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ORIGINAL ARTICLE

In vitro evaluation of the bioaccessibility of antioxidative properties in commercially baby foods

Merve Usal[1] · Yasemin Sahan[2]

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Abstract Fruit-vegetable based products are essential for infants as they widely used the first complementary solid foods. This study aimed to investigate the physicochemical properties, the antioxidant capacities, total phenolic content, and bioaccessibility of 24 different commercially fruit-vegetable based complementary foods. To determination of bioaccessibility, samples were processed by an in vitro digestive enzymatic extraction that mimics the conditions in the gastrointestinal tract. Total polyphenol content was analyzed using Folin–Ciocalteu assay, and antioxidant capacities were assessed by CUPRAC and ABTS methods. The total phenol content of the samples ranges from 892.21 to 1729.13 mg GAE mg/100 g. While the antioxidant capacity of the samples averages 256.26 µmol TE mg/100 g according to the ABTS method, they were found 2417.79 µmol TE mg/100 g for CUPRAC method. Also, the bioaccessibility of total phenol content determined 62.72–98.48% of all samples. As a result, antioxidant properties and bioaccessibility of the samples were changed according to the sample content and chemical composition. The use of fruit or fruit juice in the preparation of commercial baby food has improved antioxidant capacity and bioaccessibility, thus increasing the beneficial health effect and nutraceutical properties of the baby meal.

✉ Merve Usal
merveusal@klu.edu.tr

[1] Department of Food Engineering, Faculty of Engineering, Kırklareli University, Kırklareli, Turkey

[2] Department of Food Engineering, Faculty of Agriculture, Uludag University, Bursa, Turkey

Keywords Baby food · Bioaccessibility · Phenolic content · CUPRAC · ABTS

Introduction

Foods used in infancy and childhood feeding have significant effects on healthy growth and development in short and long terms (Mir-Marqués et al. 2015). Infancy and childhood are both critical periods of rapid physical growth and cognitive and emotional development. The right nutrition during the first 2 years of life builds the foundation for a child's ability to grow, learn, and thrive (Grammatikaki and Huybrechts 2016). Breast milk alone must be used to feed infants during the first 6 months of life properly, but from then, complementary feeding is necessary (Monteiro et al. 2016). In recent years, commercial baby food jars have become an essential part of baby food due to changes in lifestyle. These foods are sometimes the primary source of nutrition for infants between 6 and 36 months (Mir-Marqués et al. 2015).

There are jars of baby food with different contents containing fruits, vegetables, cereals or their mixtures. Recommendations for healthy diets include the consumption of fruit and vegetables, which contents different phytochemicals such as phenolic compounds. These bioactive compounds are beneficial components present in functional foods and have been implicated in reducing the risk of degenerative diseases such as cardiovascular disease, various cancers, and neurological diseases, mainly because of their antioxidant potential (Carbonell-Capella et al. 2013; Karadeniz et al. 2005).

The total amount of the antioxidant capacities and total phenol content in food does not always show the real nutritional information based on a diet since the whole digested amount of nutrients is not completely absorbed. Therefore, the bioavailability of nutrients should be determined in the food. Bioavailability is the bioactive component that is absorbed and stored in the organism and after use in physiological functions (Fernandez-Garcia et al. 2009; Rebellato et al. 2015). Bioavailability research is obtained by in vivo studies using humans or animals.

However, this approach has some analytical and ethical limitations besides, it is a large time and resources demanding experimental control. Also, bioavailability results vary due to changes in the chemical composition and processing condition of food and individual differences on component release from the matrix, digestion, absorption, and bioactivity (Cardoso et al. 2015). Thus, in vitro digestion systems have been developed to assess the bioaccessibility of food components and apply them to guides the bioavailability studies. Bioaccessibility is the fraction of a compound that is released from the food matrix in the gastrointestinal tract and happens to present for intestinal absorption (Fernandez-Garcia et al. 2009; Etcheverry et al. 2012).

In the literature, several studies about bioaccessibility are shown for different types of foods and nutrients. However, there is little information on the antioxidant properties and their bioaccessibility of complementary feeding (as baby foods) to our best knowledge. Depending on factors such as substances in the composition and interaction between each other and processing conditions in the complementary baby foods, the constituents can be more or less bioaccessible.

This study aimed to evaluate the concentration of antioxidants and total phenolic compounds as well as their bioaccessibility in commercially complimentary baby foods in Turkey.

Materials and methods

Materials

Four different brands and twenty-four fruit-vegetable based commercial baby food jars (125 g) were obtained from local markets in Bursa, Turkey. The selections were specially made to reflect the popular types and brands. Commercially baby foods were selected from conventional, organic production or gluten free labeled samples suitable from 4 months above baby feeding. It was taken three jars from each of the samples and homogenized. The details of each sample were shown in Table 1. All samples were stored at − 18 °C in the deep freezer until used.

Methods

Chemicals

All reagents were used to analytical-grade purity. Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), ABTS (2,2′-azobis(2-methylpropionamidina)-dihydrochloride), neocuproine, gallic acid and potassium chloride, sodium hydroxide, pepsin, bile extract, pancreatin, concentrated hydrochloric acid (37% w/v) and concentrated sulfuric acid (95–98%) were purchased from Sigma (St. Louis, MO, USA). Folin–Ciocalteau phenol reagent, HPLC-grade methanol, ethanol, sodium chloride, sodium carbonate, sodium acetate, ammonium acetate, and copper(II)chloride were purchased from Merck (Darmstadt, Germany). High-quality water was used, obtained by the Milli-Q system (Millipore, Bedford, MA, USA).

Determination of physicochemical parameters

Baby food was analyzed for moisture (AOAC Metod No:925.40), pH and total titratable acidity (Cemeroglu 2013). The tests were performed at least in triplicate and mean values are reported.

Sample preparation

Extractable, hydrolysable and bioaccessible fractions of baby food samples were according to the method developed by Vitali et al. (2009) with slight modifications. Extractions of each type of fraction were carried out in triplicate samples for each baby food. For extractable fraction, sample (2.0 g) was mixed with 20 mL of HCl conc/methanol/water (1:80:10, v/v) and shaken by using a rotary shaker (JB50-D; China) at 250 rpm for 2 h at 20 °C, and then the mixture was centrifuged at 3500*g* for 10 min at 4 °C (Sigma 3 K 30). The residue was separated and the supernatants were stored at − 20 °C until used.

For hydrolysable fraction, the residue combined with 20 mL of methanol/H_2SO_4 conc (10:1) and they were subjected to at 85 °C for 20 h and then cooled at room temperature. The mixtures were centrifuged at 3500 g for 10 min at 4 °C (Sigma 3 K 30). The supernatants were separated and stored at − 20 °C until used. The bioaccessible fraction was determined using an in vitro digestion enzymatic extraction method that mimics the conditions in the human gastric and gastrointestinal tract (Vitali et al. 2009).

First of all, for simulated to the gastric digestion, 10 mL of distilled water and 0.5 mL of pepsin (20 g/L in 0.1 mol/L HCl) were added to a 1 mL sample and the pH was arranged to 2 using 5 mol/L HCl. The samples were incubated at 37 °C for 1 h in a shaking water bath. And

Table 1 Composition of the various baby foods analyzed

Sample code	Main ingredients	Total main ingredients (%)	Others
1[a]	Apple, peach, carrot	80	Rice flour, water
2[b]	Apple, peach, carrot, apple juice	95	Rice flour
3[b]	Apple puree, peach puree, apple juice	78	Rice flour, rice starch, water
4[b]	Apple, apple juice, banana	55	Wheat particles, oat particles, water
5[a]	Apple, apricot, carrot, white grape juice	98	Wheat starch, corn starch
6[ab]	Banana puree, peach puree, carrot puree, apple puree, orange juice	74	Rice flour, rice starch, water
7[a]	Strawberry, apple puree, black carrot juice	–	Rice starch, corn starch water, yoghurt, sugar
8	Banana, orange juice, lemon juice	20	Modified corn starch, rice flour, water, yoghurt, sugar
9[b]	Apple, apple juice, banana, apple particles, peach, carrot, lemon juice	85	Rice flour, water
10[b]	Apple, apple juice, carrot	97	Corn starch, water
11[a]	Apple puree, banana puree, apple juice	70	Rice flour, water
12	Pineapple juice, apricot, banana, lemon juice	13	Rice flour, corn starch, Water, yoghurt, sugar
13[a]	Apple, carrot, apple juice	100	–
14[b]	Carrot, apple	100	–
15	Apple, pear, apple juice	100	–
16	Apple, apple juice, pear, carrot	96	–
17[a]	Banana puree	20	Rice starch, corn starch, water, yoghurt, sugar
18[b]	Apple juice, banana, apricot, carrot, lemon juice	95	Rice flour
19	Apple, banana, apple juice	100	–
20	Carrot, white grape juice, potato	72	–
21[b]	Carrot, potato, peace, cauliflower	74	–
22	Carrot, potato, marrow, celery, tomato juice	58	–
23	Peach, apple, banana, apricot, apple juice, orange juice	100	–
24	White grape juice, banana, peach, carrot, lemon juice	90	Corn starch

Ingredients from product label instruction

[a]Gluten free

[b]Organic

[ab]Gluten free and organic

then to mimic the intestinal digestion, pH was arranged to 7.2 and 2.5 mL of bile/pancreatin solution (0.1 mol/L $NaHCO_3$ of 2 g/L pancreatin and 12 g/L bile salt) and 2.5 mL of NaCl/KCl (120 mmol/L NaCl and 5 mmol/L KCl) were added the samples. They were kept in a shaking water bath at 37 °C for 2.5 h. At the end of the period, the samples were centrifuged at 3500*g* for 10 min and the supernatant was separated. In this research, baby foods which were liquids were not required oral digestion, mainly due to the very short residence times in the mouth (Minekus et al. 2014).

Determination of total phenolic contents (TPC)

Total phenolic contents of all fractions were determined based on Folin–Ciocalteau colorimetric method as described by Naczk and Shahidi (2004). They were expressed as gallic acid equivalents (mg GAE mg/100 g dw). Total phenolic content was calculated as the sum of extractable and hydrolysable fractions. Analyses were carried out three times for each extract.

Antioxidant capacity

In the literature, several methods were used to evaluate antioxidant capacities in foods with varying results. Two methods that are commonly used to assess antioxidant capacity in vitro are 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assay and cupric ion reducing antioxidant capacity assay (CUPRAC). Both of the methods can be used over a wide range of pH values, in both aqueous and organic solvent systems and they have rapid, simple to perform and good repeatability. For this reason, antioxidant capacities of extractable, hydrolysable, and bioaccessible fractions were determined using ABTS and CUPRAC method. Results were presented in terms of micromoles Trolox equivalent per 100 g of dry weight (μmol TE mg/100 g) using Trolox as the reference standard for methods tested. All experiments were replicated three times for each sample.

ABTS assay

The determination of the ABTS radical cation decolorization assay was conducted according to the method of Apak et al. (2007). For ABTS* + radical solution, 7 mM ABTS in water and 2.45 mM potassium persulfate, stored in the dark at room temperature for 12–16 h before use to obtain an absorbance at 734 nm. ABTS* + radical solution of blue-green color was diluted with ethanol (96%) at a ratio of 1:10. The procedure was used adding 1 mL of the ABTS solution to (x) mL of extract and (4.0–x) mL of ethanol, and the absorbance measured at 734 nm after 6 min by using UV/Vis spectrometer (Optizen 3220 UV, Mecasys).

CUPRAC assay

The antioxidant capacity of the extracts was determined spectrophotometrically following the procedure of Apak et al. (2004). Briefly, One mL of 1×10^{-2} M $CuCl_2$, 1 mL 7.5×10^{-3} M neocuproine, 1 mL ammonium acetate buffer solutions, x mL extract of samples and (4–x) mL of water were added and mixed. The final mixture at 4.0 mL total volume was let to stand at room temperature and after 30 min, the absorbance at 450 nm (Optizen 3220 UV, Mecasys) was recorded against a reagent blank.

Statistics

The results obtained from the analyses were evaluated statistically using the SPSS 13.0 program. All results were expressed as the mean ± standard deviation (SD). The significant difference was calculated by Duncan's test; values $p < 0.01$. Analyzes were performed in 3 replicates.

Result and discussion

Physicochemical properties

In Table 2 are shown the physicochemical parameters of the commercial baby foods studied in this work. The pH of the commercial baby foods ranged from 3.55 to 5.24. As expected, the pH values of the samples containing vegetables were found to be high. Carbonell-Capella et al. (2013) reported that the pH values of commercial fruit-based baby foods in the range of 3.54–4.12. Our results were close to this study. Also, they were reported that fruit-based products showed acidic properties (Jie et al. 2013; Zulueta et al. 2007).

Total titratable acidity (g citric acid mg/100 g) was between 0.15 and 0.54 g mg/100 g, obtaining the lowest values in samples 14 (carrot, apple) and 21 (carrot, potato, peace, cauliflower). It has been observed that fruit-based products exhibit acidic properties in studies conducted (Zulueta et al. 2007, Jie et al. 2013). Carbonell-Capella et al. (2013) found the total acidity in the jar-packaged baby supplement foods in the range of 0.30–0.53 g citric acid mg/100 g.

Dry matter levels of samples were varied between 81.41 and 93.10% depending on ingredients. When the dry matter of the samples was examined, the highest value was found in 14 (93.10%) sample and the lowest value in 11 (81.41%). No significant differences in physicochemical properties were found between production techniques (organic, gluten-free, etc.) of the samples ($p > 0.01$).

Total phenolic content

The content of extractable, hydrolysable, bioaccessible fraction and total TPC of baby foods are presented in Table 3. Significant differences in extractable fraction, hydrolysable fraction and total phenolic content among the different types were recorded ($p < 0.01$). It might be that the composition of baby foods, the raw material (variety, the origin of the ingredients and maturation period) and different processing methods caused these differences.

Sample 19, which contains 100% of apple, banana, apple juice, had the highest total phenolic content (1573.46 mg GAE mg/100 g), while the lowest content (1013.92 mg GAE mg/100 g) was recorded in sample 20 (main ingredients; carrot, white grape juice, potato). Following the sample 19, sample 7 (1566.02 mg GAE mg/100 g) and sample 23 (1532.39 mg GAE mg/100 g) contained a relatively high amount of total phenolic content. Generally, the high fruit content of samples showed the highest value of the total concentration of TPC, while the lowest was recorded in samples with a vegetable-rich of

Table 2 Physicochemical parameters of the commercially baby foods

Sample	PH	Total acidity (g citric acid/100 g)	Dry matters (%)
1	3.61 ± 0.01^{g}	0.39 ± 0.11^{c}	86.81 ± 0.09^{bc}
2	3.62 ± 0.01^{g}	0.31 ± 0.01^{d}	86.40 ± 1.05^{bc}
3	3.83 ± 0.00^{e}	0.31 ± 0.01^{d}	85.18 ± 0.41^{c}
4	4.06 ± 0.01^{d}	0.38 ± 0.10^{c}	85.39 ± 0.01^{c}
5	3.64 ± 0.01^{g}	0.39 ± 0.11^{c}	84.80 ± 0.91^{c}
6	4.01 ± 0.01^{d}	0.47 ± 0.01^{b}	83.75 ± 0.70^{d}
7	3.90 ± 0.01^{de}	0.31 ± 0.01^{d}	82.11 ± 1.45^{d}
8	3.87 ± 0.01^{de}	0.23 ± 0.11^{e}	84.93 ± 0.48^{c}
9	3.72 ± 0.01^{f}	0.38 ± 0.11^{c}	87.22 ± 0.51^{b}
10	3.62 ± 0.00^{g}	0.31 ± 0.01^{d}	86.90 ± 0.56^{b}
11	4.08 ± 0.01^{d}	0.39 ± 0.12^{c}	81.41 ± 0.15^{e}
12	3.60 ± 0.01^{g}	0.39 ± 0.11^{c}	85.22 ± 0.22^{c}
13	3.80 ± 0.01^{e}	0.46 ± 0.01^{b}	87.69 ± 0.16^{b}
14	4.27 ± 0.02^{c}	0.15 ± 0.01^{f}	93.10 ± 0.15^{a}
15	3.58 ± 0.01^{g}	0.47 ± 0.01^{b}	85.59 ± 0.16^{c}
16	3.55 ± 0.01^{g}	0.54 ± 0.01^{a}	86.72 ± 0.66^{bc}
17	3.99 ± 0.01^{d}	0.31 ± 0.01^{d}	82.24 ± 0.08^{d}
18	3.76 ± 0.01^{f}	0.47 ± 0.01^{b}	82.64 ± 0.49^{d}
19	3.94 ± 0.01^{de}	0.46 ± 0.21^{b}	83.79 ± 0.03^{d}
20	4.98 ± 0.01^{b}	0.23 ± 0.11^{e}	88.48 ± 0.90^{b}
21	5.24 ± 0.02^{a}	0.15 ± 0.01^{f}	89.62 ± 0.78^{b}
22	5.00 ± 0.01^{b}	0.15 ± 0.01^{f}	87.20 ± 0.87^{bc}
23	3.82 ± 0.01^{e}	0.39 ± 0.11^{c}	83.02 ± 0.05^{d}
24	3.75 ± 0.01^{f}	0.47 ± 0.01^{b}	85.84 ± 0.76^{c}
Min–Max	3.55–5.24	0.15–0.54	81.41–93.10
Mean ± SD	3.96 ± 0.46	0.35 ± 0.11	85.66 ± 2.63

Mean values represented by the same letters within the same column are not significantly different at $p \leq 0.01$

Data are expressed as means ± standard deviations (n = 3)

main ingredients (Table 3). Marinova et al. (2005) reported that the level of the total phenolic contents of apple and other fruits was higher than vegetables.

The total phenolic contents of extractable and hydrolysable fraction in this study were determined to be 150.07–599.98 mg GAE mg/100 g and 742.14–1129.15 mg GAE mg/100 g, respectively. There were significant ($p < 0.01$) differences observed between the total phenolic contents of extractable and hydrolysable fraction and there were hydrolysable fractions higher than the extractable fractions. Carbonell-Capella et al. (2013) announced that extractable phenolic compounds in fruit baby foods were in the range of 71.9–234.2 mg GAE mg/100 g. Our results were quite higher than by these researchers.

The contents of bioaccessible fractions of baby food samples ranged from 827.34 to 1542.25 mg GAE mg/100 g. The highest value (1394.83 mg GAE mg/100 g) of the bioaccessible fraction was also observed in sample 19 (contains apple, banana, apple juice). Data on the bioaccessibility of total phenolic content from baby foods are quite limited.

In this study, the total phenolic contents of conventionally and organically labeled samples had no significant differences. However, Carbonell-Capella et al. (2013) reported that blueberry baby foods prepared with raw materials from organic agriculture contained high amounts of total phenolic contents. It is difficult to make a direct comparison of conventionally and organically labeled samples found in our research and those reported by other authors in baby foods, since composition of baby foods (ingredients growing conditions, genotype, species, cultivar, fruit maturity, agro techniques, climatic factors, geographic region), processing condition and different extraction methods may affect the composition and concentration of phenolic compounds.

Table 3 Different fraction of total phenolic contents of baby foods

Sample code	Total phenolic contents (mg GAE/100 g dw)			
	Extractable fraction	Hydrolysable fractions	TPC*	Bioaccessible fractions
1	500.33 ± 5.13^{c}	947.74 ± 34.22^{d}	1448.06 ± 22.41^{b}	1394.12 ± 23.18^{b}
2	368.06 ± 7.28^{f}	1052.92 ± 20.88^{bc}	1420.98 ± 18.15^{b}	1111.48 ± 17.24^{d}
3	496.09 ± 3.78^{c}	834.49 ± 36.66^{ef}	1330.59 ± 9.56^{c}	885.32 ± 4.56^{g}
4	306.17 ± 8.46^{h}	1007.64 ± 48.01^{c}	1313.81 ± 21.01^{c}	1245.01 ± 19.76^{c}
5	553.61 ± 12.88^{b}	978.94 ± 30.75^{cd}	1532.55 ± 38.76^{a}	961.26 ± 10.18^{f}
6	362.38 ± 9.88^{f}	982.94 ± 37.73^{cd}	1345.31 ± 23.45^{c}	1080.24 ± 9.45^{de}
7	436.87 ± 12.29^{d}	1129.15 ± 48.82^{a}	1566.02 ± 19.76^{a}	1542.25 ± 31.46^{a}
8	225.57 ± 6.77^{l}	918.11 ± 26.42^{de}	1243.68 ± 10.42^{d}	1063.61 ± 15.56^{e}
9	328.15 ± 5.55^{g}	956.66 ± 53.06^{d}	1284.81 ± 18.21^{cd}	1085.18 ± 13.45^{de}
10	417.59 ± 17.01^{e}	801.69 ± 26.59^{f}	1219.29 ± 9.21^{d}	1143.84 ± 18.01^{d}
11	436.57 ± 11.06^{de}	1020.01 ± 47.84^{c}	1456.58 ± 8.96^{b}	1231.77 ± 10.96^{c}
12	247.39 ± 3.77^{jk}	916.83 ± 30.92^{de}	1164.22 ± 13.68^{e}	1063.45 ± 8.64^{e}
13	557.48 ± 13.82^{b}	779.96 ± 36.72^{fg}	1337.44 ± 26.41^{c}	1270.90 ± 16.55^{c}
14	282.21 ± 6.09^{hi}	742.14 ± 42.97^{g}	1024.34 ± 8.85^{f}	879.60 ± 5.93^{g}
15	599.98 ± 4.33^{a}	857.22 ± 4.33^{ef}	1457.19 ± 11.76^{b}	1035.11 ± 8.71^{e}
16	487.32 ± 3.43^{c}	854.78 ± 3.43^{ef}	1342.09 ± 19.08^{c}	1226.56 ± 10.18^{c}
17	242.21 ± 17.18^{kl}	1100.91 ± 58.60^{ab}	1343.11 ± 15.46^{c}	1240.40 ± 11.36^{c}
18	358.31 ± 6.64^{f}	994.31 ± 57.52^{c}	1352.62 ± 7.36^{c}	1282.61 ± 9.87^{bc}
19	489.42 ± 2.43^{c}	1084.05 ± 12.43^{b}	1573.46 ± 18.10^{a}	1394.83 ± 12.27^{c}
20	168.79 ± 1.75^{mn}	845.13 ± 11.75^{ef}	1013.92 ± 10.93^{f}	897.50 ± 11.09^{ef}
21	178.74 ± 2.51^{m}	882.97 ± 10.79^{e}	1061.71 ± 14.53^{f}	971.72 ± 6.46^{f}
22	150.079 ± 0.29^{n}	887.05 ± 10.29^{e}	1037.13 ± 9.91^{f}	954.05 ± 9.71^{f}
23	450.88 ± 3.59^{d}	1081.52 ± 13.59^{b}	1532.39 ± 13.87^{a}	1055.38 ± 10.18^{e}
24	268.35 ± 2.30^{ij}	890.74 ± 12.31^{e}	1159.09 ± 16.45^{e}	827.34 ± 6.83^{g}
Min–Max	150.07–599.98	742.14–1129.15	1013.92–1573.46	827.34–1542.25
Mean ± SD	371.35 ± 132.21	939.49 ± 106.41	1310.85 ± 174.55	1114.59 ± 170.97

Mean values represented by the same letters within the same column are not significantly different at $p \leq 0.01$

Data are expressed as means ± standard deviations (n = 3)

*Total phenol content was calculated as the sum of extractable, and hydrolysable fractions

Antioxidant capacity

The antioxidant capacities of extractable and hydrolysable fractions of the samples were determined by CUPRAC and ABTS methods. In the comparison of the levels of CUPRAC and ABTS antioxidant capacities among baby foods, differences were observed ($p < 0.01$) (Fig. 1). It is clear that the antioxidant capacities of the hydrolysable fraction of samples were significantly ($p < 0.01$) higher compared to the extractable fractions.

In the extractable fraction of CUPRAC values between 138.41 µmol TE mg/100 g and 2235.96 µmol TE mg/100 g were determined, whereas in hydrolysable fraction were 819.54 µmol TE mg/100 g and 2614.36 µmol TE mg/100 g. The highest CUPRAC total antioxidant capacity was detected in sample 19 (4849.11 µmol TE mg/100 g) followed by sample 16 (4187.23 µmol TE mg/100 g), whereas the lowest value was detected in sample 8 (957.39 µmol TE mg/100 g). Carbonell-Capella et al. (2013) reported that the antioxidant capacity levels of cereal-free foods were higher than containing cereal. In our study, similar to the results obtained by Carbonell-Capella et al. (2013).

The ABTS values were dedicated within the range of 87.62–209.18 µmol TE mg/100 g (extractable fractions) and 147.94–226.73 µmol TE mg/100 g (hydrolysable fractions) in baby food samples. Sample 11 had the highest ABTS total antioxidant capacity value (421.85 µmol TE mg/100 g), while the lowest content (238.19 µmol TE mg/100 g) was recorded in the sample 12. Following the sample 11 (apple puree, banana puree, apple juice, and rice flour), sample 1 (apple, peach, carrot, rice flour) and

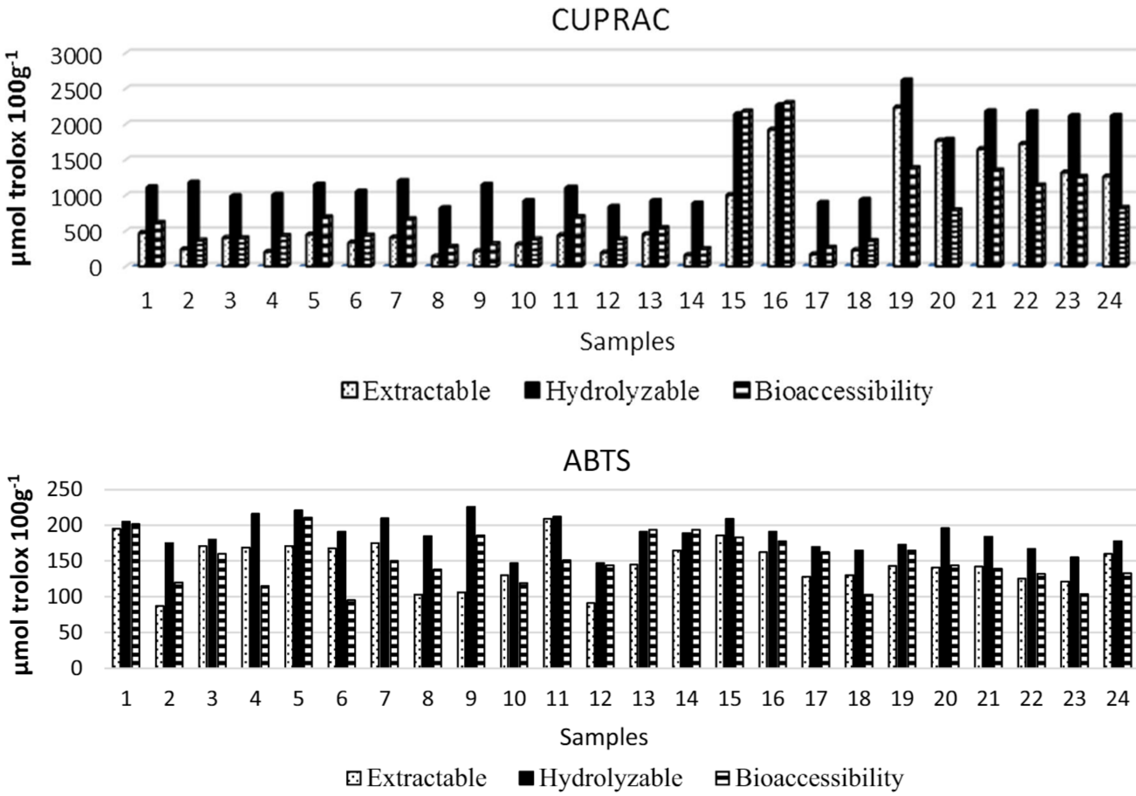

Fig. 1 Extractable, hydrolysable and bioaccessible fraction of antioxidant capacity of baby foods measured with ABTS and CUPRAC methods

sample 15 (apple, pear and apple juice) contained a relatively high amount of total antioxidant capacity value.

Both of the CUPRAC and ABTS methods are electron transfer based assays however, they have different sensitivity to the type of antioxidant measured, reagent, pH and solvent dependencies (Ozyurek et al. 2011). The present study, results showed that the total antioxidant capacity of the CUPRAC method exhibited higher than the ABTS method (Fig. 1). This might be explained by the fact that the CUPRAC method is the antioxidant capacity method use for a wide spectrum of polyphenols (flavonoids, carotenoids, anthocyanins, phenolic acids, thiols, and vitamins C and E) (Ozyurek et al. 2011).

During gastrointestinal digestion, antioxidants may interact with other food constituents, be degraded, or metabolized (Sahan et al. 2017). For this reason, the evaluation of bioaccessibility is critical for a better knowledge of the benefits associated with the consumption of baby food (Cardoso et al. 2015).

The bioaccessibility of CUPRAC and ABTS methods represented 22.18–69.31% and 26.46–60.50% of the initial contents of the samples (Fig. 2). Sample 15, 16, 13, 5 and 1 showed greater than average 50% antioxidant bioaccessibility for both of the methods. This might occur because these samples contain high contents of fruits and vegetables, such as 100% apple, apple juice and pear (sample 15), 96% apple, apple juice, carrot and pear (sample 16), 100% apple, apple juice and carrot (sample 13), 98% apple, apricot, carrot and white grape juice (sample 5) and 100% apple, peach and carrot (sample 1) which are good sources of polyphenols. Saura-Calixto et al. (2007) reported that 48% of dietary polyphenols were bioaccessible in the small intestine.

In the literature, studies on the bioaccessibility of baby foods focus on minerals and carotenoids (Jiwan et al. 2010; Da Silva et al. 2013, 2018; Dhuique-Mayer et al. 2018). To the best of our knowledge, this is the first study to report on the bioaccessibility of antioxidants from commercially baby foods. The bioaccessibility of total phenolic content and antioxidant capacity of baby foods are dependent on the ingredients used and processing methods. Additionally, antioxidative properties of the ingredients are linked to numerous factors such as variety, maturation, growing condition, seasonal variation, and agricultural practice.

No significant difference was observed in the bioaccessibility of the antioxidative properties of organic and non-organic baby foods. As a result, it was concluded that organic baby foods were generally not excellent to conventional baby foods in terms of antioxidative properties and bioaccessibility.

As a result, it was concluded that fruit-vegetable baby food is rich in bioaccessible total phenolic content and

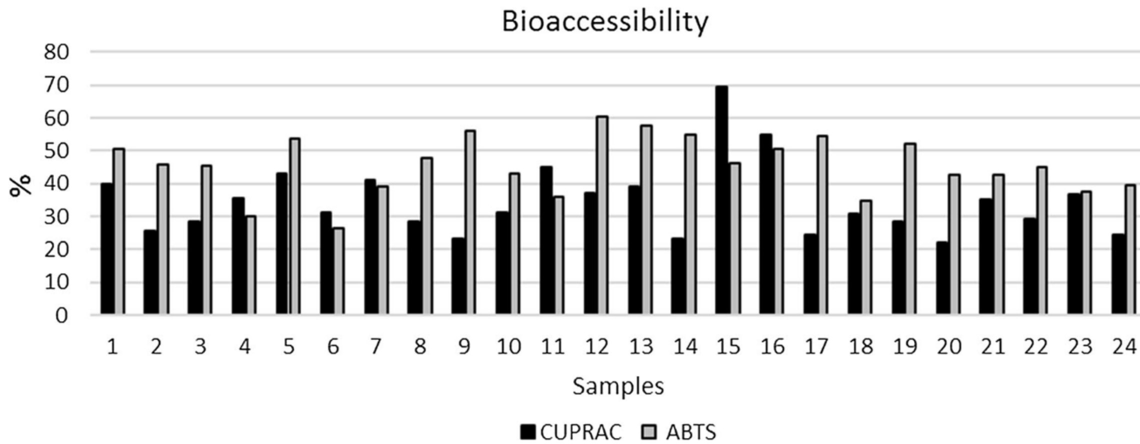

Fig. 2 Bioaccessibility (%) of antioxidant capacity for commercially baby foods

antioxidant substances which are considered to be beneficial in many ways to health and can be used as an alternative complementary foodstuff.

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