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Influence of the type of packaging on textural properties of minimally processed yellow Peruvian roots[1]

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ABSTRACT

The textural properties of minimally processed products indicate its quality, and the package is fundamental to maintain the conservation of these foods. The aim of this study was to evaluate texture alterations that occur during the storage period of minimally processed yellow Peruvian roots, using texture profile analysis (TPA) and relaxation, in function of four types of plastic packaging, combined to refrigeration. The roots were selected, sanitized, peeled and sliced. The processing continued with final sanitization, rinsing and immersion in ascorbic and citric acid solution. The slices were centrifuged and packed in expanded polystyrene trays covered with PVC film, and in high-density polyethylene bags (HDPE), polypropylene bags (PP) and multilayer polyolefin bags for vacuum, and stored at 5 ± 2 ºC and 90 ± 5% relative humidity during 12 days. For the TPA, the parameters of interest were hardness and adhesiveness, automatically calculated from the force curves (F) x time (s). For modeling the relaxation process, the generalized Maxwell model was used. The slices packed in PP and vacuum showed higher hardness and normalized force in the balance (0.7502 and 0.7580, respectively), indicating that they were more elastic, better preserving the quality during storage than slices packed in other packaging.

Key words: *Arracacia xanthorrhiza*, mathematical modeling, modified atmosphere, relaxation, texture profile analysis

RESUMO

Influência do tipo de embalagem sobre as propriedades texturais de batatas baroa minimamente processadas

As propriedades texturais dos produtos minimamente processados indicam a sua qualidade, sendo a embalagem fundamental para manter a conservação destes alimentos. Objetivou-se com este trabalho avaliar as alterações de textura que ocorrem durante o armazenamento das batatas baroa minimamente processadas através da análise do perfil de textura (TPA) e relaxação, em função de 4 tipos de embalagens plásticas, combinadas à refrigeração. As batatas baroa foram selecionadas, lavadas, sanitizadas, descascadas e cortadas em rodelas. O processamento prosseguiu com sanitização final, enxágue e imersão em solução de ácido ascórbico e ácido cítrico. As rodelas foram centrifugadas e acondicionadas em bandejas de poliestireno expandido revestidas com filme de PVC e em sacos de polietileno de alta densidade (PEAD), de polipropileno (PP) e de poliolefina multicamadas para vácuo e foram mantidas a 5 ± 2 ºC e 90 ± 5% de umidade relativa, durante 12 dias. Para o TPA, os parâmetros de interesse foram dureza e adesividade, calculados a partir das curvas de força (N) x tempo (s). Para a modelagem da relaxação utilizou-se o modelo generalizado de Maxwell. As rodelas acondicionadas nas embalagens de PP e à vácuo apresentaram valor mais elevado de dureza e maior força normalizada no equilíbrio (0,7502 e 0,7580, respectivamente) indicando que foram mais elásticas, preservando melhor a qualidade durante o armazenamento que as rodelas acondicionadas nas demais embalagens.

Palavras-chave: *Arracacia xanthorrhiza*, modelagem matemática, atmosfera modificada, relaxação, análise do perfil de textura.

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INTRODUCTION

For fruits and vegetables consumed *in natura*, texture and color are the most important quality attributes for market value definition (Liu *et al*., 2009).

Factors that affect texture can substantially change after harvest, due to intercellular adhesion change, conversion of starch into sugars, loss of water and cellular wall force (Toivonen & Brummel, 2008). In minimally processed products, several handling techniques and conservation treatments are applied to reduce texture changes, like refrigerated conservation and use of plastic wrap.

Food texture can be measured by physical tests: punching, penetration, compression, shearing and relaxation, allowing the gathering of data related to consistency and resistance of vegetable tissues by the application of any force and the specific deformation or total test time (Bourne, 2003).

Relaxation is an important test for food texture evaluation, usually used for the study of the viscoelastic behavior of biological materials (Cespi *et al*., 2007), and the modeling of a mathematical instrument is basic for analysis of this behavior (Del Nobile *et al*., 2007; Fustier *et al*., 2009).

According to Resende & Corrêa (2007), specific models can satisfactorily describe the variation of rheological parameters during food ripening, providing not only practical texture rates, but also underlying characteristics to processes that occur during storage.

Other methods have been developed to determine food texture properties, being worth highlighting the Instrumental Texture Profile, which has been efficiently applied for a large food scale. The Instrumental Texture Profile Analysis (TPA) simulates the conditions to which food is submitted along the mastication process and is offered as a way of helping food researchers to obtain descriptive and quantitative sensorial data regarding texture characteristics.

Thus, the aim of this study was to evaluate the texture alterations that occur during the storage period of minimally processed yellow Peruvian roots by texture profile analysis (TPA) and relaxation, using four types of plastic packaging, combined to refrigeration during storage.

MATERIALS AND METHODS

The present study was developed in the Laboratory of Physical Properties and Quality Evaluation of Agricultural products of the National Grain Storage Training Center (CENTREINAR), and in the Post-harvest Laboratory, of the Phytotechnology Department and Minimum Processing Unit, both at the Federal University of Viçosa, UFV (MG, Brazil).

We used yellow Peruvian roots from cultivar *Amarela de Carandaí*, obtained at the Central Food Supply (Ceasa, MG, Brazil). The tubercles with damages, visible deformations or diseases were removed to obtain a homogeneous product.

The roots were selected, washed in running water with neutral detergent to remove dirt. Subsequently, they were taken to the minimum processing room, refrigerated at 18 ± 1 °C, and sanitized in solution with 200 mg L^{-1} active chlorine, for 15 min. Next, they were peeled and manually cut into ± 1 cm thick slices and immediately placed in frozen water. For final sanitization, the slices were immersed in a solution containing 200 mg L^{-1} active chlorine, at 5 ± 2 °C, for 15 min, with subsequent rinsing in solution containing 3 mg L^{-1} active chlorine, at 5 ± 2 °C for 15 min and immersed in a 3% ascorbic acid solution and 3% citrus acid for 5 min. Water excess was removed by centrifugation at 2000 rpm for 15 s and the slices were conditioned in the following packaging types: expanded polystyrene trays covered with 16 µm-thick polyvinylchloride (PVC) film; 10 µm-thick high density polyethylene (HDPE) packaging bags; 20 µm-thick polypropylene (PP) packaging bags and 70 µm-thick multilayer polyolefin vacuum bags. The samples were maintained at 5 ± 2 ºC and 90 ± 5% of relative humidity for a period of 12 days in a biochemical oxygen demand (B.O.D.) incubator.

The texture profile analysis was carried out according to Beléia & Pereira (2004), using a texture analyzer, model TA.HD (Stable Micro System), also known as texturometer. The samples were pressed at 20% of the initial height using compression with constant speed of 0.02 m min^{-1} with an aluminum cylinder of 100 mm diameter. The interest parameters were hardness and adhesiveness, which were automatically calculated by the software program Texture Expert for Windows® from force curves (N) x time (s) produced during the test.

The experiment was delineated in four groups, containing the following packaging types: 1) expanded polystyrene trays covered with polyvinylchloride film (PVC); 2) high-density polyethylene (HDPE) packaging bags; 3) polypropylene (PP) packaging bags; and 4) multilayer polyolefin (PML) packaging bags for vacuum. The groups were subdivided based on chronological evaluation (from 0 to 12 days) in a completely randomized delineation with four replications. The data were analyzed by analysis of variance and regression. To compare means of qualitative factor, Turkey's test was used, at 5% significance level. For the quantitative factor, models were chosen based on significance of regression coefficients using t test, coefficient of determination (R^2) and biological behavior.

The relaxation test was also carried out using the texturometer. A cylindrical flat probe was used, with 100 mm diameter, at a test speed of 0.02 m min^{-1} and constant force of 4 N. For the relaxation curve modeling, the generalized Maxwell model was employed, equation 1:

$$\sigma(t) = \sigma e + A_1 \exp\left(\frac{-t}{\tau_1}\right) + A_2 \exp\left(\frac{-t}{\tau_2}\right) + A_3 \exp\left(\frac{-t}{\tau_3}\right) \quad (1)$$

where:
σ (t): force normalized at time t, dimensionless;
σe: force normalized at balance (t = ∞), dimensionless;
A_1, A_2, A_3: model constants, dimensionless;
t: time, s; and
τ_1, τ_2, τ_3: relaxation time, s.

In order to verify the adjustment degree of models to describe the relaxation of yellow Peruvian root slices, the magnitudes of determination coefficient (R^2), relative mean error *(P)* (Equation 2) and standard deviation estimates were used (SE) (Equation 3).

$$P = \frac{100}{n} \sum \frac{|Y - \hat{Y}|}{Y} \quad (2)$$

$$SE = \sqrt{\frac{\sum (Y - \hat{Y})^2}{GLR}} \quad (3)$$

where:
Y: experimentally observed value;
$\hat{Y}$: value estimated by model;
n: Number of data observed; and
GLR: Degrees of Freedom of models (number of parameters of model minus one).

RESULTS AND DISCUSSION

The texture attributes of yellow Peruvian root slices of the four packaging bags studied are presented in Table 1, according to TPA data. The packaging bags presented statistical difference for hardness.

Figure 1 shows the evolution for hardness (a) and adhesiveness (b) values of slices along storage.

Regarding hardness, a decrease was observed in all packaging bags, and slices conditioned in PP and vacuum packaging bags presented higher hardness value, which allows inferring that at the sensory level, greater intensity force is required to compress food in mouth between molars compared to slices conditioned in other packaging bags.

Nunes *et al*. (2011), in a study with minimally processed yellow Peruvian roots, treated with different antioxidants and stored at 5 ºC for fifteen days, also verified reduction of hardness of slices during storage. According to Chitarra & Chitarra (2005), hardness is associated with the force required for the product to reach a given deformation, giving an idea of cell structure transformations, cell cohesion and biochemical alterations, occurred during the product useful life as a consequence of loss of turgor and/or action of cell wall hydrolytic enzymes.

The adhesiveness profile increased (in module) as the estimate for slices conditioned in vacuum packaging bags was lower, and for slices conditioned in PVC, it was higher at the respective storage times, requiring more work to separate the compression probe from the sample. According to Junqueira *et al*. (2010), the adhesiveness increase is possibly associated with microbial growth in the sample surface. They noticed that, from day 6, minimally processed cassava sticks were sticky during handling, showing high correlation with the UV fluorescence test, detecting presence of pseudomonas.

Table 1: Result of the Texture Profile Analysis (TPA) of yellow Peruvian root slices conditioned in packaging bags studied during storage

Storage days	**Hardness**			
	PVC	**HDPE**	**PP**	**VACUUM**
0	315.0318 a	315.0318 a	315.0318 a	315.0318 a
2	220.6889 b	250.5661 ab	269.8416 ab	307.3811 a
4	208.7798 ab	190.6594 b	276.8678 a	261.0950 ab
6	245.7050 ab	174.3953 b	268.1622 a	254.5728 ab
8	201.0979 ab	162.0381 b	273.0244 b	261.6061 b
10	212.9892 a	177.3492 a	236.3736 b	216.0967 b
12	227.4100 a	178.4967 a	242.5564 b	234.3039 b
	Adhesiveness			
0	-1.9749 a	-1.9749 a	-1.9749 a	-1.9749 a
2	-0.1978 a	-0.1400 a	-0.1072 a	-0.1217 a
4	-0.2333 a	-0.1400 a	-0.1117 a	-0.1217 a
6	-2.1000 a	-0.1550 a	-0.0927 a	-0.1320 a
8	-0.2445 a	-0.1652 a	-3.0741 a	-0.1556 a
10	-0.2617 a	-0.2117 a	-1.4561 a	-0.1431 a
12	-0.2000 a	-0.2240 a	-0.1885 a	-0.1583 a

For the same variable, means followed by same small letter in line do not differ statistically by Tukey‘s test at 5% significance level.

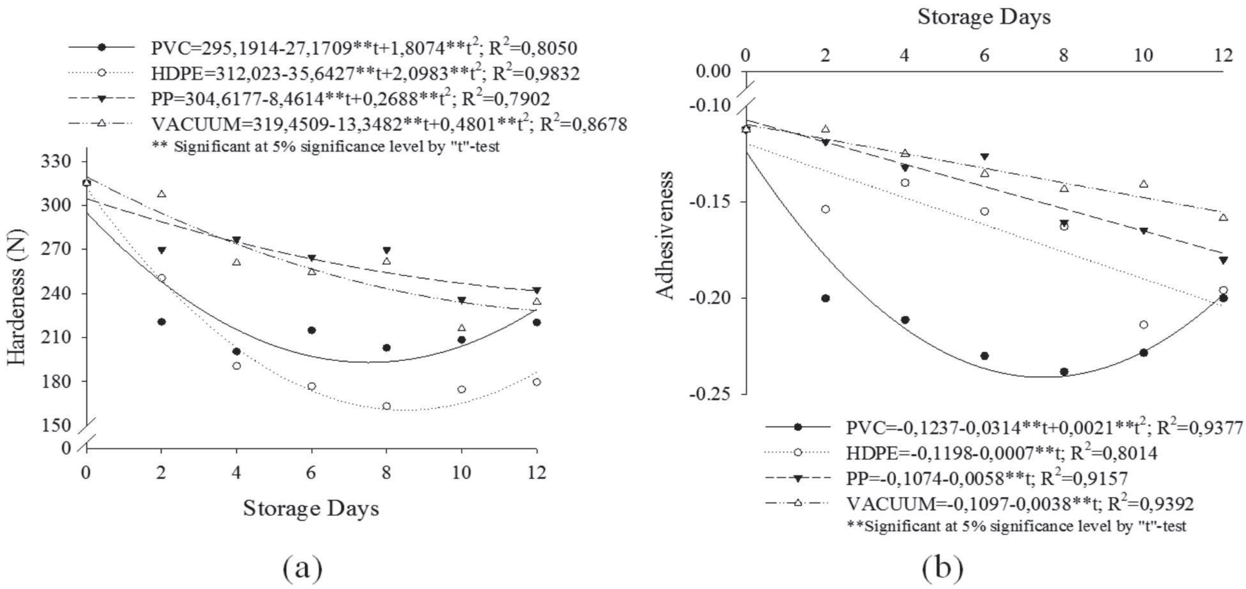

Figure 1: Observed values for the attributes hardness (a) and adhesiveness (b) in yellow Peruvian root slices conditioned in the packaging bags studied (PVC, HDPE, PP and VACUUM).

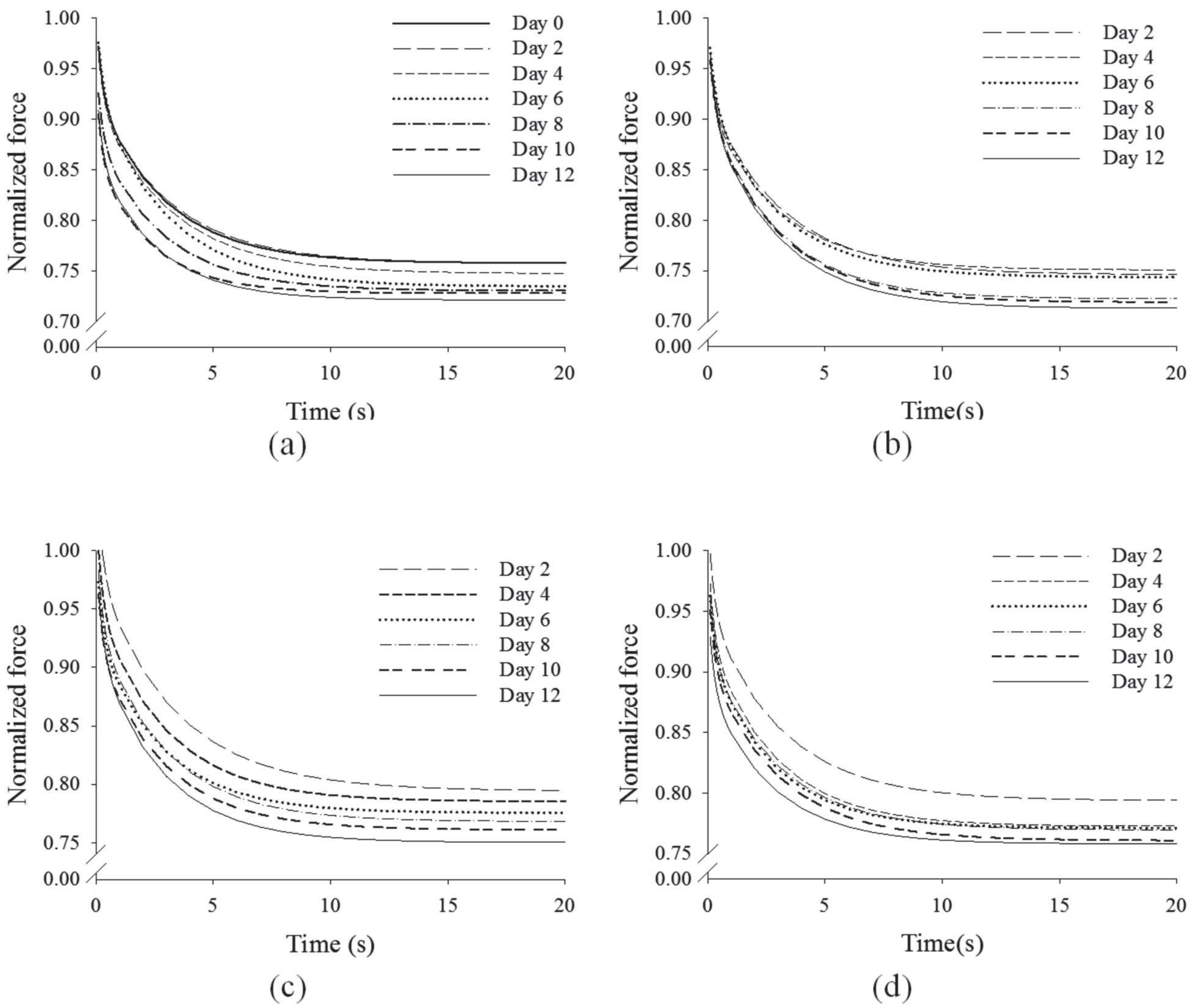

Figure 2: Relaxation curves of yellow Peruvian root slices conditioned in PVC (a), HDPE (b), PP (c) and vacuum (d) packaging bags, at different storage times.

Table 2 shows parameters of the generalized Maxwell model to describe the relaxation process of yellow Peruvian roots during storage.

The isolated use of the coefficient of determination must not be used as evaluation criterion of non-linear models (Kashaninejad *et al*. 2007; Cunningham *et al*., 2007). Hence, P and SE values were calculated (Equations 2 and 3). The estimated data variability lower than 10% indicates better model adjustment for practical purposes, which is recommended for non-linear models (Mohapatra & Rao, 2005; Cunningham *et al*., 2007). P and SE values were satisfactory, indicating that the Maxwell model represents the behavior of relaxation curves of yellow Peruvian root slices during storage.

Table 2: Values of estimated standard deviation (SE), relative mean error (P), coefficient of determination (R^2) and parameters (σe, A1, A2, A3, τ1, τ2 and τ3) of the generalized Maxwell model obtained by the adjustment of experimental data from relaxation process of yellow Peruvian root slices conditioned in all packaging bags

Time	Parameters	Packaging			
		PVC	HDPE	PP	VACUUM
0	σ_e	0.7580**	0.7580**	0.7580**	0.7580**
	A_1	0.1679**	0.1679**	0.1679**	0.1679**
	A_2	0.0761**	0.0761**	0.0761**	0.0761**
	A_3	0.0013**	0.0013**	0.0013**	0.0013**
	τ1(s)	2.9219**	2.9219**	2.9219**	2.9219**
	τ2 (s)	0.2501**	0.2501**	0.2501**	0.2501**
	τ3 (s)	0.2091**	0.2091**	0.2091**	0.2091**
	SE	0.01	0.01	0.01	0.01
	P (%)	0.63	0.63	0.63	0.63
	R^2	0.9962	0.9962	0.9962	0.9962
4	σ_e	0.7475**	0.7505**	0.7851**	0.7725**
	A_1	0.1705**	0.1637**	0.1698**	0.1566**
	A_2	0.0749**	0.0784**	0.0780**	0.0756**
	A_3	0.0008**	0.0001**	0.0021**	0.0013**
	τ1(s)	3.1270**	2.9328**	2.9298**	2.8394**
	τ2 (s)	0.2619**	0.2418**	0.2399**	0.2288**
	τ3 (s)	1.1274**	0.0209**	0.3185**	0.1910**
	SE	0.01	0.01	0.01	0.01
	P (%)	1.07	1.30	1.15	1.17
	R^2	0.9890	0.9842	0.9891	0.9851
8	σ_e	0.7306**	0.7220**	0.7681**	0.7694**
	A_1	0.1527**	0.1892**	0.1702**	1.1484**
	A_2	0.0702**	0.0814**	0.0765**	0.0739**
	A_3	0.0007**	0.0001**	0.0004**	0.0004**
	τ1(s)	2.8126**	2.9012**	2.8702**	2.9161**
	τ2 (s)	0.2549**	0.2738**	0.2478**	0.2367**
	τ3 (s)	0.1260**	0.0166**	0.0731**	0.0581**
	SE	0.01	0.02	0.01	0.01
	P (%)	1.04	1.74	0.81	1.07
	R^2	0.9874	0.9832	0.9943	0.9876
12	σ_e	0.7215**	0.7125**	0.7502**	0.7580**
	A_1	0.1437**	0.1940**	0.1689**	0.1301**
	A_2	0.0754**	0.0853**	0.0749**	0.0696**
	A_3	0.0006**	0.0001**	0.0012**	0.0003**
	τ1(s)	2.5075**	2.9737**	2.7392**	2.6929**
	τ2 (s)	0.2317**	0.2722**	0.26**	0.2369**
	τ3 (s)	0.1252**	0.0135**	0.1674**	0.0516**
	SE	0.02	0.01	0.02	0.02
	P (%)	1.46	0.53	2.28	1.80
	R^2	0.9725	0.9978	0.9617	0.9574

**Significant at 1% significance level by t-test.

Other authors, using the Maxwell model with different numbers of elements, also reported better representation of experimental relaxation data for different products by this equation (Del nobile *et al*., 2007; Rodríguez-Sandoval *et al*., 2009; Sadowska *et al*., 2009; Bellido & Hatcher, 2009; Bhattacharya, 2010; Campus *et al*., 2010). This fact demonstrates the wide use of this model for the study of viscoelastic alterations.

It is noticed, in the results of Table 2, that slices conditioned in PP and vacuum packaging bags are more elastic than slices conditioned in other packaging bags, as the parameter óe represents the elastic component of higher magnitude in the model. Therefore, higher óe values show more elastic and better quality products (Bellido & Hatcher, 2009). This can be seen in Figure 2, which shows the relaxation curves of values estimated by the generalized Maxwell model of yellow Peruvian root slices conditioned in all packaging bags studied, at different storage times. It is noticed that, by fixing a time during analysis, slices conditioned in PP (c) and vacuum (d) packaging bags present a higher normalized force than slices conditioned in PVC (a) and HDPE (b) packaging bags.

The relative normalized force at day 0 in a determined test time is higher than the normalized forces referring to day 2 of storage, and so on. This is due to the fact that slices from the first storage days are firmer than slices from the subsequent days, since they present, at each day, a less rigid structure, with less normalized force.

CONCLUSIONS

Slices conditioned in polypropylene and vacuum packaging bags presented higher hardness value.

The generalized Maxwell model represented well the relaxation process in all studied packaging bags, appropriately describing the alterations of yellow Peruvian root slices during storage.

Yellow Peruvian roots slice conditioned in polypropylene and vacuum packaging bags were more elastic than slices conditioned in other packaging bags.

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