Determination of rutin in fruits and vegetables in natura

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Summary

Rutin is one of the phenolic compounds that have aroused interest due to the beneficial effect in reducing the risk of degenerative diseases, therefore, it is extremely important to investigate new natural sources of this compound. The objective of this study was to evaluate the rutin content in edible parts of 324 plant samples, comprising 117 different fruits and vegetables commercialized in Brazil. Rutin was detected in 73 different vegetables (195 samples). Umbu, noni, blackberry, quince and cherry were the fruits with the highest content of rutin (between 43.2 mg·kg^{-1} and 162.4 mg·kg^{-1}). Among vegetables, the highest levels were found in coriander (196.6 mg·kg^{-1}) and asparagus (151.3 mg·kg^{-1}). Considering the portions normally consumed, the vegetables that presented the highest amounts were umbu, asparagus, blackberry, quince, cherry and red plum. These can be considered as rutin sources for a diversified and healthy diet.

Keywords

phenolic compounds; flavonoids; rutin; liquid chromatography; antioxidant

Recently, many studies related bioactive compounds present in fruits and vegetables to beneficial health effects, with a greater emphasis on reducing the risk of degenerative diseases [1, 2]. Among these, the most studied are the phenolic compounds derived from the secondary metabolism of plants [3]. Their production is stimulated by defense mechanisms related to stress conditions [4].

Rutin is a flavonoid from the class of flavonols, composed of quercetin and a rhamnose molecule attached at carbon three [5]. It is synthesized via the phenylpropanoid pathway, where there is conversion of phenylalanine to 4-coumaroyl-coenzyme A, followed by enzymatic reaction with transformations that result in a molecule of rutin [6]. It is one of the flavonoids of a great importance in the pharmaceutical industry, and it is a component of many medicinal and therapeutic formulations patented in several countries [3, 7].

A high antioxidant capacity was attributed to rutin, in addition to presenting important biological activities [8, 9]. Studies showed that diabetic rats that were fed with this flavonoid presented an improvement in the glycemic state [10]. In another study, efficacy in the reduction of blood glucose levels and systolic as well as diastolic blood pressures was also verified [11]. Effects on reducing myocardial hypertrophy, relieving the deposition of collagen and the accumulation of lipids [2], as well as anti-inflammatory action in treating colitis and peritonitis, and reduction of edemas and cytokines were also related to the consumption of rutin [12].

In vivo and in vitro studies demonstrated the anticarcinogenic effects of rutin, indicating that it induces apoptosis in cancer cells [13]. Karakurt [14] showed the antiproliferative and modulatory action of rutin on the human hepatocellular carcinoma, while other papers reported chemopreven-

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tive and anti-tumour effects in vivo [15]. Rutin was also related to the relief of atherosclerosis [16], as well as with protective actions regarding the hepatotoxicity of some compounds [1].

Consumption of fruits and vegetables is supported by the World Health Organization, which recommends a minimum of 400 g daily. Among this class of food, it is possible to find sources of rutin such as grains [17], açaí, banana, noni, orange, guava [18–21], basil, dandelion [22], radish, carrot [20] or lentils [23]. So, given the importance of rutin in reducing the risk of several diseases, consumption of this compound through diet can be strongly recommended. Considering the diversity of fruits and vegetables available in Brazil, as well as the benefits related to the consumption of this flavonoid, this work had the objective of identifying and quantifying rutin in 117 vegetables in natura, looking for its potential natural sources.

MATERIALS AND METHODS

Samples and reagents

A number of 117 different vegetables were studied, being 64 fruits and 53 vegetables. Each sample was acquired from three separate suppliers (except when unavailable), totalling 324 samples. The suppliers were from 16 Brazilian states of the Southeast, Northeast, South, North and Center-West regions of the country. All samples were acquired in Brazil, although some had been imported from other countries, namely, United States of America, Chile, Portugal, Spain, Colombia and Mexico. Samples in natura were obtained at the maturation stage considered fit for consumption. The amount of sample purchased from each supplier was 0.5 kg for small samples (such as blackberry or plum) and 3 units for larger samples, when 0.5 kg did not reach 3 units (such as watermelon, melon or pumpkin). For leafy samples (such as arugula or parsley), 3 bundles were purchased (as they are marketed) from each supplier.

The analytical standard of rutin was obtained from Sigma Aldrich (St. Louis, Missouri, USA). The standard stock solution of rutin was prepared in chromatographic grade acetonitrile (J. T. Baker, Phillipsburg, New Jersey, USA) at a concentration of 1 mg·ml^{-1} and it was stored at –80 °C. Formic acid was obtained from Merck (Darmstadt, Germany), chromatographic grade acetonitrile from J. T. Baker and analytical grade ethanol from Synth (Diadema, Brazil). The water employed in the experiments was ultra purified in Milli-Q system (Millipore, Burlington, Massachusetts, USA). All solutions were filtered through 0.22 μm porosity polyvinylidene fluoride (PVDF) membranes (Millipore).

Preparation of samples

After the removal of dirt and the inedible parts, the edible parts of the vegetables were ground using the blender, grinder or processor. Immediately after the preparation, the samples were submitted to the extraction for the rutin analysis. The açaí samples were pre-treated by soaking in water at 60 °C for 60 min and then submitted to pulping, separated from seeds and analysed, the embedded water content being considered.

Methods of analysis

All samples (1 g each) were extracted with 15 ml of water: ethanol (74:26) in a 50 ml Falcon tube (Thermo Fisher Scientific, Waltham, Massachusetts, USA), based on the method described by Meinhart et al. [24]. The hermetically sealed tube was subjected to homogenization by shaking (4 Hz) in a water bath at 60 °C, for 22 min. Then, the sample was filtered through a paper filter and the filtrate was further filtere through a PVDF membrane filter with a porosity of 0.22 μm. Avocado, fortune avocado and dry coconut samples had the extraction procedure preceded by a step of lipids removal by a partition with ethyl ether.

The analysis of rutin was carried out by high-performance liquid chromatography with diode arrangement detector (HPLC-DAD) operating at 325 nm, in the equipment from Agilent Technologies (Santa Clara, California, USA), model 1260, equipped with an automatic injector and quaternary pump, Zorbax Eclipse plus C18 column (4.6 mm of internal diameter, 100 mm long and 3.5 μm particle size; Agilent Technologies), kept under a temperature of 30 °C, based on the method described by Meinhart et al. [24].

Elution was conducted by a gradient system starting with 10 % of A (acetonitrile) and 90 % of B (acidified water with 0.1% formic acid, pH 2.4), with a linear increase in A until it reached 40 % at 6 min. From 6.1 min, 100 % of A was applied and this was maintained up to 7.5 min for column cleaning (due to the diversity of the samples). The column was then re-conditioned with the mobile phase of initial composition for 3.5 min. The mobile phase flow rate was 1.2 ml·min^{-1} and the injection volume was 30 μl. Identification of rutin was achieved by comparison with the analytical standard based on the retention time, the absorption spectrum of DAD and by co-chromatography. Quantification was carried out by an exter-

Tab. 1. Figures of merit of the validation of the analytical method used in the chromatographic analysis of rutin in vegetables.

Parameters		Results
Linear range of the analytical curve [mg·l⁻¹]		0.03–10.0
Calculated *F* value for linear model adjustment*		0.104
Accuracy (recovery in orange sample) recovered [%] (*n* = 3)	Level 1	98.37
	Level 2	103.58
	Level 3	100.60
Accuracy (recovery in broccoli sample) recovered [%] (n = 3)	Level 1	101.62
	Level 2	91.80
	Level 3	94.41
Precision on day in fortified orange sample, in relative standard deviation (*n* = 7)	Level 1	2.21
	Level 2	1.25
	Level 3	1.34
Precision on day in fortified broccoli sample, in relative standard deviation (*n* = 7)	Level 1	2.84
	Level 2	1.96
	Level 3	2.68
Precision between days in fortified orange sample, in relative standard deviation (*n* = 3)	Level 1	7.64
	Level 2	5.48
	Level 3	1.78
Precision between days in fortified broccoli sample, in relative standard deviation (*n* = 3)	Level 1	5.24
	Level 2	2.71
	Level 3	2.68
Quantification limit [mg·kg⁻¹]		0.015
Detection limit [mg·kg⁻¹]		0.008

* – The model presents adequate adjustment when the calculated *F* (3.11) is lower than the critical *F* (4.14) (with 95% confidence).
Level 1 – quantification limit, Level 2 – intermediate content of the linear range of the analytical curve, Level 3 – maximum content of the linear range of the analytical curve.

nal calibration curve. The statistical treatment of the results was carried out through the analysis of variance (ANOVA) and Tukey's test, with 95% confidence, using the software Statistica 7.0 (Statsoft, Tulsa, Oklahoma, USA).

Validation of the method was carried out following the recommendations of International Union of Pure and Applied Chemistry (IUPAC) [25]. Thus, the limits of detection and quantification were established as the content corresponding to the relation of 3 and 6 times the signal/noise ratio, respectively. The linear range was established in an analytical curve constructed with 6 equidistant points, in random triplicates, starting at the limit of quantification and ending at the concentration up to where linearity was ensured through the evaluation of the models regarding the lack of adjustment and significance of regression according to ANOVA. Accuracy was evaluated by recovery tests in orange and broccoli samples, at three levels represented by the limit of quantification, intermediate and maximum content of the analytical curve. The precision on the day was determined through 7 successive determinations in orange and broccoli samples (each one at three levels, identical to those of accuracy) and precision between days by carrying out analysis on 3 different days, in orange and broccoli samples (each one at three levels, identical to those of accuracy), with 7 determinations on each day.

RESULTS AND DISCUSSION

Method validation

The figures of merit of the validation of the analytical method are presented in Tab. 1. The results showed low limits of detection and quantification (0.008 mg·kg⁻¹ and 0.015 mg·kg⁻¹, respectively), adequate linearity between the concentrations of 0.03 mg·l⁻¹ and 10.00 mg·l⁻¹ (since the value of *F* for lack of fit was lower than the critical *F* (4.14), with 95% confidence) and accuracy between 91.8 % and 101.6 % considering three levels of recovery of arrays of oranges and broccoli. High precision was achieved at quantification, with relative standard deviations lower than 6 % regarding the three levels studied (limit of quantification, halfway point and maximum content of the analytical curve). These results were in accordance with the limits established by IUPAC [25], demonstrating that the method is suitable for quantitative analysis.

Determination of rutin in fruits and vegetables

Tab. 2 presents information on identity of samples, their origin, analysed parts, as well as the content of rutin. These results evidenced the presence of rutin in 61 % of the samples (195), which presented a higher content than the quantification limit (between 0.3 mg·kg⁻¹ and 479.6 mg·kg⁻¹). In 2 samples, the compound was detected at a lower content than the quantification limit and in 127 samples, the presence of the compound was not detected. The plants that had the highest average content of rutin (considering all suppliers) were coriander, umbu, asparagus, noni, blackberry, quince and cherry, with average contents of 196.6 mg·kg⁻¹, 162.4 mg·kg⁻¹, 151.3 mg·kg⁻¹, 99.2 mg·kg⁻¹, 60.6 mg·kg⁻¹, 58.3 mg·kg⁻¹ and 43.2 mg·kg⁻¹, respectively. When the 73 plants in which rutin was detected in samples from one or more of its suppliers were evaluated, in 42 % of

Tab. 2. Identification of samples and rutin content on wet basis.

Sample	OR	Analyzed parts	Rutin [mg·kg^{-1}] Mean	*SD*
Fortune avocado (*Persea americana*)	BR1	Pulp	ND	
	BR1		ND	
	BR1		ND	
Abiu (*Pouteria caimito*)	BR1	Pulp	ND	
	BR1		ND	
	BR1		ND	
Açaí (*Euterpe olearacea* Mart)	BR2	Pulp	ND	
Avocado (*Persea americana* var. Hass and Fuerte)	BR1	Pulp	ND	
	BR1		ND	
	BR3		ND	
Cajamanga (*Spondias dulcis* Som)	BR1	Pulp	ND	
	BR1		ND	
	BR1		ND	
Sugar cane (*Saccharum officinarum*)	BR1	Pulp	ND	
Chayote (*Sechium edule* Sw)	BR1	Pulp	ND	
	BR1		ND	
	BR1		ND	
Dry coconut (*Cocos nucifera*)	BR4	Pulp	ND	
	BR4		ND	
	BR4		ND	
Custard apple (*Annona squamosa*)	BR4	Pulp	ND	
	BR4		ND	
	BR4		ND	
Granadilla (*Passiflora ligularis*)	CO	Pulp	ND	
	CO		ND	
Jatoba (*Hymenaea courbaril*)	BR4	Pulp	ND	
	BR4		ND	
	BR2		ND	
Yellow melon (*Cucumis melo* L.)	BR4	Pulp	ND	
	BR4		ND	
	BR4		ND	
Portuguese pear (*Pyrus communis*)	PT	Pulp	ND	
	PT		ND	
	PT		ND	
Pupunha (*Bactris gasipaes*)	BR2	Pulp	ND	
Pomegranate (*Punica granatum*)	BR1	Pulp	ND	
	BR1		ND	
	BR1		ND	
Grapefruit (*Citrus paradisi*)	ES	Pulp	ND	
	US		ND	
Sapoti (*Manilkara acharas*)	BR2	Pulp	ND	
	BR2		ND	
	BR4		1.5	0.1
Onion (*Allium cepa* L.)	BR3	Pulp	1.6^{a}	0.1
	BR3		ND	
	BR4		1.5^{a}	0.2
Cupuaçu (*Theobroma grandiflorum*)	BR4	Pulp	1.6^{a}	0.2
	BR2		0.6^{b}	0.1
Jackfruit (*Artocarpus integrifolia* L.)	BR1	Pulp	2.3^{a}	0.0
	BR1		ND	
	BR4		1.4^{b}	0.1
Key lime (*Citrus limettioides*)	BR1	Pulp	1.9^{a}	0.1
	BR1		2.1^{a}	0.1
	BR1		1.4^{b}	0.1
Apricot (*Mammea american*)	BR2	Pulp	1.5^{a}	0.2
	BR2		2.1^{a}	1.4
Mango (*Mangifera indica*)	BR4	Pulp	1.3^{b}	0.2
	BR1		2.3^{a}	0.1
	BR4		1.8^{ab}	0.2
Lemon Tahiti (*Citrus aurantifolia*)	BR1	Pulp	2.6^{ab}	0.2
	BR1		2.2^{b}	0.0
	BR1		3.1^{a}	0.2
Papaya Formosa (*Carica papaya* L)	BR4	Pulp	2.7^{b}	0.3
	BR1		2.3^{b}	0.1
	BR1		4.0^{a}	0.2
Jabuticaba (*Plinia cauliflora*)	BR1	Pulp	3.5	0.2
Pumpkin cabotiá (pumpkin × winter squash) (*Cucurbita moschata* Duch × *Cucurbita maximum* Duch	BR1	Pulp	3.1^{b}	0.5
	BR1		5.4^{a}	0.2
	BR1		2.7^{b}	0.4
Cocoa (*Theobroma cacao*)	BR1	Pulp	3.8^{ab}	0.3
	BR2		3.1^{b}	0.1
	BR4		4.7^{a}	0.5
Atemoya (*Annona cherimola* Mill × *Annona squamosa* L.)	BR1	Pulp	4.7^{a}	0.1
	BR1		4.0^{a}	0.5
	BR1		4.7^{a}	0.1
Tamarind (*Tamarindus indica* L.)	BR1	Pulp	4.9^{a}	0.3
	BR4		4.7^{a}	0.3
	BR4		5.1^{a}	0.5
Rambutan (*Nephelium lappaceum*)	BR1	Pulp	0.6^{c}	0.1
	BR3		6.7^{b}	0.3
	BR1		11.0^{a}	1.3
Tangerine (*Citrus reticulata*)	BR1	Pulp	3.0^{c}	0.2
	BR1		13.2^{a}	1.5
	BR1		4.7^{b}	0.3
Jenipapo (*Genipa americana*)	BR2	Pulp	7.4^{b}	0.3
	BR2		15.1^{a}	0.9
	BR4		1.3^{c}	0.1
Orange (*Citrus sinensis*)	BR1	Pulp	10.5^{a}	0.1
	BR1		7.0^{b}	0.1
	BR1		7.0^{b}	0.2
Watermelon Crimson (*Citrullus lanatus*)	BR5	Pulp	5.8^{b}	0.1
	BR5		9.1^{a}	0.3
	BR4		9.9^{a}	0.4
Pineapple (*Ananas comosus* L. Merrill)	BR1	Pulp	27.9^{a}	0.2
	BR1		8.7^{b}	0.1
	BR1		8.5^{b}	0.4
Mangosteen (*Garcinia mangostana*)	BR2	Pulp	11.6	0.8

Tab. 2. *continued*

Sample	OR	Analyzed parts	Rutin [mg·kg-1] Mean	*SD*
Lime	BR1	Pulp	11.5^{b}	0.5
(*Citrus aurantifolia*)	BR1		10.9^{b}	0.3
	BR1		14.6^{a}	0.4
Graviola	BR4	Pulp	15.4^{b}	1.7
(*Annona muricata*)	BR4		26.1^{a}	2.2
	BR4		20.5^{ab}	0.6
Star fruit	BR1	Pulp, peel	ND	
(*Averrhoa carambola*)	BR1		ND	
	BR1		ND	
Kinkan	BR1	Pulp, peel	ND	
(*Fortunella*)	BR1		ND	
	BR1		ND	
Maxixe	BR1	Pulp, peel	ND	
(*Cucumis anguria* L)	BR1		ND	
	BR1		ND	
Green pepper	BR1	Pulp, peel	ND	
(*Capsicum annuum* L.)	BR1		ND	
	BR1		ND	
Persimmon	BR1	Pulp, peel	1.3^{a}	0.1
(*Diosyrus kaki*)	BR1		nq	
	BR1		0.4^{b}	0.1
Cashew	BR4	Pulp, peel	1.6^{a}	0.2
(*Anacardium occidentale*)	BR4		2.0^{a}	0.2
	BR2		1.5^{a}	0.1
Grape	CL	Pulp, peel	2.7^{a}	0.2
(*Vitis vinifera*)	BR4		3.2^{a}	0.4
	CL		1.5^{b}	0.1
Peach	ES	Pulp, peel	1.6^{b}	0.1
(*Prunus persica*)	CL		2.1^{b}	0.2
	ES		4.2^{a}	0.1
Nectarine	ES	Pulp, peel	4.1^{a}	0.3
(*Prunus persica*)	ES		2.9^{b}	0.3
	CL		2.8^{b}	0.1
Pitanga (*Eugenia uniflora*)	BR1	Pulp, peel	3.7	0.4
Tomato	BR1	Pulp, peel	3.1^{b}	0.2
(*Lycopersicon esculentum*)	BR1		4.4^{b}	0.5
	BR1		9.2^{a}	0.9
Apple	BR3	Pulp, peel	3.4^{b}	0.5
(*Malus Communis*)	BR3		13.6^{a}	1.3
	BR3		2.3^{b}	0.1
Red plum	US	Pulp, peel	21.0^{b}	0.6
(*Prunus domestica* L)	US		32.4^{a}	0.4
	AR		23.2^{b}	1.7
Cherry	US	Pulp, peel	42.2^{a}	3.1
(*Prunus avium*)	AR		42.2^{a}	1.1
	US		45.1^{a}	1.6
Quince	BR1	Pulp, peel	68.5^{a}	11.7
(*Cydonia oblonga*)	AR		48.0^{a}	3.9
Noni	BR3	Pulp, peel	143.6^{a}	11.5
(*Morinda citrifolia*)	BR4		30.8^{b}	3.9
	BR1		123.1^{a}	9.5

Sample	OR	Analyzed parts	Rutin [mg·kg-1] Mean	*SD*
Umbu	BR3	Pulp, peel	288.8^{a}	11.7
(*Spondias tuberosa*)	BR1		86.1^{b}	10.7
	BR4		112.5^{b}	12.4
Caxi / Porongo edible (*Cucurbita* sp.)	BR1	Pulp, seed	ND	
Sour passion fruit	BR1	Pulp, seed	ND	
(*Passiflora edulis* Sims)	BR1		ND	
	BR1		ND	
Sao Caetano melon (*Mormodica charantia* L.)	BR1	Pulp, seed	ND	
Japanese cucumber	BR1	Pulp, seed	ND	
(*Cucumis sativus* L.)	BR1		ND	
	BR1		ND	
Yellow pitaya	MX	Pulp, seed	ND	
(*Cereus undatus*)	MX		ND	
Dwarf banana	BR1	Pulp, seed	0.5^{b}	0.0
(*Musa paradisiaca*)	BR4		0.5^{b}	0.0
	BR3		3.0^{a}	0.5
Kiwi	BR3	Pulp, seed	1.5^{b}	0.2
(*Actinidia deliciosa*)	BR3		3.8^{a}	0.7
	BR3		3.6^{a}	0.7
Zucchini Italia	BR1	Pulp, peel, seed	ND	
(*Cucurbita pepo* L.)	BR1		ND	
	BR1		ND	
Scarlet eggplant	BR1	Pulp, peel, seed	2.4^{a}	0.4
(*Solanum gilo* Raddi)	BR1		2.3^{a}	0.4
	BR1		2.1^{a}	0.2
Eggplant	BR1	Pulp, peel, seed	1.6^{c}	0.0
(*Solanum melongena* L.)	BR1		2.9^{a}	0.1
	BR1		2.4^{b}	0.1
Raspberry (*Rubus idaeus*)	BR1	Pulp, peel, seed	2.7	0.4
Red guava	BR1	Pulp, peel, seed	3.1^{a}	0.4
(*Psidium guajava*)	BR1		2.5^{a}	0.3
	BR1		4.3^{a}	0.5
Okra	BR1	Pulp, peel, seed	3.7^{ab}	0.7
(*Abelmoschus esculentus*	BR1		2.5^{b}	0.1
(L.) Moench)	BR1		6.7^{a}	1.1
Strawberry Albion	BR1	Pulp, peel, seed	6.2^{a}	0.3
(*Fragaria* × ananassa	BR1		5.7^{a}	0.6
Duch.)	BR1		5.3^{a}	0.1
Blueberry	US	Pulp, peel, seed	22.3^{a}	1.2
(*Vaccinium myrtillus*)	BR1		10.9^{b}	0.5
	US		2.1^{c}	0.2
Physalis	BR3	Pulp, peel, seed	13.3^{b}	1.9
(*Physalis peruviana*)	CO		19.7^{a}	2.1
	CO		11.4^{b}	0.5
Acerola	BR2	Pulp, peel, seed	14.0^{b}	0.2
(*Malpighia emarginata*	BR2		13.2^{b}	0.5
DC.)	BR4		40.6^{a}	1.4

Tab. 2. *continued*

Sample	OR	Analyzed parts	Rutin [mg·kg-1] Mean	SD
Red fig (*Ficus carica* L.)	BR1	Pulp, peel, seed	21.0 [a]	2.6
	BR1		21.8 [a]	3.0
	BR1		28.6 [a]	3.9
Blackberry (*Morus nigra*)	BR1	Pulp, peel, seed	139.4 [a]	1.8
	BR1		17.0 [c]	0.7
	BR1		25.3 [b]	2.4
Fresh peas (*Pisum sativum* L.)	BR1	Seed	ND	
	BR3		2.4 [a]	0.1
	BR3		1.2 [b]	0.1
Pod sweet (*Lablab purpureus* L.)	BR1	Seed, pod	ND	
	BR1		ND	
	BR3		ND	
Pod (*Phaseolus vulgaris* L.)	BR1	Seed, pod	3.9 [ab]	0.5
	BR1		2.5 [b]	0.2
	BR3		5.7 [a]	0.4
Radish (*Raphanus sativus* L.)	BR1	Peel, root	ND	
	BR1		ND	
	BR1		ND	
Rosemary (*Rosmarinus officinalis* L.)	BR1	Leaf	ND	
	BR1		ND	
	BR1		ND	
Escarole (*Cichorium endivia* L.)	BR1	Leaf	ND	
	BR1		ND	
	BR1		ND	
Cabbage (*Brassica oleracea* L. var. *acephala* DC)	BR1	Leaf	ND	
	BR1		ND	
	BR1		ND	
Bay leaf (*Laurus nobilis* L.)	BR1	Leaf	ND	
	BR1		ND	
	BR1		ND	
Oregano (*Origanum vulgare*)	BR1	Leaf	ND	
	BR1		ND	
	BR1		ND	
Parsley/celery (*Apium graveolens*)	BR1	Leaf	ND	
	BR1		ND	
	BR1		ND	
Sage (*Salvia officinalis*)	BR1	Leaf	ND	
	BR1		ND	
Spinach (*Spinacea oleracea* L.)	BR1	Leaf	1.4	0.1
	BR1		nq	
	BR1		ND	
Ruby lettuce (*Lactuca sativa* L.)	BR1	Leaf, stem	ND	
	BR1		ND	
	BR1		ND	
Red lettuce (*Lactuca sativa* L.)	BR1	Leaf, stem	ND	
	BR1		ND	
	BR1		ND	
Chicory (*Cichorium intybus* L)	BR1	Leaf, stem	ND	
	BR1		ND	
	BR1		ND	

Sample	OR	Analyzed parts	Rutin [mg·kg-1] Mean	SD
Red cabbage (*Brassica oleracea* L./ *Brassica oleracea* var. *capitata* ''f. rubra")	BR1	Leaf, stem	ND	
	BR1		ND	
	BR1		ND	
Rucola (*Eruca sativa* L.)	BR1	Leaf, stem	ND	
	BR1		ND	
	BR1		ND	
Parsley (*Petroselinum crispum* (Mill.) Nym)	BR1	Leaf, stem	ND	
	BR1		ND	
	BR1		ND	
Cabbage (*Brassica oleracea* L./ *Brassica oleracea* var. *capitata* ''f. alba")	BR1	Leaf, stem	1.1 [b]	0.1
	BR1		1.0 [b]	0.2
	BR1		3.9 [a]	0.1
Watercress (*Nasturtium officinale* sp.)	BR1	Leaf, stem	3.0 [a]	0.3
	BR1		4.2 [a]	0.7
	BR1		ND	
Napa cabbage (*Beta vulgaris* L. var. *cicla*)	BR1	Leaf, stem	4.4 [b]	0.1
	BR1		7.1 [a]	1.2
	BR1		1.1 [c]	0.2
Green onion (*Allium schoenoprasum* L.)	BR1	Leaf, stem	10.5 [a]	0.9
	BR1		6.2 [b]	0.4
	BR1		5.3 [b]	1.0
Basil (*Ocimum basilicum* L.)	BR1	Leaf, stem	20.3 [b]	3.4
	BR1		26.7 [ab]	2.6
	BR1		36.7 [a]	2.7
Mustard (*Brassica juncea* L. Coss)	BR1	Leaf, stem	23.0 [a]	0.8
	BR1		25.1 [a]	0.2
Asparagus (*Asparagus officinalis* L.)	PE	Leaf, stem	48.4 [c]	3.4
	CL		233.3 [a]	8.4
	CL		172.1 [b]	4.6
Coriander (*Coriandrum sativum* L.)	BR1	Leaf, stem	58.3 [b]	6.0
	BR1		51.9 [b]	6.3
	BR1		479.6 [a]	3.7
Leek (*Allium ampeloprasum* L.)	BR1	Stem	1.9 [ab]	0.4
	BR1		4.3 [a]	0.4
	BR1		3.6 [b]	0.4
Cauliflower (*Brassica oleracea* var. *botritys*)	BR1	Stem, flower	9.9 [a]	0.2
	BR1		14.9 [a]	2.0
	BR1		11.0 [a]	1.4
Broccoli (*Brassica oleracea* L. var. *italica* Plenck)	BR1	Stem, flower	18.4 [b]	2.2
	BR1		6.3 [c]	1.0
	BR1		26.0 [a]	1.4
Bean sprouts (*Vigna radiata*)	BR1	Sprout	29.5 [b]	1.7
	BR1		34.9 [b]	2.9
	BR1		47.8 [a]	1.0
Beet (*Beta vulgaris* L.)	BR1	Root	ND	
	BR1		ND	
	BR1		ND	
Carrot (*Daucus carota* L.)	BR1	Root	ND	
	BR1		ND	
	BR1		ND	

Tab. 2. *continued*

Sample	OR	Analyzed parts	Rutin [mg·kg-1] Mean	SD
Pink sweet potato (*Ipomoea potatoes* L.)	BR1	Root	0.9	0.2
	BR1		ND	
	BR1		ND	
Turnip (*Brassica rapa* var. *rapa* (L.) Thell.)	BR1	Root	0.7 [c]	0.0
	BR1		2.9 [a]	0.1
	BR1		1.2 [b]	0.1
Cassava (*Manihot esculenta* Crantz)	BR1	Root	2.4 [b]	0.0
	BR1		4.3 [a]	0.2
	BR1		1.0 [c]	0.0
Mandioquinha (*Arracacia xanthorrhiza* Banc.)	BR1	Root	4.3 [a]	0.6
	BR1		2.0 [b]	0.4
	BR1		2.5 [b]	0.1
Ginger (*Zingiber officinale* Roscoe)	BR1	Rhizome	3.8 [b]	0.2
	BR1		3.9 [ab]	0.5
	BR1		4.6 [a]	0.3
Red yam (*Colocasia esculenta* L. Schott)	BR1	Rhizome	4.8 [b]	0.9
	BR1		5.0 [b]	0.5
	BR1		7.3 [a]	0.2
Cara (*Dioscorea alata* L.; *Dioscorea rotundata* Poir; *Dioscorea cayenensis*)	BR1	Tuber	1.0 [a]	0.0
	BR1		0.6 [b]	0.0
	BR1		0.8 [ab]	0.1
Potato (*Solanum tuberosum* ssp. *Tuberosum*)	BR3	Tuber	2.7 [a]	0.4
	BR3		1.0 [b]	0.2
	BR3		2.3 [ac]	0.1
Red garlic (*Allium sativum* L.)	AR	Bulb	ND	
	AR		4.2 [a]	0.1
	AR		2.2 [b]	0.2

The samples were identified according to their scientific and popular names regarding the data of the Brazilian Agricultural Research Corporation (EMBRAPA). Results of triplicate analyses are given. Different letters in superscript indicate that there is a difference between the different suppliers of the same vegetable, according to the Tukey's test, with 95% confidence. Average between suppliers considering quantification limit.

OR – origin of the samples: BR1 – Brazil (Southeast), BR2 – Brazil (North), BR3 – Brazil (South), BR4 – Brazil (Northeast), BR5 – Brazil (Centre-West), CO – Colombia, ES – Spain, PT – Portugal, US – United States, CL – Chile, AR – Argentina, MX – Mexico, PE – Peru.

SD – standard deviation (0.0 indicates standard deviation lower than 0.005 mg·kg-1), ND – not detected, nq – below the quantification limit.

them a variation greater than 50 % (as relative standard deviation) in content between different suppliers was observed.

Msaada et al. [26] evaluated coriander samples and determined values between 1.1 mg·kg-1 to 139.6 mg·kg-1 on dry basis. The differences in the contents in relation to this work (58.3 mg·kg-1 to 479.6 mg·kg-1 on fresh basis or, considering moisture of the sample of 89 %, 530.0 mg·kg-1 to 4360.0 mg·kg-1 on dry basis) were probably related to the different parts of the vegetable being analysed, since the mentioned authors used fruits of coriander instead of leaves and stems. In both works, considerable differences were observed among the suppliers assigned to the provenance of different localities.

Umbu presented the second highest average content of rutin among the vegetables analysed and this was the first time that the analyte was identified and quantified in this fruit. Asparagus was also studied by Solana et al. [27] with 100.0 mg·kg-1 to 2810.0 mg·kg-1 on dry basis being reported, which were the value similar to those found in this study (48.4 mg·kg-1 to 172.1 mg·kg-1 on fresh basis or, considering 94% moisture, 806.7 mg·kg-1 to 2868.3 mg·kg-1 on dry basis).

Pandy et al. [21] quantified rutin in noni produced in Malaysia, obtaining results of 1.66 mg·kg-1 on dry basis. This value was lower than those found in the present study (30.83 mg·kg-1 to 143.6 mg·kg-1 on fresh basis or, considering 88% moisture, 256.73 mg·kg-1 to 1196.7 mg·kg-1 on a dry basis), differences being attributable to factors such as extraction conditions, the cultivar, the maturation level, the climate and the location of vegetable cultivation [3].

Rutin was also determined in blackberries of Turkey by Gundogdu et al. [28], the average content of 1423.0 mg·kg-1 being determined, which was a higher value than those of the present work (17.0 mg·kg-1 to 139.4 mg·kg-1) for blackberries grown in Brazil. Cropping conditions of blackberries, for example, use of fertilizers, irrigation, in addition to intrinsic local-environmental conditions (light, temperature, nutrients) as well as distinct varieties, may account for such differences [29].

Quince and cherry were previously analysed for rutin by Stojanović et al. [30] and Sotelo et al. [31], respectively. The values for quince from different regions of Serbia ranged from 126.4 mg·kg^{-1} to 259.9 mg·kg^{-1}, being higher than those recorded for Brazil samples in this work (48.0 mg·kg^{-1} to 68.5 mg·kg^{-1}). For cherry, originally from New Zealand, the authors found content in the range of 3.0–8.1 mg·kg^{-1}, which was significantly less than determined in this study (42.2 mg·kg^{-1} and 45.1 mg·kg^{-1}).

Correlations between the botanical classification of plants and the presence of rutin, and/or the content of it, were not found. As for the presence of the compound regarding the different parts analysed, we detected rutin in 100 % of samples whose edible parts analysed were: stems + flowers, sprouts, rhizomes, tubers and stems only. In the samples constituted of pulp + peel + seed, rutin was present in 91.2 % of the vegetables. The presence of rutin was lower in samples composed of pulp + seed (37.5 %) and of leaves (8.7 %). In the samples composed of peels or roots, rutin was not found.

Regarding the content of rutin in different parts, the highest average values were observed in samples containing leaves + stems (55.6 mg·kg^{-1}), followed by sprouts (37.4 mg·kg^{-1}) and pulps + peel (33.7 mg·kg^{-1}). However, the variations were very large within the groups, for example, for leaves + stems, where the contents fluctuated between "undetected" (for lettuce, dandelion, red cabbage, arugula and parsley) and 479.6 mg·kg^{-1} (for coriander). These results indicate that there is no overall conformity regarding the quantity present in the plant parts, but that such characteristic is intrinsic for each plant specifically. Thus, the plants with the highest contents can be studied in the future in order to elucidate in which part of the plant rutin is present in highest quantities.

Rutin content regarding consumption

The data acquired were related to normally consumed portions of each vegetable to determine their potential as a source of contribution of

Tab. 3. Estimated mean amount of rutin ingested per portion consumed.

Vegetable	Portion [g]	Rutin in portion [mg]	Vegetable	Portion [g]	Rutin in portion [mg]	Vegetable	Portion [g]	Rutin in portion [mg]
Umbu	200	32.49	Tomato	200	1.11	Jackfruit	200	0.25
Noni	200	19.83	Atemoya	200	0.89	Eggplant	100	0.23
Asparagus	100	15.13	Cocoa	200	0.78	Scarlet eggplant	100	0.23
Blackberry	200	12.12	Pitanga	200	0.73	Cupuaçu	200	0.22
Quince	200	11.65	Jabticaba	200	0.71	Napa cabbage	50	0.21
Cherry	200	8.63	Guava	200	0.66	Potato	100	0.20
Red plum	200	5.10	Nectarine	200	0.65	Leek	50	0.16
Red fig	200	4.77	Lime	50	0.62	Turnip	100	0.16
Graviola	200	4.13	Papaya	200	0.60	Lemon tahiti	50	0.13
Pineapple	200	3.01	Kiwi	200	0.59	Fresh pea	100	0.12
Physallis	200	2.97	Red yam	100	0.57	Watercress	50	0.12
Blueberry	200	2.35	Raspberry	200	0.54	Persimmon	200	0.11
Mangosteen	200	2.32	Peach	200	0.53	Sapoti	200	0.10
Acerola	100	2.26	Grape	200	0.50	Cabbage	50	0.10
Bean sprouts	50	1.87	Tamarind	100	0.49	Coriander	1	0.10
Broccoli	100	1.69	Okra	100	0.43	Cara	100	0.08
Watermelon	200	1.65	Pod	100	0.40	Onion	50	0.05
Orange	200	1.64	Pumpkin Cabotiá	100	0.38	Pink sweet potato	100	0.03
Jenipapo	200	1.59	Mango	200	0.37	Spinach	50	0.02
Tangerine	200	1.40	Key lime	200	0.36	Chives	2	0.01
Apple	200	1.29	Apricot	200	0.36	Basil	1	0.01
Rambutan	200	1.22	Cashew	200	0.34	Red garlic	2	0.00
Mustard	50	1.20	Mandioquinha	100	0.29	Ginger	1	0.00
Cauliflower	100	1.19	Dwarf banana	200	0.27			
Strawberry Albion	200	1.15	Cassava	100	0.26			

The values in brackets next to the vegetables' names are the amount, in grams, that a person consumes considering one portion.

rutin as a bioactive compound in the human diet. Considering the amount of each vegetable that is consumed (portion in a meal) it could be stated that the mass of orange or banana consumed, per serving, will be greater than the mass of garlic, basil or coriander, for example. With this in mind, Tab. 3 presents estimates of the portions that the consumers eat in a meal and the average content of rutin in the portion. We considered the vegetables in natura, emphasizing that the contents may be subject to variations depending on the preparation method of the food and the amount of water incorporated during the processing.

Previously, when just the rutin content present in the plant was observed, samples such as coriander, bean sprouts and basil had accentuated contents (196.6 mg·kg^{-1}, 37.4 mg·kg^{-1} and 27.9 mg·kg^{-1}, respectively). However, when considering the amount ingested by the consumer in one portion, the values are of only 0.1 mg·kg^{-1}, 1.9 mg·kg^{-1} and 0.01 mg of rutin, respectively, since they are consumed in small quantities (1.0 mg·kg^{-1}, 50.0 mg·kg^{-1} and 1.0 g, respectively). In a scenario of the estimated intake per portion consumed, vegetables which enable greater intake of rutin are: 200 g of umbu (32.5 mg/portion), 200 g of noni (19.8 mg/portion), 100 g of asparagus (15.1 mg/portion), 200 g of blackberry (12.1 mg/portion), 200 g of quince (11.7 mg/portion), 200 g of cherry (8.6 mg/portion) and 200 g of red plum (5.1 mg/portion).

It was reported that rutin offers beneficial effects on health, such as antihyperglycemic effects, in doses greater than 5.0 mg per kilogram of body mass per day [5]. Thus, for a 70 kg adult, a minimum intake of approximately 350.0 mg of rutin is required, although this value can vary for each individual according to one's metabolism and bioavailability of rutin [32].

When comparing the portions of fruits and vegetables with other foods present in the diet, it can be observed that there is an extensive range of sources of this flavonoid, which allows its consumption for people who present diversified preferences. A portion (240 ml) of green or black tea, prepared with 2.0 g of the plant, contains, on average, 11.9 mg of rutin [33]. These quantities would be reached when ingesting 72.9 g of umbu, 78.5 g of asparagus, 195.9 g of cranberry or 206.0 g of quince. According to Fratianni et al. [23], the same amount is present in 177.3 g of lentils. Taking into consideration that a balanced diet is made up of different foods and beverages, it is possible to achieve a sufficient intake of rutin to present health benefits.

CONCLUSIONS

In this study, the content of rutin in 117 vegetables that are commercialized in Brazil was determined, its presence being detected in more than 60 % of the samples. The vegetables that stood out because of the high content of the analyte were coriander, umbu, asparagus, noni, blackberry, quince and cherry, with an average content ranging from 43.2 mg·kg^{-1} to 196.6 mg·kg^{-1}. When taking into consideration the portions of the plants usually consumed, it was possible to observe that the fruits and vegetables got close to other sources of rutin. The fruits which could provide the greatest amount were umbu, noni, blackberry, quince, cherry and red plum. Among vegetables, asparagus could provide the greatest amount of rutin. On the basis of the results of this study, it can be suggested that a diversified diet can provide sufficient amounts of rutin to present biological activity with benefits to human health.

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