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Nutritional and physicochemical quality in fresh and fresh-cut carrot (*Daucus carota* l.)

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Abstract

Introduction: Carrot (*Daucus carota* L.) is one of the most produced and consumed vegetables by Brazilian population and has been commercialized either fresh or fresh cut. The nutritional quality of carrots after processing may change their chemical composition and physicochemical profile. *Objective*: To determine and compare the nutritional and physicochemical quality in fresh and fresh-cut carrot. *Material* and *Methods*: Fresh and fresh-cut carrots were acquired in Uberlândia, Minas Gerais state, Brazil, and the following parameters were determined: moisture, proteins, lipids, "available" carbohydrates, dietary fiber (DF), ash, total energetic value (TEV), phenolics, vitamin C, carotenoids and other pigments, some physicochemical parameters (pH, titratable acidity, soluble solid and antioxidant activity). All results were analyzed by *t* test at 5% significance. *Results*: The moisture, protein, lipids, carbohydrates (difference), DF, ash, TEV (kcal/100g), phenolics, vitamin C, total carotenoids, lycopene, β-carotene, chlorophyll A, chlorophyll B, antioxidant activity, soluble solids, titratable acidity and pH for fresh carrot were, respectively: 90.0%; 0.6%; 0.2%; 5.1%; 3.3%; 0.8%; 24.2 kcal/100g; 32.8mg%; 21.3mg%; 2.0mg%; 0.0mg%; 2.0mg%; 0.2mg%; 0.0mg%; 38.7%; 12.0 ºBrix; 1.4%; 6.0. For fresh-cut carrot the values were, respectively: 89.8%; 0.6%; 0.1%; 5.7%; 3.0%; 0.8%; 26.1 kcal/100g; 39.9mg%; 18.3mg%; 1.6mg%; 0.0mg%; 1.6mg%; 0.2mg%; 0.0mg%; 24.0%; 12.0 ºBrix; 1.9%; 5.5. *Conclusion*: By analyzing both treatments, one can conclude that fresh carrots have higher nutrient content than fresh-cut carrots. These findings were important and showed that further studies must be made in order to investigate the effect of minimal processing on carrots.

Keywords: Carrot. Minimal Processing. Nutritional Quality. Physicochemical Parameters.

Introduction

The fruit and vegetables industry has contributed to the creation of wealth in Brazil due to its high and diversified production.[1] Current consumer buying trend is for products that fit today's lifestyle and, at the same time, are healthy, practical, convenient, innovative and safe.[2] Along with this contemporary perspective and consumers' demand, minimally processed vegetables (MPV), or fresh-cuts, have emerged.[3] Briefly, MPVs are fruits and vegetables that undergo several previous processing stages (pre-preparation stages) such as selection, cleaning, sorting, sanitizing, centrifugation, peeling, cutting, packaging and storage, without affecting too much the fresh appearance of the vegetable.[4,5]

Minimal processing of fruits and vegetables has been developed in Brazil more consistently from the 1990s, which is a recent activity if compared to the developed countries.[5] However, the MPV market has grown sharply and consolidated in the country over the years.[6] It is worth noting that the main consumers of MPVs are from high income classes, because minimal processing adds value to the product, making it more expensive than fresh foods.[4]

Fresh-cuts are usually more perishable than intact, fresh vegetables due to the respiration rate, microbiological activity, water evaporation and faster texture loss of fruits and vegetables, which may cause sensory (color, aroma, flavor) and nutritional changes.[1]

In general, fruits and vegetables have considerable amounts of bioactive compounds, particularly phenolic compounds, glucosinolates and carotenoids and certain vitamins, especially vitamins C and E.[7,8] Minimally processed vegetables suffer tissue damages that may result in nutritional losses.[9] Various examples of physicochemical changes after minimal processing can be cited, such as ethylene production, water loss and enzymatic browning.[10]

Carrot (*Daucus carota* L.) is a vegetable of the group of roots of the family *Apiaceae* and is considered one of the most common vegetable crops grown in Brazil.[11] From the nutritional point of view, carrot contains "available" carbohydrates, dietary fibers, proteins, lipids, minerals (calcium, magnesium, potassium, sodium, phosphorous, manganese, iron, cupper, and zinc), vitamin C, and carotenoids, especially β-carotene (provitamin A).[12] In addition, carrot is one of the most marketed MPVs and can be found in diverse shapes such as diced cubes, threads, sticks, grated, sliced, and mini carrots (or "cenourete", similar to the American baby carrot, or "catetinho", which are small balls of carrot).[9]

Studies on MPVs are important for indicating intrinsic quality aspects, due to the rising consumption of these produces, especially carrot. Given the above, this research aimed to analyze and compare the nutritional and physicochemical quality of fresh and fresh-cut carrot.

Material and Methods

Fresh carrots (*Daucus carota* L.), cultivar Nantes, were purchased from a commercial establishment located in Uberlândia state of Minas Gerais, which were grown by the same producer in the region. Fresh-cut carrots were obtained from the same fresh sample and processed at a minimally processing establishment located in the same town. Carrots were harvested from November 2013 to September 2014. The production flow chart of fresh-cut carrots consisted of the following steps: selection, prewashing, hand peeling, chlorination, thermal shock in water at 5ºC, machine cutting (AJM, industrial multiprocessor), centrifugation, packaging and storage. Fresh carrots were assumed as "control sample", to be later used for comparison of results with fresh-cut carrots.

Fresh-cut carrots were obtained at the day of conduction of analysis and came from the same fresh carrots sample (before processing). The fresh carrots were grated and packaged in plastic bags using passive atmosphere packaging. The fresh carrots were peeled with a hand peeler and grated with home grater at the time of performance of the tests.

Samples of fresh carrot (about 3.5 kg) and fresh-cut carrot (about 3.5 kg) were transported in previously-cleaned isothermal boxes containing reusable ice packs and sent for analysis at the Laboratory of Foods Bromatology and Microbiology of the Medical School, Federal University of Uberlândia. A completely randomized experimental design was used, as follows: 1 test portion, 1 carrot sample unit (about 7 kg in total = fresh carrots + fresh-cut carrots), 2 treatments (one of fresh carrots and one of fresh-cut carrots), 1 site, 3 analyses (triplicate), with the following factorial schematic design: 1 x 1 x 2 x 1 x 1 x 3.[13-15]

The methods used for determination of proteins, lipids, available carbohydrates, ash, phenolic compounds, vitamin C, total carotenoids (lycopene and β-carotene) and other pigments (chlorophyll A and chlorophyll B) and physicochemical parameters (pH, titratable acidity, soluble solids and antioxidant activity) were performed as described by Da-Paz et al.[13] and Pacheco et al.,[15] using methods consolidated by the Association of Official Analytical Chemists (AOAC) and the Adolfo Lutz Institute, namely: lipid contents were determined by the Goldfish method, using ethylic ether.[16] Ash contents corresponded to the weight of the matter left after incineration in muffle at 550ºC during 6-8 hours.[17]

The micro-Kjeldhal (960.42) method[18] was used to estimate the amount of proteins; the nitrogen value was multiplied by the conversion factor for plant proteins (N x 5.75).[19] The available amount of carbohydrates was determined by the phenol-sulfuric method and expressed in wet basis (g/100g).[20] The available carbohydrates determined by difference were obtained by the sum of the values of moisture, proteins, lipids, ashes, dietary fibers and subtracted from 100.[19] Phenolic compounds were determined by using gallic acid as standard (mg of gallic acid equivalents – GAE per 100g of carrot in wet basis).[21] Determination of vitamin C was achieved by the iodometric method (method 364/IV).[17] Carotenoids (lycopene and β-carotene) and other pigments (chlorophyll A and chlorophyll B) were determined by spectrophotometry.[22]

The antioxidant activity was determined by the DPPH method (2,2-diphenyl-1-picrylhydrazil) by ethanol extraction.[23] For analysis of soluble solids, the method 932.12 was used, and the results were expressed in ºBrix.[18] To obtain titratable acidity, 50ml of distilled water was added for complete maceration of the samples, and five drops of phenolphthalein were added to the sample for subsequent titration with 0.01M sodium hydroxide until a pink color was achieved. The result was expressed in % of citric acid.[17] The pH value was adjusted by the 017/IV and measured by potentiometer. [17]

The moisture content was determined by the weight loss of the sample heated in oven to 65ºC during 48 hours. Dietary fiber was determined by the nonenzymatic-gravimetric method (AOAC 993.21), by which the samples were subjected to precipitation, filtration, drying and determination of proteins and ashes with residues.[18]

The energy was expressed in kilocalories (kcal) and kilojoules (kJ). The energy value (in kcal) was calculated by multiplying the available carbohydrates (by difference) by 4 kcal/g; proteins by 4 kcal/g; and lipids by 9 kcal/g. The energy value (in kJ) was obtained by the following formula: kJ = kcal x 4.184.[24]

The statistical analysis was carried out using the SAEG software, version 9.1. To compare the means of the treatments (fresh and fresh-cut), the non-paired t-test was used, considering a significance level of 5%.

Results and Discussion

Table 1 shows the comparison of the centesimal composition and energy value (kcal/100g and kJ/100g) between fresh carrot and fresh-cut carrot in wet basis. There were no differences ($p>0.05$) between fresh and fresh-cut carrots with respect to the contents of moisture, proteins, available carbohydrates (by difference), dietary fiber, ash and TEV (kcal/100g and kJ/100g). There were differences ($p<0.05$) between the treatments regarding the contents of lipids and carbohydrates (by the phenol-sulfuric method).

Table 1. Centesimal composition (g/100g) and energy value (kcal/100g and kJ/100g) of fresh and fresh-cut carrots (*Daucus carota* L.), wet basis. Uberlândia-MG, 2013-2014.

Centesimal composition	Fresh carrot	Fresh-cut carrot
Moisture	90.0 ± 0.14^{a}	89.8 ± 0.73^{a}
Proteins	0.6 ± 0.02^{a}	0.6 ± 0.03^{a}
Lipids	0.2 ± 0.02^{a}	0.1 ± 0.00^{b}
Available CHO[1]	5.1 ± 0.19^{a}	5.7 ± 0.98^{a}
Available CHO[2]	7.7 ± 0.31^{a}	6.8 ± 0.10^{b}
TDF	3.3 ± 0.14^{a}	3.0 ± 0.26^{a}
Ash	0.8 ± 0.00^{a}	0.8 ± 0.03^{a}
TEV (kcal/100g)	24.2 ± 0.58^{a}	26.1 ± 3.77^{a}
TEV (kJ/100g)	101.4 ± 2.42^{a}	109.8 ± 15.83^{a}

Mean values ± standard deviation; CHO[1]= available carbohydrates determined by difference; CHO[2]= available carbohydrates determined by the phenol-sulfuric method; TDF= total dietary fiber; TEV[3]= total energy value in kcal/100g; TEV[4]= total energy value in kJ/100g. Different lower case letters in same row indicate statistical difference ($p<0.05$, *t*-test).

Table 2 shows the comparison of bioactive compounds between fresh carrot and fresh-cut carrot in wet basis. There were no differences ($p>0.05$) in the contents of vitamin C, chlorophyll B and lycopene between fresh and fresh-cut carrots, but for total phenolic compounds, total carotenoids, chlorophyll A and β-carotene there were differences ($p<0.05$) between the two treatments.

Table 2. Bioactive compounds (mg/100g) of fresh and fresh-cut carrot (*Daucus carota* L.), wet basis. Uberlândia-MG, 2013-2014.

Bioactive compounds	Fresh carrot	Fresh-cut carrot
Total phenolics	32.8 ± 0.48^{b}	39.9 ± 0.66^{a}
Vitamin C	21.3 ± 0.50^{a}	18.3 ± 2.28^{a}
Total Carotenoids, of which:	2.0 ± 0.01^{a}	1.6 ± 0.05^{b}
Lycopene	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
β-carotene	2.0 ± 0.01^{a}	1.6 ± 0.05^{b}
Other pigments, of which:		
Chlorophyll A	0.2 ± 0.01^{a}	0.2 ± 0.0^{b}
Chlorophyll B	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}

Mean values ± standard deviation. Lower case letter in same row indicate statistical difference ($p<0.05$, *t*-test).

Table 3 shows the comparison between the physicochemical parameters for fresh carrot and fresh-cut carrot (wet basis). Among the physicochemical parameters, there was no difference ($p>0.05$) in soluble solids between fresh and fresh-cut carrots. On the other hand, the antioxidant activity, titratable acidity and pH ($p<0.05$) indicated contents reduction when compared to fresh carrots.

Table 3: Physicochemical parameters in fresh and fresh-cut carrot (*Daucus carota* L.), wet basis. Uberlândia-MG, 2013-2014

Physicochemical parameters	Fresh carrot	Fresh-cut carrot
Antioxidant activity (%)	38.7 ± 1.39[a]	24.0 ± 0.91[b]
Soluble solids (ºBrix)	12.0 ± 0.00[a]	12.0 ± 0.00[a]
Titratable acidity (% citric acid)	1.4 ± 0.02[a]	1.9 ± 0.04[b]
pH	6.0 ± 0.07[a]	5.5 ± 0.08[b]

Mean values ± standard deviation. Lower case letters in same row indicate statistical difference ($p<0.05$, *t*-test).

Despite numerous researches on food composition, there are few studies addressing the effects of minimal processing of vegetables, having fresh foods as control.

Firstly, the results for moisture contents, proteins, available carbohydrates (by difference), dietary fibers, ashes and total energy value (kcal and kJ) in the present study did not show a significant difference ($p>0.05$) between fresh carrot and fresh-cut carrot. The results show that some nutritional components of carrots such as moisture, proteins, available carbohydrates (by difference), dietary fibers and ashes resisted to the damage effects caused by minimal processing.

Furthermore, the divergence found between the results for carbohydrates in carrots, obtained by difference and by the phenol-sulfuric method, either for fresh carrot or fresh-cut carrot, can be explained by the analytical errors that added up at each measurement of the centesimal composition components (moisture, proteins, lipids, ash and dietary fiber).[13] The total energy value (in kcal and kJ) did not exhibit significant difference ($p>0.05$) between fresh carrot and fresh-cut carrot.

This study demonstrated that the content of total phenolic compounds found in fresh-cut carrot was higher than the content found in fresh carrot ($p<0.05$). In a research carried out with minimally processed produces,[25] it was found that fresh-cut carrot had a decreased content of total phenolic compounds when compared to fresh carrot. In general, it was expected a decrease of total phenolic compounds after minimal processing, due to vegetable tissue damage.[25] However, it has also been discussed that in certain vegetables there may be an increased content of phenolic compounds after minimal processing when compared to fresh foods, probably due to the kind of cutting and handling (manual or with equipment) used. It is suggested that preparation of the food for minimal processing using appropriate equipment (sharp blade) causes fewer losses of phenolic compounds than using home utensils, e.g., knives and hand grater.[25,26]

Vitamin C content in fresh-cut carrots was the same as that found in fresh carrot ($p>0.05$), although there was a tendency of decrease of this vitamin in fresh-cut carrot (18.3mg/100g) compared to fresh carrot (21.30 mg/100g). Alves et al.[27] found 10mg/100g of vitamin C in fresh-cut carrots, much lower than the amount found in this work (18.3mg/100g). Such variation in vitamin C content may be due to different carrot cultivar, harvest time, soil and climate.[13]

With regard to carotenoids contained in the carrots analyzed, both in fresh and fresh-cut carrot, β-carotene was present in higher quantities. β-carotene has a pro-vitamin A activity, prevents noncommunicable chronic diseases and accounts for the yellow-orange color of carrots.[28]

With respect to other carotenoids and pigments, it was not found significant amounts of chlorophyll A, and lycopene and chlorophyll B were not identified. Regarding the treatments, fresh carrot exhibited greater amounts ($p<0.05$) of total carotenoids and β-carotene compared to the fresh-cut carrot. The β-carotene level in fresh-cut carrot (1mg/100g) that was found in earlier study was numerically close to the amount found in the present work (1.6mg/100g).[27]

Of the physicochemical parameters (antioxidant activity, soluble solids, titratable acidity and pH value), only soluble solids did not indicate difference ($p>0.05$) between fresh carrot and fresh-cut carrot, showing that, in general, these parameters are sensitive to the minimal processing stages. Soluble solids found in both samples (12.0 ºBrix) were numerically close to the values found in fresh-cut pumpkin (12.2 ºBrix).[29]

The pH value of fresh-cut carrot exhibited a decrease ($p<0.05$) when compared to fresh carrot. The pH value of fresh-cut carrot (around 6.0) in a previous study[27] was numerically close to the pH value found in this study (5.5). As a consequence, the titratable acidity of fresh-cut carrot in this study was higher ($p<0.05$) than in fresh carrot. Conversely, in a study conducted by Ayub, Spinardi and Gioppo,[30] the titratable acidity (as expressed in malic acid) in fresh-cut radish samples (considered a root) was lower than in fresh radish.

Post-harvest conditions and processing of vegetables, including minimal processing, usually reduce considerably the contents of vitamin C and carotenoids, influencing adversely the vegetable antioxidant activity.[31] In the present study, the antioxidant activity of fresh-cut carrot (24.0%) was lower ($p<0.05$) than in fresh carrot (38.7%), and this outcome was expected due to the decline of carotenoids and vitamin C (although not significant), which have high antioxidant capacity.[32]

It is worth noting that no studies were found comparing possible changes in centesimal composition, content of vitamin C, carotenoids, soluble solids, titratable acidity (% citric acid), pH and antioxidant activity in fresh and fresh-cut carrot.

Of 18 nutritional and physicochemical quality parameters (moisture, proteins, lipids, available carbohydrates, ash, energy, total phenolic compounds, vitamin C, total carotenoids, lycopene, β-carotene, chlorophyll A, chlorophyll B, antioxidant activity, soluble solids, titratable acidity and pH), eight parameters (about 44% of total) presented changes in relation to fresh carrot, i.e., there was a significant alteration ($p<0.05$) in great part of the parameters assessed in fresh-cut carrots. Fresh-cut carrots exhibited lower values ($p<0.05$) in six parameters analyzed (lipids, total carotenoids, β-carotene, chlorophyll A, antioxidant activity and pH when compared to fresh carrot and higher values ($p<0.05$) in two parameters analyzed (titratable acidity and phenols).

Thus, considering the findings of this study, fresh carrot had higher nutritional value when compared to fresh-cut carrot. The loss of part of the nutritional and physicochemical quality of carrot after minimal processing can be explained by the changes and/or disruption of the plant tissue structure during the pre-preparation stage, causing tissue damage in the vegetable. Such damage is a consequence of peeling and slicing of the carrot samples, resulting in an increased rate of respiration rate, of microbiological activity and water evaporation.[1,25,33]

As a limitation of the present study, only one test portion was tested for one carrot sample, suggesting that the data are only indicative, and further studies should be conducted to determine possible nutritional and physicochemical changes in vegetables, especially carrot, following minimal processing.

Further studies in the field of minimal processing of vegetables are key to determine their quality, especially regarding the nutritional and physicochemical parameters and provide knowledge to health professionals in order that they can offer proper guidance to the population, since these products are very popular in the current food market.

Conclusions

The analyses of two treatments of carrots indicated that fresh carrot has a higher nutritional and physicochemical quality than fresh-cut carrot, since the levels of lipids, total carotenoids, β-carotene, chlorophyll A, antioxidant activity and pH decreased after the minimal processing of carrots.

Vegetables, particularly carrot, have considerable levels of bioactive compounds, especially phenolic compounds and carotenoids, and high antioxidant activity. Therefore, consumption of fresh carrot would be advantageous since the contents of some nutrients and antioxidant potential tend to diminish after minimal processing. However, considering the current consumers' need for convenient, innovative and healthy foods, fresh-cut carrots meet these expectations, in spite of the decreased contents of some nutrients.

Although there are natural quality losses in carrots caused by physiological changes after harvesting, it is suggested that the minimal processing system be optimized and continuously monitored with the use of calibrated, standardized and modern equipment in order to prevent the nutritional and physicochemical losses of this vegetable.

To finalize, more studies addressing the nutritional quality and physicochemical parameters of fresh-cut carrot would be advisable to investigate the effect of minimal processing.

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