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Kumquat (*Fortunella margarita*): A Good Alternative for the Ingestion of Nutrients and Bioactive Compounds †

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Abstract: Citrus fruit is preferred in the choice of consumers. Kumquat (*F. margarita*) is an unconventional citrus of increasing consumer interest because of its exotic flavor, and its functional potential that offers health benefits to consumers. It is a fruit traditionally consumed by whole fruit (peel and pulp), giving this fruit a distinctive flavor. For this reason, this study analyzed the physical, chemical, and nutritional characteristics of kumquat (peel and pulp). The physicochemical analysis was performed according to the Adolfo Lutz Institute. Analysis of moisture, ashes, macronutrients, and total dietary fiber was carried out according to AOAC. Minerals were analyzed by inductively coupled plasma optical emission spectrometry. Vitamins C and E, carotenoids and flavonoids were analyzed by HPLC. Phenolic compounds (Folin-Ciocalteu) and antioxidant capacity (DPPH) were determined by spectrophotometry. The kumquat had low pH, soluble solids content and low caloric value. It was a source of dietary fiber, minerals (K, Ca, P, Mg) and carotenoids; the most expressive was α-carotene (661.81 µg 100 g^{-1}). The ascorbic acid concentration was 2326.24 µg 100 g^{-1}. α-tocopherol (569.00 µg 100 g^{-1}) was the most expressive component of vitamin E. There was a presence of apigenin and eriodictyol. The fruit (peel and pulp) has a high concentration of total phenolic compounds (98.55 ± 1.93 mg GAE 100 g^{-1}) and good antioxidant capacity (62%) was found. Kumquat is a good source of fiber and vitamin A, and due to its antioxidant capacity and the presence of other essential and beneficial nutrients for a diet, consumption of kumquat can be suggested to complement the diet. This fruit is a viable food alternative, and its consumption should be encouraged, contributing a source of income, sovereignty, and food security.

Keywords: antioxidant; alternative food; citrus; exotic fruit; phenolics; vitamins

1. Introduction

Citrus fruits are among the most produced and traded food sources in the world [1]. Kumquat is the smallest existing citrus, of Asian origin, specifically China and India, and belongs to the Rutaceae family [2]. The presence of this fruit is reported in rural backyards, in agroecological markets, as well as in the preparation of value-added foods such as jams, jellies, sweets and liqueurs [3,4]. However, it is still a little-known and consumed fruit in Brazil, different from China, where the fruit is native and popularly consumed in nature (peel and pulp). The commercialization of kumquat in Brazil is incipient in some states, being sold in markets or large supermarkets as exotic fruits of high added value or in free markets present in small cities, be it fruit or jellies, cakes, and other products. The kumquat is consumed preferably in natura, whole, peel and pulp included. However, few studies are described in the literature, so far, with the species *F. margarita* [5–8]. The fruit pulp showed antioxidant effects against the prevention of non-transmissible chronic diseases [8], activity against the inhibition of prostate cancer cells [9] and antimicrobial activity [5]. Due to its functional potential, it has increased the interest in the consumption of this fruit by Brazilians.

2. Materials and Methods

The preparation and analysis in kumquat (peel and pulp) were performed in four replicates. The fruits of each replicate were randomly selected for the measurement of length (cm), diameter (cm) and fruit weight (g) using analytical balance (Gehaka, AG200) and pachymeter (Disma, 150 mm). The analyses of pH, soluble solids and titratable acidity were performed according to Adolfo Lutz Institute [10], the lipids by the Soxhlet method, and the total ashes quantified using a muffle (Quimis, model Q320 M, Brazil). The protein was determined by the Kjeldahl [11]. The carbohydrates content was calculated following the equation: [100 − (% moisture + % lipids + % protein + % total fiber + % ash)]. The chemical elements (the minerals calcium-Ca, potassium-K, phosphorus-Pb, magnesium-Mg, sulfur-S, copper-Cu, iron-Fe, zinc-Zn, manganese-Mn, sodium-Na, chrome-Cr and the heavy metals cadmium-Cd, aluminum-Al, nickel-Ni and lead-Pb) were determined by inductively coupled plasma optical emission spectrometry (ICP-OES). The vitamin C, carotenoids and flavonoids were performed in a high-performance liquid chromatography system (HPLC) (Shimadzu, SCL 10AT VP) detector (DAD) (Shimadzu, SPD-M10A); vitamin E used an HPLC system (Shimadzu, SPD-M10A); fluorescence detector (290 nm excitation and 330 nm emission) (RF-10A XL). Each extraction and analysis followed an actor with modifications for vitamin C [12] and vitamin E components (α, β, γ and δ-tocopherols and tocotrienols) [13]. The α-carotene, β-carotene and lutein followed the extraction methodology [14]. The 3-desoxyanthocyanidins (3-DXAs—luteolinidin, apigeninidin, 7-methoxyapigeninidin and 5-methoxy-luteolinidin), flavones (luteolin and apigenin) and flavanones (naringenin and eriodictiol) [15]. The total phenolic compounds were determined using the Folin–Ciocalteu reagent [16]. The antioxidant capacity was determined using methanolic DPPH solution (1.1-diphenyl-2-picrylhydrazyl).

3. Results and Discussion

The biometric analysis of the fruit is shown in Figure 1. An examination of the kumquat reported values for fruit length and diameter from 2.0 and 3.0 cm and weight ranging from 5 to 20 g [17]. The kumquat of the present study had low pH. The authors of [7] found a pH of 4.22, higher than in the present study. The authors of [7], analyzed different citrus fruits, reported the value of soluble solids in kumquat of 21.1 Brix and 8.35 Brix in the 'Tahiti' lemon; the concentration found in the kumquat of the present study—16.41 Brix—was smaller than that reported by the authors. Our result for the soluble solids in kumquat was higher than in [18] with a titratable acidity of 2.43 mg of citric acid, 100 g^{-1} higher than the values found in citrus varieties by [19]. The centesimal composition is shown in the Table 1.

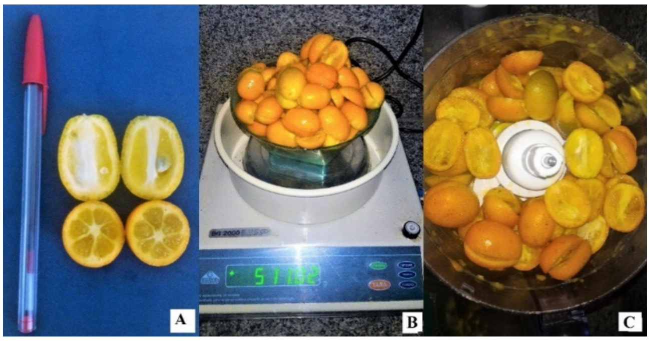

Figure 1. Images of kumquat fruits collected in Brazil. (**A**) longitudinal and cross-section; (**B**) weighing in semi-analytical balance; (**C**) processing. Source: Personal collection.

Table 1. Centesimal composition of kumquat (*F. margarita*) (peel and pulp) collected in Brazil.

Centesimal Composition				
Moisture [1] (g·100 g^{-1})	**Lipids [1] (g·100 g^{-1})**	**Total Ash [1] (g·100 g^{-1})**	**Protein [1] (g·100 g^{-1})**	**Carbohydrates [1] (g·100 g^{-1})**
76.79 ± 0.98	1.18 ± 0.06	3.66 ± 0.18	7.38 ± 0.39	5.23 ± 0.30
Total fiber [2] (g·100 g^{-1})	Insoluble fiber [2] (g·100 g^{-1})	Soluble fiber [2] (g·100 g^{-1})	TEV [3] (kcal·100 g^{-1})	
5.31 ± 0.06	3.28 ± 0.15	2.03 ± 0.09	61.06	

[1] Data expressed as fresh basis, as mean ± standard deviation, [2] Data expressed as fresh basis, as mean ± standard deviation, [3] TEV–Total energy value.

The moisture was lower than that found for orange (*Citrus sinensis*) [1]. The ash, lipids and fiber were higher than orange (*C. sinensis*) [1]. Among the chemical elements, the most expressive in kumquat were K, Ca, Pb and Mg (Table 2). The concentration of AA in kumquat (Table 3) was lower than that observed in *C. sinensis* [1]. The concentration of vitamin C in Citrus is quite varied according to the species and maturation time, and the method of analysis used may also influence the total value of vitamin C. The α-tocopherol was the major vitamin E component found in kumquat.

Table 2. Composition of chemical elements present in kumquat (*F. margarita*) (peel and pulp) collected in Brazil.

Chemical Elements	Concentration (mg·100 g^{-1})
Phosphor	16.94 ± 0.23
Potassium	163.16 ± 3.29
Calcium	64.99 ± 1.41
Magnesium	16.71 ± 0.40
Sulfur	13.92 ± 0.23
Copper	0.07 ± 0.01
Iron	0.30 ± 0.06
Zinc	0.09 ± 0.00
Manganese	0.10 ± 0.00
Sodium	2.63 ± 0.00
Chrome	0.01 ± 0.33
Cadmium	0.00 ± 0.00
Aluminum	0.57 ± 0.33
Nickel	0.00 ± 0.00
Lead	0.00 ± 0.00

Data expressed as fresh basis, as mean of triplicates ± standard deviation.

The total vitamin E concentration found in kumquat was almost three times higher than that found in orange (*C. sinensis*) [20]. There are few studies in the scientific literature relating the concentration of vitamin E in citrus. The most expressive vitamin E compounds is α-tocopherol (569.00 μg·100 g^{-1}), followed by β-tocopherol (66.89 μg·100 g^{-1}) (Table 3) (Figure 2). The α-carotene was the most expressive carotenoid in kumquat (661.81 μg·100 g^{-1}) (Table 3). Among the analyzed flavonoids, apigenin (38,157.30 μg·100 g^{-1}) was detected in a higher concentration in the present study (Table 3); one old study identified eight different classes of flavonoids in *F. margarita* but did not find apigenin in *Fortunella* sp. [21]. Other studies have demonstrated the presence of flavonoids [22,23]. The concentration of total phenolic compounds in kumquat (98.55 ± 1.93 mg GAE·100 g^{-1}) was much lower than the *F. crassifolia* collected in Taiwan, China (229 mg GAE·100 g^{-1}) [8]. The kumquat presented good antioxidant capacity (62%) (Table 3). In general, phytochemicals are present in different parts of the same fruit. As the peel is the part that gives protection to the fruit, it tends to have higher amounts of phenolic compounds and other bioactive compounds compared to the pulp [24].

Table 3. Occurrence and concentration of vitamins, carotenoids and bioactive compounds in kumquat (*F. margarita*) (peel and pulp) collected in Brazil.

Components	Concentration
Vitamin C (mg·100 g^{-1})	
Ascorbic acid	2.32 ± 44.24
Vitamin E (μg·100 g^{-1})	
α-tocopherol	569.00 ± 10.20
α-tocotrienol	35.76 ± 4.03
β-tocopherol	nd
β-tocotrienol	66.89 ± 39.93
γ-tocopherol	4.22 ± 0.13
γ-tocotrienol	nd
δ-tocopherol	nd
δ-tocotrienol	nd
Total Vitamin E	675.87 ± 54.29
Carotenoids (μg·100 g^{-1})	-
α-carotene	661.81 ± 22.76
β-carotene	447.74 ± 19.90
Lutein	173.60 ± 33.61
Sum of carotenoids	1283.15
Vitamin A value (RAE 100 g^{-1}) [1]	129.77
3-desoxyanthocianidins (μg·100 g^{-1})	
Luteolinidin	nd
Apigeninidin	nd
5-methoxy-luteolinidin	nd
7-methoxy-apigeninidin	nd
Flavones (μg·100 g^{-1})	
Apigenin	38,157.30 ± 531.00
Luteolin	nd
Sum of flavones	38,157.30 ± 531.00
Flavanones (μg·100 g^{-1})	
Eriodictiol	36,880.95 ±384.02
Naringenin	nd
Sum of flavanones	36,880.95 ± 384.02
Total phenolics (mg GAE·100 g^{-1})	98.55 ±1.93
Antioxidant capacity *(%)*	62.01 ± 3.41

Data expressed as fresh basis, as an average ± standard deviation. [1] Equivalent of retinol activity, Nd: not detected.

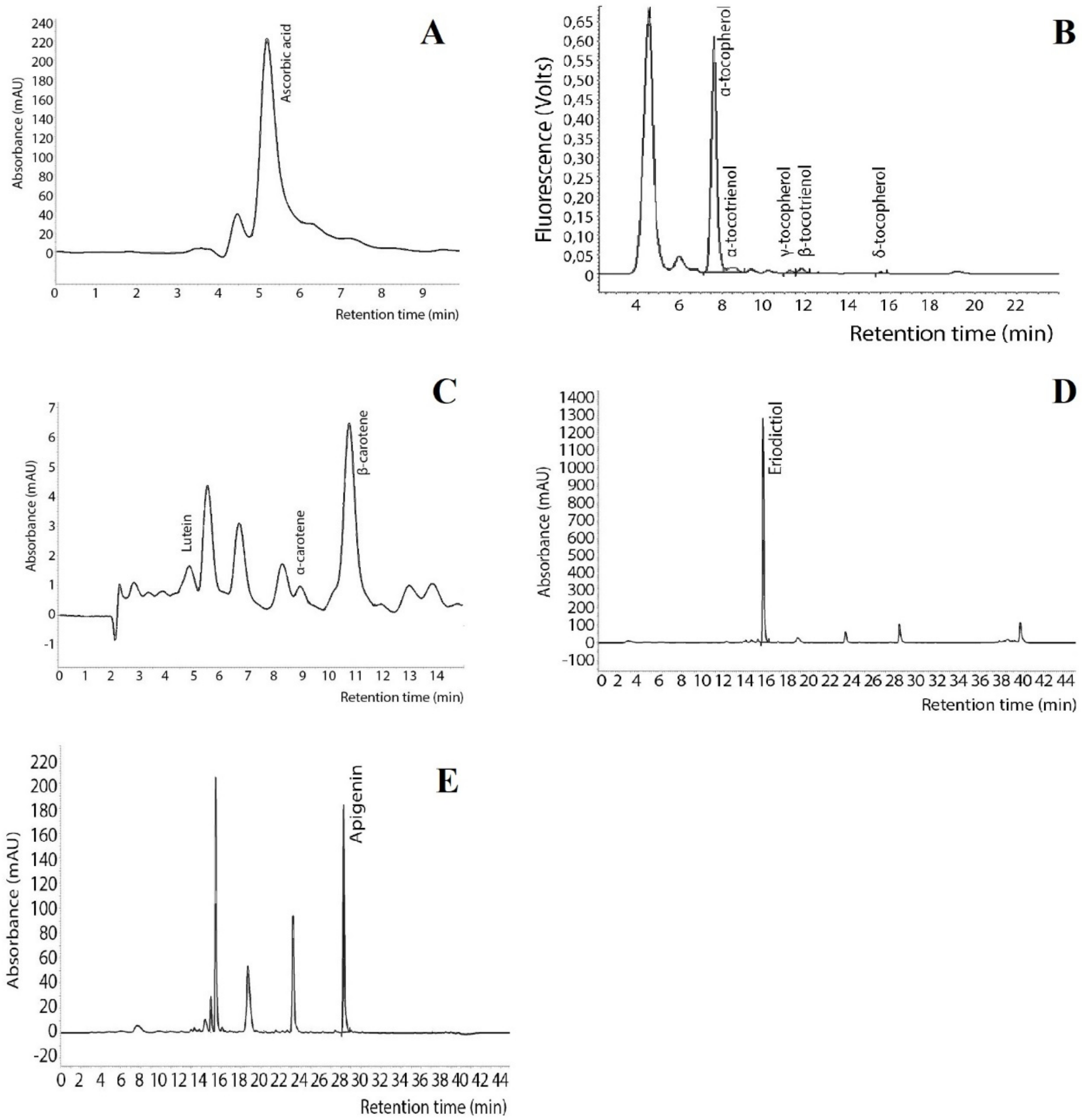

Figure 2. Analysis by HPLC in kumquat (peel and pulp) collected in Brazil. Vitamin C (**A**); vitamin E (**B**); carotenoids (**C**); eriodictiol (**D**) and apigenin (**E**).

4. Conclusions

Kumquat (peel and pulp) is a good source of dietary fiber and vitamins. The fruit contains ascorbic acid, carotenoids, flavonoids (eriodictyol and apigenin) and high concentration of total phenolic compounds, which contribute to its good antioxidant capacity. Thus, Kumquat is a good alternative for planting, marketing and consumption, which can contribute to food and nutritional sovereignty and security and provide a source of income for farming families. Kumquat fruit show good potential for consumption although more scientific researches are needed.

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Conflicts of Interest: The authors declare no conflict of interest.

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