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TEXTURE EVALUATION AFFECTED BY PHYSICAL CHARACTERISTICS OF CARROTS DURING STORAGE

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ABSTRACT Texture is one of the most important factors that determine consumer choices among different products. Texture is a sensorial parameter, measured indirectly by imitative tests that are the combination of different tests that provide mechanical properties of a product. These properties can provide information essential to optimize postharvest procedures, such as handling, transport and storage of agricultural products that suffer alterations during the shelf-life, due to temperature and relative humidity conditions during storage and physical aspects of the product. Thus, the objective of this work was to evaluate the influence of physical characteristics on the texture of carrots (*Daucus carota* L.) cv. Brasília during storage. Carrots with conic shape type were classified by means of surface-volume ratio values, in three different classes: short, average and long (0.1214, 0.0847 and 0.0710 $mm^2\ mm^{-3}$, respectively). The roots were stored in climatic chambers at temperatures of 10, 20 and 30 ºC, and air relative humidity of 45, 65 and 95 %, during 120 h. Texture was analyzed through penetration test during 10 s using a probe of 1.0 cm of diameter with a force of 4 N and a loading rate of 10 mm s^{-1}. Surface-volume ratios were calculated by means of the dimension characteristics of the roots, with the aid of a digital caliper. It presented significant influence on the texture. Short carrots obtained the lowest resistance to penetration force during storage. All classes studied at temperature of 10 ºC and relative humidity of 95 % maintained texture at a good commercialization value.

Keywords: Surface-volume ratio, *Daucus carota* L., rheological properties.

INTRODUCTION

Nowadays, the market demands quality. Appearance (size, shape, color, integrity), flavor, odor and texture of foodstuffs are the main attributes evaluated by the consumer. To assure this market, post-harvest technologies are required (handling, processing, storage and transport), in which are vital for the production chain (Chitarra and Chitarra, 1990).

Fruits and vegetables remain alive after harvest, maintaining active all its biological processes. For this reason and due to the high moisture content, these products are highly perishable. In order to increase conservation time and reduce post-harvest losses, it's important to know and utilize adequate handling procedures during harvest, storage and commercialization.

According to Abbott (1999), the principal rheological tests to evaluate texture in foodstuffs include penetration, compression, shear and relaxation. These tests provide information that can aid industry to develop and improve machinery to process the products, as well to optimize handling operations, storage and transport (Santos, 2004). In addition, texture alters and it is a function of the storage conditions, as well as shape, size and components of agricultural products.

Low temperature and high relative humidity increases the commercialization period of vegetables. Such methods of storage are, in general, considered effective to diminish respiration rates of fresh vegetables, maintaining the quality of these products (Baxter and Waters Jr., 1990). However, singularities of a product, such as surface-volume ratio, nature of the protective surface and physical integrity also determinate the water diffusion rate of the product to the environment (Matos et al., 1997).

Thus, the aim of this work was to study the influence of physical characteristics over the texture properties of carrots (*Daucus carota* L.), cv. Brasília, during storage.

MATERIALS AND METHODS

The present work was conducted in the Laboratory of Physical Properties and Quality Evaluation of Agricultural Products at the National Grain Storage Training Center – CENTREINAR, Federal University of Viçosa, Viçosa, MG, Brazil.

Carrots (cv. Brasília) obtained from a commercial plantation located at São Gotardo, Minas Gerais state. The carrots were submitted to a pre-cleaning and strict classified accordingly to its shape and size, mechanical damage, cracks, bifurcation, plagues, diseases and others. The roots were selected with conic type shape, of three different sizes: short (10 to 14 cm), average (15 to 20 cm) and long (20 to 25 cm).

Once selected, carrots had their aerial part eliminated with the aid of a scissor, and later conditionated in metallic perforated trays to allow airflow. Afterwards they were stored in climatic chambers with temperature and relative humidity controlled. The temperatures used were 10, 20 and 30 ºC and relative humidity of 45 ± 3 % (low); 65 ± 5 % (average); and above 95 % (adequate to storage). The analysis was made immediately after harvest and daily until the sixth day of storage (120 h).

In order to calculate the surface-volume ratio (Equation 1), the dimensions characteristics were obtained with the aid of a digital caliper.

$$R = \frac{S}{V} = \frac{3\left(D + \sqrt{D^2 + h^2}\right)}{Dh} \qquad (1)$$

In which:

h: length, mm;

D: diameter, mm;

S: carrots surface area, mm^2; and

V: carrots volume, mm^3.

Roots texture were analyzed in a universal testing machine, *TA.HD Texture Analyser*, *Stable Micro Systems*, with the software *Texture Expert for Windows*®, through the resistance to penetration test (Figure 1). These were made in triplicates, using the following parameters: a probe with a radius of 5 mm, penetration force of 4 N and loading rate of 10 mm s^{-1}. After penetration test, the force was kept constant and registered during 10 seconds.

Figure 1. Illustration of the penetration test.

RESULTS AND DISCUSSION

Storage at 10 ºC

The results from the maximum penetration force can be observed in Table 1.

Table 1. Average values of maximum penetration force (N) in carrots of short, average and long classes stored at 10 ºC and low (45 %), average (65 %) and high (95 %) relative humidities, during storage.

Classes	Storage time (hours)					
	0			24		
	45 %	65 %	95 %	45 %	65 %	95 %
Short	279.88b	270.87b	287.58b	310.26b	287.01b	299.38b
Average	356.94a	373.47a	357.30a	369.09a	389.61a	380.75a
Long	295.27b	313.09ab	337.85ab	345.88ab	331.81a	327.04b
	48			72		
Classes	45 %	65 %	95 %	45 %	65 %	95 %
Short	337.38a	293.09c	301.48b	343.52ab	294.60b	305.80b
Average	386.31a	397.96a	365.11ab	392.09a	346.37ab	383.34a
Long	349.33ab	346.08a	344.95ab	358.76a	352.53a	378.01a
	96			120		
Classes	45 %	65 %	95 %	45 %	65 %	95 %
Short	345.91b	334.80a	357.18a	350.65a	360.38a	350.65a
Average	404.73a	401.34a	423.20a	466.81a	457.92a	424.26a
Long	383.24a	378.59b	379.16a	435.19a	392.58a	395.33a

Average values followed by the same letters at the column, at each storage condition, do not differ among each other, at 5 % of probability through Tukey test.

From these results, it can be noticed that the differences of maximum penetration force are significant between the carrots classes, except on storage time of 120 h. Also, throughout storage time, the maximum penetration force values of short class were inferior to the remaining classes. These results, also observed by Calbo and Nery (1995), evidences that rapid loss of firmness and the appearance of stains and wrinkles are influenced by size and, consequently, by surface-volume ratio of short class carrots.

It can be observed that the final values of maximum penetration force from the three carrot classes increased during storage. The carrots from average and long classes provided a higher resistance to the penetration test, due to its higher elasticity granted by the increase of moisture loss during storage. This result can be explained by the wrinkled tissues, in which gives a more elastic behavior to the carrots, resulting in a more difficult skin to be penetrated. Such wrinkles are due to dehydration, also reported by Hidalgo et al. (1997), cited by Artés and Artés-Hernández (2003), and Lurie and Crisosto (2005).

The three carrot classes stored at temperature of 10 ºC and at high relative humidity satisfactory preserved its texture during the period analyzed.

Storage at 20 ºC

Table 2 presents the results of maximum penetration force during storage for short, average and long carrot classes during storage in low, average and high relative humidities.

Table 2. Average values of maximum penetration force (N) in carrots of short, average and long classes stored at 20 ºC and low (45 %), average (65 %) and high (95 %) relative humidities, during storage.

	Storage time (hours)					
Classes	0			24		
	45 %	65 %	95 %	45 %	65 %	95 %
Short	280.29a	293.09a	268.56b	257.01b	285.11a	297.90a
Average	323.99a	327.89a	326.44a	356.17a	332.02a	345.32a
Long	318.13a	299.59a	306.61ab	303.28ab	333.87a	346.10a
Classes	48			72		
	45 %	65 %	95 %	45 %	65 %	95 %
Short	265.42a	277.86a	239.90b	289.10b	266.69b	221.92
Average	326.54a	359.71a	330.71a	377.84a	442.68a	317.35a
Long	324.88a	375.13a	304.71ab	351.17ab	326.59a	300.39a
Classes	96			120		
	45 %	65 %	95 %	45 %	65 %	95 %
Short	348.69b	311.90b	282.92a	283.09b	304.74ab	223.63
Average	450.19a	455.31a	291.53a	497.22a	486.67a	350.82
Long	373.72b	372.65a	327.61a	452.71a	426.25a	277.31ab

Average values followed by the same letters at the column, at each storage condition, do not differ among each other, at 5 % of probability through Tukey test.

It can be observed through Table 2 that during the experiment, the differences of maximum penetration force were significant among the carrot classes. The values of maximum penetration force of carrots from short class kept below than the remaining classes. Carrots from average and long classes possess higher resistance to maximum penetration force due to its mass loss during the observed period.

The average values of maximum penetration force of carrots from short class stored at low, intermediate and high relative humidity were respectively 287.26, 289.89 and 255.80 N; carrots from average class stored at low, intermediate and high relative humidity presented values of 419.01, 405.75 and 327.02 N; for carrots of long class these values were 353.98, 355.68 and 310.45 N for low, stored at intermediate and high relative humidity, respectively. It can be noticed that, in general, the values of maximum penetration force of carrots at all conditions studied increased during storage. These results can be due to the fact that the carrots becomes wrinkled, leading the product to a more elastic behavior, resulting in a more difficult tissue to be penetrated. The wrinkle occurs due to dehydration.

Storage at 30 ºC

The results of the maximum penetration force of carrots stored at 30 ºC are shown in Table 3. From this table it can be concluded that the surface-volume ratio from the three classes of carrots presented influence upon the average values of texture during storage.

Table 3. Average values of maximum penetration force (N) in carrots of short, average and long classes stored at 30 ºC and low (45 %), average (65 %) and high (95 %) relative humidities, during storage.

	Storage time (hours)					
Classes	0			24		
	45 %	65 %	95 %	45 %	65 %	95 %
Short	332.20a	306.82a	270.57a	280.92b	277.26b	287.58b
Average	315.05a	343.83a	265.77a	414.21a	381.76a	388.19a
Long	342.14a	323.51a	324.52a	387.27a	345.08ab	344.70ab
Classes	48			72		
	45 %	65 %	95 %	45 %	65 %	95 %
Short	271.45b	311.53b	292.22b	257.45b	344.42b	293.62a
Average	450.47a	418.16a	373.93a	453.64a	422.00ab	359.75ab
Long	435.35a	404.69a	341.15ab	426.70a	462.90a	299.21a
Classes	96			120		
	45 %	65 %	95 %	45 %	65 %	95 %
Short	273.30b	327.78a	327.78a	274.05b	359.72b	268.49b
Average	487.62a	322.72a	322.72a	525.97a	544.28a	373.04a
Long	451.79a	296.62a	296.62a	518.36a	493.18a	321.74ab

Average values followed by the same letters at the column, at each storage condition, do not differ among each other, at 5 % of probability through Tukey test.

The maximum penetration force at all experimental conditions increased during storage. The values of maximum penetration force for carrots of short class stored at low, intermediate and high relative humidity were respectively 281.56, 352.32 and 290.04 N. For carrots of average class these values were 531.55m 405.45 and 347.23 N, and for carrots of long class were 503.76, 387.66 and 321.33 N.

CONCLUSION The carrots from short class presented highest resistance to penetration force than carrots of average and long classes. The values of maximum penetration force, in general, increased during storage, being that a more elastic behavior of carrots was the reason for this trend.

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