Post-harvest quality attributes in carrot produced with organic compost in semi-arid region

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The work was developed to evaluate the effect of organic compound in carrots cultivation of the "Brasilia" cultivar and its influence on the post-harvest phase of this vegetable. Experiments were conducted in a communal kitchen garden, cultivated in traditional irrigated farming system, located in the city of Petrolina - PE. The formulation of the organic compound was made of 40% tanned goat manure and 60% waste vegetable residues. The roots were harvested 90 days after sowing, and were soon taken to the postharvest laboratory for analysis. The two treatments for the cultivation of carrot were evaluated as of harvest to check the influence of the compound on the harvested product through moisture analysis, soluble solids (TSS), total titratable acidity (TTA), TSS / TTA ratio, total carotenoid and firmness. Statistical analysis showed a significant difference between the main physical and chemical characteristics of the carrot at 5% between treatments in the various analyzes carried out, indicating that the use of organic compound in the cultivation of carrot is a promising tool in maintaining quality and nutritional content for post-harvest stage.

Keywords: vegetable; post-harvest; nutritional quality

1. Introduction

The use of chemical fertilizer in carrots is an agricultural practice that brings satisfactory results in terms of productivity. However, one should take into account the quality of the final product, since it is known that its disordered use can harm consumers' health, as well as increase production costs and degrade the local environment.

Currently, there are organic fertilizers employed from various sources in the cultivation of vegetables, especially organic compound, which in addition to providing improved physical and chemical properties to the soil, reduces the need for use of mineral fertilizers and also allows vegetable nutritional increase [1].

The carrot (*Daucus carota* L.) is native to Southeast Asia (semi-arid region of Afghanistan), and is a vegetable of the Apiaceae family, of the tuberous roots group, cultivated on large scale in the Southeast, Northeast and South of Brazil [2].

This root responds to organic fertilization especially in low fertility or compacted soils. However, it is essential that the organic fertilizer be well tanned, once it is released on the beds, and then incorporated before planting [3]. The way to minimize the negative effects of these soils which have low fertility would be the use of decomposed or semi-decomposed organic waste [4].

According to [5], vegetables mostly require large amounts of nutrients due to their short cycles. It is known that the use of organic matter positively influences on the germination and rooting of vegetables. The availability of organic compound close to the root system of plants is a desirable feature. The organic matter in the soil stimulates the growth and nutrient uptake by the plant [6].

The beneficial effects of organic waste to the culture of carrot relate to increased organic matter contente in the soil, allowing greater penetration and root distribution, increase in the aggregation index, aeration and infiltration capacity and water storage [7,8].

The choice of organic waste depends on the availability varying between regions and according to the culture that will be used [9]. In the region of Petrolina - PE, goat and sheep breeding has been developing, with the rearing of goats and sheep for the use of milk and meat respectively. With this regional capability, it is possible to obtain the residues of these ruminant animals with ease and quantity, which leads to the search for alternative uses of this organic waste. Among others, it is incorporated and used in ground cover to improve soils cultivated with vegetables. Experimental results showed that for the culture of carrots, the incorporation of 7t ha-1 of poultry litter provided greater leaf mass (45-73 days after sowing) and greater root mass (115 days after sowing) [4].

According to [10], the supply of mineral nutrients, especially those that the soil does not possess in satisfactory conditions during the growing season, and the accumulation of these nutrients by the plant, can influence the quality of the roots in storage. Therefore, when there is a need to opt for post-harvest storage aspect of life, it is convenient to choose carrots grown in soils more nutritionally balanced, harvested at the proper stage of maturity, whole, firm, without insects and microorganisms attack and free of impurities [11].

The existing carotenoids in carrots, responsible for the orange color of the roots, have provitamin A activity, that is, when ingested by humans, they are transformed into vitamin A, constituting one of the main sources of this vitamin for

the population [12]. However, techniques that enable its production without the use of chemicals are needed, in view of product quality. According to [11], the properties that make fruit and vegetables appreciated as food relate to their appearance, taste, odor, texture and nutritional value.

Considering the importance of the theoretical and practical study of quality parameters for the "Brasilia" carrot grown in the region of Petrolina – PE (Brazil), this study aimed to evaluate the effect of organic compost application and its influence on the physical and chemical characteristics in the post-harvest phase of this such appreciated vegetable.

2. Material and Methods

The roots were harvested in an experimental vegetable garden of Farm Project 'Mandacaru', located in the city of Juazeiro-BA, a region of BSwh type climate, according to Koppen classification, having as geographical coordinates 9º24'45.85 "S and 40º30'53.51"O with an altitude of 374m, in the Lower Basin of the São Francisco Valley, a semi-arid region, under traditional irrigated cultivation, following the production phase during the period from March to May 2016. The cultivar used was 'Brasilia' and after 90 days the roots were harvested, and were then stored in the laboratory for proper analysis of their nutritional quality. The data relating to climate variables collected at the meteorological station of Embrapa, during the execution of the experiment are shown in Table 1.

Table 1 Average temperature, relative humidity, precipitation, solar radiation and insolation from March to June 2016.

Month	T (°C)	RH (%)	Pt (mm)	SR (ly/day)	I (hours)
March	24,6	64,93	2	461	7
April	24,3	63,98	2	501	8,1
May	26,4	57,11	0	558	9,5
June	27,7	56,36	0	623	9,7
Average	25,7	60,5	-	535,7	8,5

T = air temperature; RH = relative humidity; Pt = precipitation; SR = solar radiation; I = insolation.

The carrots were cultivated with organic compound (T1) and without organic compound (T2) for subsequent comparison of treatments. The formulation of the organic compound was made of 40% tanned goat manure and 60% vegetable waste residues, which resulted in an organic material which still passed 45 days being revolved and incorporated for proper application in the beds. The physical and chemical characteristics of the soil in the field before the installation of the experiment (Quartzipsamment soil) are in Table 2

Table 2 Chemical and soil particle size characteristics prior to implantation of the experiment at depths of 0-20 and 20-40 cm.

Variable	Soil 0 – 20 cm	Soil 20 – 40 cm
pH	6,9	6,8
	$cmol_c dm^{-3}$	
Ca^{2+}	3,2	2,5
Mg^{2+}	1,8	1,0
Ca + Mg	5,0	3,50
Al^{3+}	0,05	0,05
$H + Al^{3+}$	2,8	2,47
K^+	0,20	0,16
Na	0,04	0,04
SB	5,24	3,7
CEC	8,04	6,17
	$mg\ dm^{-3}$	
P –Melich	29,77	25,66
	%	
OM	0,6	0,44
V	65	60
	$g\ kg^{-1}$	
Clay	7,8	47,4
Silt	80,5	53,5
Sand	911,7	925,0

OM = Organic matter; CTC = Cation exchange capacity [$Ca^{2+} + Mg^{2+} + Na^+ + K^+ + (H^+ + Al^{3+})$]; SB = Sum of bases; V = Base saturation ($Ca^{2+} + Mg^{2+} + Na^+ + K^+$/CTC) x 100

After harvesting, the roots were immediately transported in sanitized cool boxes to the Agricultural Products Storage Laboratory of the Federal University of the São Francisco Valley (UNIVASF) at the Engineering campus in Juazeiro, Bahia, Brazil.

Methods - Physical and Chemical Analysis

After the treatments referring to the use of the compound and its absence, the carrots were evaluated using the following parameters in the post-harvest phase:

Moisture: Moisture content was determined according to the methodology [13] for fruit, adapted to carrot, when approximately 2 g of sample, cut into thin slices and placed in pre-weighed aluminum crucible was weighed. The crucible and sample were placed together in a vacuum oven for a period of 24h at 70 ° C.

Total soluble solids (TSS): The soluble solids content (° Brix) was determined by direct reading on a countertop refractometer, with temperature correction performed by the proposed table from the [14].

Total Titratable Acidity (TTA): determined by titration according to norms of the [14], with results expressed as % of citric acid.

TSS / ATT Ratio: determined by the ratio between the two variables.

Carotene content: The extraction of carotenoids was performed according to the methodology described by [13]. The determination is based on the extraction of the same in hexane and isopropyl alcohol, with subsequent reading in a spectrophotometer at a wavelength of 450 nm.

Total phenolics: these were determined with the use of gallic acid as standard (mg gallic acid equivalents per 100g of carrots on a wet basis [15].

Antioxidant activity: was determined by DPPH (2,2-diphenyl-1-pircril-hydrazyl) method with the use of ethanol extract [16]. The methodologies for the determination were described as consolidated analysis by the Association of Official Analytical Chemists (AOAC) and the Adolfo Lutz Institute.

Firmness: determined with the aid of a countertop penetrometer through two measurements at the equatorial section of the same root, achieving the required pressure for penetration in Newtons [17]. We also used the same procedure for the replicates that were stored for five days to analyze the postharvest life of carrots.

Data were analyzed by ANOVA, evaluated and compared using the SISVAR 4.2 [18], where the experimental design was completely randomized with three replicates for each physical and chemical analysis. Tukey test, considering a 5% significance level was used.

3. Results and Discussion

The average values of physical-chemical analysis of different carrot treatments are shown in Table 3. Moisture is an important factor in the quality of vegetables, since it provides information about its texture, it also increases the economic value since the vegetable has greater mass, so it is remarkable that the carrots treated organically (T1) showed higher values for this feature.

As for the total carotenoid content it is noticeable that the carrots that received the application of organic compost in its cultivation had higher levels of carotenoid (Table 3), confirming the research by [19] in the evaluation of carrot quality in organic crops, which found higher concentrations of carotenoids when compared to those crops with mineral fertilizer.

Table 3 Physical and chemical characteristics of carrots produced with and without organic composto1, Juazeiro - BA, 2016.

Treatments	Variables				
	Humidity %	**Total Carotenoid (mg/100g)**	**Acidity % (AC)**	**TSS (°Brix)**	**TSS/AC**
T1	89,6a	6,54a	0,23a	7,2a	30,6a
T2	87,8b	4,81b	0,24a	6,4b	24,1b
CV%	0,36	2,82	3,50	2,91	3,75

T1 – With organic compound; T2 – No organic compounds. (Averages followed by the same letter in the columns do not differ by Tukey test at 5% probability)

It is found that the use of the compound allows the root of this vegetable to have a good amount of carotenoids, ideal for post-harvest consumption of this product. According to [20], the more intense the color, the higher the beta-carotene content and higher the nutritional value.

The average results obtained for acidity of carrots were expressed as % of citric acid. The organic acids generally decrease after ripening, harvesting and during storage due to oxidation for energy production in the Krebs cycle [21], there was no noticeable difference between treatments in regards to the acidity level of 5% probability.

The values of total soluble solids concentration represent the acids, salts, vitamins, amino acids, some pectins and sugars in vegetables. They are used as an index of total sugars, indicating the degree of maturity [22]. The average results obtained of TSS were expressed in °Brix. After analysis of variance, significant differences were observed between the two carrot treatments, especially higher value for the carrot treated organically.

According [11] TSS / TTA ratio in plants can be regarded as an evaluation criterion of "flavor", and an increase can mean an increase of flavor, and is indicative of the maturity level. In this particular case, there was a significant difference between treatments, and the application of organic compost increased the TSS / TTA ratio, due to the increase in soluble solids, thus indicating an improvement in the organoleptic characteristics of carrots.

Table 4 shows the comparison of the parameters and results of the bioactive compounds in 'Brasília' carrot variety in the two fertilization treatments.

Table 4 Physico-chemical characteristics of carrots produced with and without[1] organic compound, Juazeiro - BA, 2016.

Treatments	Variables			
	Vitamin C (mg/100g)	**Total phenolics (mg/100g)**	**Betacarotene (mg/100g)**	**Antioxidant activity (%)**
T1	22,4a	31,3a	2,20a	42,6a
T2	19,6b	30,5a	1,96a	38,5b
CV%	2,23	1,82	2,35	3,51

[1]T1 – With organic compund; T2 – Without organic compund. (Averages followed by the same letter in the columns do not differ by Tukey test at 5% probability)

The effectiveness of the antioxidant action of bioactive compounds depends on their chemical structure and concentration of these phytochemicals in the food. According to [23] the content of these phytochemicals in vegetables is largely influenced by genetic factors, environmental conditions, in addition to the degree of ripeness, variety of vegetable and growing conditions. It is evident therefore, that the intensity of antioxidant activity of vegetables, especially the 'Brasilia' carrot variety is similar to that reported in other studies. Several factors related to the cultivation of vegetable, like climate and soil conditions, influence the profile of phenolic compounds of vegetables and consequently its antioxidant action.

Physical measurements are highlighted in Table 5. Note that the average weight of carrots treated with the organic compound was statistically higher than those that have not been subjected to organic treatment; this result is important because it demonstrates that it is possible to obtain higher profits since these are sold on weight. However, the length and diameter showed no significant difference between treatments at 5% significance level.

Table 5 Measurements of the physical parameters of carrots with (T1) and without (T2) organic treatment during post-harvest phase of the "Brasilia" carrot.

Treatments	Variables			
	Weight (g)	Length (mm)	Diametre (mm)	Firmness (N)
T1	126,5a	135,7a	33,2a	98,6a
T2	83,8b	137,5a	30,2a	93,8b
CV%	18,77	9,05	10,64	3,11

(Averages followed by the same letter in the columns do not differ by Tukey test at 5% probability)

The firmness of vegetables decreases with maturity and it is a physical characteristic which interferes with consumer acceptability of the roots. This characteristic is obtained by employing resistance gauges or texture, the penetrometer machine being the most used. After compression of the vegetable, a measurement which equals the force needed to overcome the resistance of the plant tissue is obtained [17]. Note that there was no significant difference between treatments at 95% confidence level, and that organically treated carrots had higher stiffness values having thus greater crispness, ie a better texture.

The main variables used to determine the carrot post-harvest quality are firmness, soluble solids, weight loss and the external and internal appearance. But the firmness indicates the direct acceptance of the product by the consumer, weight loss and the carrot's own external appearance provides indication of the potential post-harvest life of this vegetable.

Table 6 states the firmness values of the "Brasilia" carrot over a five days post-harvest life of this vegetable, with no statistical difference in the first two days; however, from the third day there is a statistical difference between treatments. Observations showed that the treatment with organic compound remained at statistically adequate firmness, whereas treatment with no organic compound decreased considerably.

Table 6 Carrot firmness assessment over five days post-harvest life.

Treatment	Days (Firmness N)				
	D1	D2	D3	D4	D5
T1	96,8aA	92,3aA	89,1aA	89,0aA	88,8aA
T2	95,2aA	91,4aA	88,4bA	87,8bA	84,0bA
CV% = 3,88					

(Averages followed by the same letters, lowercase and uppercase lines in columns, do not differ by Tukey test at 5% probability).

4. Conclusion

The application of organic compost in the cultivation of "Brasilia" cultivar carrots through the evaluations of moisture, carotenoid content, soluble solids, TSS/AC, weight and strength characteristics showed better quality aspects when compared to carrots which did not undergo organic treatment.

The increase in concentration of soluble solids and the increase of the TSS/ATT ratio in the organic treatment indicates an improvement in the organoleptic characteristics.

The average values of total carotenoids were more significant for carrots treated organically, showing better nutritional characteristics. The significant levels of bioactive compounds for carrots produced with organic compound were significant in the face of those produced with no compound.

Regarding root firmness feature in post-harvest life, the treatment which received application of the organic compound was more effective, making the application of this compound recommendable for this important vegetable.

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