid, vanillic acid, 2.4-dihydroxybenzoic acid, vanillin, *p*-coumaric acid, ferulic acid, sinapinic acid, rutin and Myricetin also from Sigma-Aldrich Chemical Company (MO, USA).

2.2. Sample

The following species of fruits were used: Sweet orange (*Citrus sinensis*), passion fruit (*Passiflora edulis*) and watermelon (*Citrullus lanatus*). The following species of vegetables were used: lettuce (*Lactuca sativa*), courgette (*Cucúrbita pepo*), carrot (*Daucus carota*), spinach (*Spinacea oleracea*), mint (*Mentha* s.p.), taro (*Colocasia esculenta*), cucumber (*Cucumis sativus*) and rocket (*Eruca sativa*). All species were purchased from a local supermarket (Rio de Janeiro, Brazil) on the same day, in march 2016, then taken to the laboratory for immediate use. Fruits and vegetables were properly washed in flowing water, then sanitized for 30 min in a bath containing 200 ppm of sodium hypochlorite (NaClO) before rinsing in flowing water again, as previously reported[8].

After pasteurization, whole fruits and vegetables were cut into pieces, weighed and processed by using a centrifugal Juicer (Phillips Wallita, Brazil) and, 46L of a concentrated juice of fresh fruit and vegetables[11] was spray dried using a centrifugal atomizer (GEA, AS0340D Niro Atomizer, Germany), with an inlet and outlet air temperatures of 190ºC and 90ºC, respectively. Maltodextrin (1:4; w/w) was used as adjuvant setting the final concentration of soluble solids in 32 ºBrix. All beverage was filtered before atomization, to improve the drying process. Then, 10.5 Kg (22.82 %) of fruits and vegetable supplement (FVS) was placed in packaging type PET, sealed and kept in a clean, dry environment until analysis.

After processing of the concentrated juice, the remaining solid waste (FVR) was immediately dried in a drying oven with air renewal and circulation (Marconi, MA035, Brazil) at 65ºC for 6 h. Finally, the dehydrated residue was ground using a food processor for 5 min and dried out for 1 h at 90°C before grinding once more for 1 min. Flour samples were stored at room temperature (RT) in aluminized aseptic bags until analysis[8].

2.3. Extraction

Since the total phenolic compounds of FVR has been previously reported by Santos and Gonçalves (2016), the extraction procedures to perform thia analyses were carried out only to FVS.

Atomized samples of FVS were weighed (10 mg) and dissolved in distilled water (10 mL). Then, samples were centrifuged (Thermo Fisher Scientific, Mega Fuge 16R, USA) at 2000g for 15 minutes and the supernatant was recovered and stored at -18ºC until analysis[10].

2.4. Total phenolic compounds assay

Total phenolic content was assessed using a modified version of the Folin–Ciocalteu assay described by Singleton et al. [12]. Aqueous extracts were oxidized with Folin-Ciocalteu reagent (2.5 ml) and, after 5 min, neutralized with saturated sodium carbonate solution (2.0 ml). Samples were adjusted to 5.5 ml, with distilled water.

The final volume (5.5 ml) was shaken in a vortex (Warmnest, VX-28, Brazil) and allowed to stand for 120 min at room temperature in the dark; then the absorbance was measured at 750 nm using a spectrophotometer (Shimadzu, UV-2700, Japan).

An aqueous Gallic acid solution was used as a standard to prepare a calibration curve (ranges of 0.0 - 40µg of Gallic acid/mL), and the content of phenolic in each extract was calculated from the regression equation of gallic acid calibration curve and expressed as milligrams of gallic acid equivalent (GAE) per gram of dry sample.

2.5. Phenolic compound profile by HPLC-DAD

Atomized samples of FVS (10 mg) were weighed in 1.5mL Eppendorf tubes, dissolved in 3% methanol aqueous solution, homogenized in a vortex (Warmnest, VX-28, Brazil) and filtered through a 0.45µm PTFE membrane filter (Millex, Millipore, Germany), and transferred to amber-colored vials (Allcrom, Brazil).

FVR samples (2g) were weighed into 50 mL centrifuge tube, extracted with 30 mL of ethanol: water (75:25; v/v) solution in a shaker at 40ºC for 60 min. Then samples were centrifuged (Thermo Fisher Scientific, Mega Fuge 16R, USA) at 2000g for 15 minutes. The supernatant was transferred to 1.5mL Eppendorf (Aton) tubes and concentrated under vacuum (Thermo Scientific, Speedvac, USA).

The concentrated extract was recovered in 3% methanol aqueous solution, homogenized in a vortex (Warmnest, VX-28, Brazil) and filtered through a 0.45µm PTFE membrane filter (Millex; Millipore, Germany). When necessary, samples were stored at -16 ± 2ºC until analysis. The extractions were performed in triplicate.

Samples and standards were analyzed in an HPLC system (Perkin Elmer, Flexar, USA) equipped with a degasser, a column oven and a photodiode array detector (PDA; Perkin Elmer, Flexar, USA) set at an acquisition data on 260 nm, 280 nm, and 320 nm. Samples were automatically injected, and phenolic compounds were eluted from a reversed-phase C_{18} column (5µm x 150 mm x 4.6 mm; Kromasil; Akzobel, Sweden) fitted with a Phenomenex (Torrance, CA, USA) security guard column (4 x 3.0 mm) operated at 40ºC.

The mobile phase consisted of 0.3% (v/v) formic acid in water (A), methanol (B) and acetonitrile (C), the flow rate was 0.8 ml/min and the elution gradient was performed as describe by Gomes and Torres (14) with few modifications as outlined in *Table 1*. Total run time was 33.2 min and the injection volume for all samples and standards was 20µL.

Table 1: Mobile phase gradient to phenolic compounds elution from HPLC-DAD reversed-phase C18 Column.

Time (min)	Solvent (%)		
	A	**B**	**C**
0.1	85.0	14.5	0.5
7.0	55.0	43.5	1.5
7.0	5.0	93.0	2.0
6.0	1.0	97.0	2.0
3.0	15.0	83.0	2.0
0.1	85.0	14.5	0.5
10.0	85.0	14.5	0.5

A: 0.3% aqueous formic acid; B: methanol; C: acetonitrile.

All data acquisition and monitoring at 260nm, 280nm, and 320 nm were performed using the software Chromera Data System 2012 (Perkin Elmer, USA). Peak identities were determined by comparing the retention times and PDA UV-Vis spectra of commercial standards.

Quantification of individual phenolic compounds by HPLC-DAD was performed according to external 5-points calibration curves with each corresponding standard (*Table 2*). For this purpose, stock solutions (500ppm) were diluted to concentrations of 1 to 10 ppm. The final concentrations of phenolic compounds were individually calculated using the peak area and were expressed in $mg.kg^{-1}$

Table 2: Calibration curves of phenolic compounds standards.

Phenolic compound	R2	LoD	LoQ
3,4-Dihydroxyphenylacetic acid	0.9851	1.437	4.355
Catechin	0.9895	1.204	3.648
4-Hydroxybenzoic acid (*p*-Hydroxybenzoic acid)	0.996	0.742	2.248
Epicatechin	0.9829	1.541	4.670
Trans-Caffeic acid	0.9932	1.530	4.635
Vanillic acid	0.9961	0.730	2.213
2,4-Dihydroxybenzoic acid	0.9956	0.777	2.354
Vanillin	0.993	0.979	2.966
p-Coumaric acid	0.9942	0.891	2.700
Ferulic acid	0.9977	0.560	1.693
Sinapinic acid	0.9849	1.451	4.396
Rutin	0.9905	1.147	3.475
Myricetin	0.9981	0.514	1.558
2-Hydroxybenzoic acid	0.9943	0.884	2.679

R^2 for each regression curve obtained from a 5-points calibration curve.
LoD: Limit of detection LoQ: Limit of quantification

2.6. Carotenoids extraction and quantification

Approximately 10 g of the samples plus 3 g of celite 454 were weighed, and successive additions of 25 mL of acetone were made to obtain a paste, which was transferred into a sintered funnel coupled to a 500 mL Buchner flask and filtered under vacuum. This procedure was repeated three times or until the sample became colorless, followed by a filtration step. After filtration, the extract was quantitatively transferred to a volumetric flask as described by Lima et al. (2009)[15]. Finally, the extract was transferred to a volumetric flask of 25 mL using a funnel with glass wool and sodium sulfate to remove the exceeding water from the extract. The volume was adjusted with petroleum ether, and 1 mL of all samples were read at 450 nm in a spectrophotometer to quantify the total concentration of carotenoids.

Identification and quantification of carotenoids by HPLC-DAD: 1 mL of saponified extract was dried in an amber flask under nitrogen flow, then reconstituted in 200 µL of acetone for identification. Carotenoids were analyzed with an HPLC coupled to a UV/Visible photodiode array detector and scanned between 350 – 550 nm and the compounds were identified by comparison of retention time and UV spectra of the Standards. Separation was achieved using a YMC® C30 Carotenoid chromatographic column (250 x 4.6xmm; 3µm), temperature of 33 ± 2ºC, eluting in a gradient of methyl tert-butyl ether and methanol. The mobile phase flow rate was 0.8 mL/min, and 15 µL of an acetone extract sample was injected[16].

2.7. Statistical Analysis

The one-way ANOVA analysis of variance followed by Tukey's test was applied, and results were considered statistically significant with a 95% confidence level ($p<0.05$). A triplicate was performed to each analysis, unless stated otherwise. Results were expressed as mean ± sd.

3. RESULTS

All identified phenolic compounds are presented in *Figures 1* (FVS) and *Figure 2* (FVR). The elution order, retention times and concentration of phenolics are specified in *Table 3*.

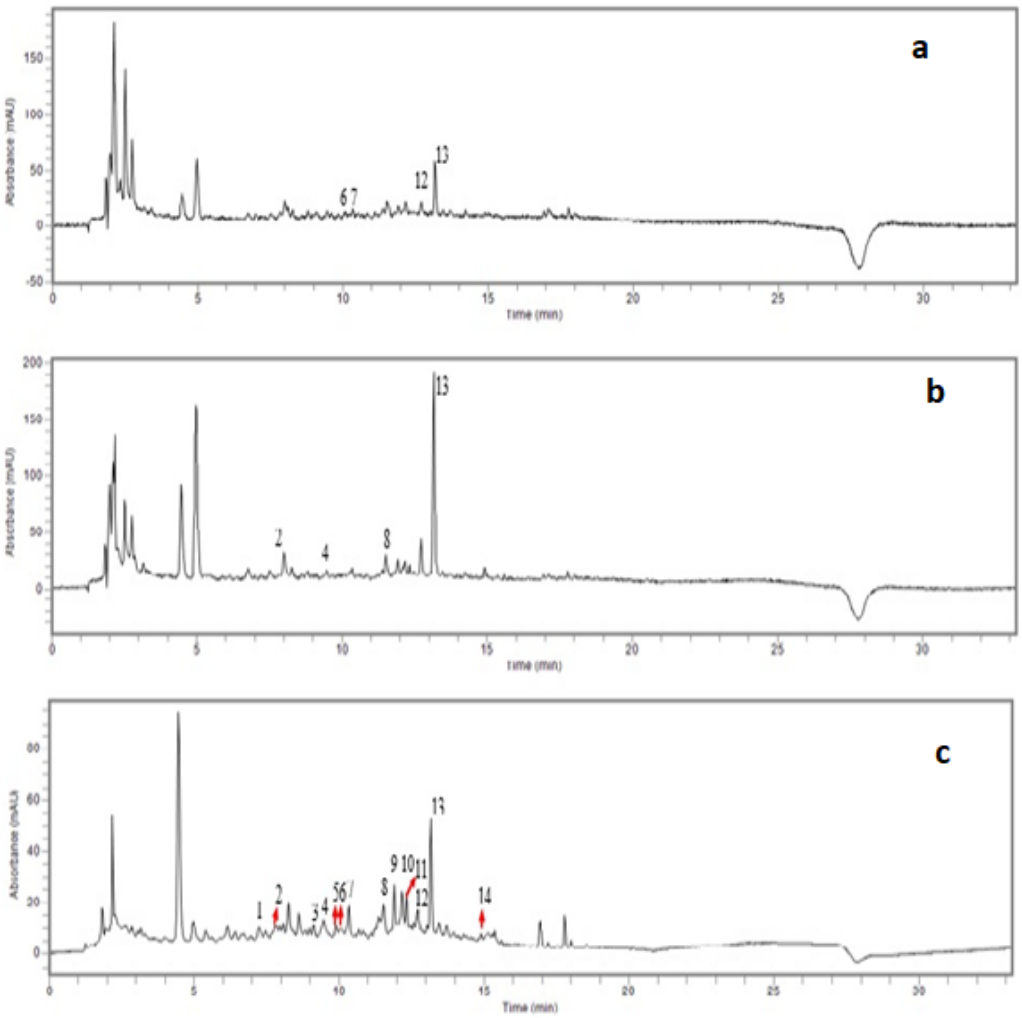

Figure 1. Phenolic compounds identified in FVS at 260(a), 280(b) and 320(c) nm.
Peaks assignments 1: 3.4-Dihydroxyphenylacetic acid; **2**: Catechin; **3**: 4-Hydroxybenzoic acid; **4**: Epicatechin; **5**: Trans-Caffeic Acid; **6**: Vanillic acid; **7**: 2.4-Dihydroxybenzoic acid; **8**: Vanillin; **9**: p-Coumaric acid; **10**: Ferulic acid; **11**: Sinapinic acid; **12**: Rutin; **13**: Myricetin; **14**: Salicylic acid.

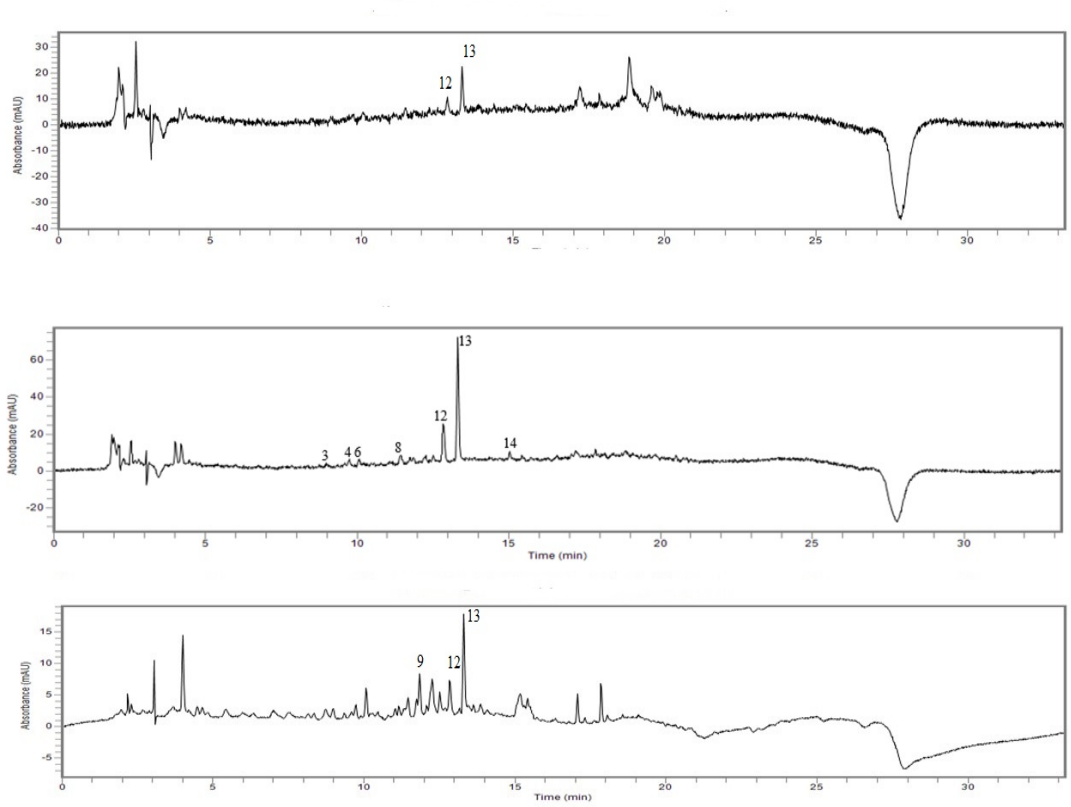

Figure 2. Phenolic compounds identified in FVR at 260, 280 and 320 nm.
Peaks assignments 3: 4-Hydroxybenzoic acid; **4**: Epicatechin; **6**: Vanillic acid; **8**: Vanillin; **9**: p-Coumaric acid; **12**: Rutin; **13**: Myricetin.

As noted in *Table 3*, 14 phenolic compounds were identified in FVS samples, while only 4 were found in FVR samples. The major phenolics present in the FVS were *p*-Coumaric acid (1342.74 mg.Kg^{-1}) and Sinapinic acid (1183.85 mg.Kg^{-1}), while lower concentrations of other phenolic compounds were also observed, ranging from 35.11 mg.Kg^{-1} of 2-Hydroxybenzoic acid to 591.13 mg.Kg^{-1} of Vanillic acid.

As observed to FVS, free *p*-Coumaric was also the major phenolic found in the FVR (1348.57 mg.Kg^{-1}), followed by 4-Hydroxybenzoic acid (858.02 mg.Kg^{-1}), Vanillic acid (606.76 mg.Kg^{-1}) and Epicatechin (442.19 mg.Kg^{-1}).

Total phenolic compound, assessed by Folin Ciocalteau method, was 12.15 times higher for FVR in comparison to FVS.

Table 3: Identification and quantification of phenolic compounds in fruits and vegetable supplement (FVS) and its residue (FVR).

Peaks Assignment	RT (min)	Concentration (mg.kg^{-1})	RT (min)	Concentration (mg.kg^{-1})
	FVS		**FVR**	
3.4-Dihydroxyphenylacetic acid	7.41**	227.26	NI[a]	-
Catechin	7.72**	353.80	NI[a]	-
4-Hydroxybenzoic acid	9.07*	398.44	9.06*	858.02
Epicatechin	9.63**	210.81	9.60**	442.19
***Trans*-Caffeic acid**	9.87***	266.27	NI[a]	-
Vanillic acid	10.06*	591.13	10.09*	606.76
2.4-Dihydroxybenzoic acid	10.53*	561.15	NI[a]	-
Vanillin	11.3**	222.13	11.42**	-
***p*-Coumaric acid**	12.02***	1342.74	12.05***	1348.57
Ferulic acid	12.28***	471.63	NI[a]	-
Sinapinic acid	12.38***	1183.85	NI[a]	-
Rutin	12.84*	330.07	12.83**	-
Myricetin	13.14***	79.35	13.16***	-
2-Hydroxybenzoic acid	14.96***	35.11	ND[a]	-

[a]Not Identified. Mean obtained from triplicate of injection. *260 nm; **280 nm; ***320 nm.

Among the carotenoids identified (Figure 3), *β*-carotene was found to be present over 2.7-fold higher in FVR than in the FVS. While *α*-carotene, the second major carotenoid found in both FVS and FVR, was 1.92-fold higher in residue, followed by lycopene, also 1.5 times higer in FVR than FVS, as described in *Table 4*

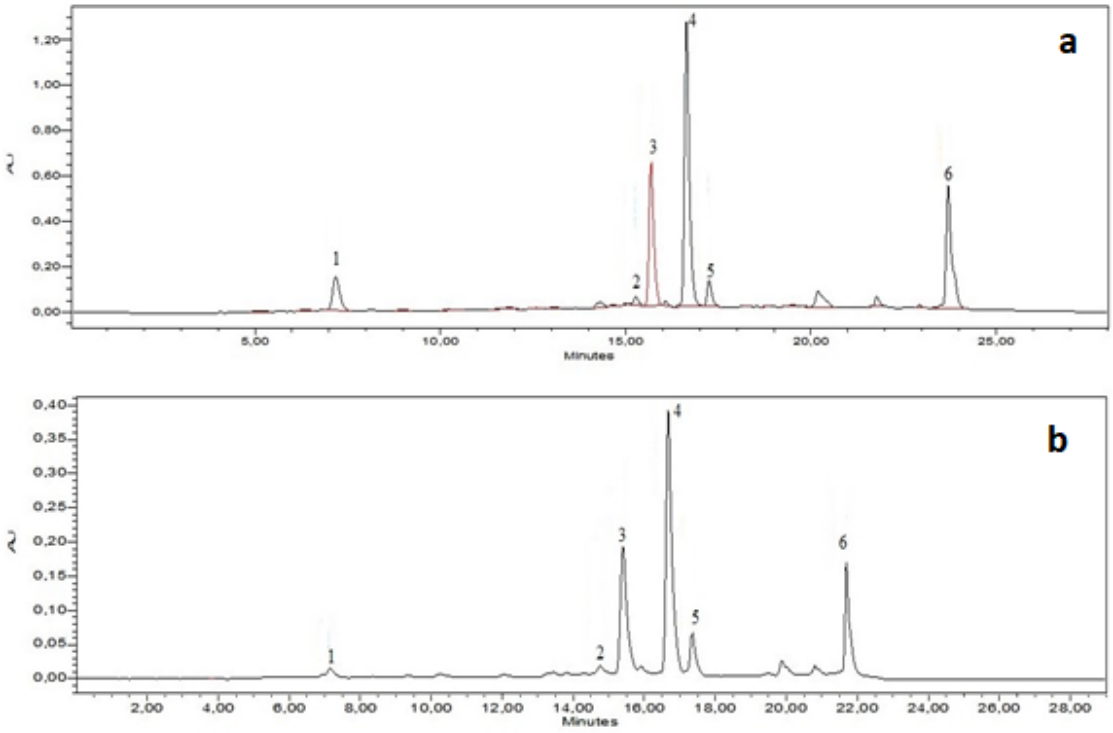

Figure 3. Chromatogram for the identified carotenoids scanned from 350 – 550 nm: lutein (1), 13-cis-β-carotene (2), α-carotene (3), β-carotene (4), 9-cis-β-carotene (5) and lycopene (6) of FVS (a) and FVR (b).

Table 4: Total carotenoids, lutein, *α*-carotene, *β*-carotene, 9 and 13- *β*-carotene isomers and Lycopene of fruits and vegetables supplement (FVS) and fruits and vegetables residue (FVR) (n=2).

	FVS (µg.100g^{-1})	RE value	**FVR (µg.100g^{-1})**	RE value
Total content	1160.5 ± 53.03	-	2643 ± 479	-
Lutein	20 ± 0.0	-	169 ± 125	-
α-carotene	256.5 ± 10.61	21.37[1]	493 ± 74	41.08[1]
***β*-carotene**	486.5 ± 19.09	81.08[2]	1317 ± 207	219.5[2]
13-*cis β*-carotene	21 ± 2.82	-	44 ± 3.5	-
9-*cis β*-carotene	21 ± 2.82	-	167 ± 30	-
Lycopene	194 ± 14.14		296 ± 62	

Standard Deviation and mean (n= 2). [1]1RE = 12 µg of *β*-carotene; [2]1RE = 6 µg of *β*-carotene

4. DISCUSSION

Identification and quantitation of phenolic compounds from FVR has undergone significant interference, probably during the extraction, so that a smaller number of compounds has been identified; it is well known that efficiency of the extraction process of phenolic compounds involves a number of factors (e.g. diverse structure and composition of the food, different water: alcohol ratio)[17,18], which can reduce the ability to release these phenolic compounds from the vacuolar structures where they are found. Also, it is possible that bound phenolic compounds have not been extracted in the FVR samples because a hydrolysis would be required for this[19,20].

However, both extraction conditions favored the extraction of vast chemical varied of phenolic compounds, from phenolic acids to flavonoids.

Free *p*-coumaric has been described as an important phenolic acid with a significant biological activity[23]. And, is usually found in lower amounts in cereals, berry fruits, and other vegetables. However, both samples presented substantial concentrations of this phenolic acid. Two others important phenolics found in FVS were Ferulic acid and *trans*-Caffeic acid, contributing to the functional potential of fruits and vegetables[24].

The differences in the phenolic content showed in Tables 3 can be explained by the non-identification of many phenolic compounds present in the FVR, caused by the lack of standards available for their identification and quantification. Also, the results showed in Table 5 shows that FVR results could have been affected by the presence of non-phenolic compounds reacting with the Folin–Ciocalteau reagent, overestimating the results of this assay[25].

Table 5 - Total phenolic content of aqueous extracts of FVS and FVR.

	FVS	**FVR**
Phenolic compounds (mg.Kg^{-1} db[a])	1,850.0 ± 3.0	22,490.0 ± 1590.0*

Mean and standard deviation obtained from triplicate.
*Data from Santos and Gonçalves (2016). [a]Dried basis

The total carotenoid content found in this study was 2643 ± 479µg.100g^{1} to FVR and 1160.5 ± 53.03 µg.100g^{-1} to FVS, higher than the content found in other residues reported in the literature where the average amount was 6 mg.kg^{-1} [26].

However, these findings are low compared to other tropical fruits such as papaya (44 – 46 mg.kg^{-1}), similar to mango (18 – 25 mg.kg^{-1})[27], and high compared to camu-camu (3.54 – 10.95 mg.kg^{-1}) a native berry from Amazon[28] and cagaita (7.7 ± 0.3 mg.kg^{-1}) a native fruit from the Cerrado of Minas Gerais, Brazil[29].

β-carotene amounts found in FVR were higher than those observed in other residue described in the literature. Albuquerque and researchers (2016) found 117 ± 21 (µg/100g) in saponified extracts of *Annona cherimola* Mill peel of Mateus II cultivar[30].

On lutein FVR presented a similar concentration compared to dried corn (1.99 mg.kg^{-1}) a recognized cereal rich in lutein, but very low concentration compared to dried onion stalk (8.76 mg.kg^{-1}) and broccoli (11.33 mg.kg^{-1})[31].

The FVR has also demonstrated a relevant potential as source of vitamin A (retinol) with lower values found in other fruits and vegetables recognized as source of carotenoid, such as acerola (192 RE), mango 'Extreme' (215 RE), melon (184 RE) and hydroponic lettuce (208 RE)[32].

During food processing, the levels of *cis*-isomers increase due to the isomerization of the *trans*-isomers. *Trans–cis* isomerization of carotenoids leads to a decrease in color intensity, and some of these isomers were found to be less effective than all-*trans*-*β*-carotene to scavenge reactive oxygen species and are degraded faster that the all-*trans* isomer[33]. Thereby, lower amounts of these *cis*-carotene forms are desired

to be found in food, to preserve the functional property of the product, as the observed in the FVR extracts in this study.

Gupta, Sreelakshmi, & Sharma (2015) highlight the need to quantify carotenoids in both foods and biological samples to understand their importance and pathway in body metabolism and health. Also, the synergistic effect of several carotenoids in different combinations has been reported as a more efficient way to obtain their functional property[35] . In this aspect, the composition of FVS and FVR ensures the presence of several different carotenoids, in concentrations unusually found in nature[32], that can act in synergism.

It is known that the identification and quantification of individual compounds do not reflect the actual potential of bioactive compounds in plants, due to the synergism between these compounds[36]. This statement reinforces the idea that a complex mixture of bioactive compounds (phenolic compounds and carotenoids) extracted from fruits and vegetables could contribute more significantly to the achievement of such effects.

Finally, the wide variety of compounds identified points to the possibility of synergistic actions between the phenolic compounds and the carotenoids, which can improve its functional potential *in vitro* and *in vivo.* Nevertheless, most studies regarding these activities are still conducted considering one single group (e.g. anthocyanins) or an isolated compound[35,37,38].

The production of fruit-based juices and drinks is possibly one of the main food production chains with the highest generation of waste. Thus, promoting the complete use of food through technological processes that culminate in better exploitation of the functional potential of waste can be considered a form of sustainable production, with less waste generation and greater use of all parts of food.

In addition, drying processes for both concentrated juice and waste, increase storage time, and ensure greater stability of bioactive compounds.

Further studies on bioaccessibility, extraction optimization of phenols and flavonoids would be a valuable contribution for the characterization of functional properties of both samples.

5. CONCLUSION

This study reported a possible and sustainable food processing whit low waste generation. The FVS demonstrated a great potential as a dietary source of phenolic compounds and carotenoids. FVR has a great potential as a natural source of carotenoid, with a considerable amount of compounds that are known for their functional potential and health promotion benefits. These results highlight the functional properties and support their employment in different food processing industries. Furthermore, this work will contribute to promoting the sustainable development and exploitation of these fruits and vegetables in Brazil.

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[1] Laboratory of Bioactives – LabBio - Food and Nutrition Master Program (PPGAN) – Federal University of Rio de Janeiro State (UNIRIO), Brazil. E-mail: monicamensagens@gmail.com;
[2] Federal Institute of Rio de Janeiro (IFRJ), Brazil. E-mail: suellenquimica2008@gmail.com;
[3] Nutrition School, Federal University of Rio de Janeiro State (UNIRIO), Brazil. E-mail: marianaseljan@gmail.com;
[4] Laboratory of High-Performance Liquid Chromatography, EMBRAPA food agroindustry, Brazil. E-mail: ronoel.godoy@embrapa.br