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Effect of blanching pretreatment on carrot texture attribute, rheological behavior, and cell structure during cooking process

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ABSTRACT

The effect of blanching pretreatment on carrot texture attribute, rheological behavior, and cell structure was explored. Compared with 90 °C for 4 min, blanching at 60 °C for 40 min increased the texture attributes and elasticity strength, and reduced the viscosity of carrots. Rheological characterizations (from large-scale texture profile analysis (TPA) and small-scale dynamic oscillatory and creep/recovery tests) could well explain the variability of texture attributes in blanched carrots. Partial least squares regression analysis (PLS) revealed that the parameters of TPA, dynamic oscillatory test, and creep/recovery test explained 93.35, 91.76, and 89.27% of the variability of texture attributes using PLS factor 1 and 2, respectively. Hardness, fracturability, sensory cohesiveness, and crispness were positively correlated with hardness 1 and 2, cohesiveness, storage modulus at 100 1/s, loss modulus at 100 and 0.1 1/s, and viscosity coefficient, and negatively correlated with retarded compliances and retardation time (λ_2). Rheological parameters well predicted each of the texture attributes using standard partial regression equations ($P < 0.01$). Collectively, the poor texture of thermally processed carrots could be attributed to their reduced elasticity and increased viscosity. Cell structural changes (e.g., cell membrane disruption, turgidity loss, and cell wall matrix dissociation) could be the underlying causes.

1. Introduction

Vegetables are usually blanched preceding a thermal process. Blanching can inactivate the (quality related) enzymes and destroy microorganisms, which may prevent quality deterioration during processing. In the case of carrots, most studies have concentrated on the influence of blanching on their qualities, such as color, firmness, nutritional ingredients, and peroxidase activity (Fuchigami, Miyazaki, & Hyakumoto, 1995; Gonçalves, Pinheiro, Abreu, Brandão, & Silva, 2010; Lemmens et al., 2009), or on improving the blanching conditions (Hiranvarachat, Devahastin, & Chiewchan, 2011; Neri et al., 2014; Patras, Tiwari, & Brunton, 2011). However, to our knowledge, the effect of blanching pretreatment on the rheological behaviors of carrot slices during further cooking process has not been investigated.

A fundamental understanding of food texture and rheological attributes is crucial for obtaining a product with favorable quality in the food industry. Texture is an important sensorial property dominating a product quality and affecting the acceptance of consumers. It is defined as “the sensory manifestation of food structure and its way reacting to the forces used”. It links to the deformation, disintegration, and flow of foods when a force is exerted (Bourne, 2002). Studying the rheology of plant foods can well understand the changes of tissue structure and the development laws of mechanical property during processing. This is in favor of controlling product quality and providing a guidance for the improvements of process conditions. Currently, instrumental measurements have been used to apples (Martínez, Nieto, Castro, Salvatori, & Alzamora, 2007), herbal gel (Cui, Yu, Hu, & Wei, 2011), pears (Garcia Loredo, Guerrero, & Alzamora, 2013), and carrots (Xu & Li, 2015), in an effort to explore the correlations between texture and rheological attributes. Well understanding their relationship is in favor of improving or optimizing instruments to assess the quality control parameters and predict consumer responses to products. However, because of the diversity of varieties and processing conditions, the material properties are difficult to predict and explain. Thus, the investigation on the relationship between texture and rheological characterizations of thermally processed carrots may be of increasing importance.

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Table 1
Texture attributes of carrots.

Treatment	Hardness	Fracturability	Sensory cohesiveness	Crispness
Control	8.9 ± 0.8[a]	6.9 ± 0.5[a]	4.0 ± 0.6[a]	14.6 ± 1.6[a]
LTB	5.6 ± 0.5[b]	4.7 ± 0.6[b]	2.8 ± 0.3[b]	7.2 ± 0.7[b]
HTB	2.4 ± 0.8[c]	1.5 ± 0.3[c]	1.8 ± 0.4[c]	2.8 ± 0.6[c]
WB	2.1 ± 0.9[c]	1.5 ± 0.5[c]	1.3 ± 0.4[c]	2.3 ± 0.8[c]

[a–d]Mean ± standard deviation. Different superscripts within a column represent significant differences ($P < 0.05$). At least ten measurements were performed for each treatment.
Control: raw tissue; LTB: low temperature blanching (60 °C for 40 min) pretreatment; HTB: high temperature blanching (90 °C for 4 min) pretreatment; WB: cooking (for 20 min) without blanching.

Additionally, mechanical properties of plant tissues appreciably depend on the cellular structure (Alzamora, Viollaz, Martínez, Nieto, & Salvatori, 2008). During thermal processing, the combination of membrane damage and the depolymerization of pectin polymers could induce a dramatic loss of cell turgidity, causing tissues softening (Plat, Ben-Shalom, & Levi, 1991; Xu & Li, 2014). Rheological characterizations depend on both soluble solids (including sugars, organic acids, and pectin materials) in the liquid and the particle volume fraction of insoluble solids (e.g., cell wall materials) in the plant foods (Lopez-Sanchez et al., 2011). They may be affected by mechanical or thermal treatments (Lopez-Sanchez et al., 2011). Martínez, Nieto, Viollaz, and Alzamora (2005) have shown that the variations of cell structural components may change the rheological parameters after blanching and osmotic dehydration in melon tissues. Decreasing the levels of cell turgor pressure may directly reduce the elastic modulus of Korla pear (Wu & Guo, 2010). Therefore, monitoring the changes appearing at the cell structural levels during processing is necessary.

Along these lines, our study was conducted to assess the effect of blanching pretreatment on carrot texture (from a trained sensory panel), rheological characterizations at small and large deformations (from large-scale texture profile analysis and small-scale dynamic oscillatory and creep/recovery tests), and cell structure (from optical and transmission electronic microscopy) during further cooking process. Furthermore, the relationship between texture and rheological characterizations was explored using partial least squares regression analysis in thermally processed carrots.

2. Material and methods

2.1. Sample preparation

Carrots (*Daucus carota* L.) were harvested in April 2014, in Shanghai (China). Fresh carrots without any physical damage were purchased from a local market and stored at 20 °C for 3 h prior to sample preparation. Carrots were cut into discs (5 ± 1 mm thickness and 30 ± 2 mm diameter) and randomly packed in a thin layer in the plastic bags (about 100 g per bag). According to the report by Lemmens et al. (2009), samples were blanched at low temperature for a long time (60 °C for 40 min) and at high temperature for a short time (90 °C for 4 min), respectively. After pretreatment, samples were cooked for 20 min. As a result, there were 4 groups: control group (raw tissue), LTB group (60 °C for 40 min), HTB group (90 °C for 4 min), and WB group (cooking without blanching). The treatments were performed in a water bath (conventional heating) and terminated by placing the samples under ice water bath for 1.5 min. After removing surface water with blotting paper, the samples were analyzed.

2.2. Texture analysis

Twenty-five individuals (13 males and 12 females with a mean age of 33) from Shanghai Jiao Tong University were pre-screened using psychological and physiological tests (Civille & Szczesniak, 1973). Ten candidates, who passed the tests, were trained on texture profile methods (Civille & Szczesniak, 1973). The panelists participated in daily (3 h) orientation sessions for two weeks, followed by 10 weeks of practice sessions (1 h) three times a week. In orientation sessions, the panelists fully understood the texture concepts and the usage of the rating scale. In practice sessions, panelists evaluated the references, properly matched them with their hardness, fracturability, cohesiveness, and crispness values in the scale (Garcia Loredo, Guerrero, & Alzamora, 2014), and discussed to reach a general consensus. During the formal test, samples were randomly presented to panelists in white plastic cups coded with three-digit number. Two food references (egg white (boiled 5 min) and hard candy for hardness, biscuit and hard candy for fracturability, cake and chewing gum for cohesiveness, and banana and carrot for crispness) were also provided to panelists. A glass of water was prepared for rinsing mouth after one evaluation. Tests were carried out in isolated booths under white light. The descriptive analysis of samples was replicated two times in different sessions.

2.3. Texture profile analysis (TPA)

The TPA was conducted in a TA-XT Plus Texture Analyzer (Stable Micro Systems Ltd, Surrey, UK) using a 500 N load cell. A two cycle compression test was performed using an aluminum cylinder probe (50 mm diameter), which was used to compress samples to 40% of their original thickness at a compression rate of 1 mm/s. Hardness 1 and hardness 2 during the first and second compression cycles, respectively, springiness, cohesiveness, gumminess, chewiness, and resilience were obtained from the force–time curves (Bourne, 1978). At least ten measurements were performed for each treatment.

2.4. Dynamic oscillatory and creep/recovery tests

Dynamic oscillatory and creep/recovery tests were performed at 25 °C in a Physica MCR 301 rheometer (Anton Paar GmbH, Graz, Austria). Carrot slices (25 mm diameter and 1 mm thickness) were

Table 2
Data from texture profile analysis of carrots.

Treatment	Hardness 1 (N)	Hardness 2 (N)	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N)	Resilience
Control	455 ± 13[a]	442 ± 14[a]	0.96 ± 0.03[a]	0.96 ± 0.06[a]	440 ± 23[a]	425 ± 23[a]	0.82 ± 0.07[a]
LTB	326 ± 8[b]	282 ± 15[b]	0.74 ± 0.05[b]	0.76 ± 0.04[b]	244 ± 13[b]	187 ± 12[b]	0.59 ± 0.05[b]
HTB	207 ± 11[c]	172 ± 16[c]	0.62 ± 0.02[c]	0.62 ± 0.05[c]	150 ± 6[c]	101 ± 9[c]	0.43 ± 0.06[c]
WB	234 ± 10[d]	181 ± 14[c]	0.66 ± 0.04[d]	0.63 ± 0.03[c]	183 ± 7[c]	107 ± 2[c]	0.46 ± 0.03[c]

[a–d]Mean ± standard deviation. Different superscripts within a column represent significant differences ($P < 0.05$). For each treatment, twenty evaluations were performed.
Control: raw tissue; LTB: low temperature blanching (60 °C for 40 min) pretreatment; HTB: high temperature blanching (90 °C for 4 min) pretreatment; WB: cooking (for 20 min) without blanching.