EFFECT OF HEAT TREATMENT ON THE RHEOLOGICAL PROPERTIES AND COLOR OF PUMPKINS (*Cucurbita moschate)*

Keila de Souza Silva*
Carolina Castilho Garcia**
Javier Telis Romero***
Maria Aparecida Mauro****

The aim is to investigate the effects of stepwise blanching and its combination with drying on rheological properties and change of color in pumpkins (*Cucurbita moschata*). 1 cm thick samples were immersed in water at 55 °C for different times, followed by different holding times prior to inactivation of the enzyme (97 °C/5minutes). Controled samples were obtained after blanching at 97 °C for 5 minutes. The texture and color of the samples were measured and the rheological parameters calculated according to the Maxwell model. The results showed that stepwise blanching for 40 minutes with 30 minutes of holding time provided samples with equilibrium modulus of elasticity greater than the control samples. These parameters were used as blanching pre-treatment to convective drying with air at 60 °C and a velocity of 1.5 m/s for different drying times. Stepwise blanched samples showed firmer tissues than control samples after drying. There were no significant differences in the lightness and redness of stepwise blanched samples and control samples during drying.

KEYWORDS: *STEPWISE BLANCHING, DRYING, TEXTURE, COLOR, MAXWELL MODEL.*

* Professor (Doctor) of the Chemical Engineering Department at Northern Paulista University Center (UNORP). e-mail: keilasouzas@yahoo.com.br

** Professor (Adjunct) of the School of Food Science at Federal Technological University of Paraná (UTFPR). e-mail: carolinacgarcia@utfpr.edu.br

*** Professor (Full) of the Department of Food Engineering and Technology at São Paulo State University (UNESP), Institute of Biosciences, Language, and Physical Sciences (IBILCE). e-mail: javier@ibilce.unesp.br

**** Professor (Assistant) of the Department of Food Engineering and Technology at São Paulo State University (UNESP), Institute of Biosciences, Language, and Physical Sciences (IBILCE). e-mail: cidam@ibilce.unesp.br

1 INTRODUCTION

Both the texture and color are important attributes of the quality of dehydrated foods, being used often as a criteria of judgement among consumers. Texture attributes of food have been related to physical parameters of the force-deformation curve obtained through the testing of compression-relaxation. Rheological parameters such as elastic modulus, relaxation time, the maximum deformation behavior of solids and measured hardness of the material are important measures that contribute to the understanding of how the processing of food influences its structure. Thermal blanching is one of the most widely used pre-treatments to decrease the initial load of micro-organisms, as well as to prevent off flavors and color changes resulting from enzymatic reactions that affect the product quality. Moreover, thermal blanching enhances mass transport in the tissue during convective drying (DOYMAZ, 2010; JAISWAL et al., 2012). However, conventional thermal blanching can cause undesirable alterations in the structure and color of vegetables due to the heat (SILVA et al., 2011).

Stepwise blanching treatment can reduce losses of texture during subsequent heating (BARTOLOME; HOOFF, 1972). This kind of treatment consists of initial blanching at low temperatures, followed by holding time at room temperature and finally rapid blanching at high temperatures (SANJUÁN et al., 2001; SILVA et al., 2011). The firming effect is attributed to the activation temperature of the pectin methyl-esterase (PME) at temperatures of between 50-70^{o}C (VAN BUREN, 1979). The enzyme hydrolyzes the methyl ester linkages in pectin molecules, producing free carboxyl groups. The de-esterified pectin, in turn, can bind calcium ions present in the middle lamella, producing insoluble pectates that reinforce the cell wall and improve the product texture. The subsequent high temperature blanching is performed to inactivate the enzyme (BARTOLOME; HOOFF, 1972; VAN BUREN, 1979). Subsequently, stepwise blanching results in a firmer structure than conventional blanching at high temperature (SANJUÁN et al., 2001). Concentrations of 10% to 30% of pectin can be found in the middle lamella of plants (VAN BUREN, 1991), which can substantially contribute to the success of this type of blanching. Dutta e Chaudhuri (2006) showed the presence of PME in a study on thermal treatment of *Cucurbita moschata* cv 'Akra Chandan' pumpkins.

Sanjuán et al. (2001) verified that stepwise blanching ensured a firmer texture to broccoli. The same behavior was verified by other researchers for canned carrots (LEE et al., 1979), green beans (BOURNE, 1987), carrots (QUINTERO-RAMOS et al., 1992), cauliflower (GARCÍA-REVERTER, 1994), sweet potatoes (MORENO-PEREZ et al., 1996) and pumpkin, *Cucurbita pepo* variety, Grey Zucchini (QUINTERO-RAMOS et al., 1998). No published results on rheological properties of stepwise blanched pumpkin *Cucurbita moschata* are available, neither of stepwise blanched pumpkin followed by drying.

Drying is a useful technique for food preservation, since, as a result of removing water, it reduces the water activity of food to levels that prevent the growth and reproduction of micro-organisms and the occurrence of enzymatic/ biochemical reactions in the food (DOYMAZ, 2010; GARCIA et al., 2014; SILVA et al., 2015). However, the quality of degradation of the food submitted for drying is a concern, leading the researchers to study the use of pre-treatments prior to drying, attempting to reduce the physical, chemical, and biochemical changes which could occur. Blanching is a popular pre-treatment used usually to denature or inactivate enzymes, reducing off-flavors and color changes in vegetables and fruits (BARRETT; THEERAKULKAIT, 1995). Doymaz and Göl (2011) studied the use of conventional blanching as a pre-treatment for drying of egg plants and verified that blanched samples presented shorter drying times and higher water diffusivity than un-blanched vegetables.

Mechanical tests, such as compression–relaxation, can be used to correlate textural attributes of foods with physical parameters obtained by analyzing force–deformation curves. The stress relaxation test on food products is applied to constant strain (ε_0), where stress (σ) is measured as a function of time (t) resulting in a curve that determines the visco-elastic properties of the product (KROKIDA et al., 1998). The relaxation which occurs after applying a stress in a visco-elastic material consists of a process of disruption and stress-free reformation of the bonds between the structural elements in the material. Relaxation can continue for seconds or days. During this time, the stress decays at a specific rate (VLIET, 1999). The time required for the stress to decrease to 36.8% of its initial value is called the relaxation time (λ), and is directly proportional to viscosity and indirectly proportional to the elasticity (MOHSENIN, 1986).

The result of applying a stress or strain to a food consists partly of a viscous contribution and partly of an elastic one, which means that foods behave as visco-elastic materials. Most visco-elastic foods require a complex equation to describe its behavior. One of the most widely used mathematical models to represent visco-elastic behavior is the Maxwell model, which consists of a number of Maxwell elements in parallel with an independent spring, suitable for understanding stress relaxation data, but does not consider the equilibrium stress (DEL NOBILE et al., 2007). For this reason, the visco-elastic behavior of food can be better described by using a generalized Maxwell model consisting of several elements in parallel with a spring (STEFFE, 1992). In a three-element model (two Maxwell elements and a spring), the stress is given by Equation 1.

$$(1) \qquad \sigma(t) = \varepsilon_0 \left[E_e + (E_1 - E_e)\exp\left(\frac{-t}{\lambda_1}\right) + \left(E_2 - E_e\right)\exp\left(\frac{-t}{\lambda_2}\right) \right]$$

where: E_1 and E_2 are the elastic modulus, E_e is the equilibrium elasticity modulus, λ_1 and λ_2 are the relaxation times, which are defined in terms of the standard Maxwell portion of the model as in Equation 2.

$$(2) \qquad \lambda = \frac{h}{E}$$

where: h is a viscous constant (STEFFE, 1996).

The generalized model of Maxwell was the best alternative to describe the sample's visco-elastic behavior of dehydrated prunes (GABAS et al., 2002), carrots and potatoes, both dehydrated (LUZURIAGA et al., 1997).

The aim of this study was to evaluate the influence of stepwise and conventional blanching, after and before drying, on color and rheological parameters of the *Cucurbita moschata*cultivar pumpkins.

2 MATERIALS AND METHODS

2.1 MATERIAL

Pumpkins (*Cucurbita moschata*) from the State of Bahia (Brazil), weighing between 40 and 50 kg, with moisture of approximately 94 ± 2.28 g/100 g, reducing sugar content of 2.27 ± 0.40 g/100 g and sucrose content of 0.96 ± 0.30 g/100 g were cut into three portions at the transversal direction to their axis, and each portion cut into four longitudinal pieces. Two opposite slices of each longitudinal portion were used in the same experiment. For each trial, a different pumpkin was used. The pieces were peeled, seeded and sliced (1 ± 0.1 cm thick) using an electric cutter. The slices were cut based on the following dimensions: length of 5 ± 0.1 cm and width of 4 ± 0.1 cm using a manual cutter designed for this purpose. The samples were placed into plastic bags to avoid contact with oxygen, which could degrade carotenes, and randomly selected to be used in the experiments.

2.2 STEPWISE BLANCHING:

For the first stage of stepwise blanching, the samples were immersed in beakers containing water, previously placed in a thermostatically controlled water bath (Marconi, model MA-184 - Brazil) at 55°C (aiming at the activation of pectin ametylesterase), for a blanching time of 30, 40, 50 and 60 minutes. The slices were then removed from the beakers and left into desiccators at room temperature for a holding time of 30 minutes. After this period of time, the slices were submitted to the second stage of blanching, which consisted of immersion in boiling water (98.2 °C is the boiling temperature at São José do Rio Preto – SP – BR) for 5 minutes, followed by cooling for 2 minutes under tap water. The second stage of blanching ensured the inactivation of peroxidases, enzymes related to the browning of the pumpkins, which decreases the quality of the product.

The effects of holding time on the texture and color of the pumpkin were investigated. For this, the combination of temperature and time of the first stage of stepwise blanching, which resulted in harder samples than the control was kept constant, and the holding time was changed: 0, 30 and 50 minutes.

2.3 CONVENTIONAL BLANCHING (CONTROL TREATMENT):

The samples were placed in a perforated basket and immersed in boiling water (98.2 °Cat São José do Rio Preto – SP – BR) for 5 minutes. This treatment was carried out in order to compare its effect with that of stepwise blanching.

Each trial of stepwise blanching used different lots of pumpkins. Considering the heterogenity among the vegetables and a lack of uniformity in their internal structure, authors recognize that this procedure could affect the results, since the mechanical properties of a biological material are determined by the structure and by the cell wall constituents, which are affected by the conditions of the process and all variations in the degree of maturation and harvest.

To reduce the effect of using different raw materials in the experiments, stepwise blanching treatment was conducted with a control (conventional blanching), with a control allowed for each experiment.

2.4 DRYING:

The samples which wereharder than the control and the lowest changes in color parameters and the controls (conventional blanched pumpkin slices at boiling water for 5 min) were subjectedto drying. Drying was conducted in a laboratory scale drier operating with air-velocity of 1.5 m/s. The drier was equipped with an electronic balance with an accuracy of 0.01 g. The weight was continuously registered in a microcomputer using a RS232 interface. The air-flowed parallel to the bed that consisted of three wire nets supported by a structure, which substituted the balance plate. Approximately 0.3 kg of blanched samples were dried at 60 °C for 1, 2, 4 and 6 hours.

At each time, an amount of stepwise blanched samples and controls were removed from the dryer and their texture and color were evaluated.

2.5 ANALYTICAL METHODS AND STATISTICAL ANALYSIS

Compression-relaxation tests applied in the stepwise blanched sample, control sample and dried pumpkins previously blanched were performed in a texturometer TA-XT2i Texture Analyzer (Stable Micro System, Surrey, UK.). The samples were cut in cylinders of 10 mm in length with a cross sectional area of 260.155 mm^2 (the diameter of the samples was measured using a capiler and the area was calculated based on the geometry of the samples) and were compressed individually by a 35 mm acrylic probe. The initial constant strain was 1 mm/s and the total strain was limited to 10% in order to ensure minimum changes in the transversal section area during the compression tests. The compression-relaxation test was conducted in eight replicates for each condition studied (stepwise blanched sample, control sample and dried pumpkins previously blanched).

The generalized Maxwell model was the mathematical model used to predict the stress-strain curve of the compression tests (Equation 1). This model fitted the experimental relaxation curves, using the Non-Linear Estimation Procedure of the software Statistica 7.0 (StatSoft Inc.

South America, Tulsa, OK, USA). The adequacy of the model was evaluated by the determination coefficient (R^2) and the root mean squared residuals (*RMS*) expressed in percentage and calculated as Equation (3).

$$(3) \qquad \boldsymbol{RMS} = 100.\sqrt{\frac{\sum\left[\left(\sigma_{\exp} - \sigma_{\boldsymbol{c}}\right)/\sigma_{\exp}\right]^2}{\boldsymbol{N}}}$$

Where $\sigma_{\exp}$ is the experimental stress, σ_c is the calculated stress and N is the total number of experimental points.

The color parameters of the samples were obtained using the methodology proposed by Luzuriaga et al. (1997). The methodology used a digital camera of 7.0MP (DC7325BR, MITSUCA, China) installed in a light box. The light box, with dimensions of 43 cm (w) X 61 cm (L) X 70 cm (h), was built with plywood and the inside walls were painted white to reflect light in all directions, minimizing shadow formation. The illumination was made with four fluorescent lamps (Sadokin T8/6400K, 15 Watt, 2007/4) and the lens of the digital camera was positioned 49.5 cm above the samples. The recorded images were analyzed by the academic software V-01 E&CS Programs (Gainesville, Florida, USA, version 9.7.6) using the following standard parameters: *L** = 62.661; *a** = 36,067 and *b** = 57.096. The image system was calibrated, placing the standard color chart beside the samples.The color analyses were conducted with four replicates. Garcia et al. (2012) also used this methodology to assess color parameters of papaya slices.

Color and texture results were statistically evaluated using the analysis of variance (ANOVA), with the sources of variation being the sample type and number of samples, and the Tukey´s Test applied at the 5% level of significance.

The chromaticity (Equation 4) and the total color difference (Equation 5) were also calculated.

$$(4) \qquad C = \sqrt{(a_t*)^2 + (b_t*)^2}$$

$$(5) \qquad \Delta T = \sqrt{\left(L*_t - L*_f\right)^2 + \left(a*_t - a*_f\right)^2 + \left(b*_t - b*_f\right)^2}$$

Where: lower case letter "t" represents the thermal treated samples and the lower case letter "f" indicates the fresh samples.

3 RESULTS AND DISCUSSIONS

The rheological parameters of the stepwise blanched pumpkins and of the conventional blanched (control) pumpkin slices, obtained by the generalized Maxwell model with two elements, as well as lightness and chromaticity of the samples, are presented in Table 1. The experimental data was well fitted by the generalized Maxwell model, as high values of R^2 (above 0.98) were verified. RMS values lower than 10% are indicatives of a good fit for practical purposes (LOMAURO et al., 1985). For all the stepwise blanched samples RMS were lower than 10%, meaning that the experimental data was well fitted by the generalized Maxwell model. However, *RMS* values of trials 4 and 10 were higher than 10%, suggesting that a higher number of samples should have been used in order to minimize the differences related to the vegetable tissue.

It was verified that for most of the stepwise blanched samples, the equilibrium modulus (E_e) is higher than the respective control treatment (Table 1). Higher values of equilibrium modulus can be attributed to the activity of pectin methylesterase that produces free carboxyl groups which can bind calcium ions, producing insoluble pectates and thus resulting in firmer texture (SANJUÁN et al.,

2001; VAN BUREN, 1979; BARTOLOME; HOOF, 1972).

Trial 9 presents a different condition, in which the holding time was zero. It can be verified that the equilibrium elasticity modulus (E_e) of the stepwise blanched samples was lower than E_e of the control sample (Table 1). This result shows that holding time is an important variable to maintain the resistance of the plant tissue after treatment. Similar results were verified by Pérez-Alemán et al. (2005) working with frozen jalapeño pepper blanched at low temperature in calcium chloride solution.

Statistical analyses revealed that the stepwise blanched samples did not present significant difference in the lightness (L^*) and color intensity of (C^*) when compared with the corresponding control samples, at a 5% significance level.

The blanching condition that resulted in the high valor of equilibrium elasticity modulus was selected as the pre-treatment for drying experiments. It can be calculated from data in Table 1 that trial 3 was the one with the highest increase of E_e compared with the corresponding control sample (trial 4).

So, to study the effect of stepwise blanching followed by the hot-air-drying on the texture of the samples, the thermal treatment at 55 °C for 40 minutes with 30 minutes of holding time and subsequent treatment at 97 °C for 5 minutes with the aim of inactivating peroxidase was selected, since this combination resulted in an increase of 54% in the equilibrium modulus elasticity in relation to the control (trial 4).It must be considered that stepwise blanched samples less hard than the control indicate that the pre treatment was not effective and, probably, insoluble pectates, which reinforce the cell wall and improve texture, were not formed.

Table 2 presents the visco-elastic properties of pre-blanched (stepwise and control) *Cucurbita moschata* dried at 60 °C, as a function of time. Visco-elastic properties were obtained by fitting the generalized Maxwell model with 3 elements. The determination coefficients (R^2) and *RMS* values are also shown.

TABLE 3: COLOR PARAMETERS OF STEPWISE AND CONTROL BLANCHED SAMPLES DURING THE DRYING PROCESS AT 60 °C.

Sample	Drying time (minutes)	L^*	a^*	b^*	ΔT
Fresh	------	71.66 ± 0.24[a]	34.11 ± 1.48[a]	64.11 ± 0.90[a]	--------
Stepwise blanched	0	72.61 ±0.33[a]	41.68 ± 3.16[b]	66.50 ± 0.20[b]	8.04
Control	0	72.50 ±0.80[a]	42.26 ± 3.22[b]	65.91 ± 0.05[a]	8.39
Stepwise blanched	15	71.78 ± 1.02[a]	44.3 ± 1.69[b]	65.49 ± 1.12[a]	10.28
Control	15	71.56 ± 0.42[a]	43.67 ± 1.53[b]	65.69 ± 0.56[a]	9.69
Stepwise blanched	30	71.32 ± 0.59[a]	42.88 ± 2.14[b]	65.67 ± 0.62[a]	8.91
Control	30	70.31 ± 0.80[a]	44.18 ± 1.63[b]	65.29 ± 0.71[a]	10.23
Stepwise blanched	80	70.22 ± 1.72[a]	44.66 ± 2.73[b]	65.11 ± 1.30[b]	10.69
Control	80	69.67 ± 1.29[a]	44.59 ± 1.48[b]	64.59 ± 1.02[a]	10.68
Stepwise blanched	120	70.01 ± 1.21[a]	45.61 ± 2.01[b]	64.51 ± 1.06[b]	11.62
Control	120	70.95 ± 1.62[a]	45.94 ± 0.18[b]	66.20 ± 1.24[b]	12.03

* Means with the same letter in the same column did not differ significantly at p ≤ 0.05 according to the Tukey's test.

TABLE 1:COLOR AND RHEOLOGICAL PARAMETERS OF THE STEPWISE BLANCHED SAMPLES AND THE CONTROL SAMPLES.RHEOLOGICAL PARAMETERS WERE OBTAINED USING THE GENERALIZED MAXWELL MODEL.

Trials	T (°C)	Blanching time (min)	Holding time (min)	E_e (kPa)	E_1 (kPa)	λ_1 (s)	h_1 (kPa.s)	E_2 (kPa)	λ_2 (s)	h_2 (kPa.s)	R^2	RMS	L^*	C^*
1	55	30	30	4.02	11.03	25.97	286.45	80.45	1.65	132.74	0.99	8.99	83.15 ± 1.26	81.55
2	98.2	5	0	3.90	14.23	26.01	370.12	76.42	1.70	129.91	0.99	8.28	83.10 ± 0.70	81.19
3	55	40	30	2.49	13.01	10.88	141.55	330.16	0.55	181.59	0.98	8.09	82.65 ± 1.30	82.50
4	98.2	5	0	1.62	7.89	15.22	120.09	113.12	0.68	76.92	0.99	36.0	82.16 ± 1.19	80.62
5	55	50	30	2.13	7.93	13.68	108.48	171.27	0.60	102.76	0.98	8.52	84.82 ± 0.58	81.40
6	98.2	5	0	2.65	10.35	31.19	322.82	52.29	1.78	93.08	0.98	9.65	86.34 ± 0.16	81.60
7	55	60	30	4.82	12.85	24.23	311.36	139.01	1.46	202.95	0.99	8.89	84.94 ± 0.65	80.81
8	98.2	5	0	4.02	13.93	33.48	466.38	75.70	1.94	146.86	0.99	9.70	83.51 ± 0.54	82.17
9	55	40	0	2.42	11.52	16.87	194.34	124.86	0.95	118.62	0.98	9.97	83.84 ± 1.06	79.92
10	98.2	5	0	3.21	16.65	28.35	472.03	99.05	1.74	172.35	0.99	10.6	80.72 ± 0.04	80.53
11	55	40	50	2.43	7.91	16.70	132.10	96.29	0.87	83.77	0.98	8.56	81.25 ± 0.47	81.81
12	98.2	5	0	2.27	7.71	31.24	240.86	42.77	1.72	73.56	0.98	9.44	84.14 ± 1.07	80.12

Treatments 1, 3, 5, 7, 9 and 11: Stepwise blanched pumpkin slices; treatments 2, 4, 6, 8, 10 and 12: Control pumpkin slices (Blanched at 98.2 °C/5 min). E_1 and E_2 are the elastic modulus; E_e is the equilibrium elasticity modulus; λ_1 and λ_2 are the relaxation times; h_1 and h_2 are viscous constants.

TABLE 2: RHEOLOGICAL PARAMETERS, OBTAINED WITH THE GENERALIZED MAXWELL MODEL, OF BOTH STEPWISE BLANCHED AND CONTROL BLANCHED SLICES OF *CUCURBITA MOSCHATA* DURING THE DRYING PROCESS AT 60 °C.

Sample	Drying time (min)	E_e (kPa)	E_1 (kPa)	λ_1 (s)	h_1 (kPa.s)	E_2 (kPa)	λ_2 (s)	h_2 (kPa.s)	R^2	*RMS*
Stepwise blanched	0	3.91	160.14	1.18	188.97	17.07	19.40	331.16	0.99	9.51
Control	0	3.40	132.38	1.17	154.88	13.60	20.58	279.89	0.98	9.48
Stepwise blanched	15	3.38	113.66	1.03	117.07	11.80	18.12	213.82	0.98	8.14
Control	15	3.34	38.84	2.05	79.62	8.70	43.88	381.76	0.98	10.33
Stepwise blanched	30	4.16	129.75	1.24	160.89	14.72	20.89	307.50	0.99	8.51
Control	30	2.50	19.61	2.65	51.97	5.78	57.76	333.85	0.98	11.71
Stepwise blanched	80	4.57	25.70	4.06	104.34	10.66	79.99	852.69	0.99	13.50
Control	80	3.74	18.17	4.72	85.76	8.70	98.69	858.60	0.99	14.97
Stepwise blanched	120	2.60	9.70	5.55	53.84	5.59	119.08	665.66	0.99	17.00
Control	120	1.65	5.80	6.69	38.80	3.90	122.46	477.59	0.99	16.58

E_1 and E_2 are the elastic modulus; E_e is the equilibrium elasticity modulus; λ_1 and λ_2 are the relaxation times; h_1 and h_2 are viscous constants.

It can be seen in Table 2 that the data was well fitted to the model as it presented high values of R^2 and *RMS* lower than 17%. It must be pointed that *RMS* value below 10% is an indicative of a good fit for practical purposes (LOMAURO et al., 1985). However, the *RMS* values verified in the present work are justified by the low equilibrium moisture contents obtained in relative moisture around 5% since the *RMS* calculation is based on the relative residual (Equation 3), which amplifies the deviations when the moisture is quite low.

Drying affected the initial elasticity of the samples, reducing its value with increase intime. The values of the elastic (E_1) and viscous (E_2) constants of the stepwise blanched samples were higher than the values of the control samples after drying (Table 2). According to Gabas et al. (2003), this result suggests that the stepwise blanched samples have structural components associated with the elastic behavior, such as cell wall material, and to the viscous behavior, such as the intra-cellular content, which were less affected by drying than the structural components of the control samples.

The stepwise blanched samples presented more resistant tissues (higher E_e) than the control samples during drying, and the differences between the firmness of both tissues (stepwise blanched and control blanched) became pronounced after 30 minutes of dehydration.

According to Mohsenin (1986), the relaxation time for the generalized Maxwell model can be obtained by the average relaxation times. It was verified that the average relaxation time increased with the drying time, indicating a more elastic and less viscous behavior of the samples. Krokida et al. (2004) verified that carrots and potatoes dried at 70°C and showed increased relaxation time with decreasing moisture content of samples. Nicoleti et al. (2005) and Gabas et al. (2003) also verified similar results for convective dried papayas and persimmons.

Table 3 presents the color parameters of the pre-blanched and dried samples. It can be seen that both blanching treatments did not significantly change ($p>0.05$) the lightness of the samples compared to the fresh pumpkin slices.However, significant changes in the parameters *b** due to stepwise blanching and in the parameters *a** due to both pre-treatments were observed, in relation to fresh samples (Table 3). The lowest color changes of the samples, in comparison with fresh pumpkin, were obtained in the shortest blanching times, ie, when pre-treating with the conventional blanching. This fact is possibly related to higher carotenoid retention in the samples submitted to the lowest pre-treatment times. This result is in agreement with Rodriguez-Amaya et al. (2008), who attested that milder thermal treatments affect the isomerization and oxidation of the loss of carotenoids. The differences in colour between stepwise blanched and control samples after 80 minutes of drying were not verified.

It was verified that drying time did not significantly affect *L** and *a** color parameters at a 95% reliability. However, drying time significantly increased the *b** values, resulting in more yellowness in samples, at a 5% significance level.

4 CONCLUSIONS

Stepwise blanching provided firmer samples than the conventional blanching (control), even after convective drying. The holding time of the stepwise blanching positively influenced the texture of the product. The color of the samples was significantly influenced by the pre-treatment used and by the 60 °C drying time.

RESUMO

EFEITO DO TRATAMENTO TÉRMICO NAS PROPRIEDADES REOLÓGICAS E COR DE ABÓBORAS *CUCURBITA MOSCHATA*

Com o objetivo de investigar os efeitos do branqueamento por etapas e sua combinação com secagem nas propriedades reológicas e alterações de cor de abóboras (*Cucurbita moschata*), amostras com 1 cm de espessura foram imersas em água a 55 °C por tempos diferentes seguido de diferentes tempos de espera previamente à inativação enzimática (97 °C/5minutos). Consideraram-se amostras branqueadas a 97 °C por 5minutos como controle. A textura e a cor das amostras foram

medidas e os parâmetros reológicos foram calculados segundo o modelo de Maxwell. Os resultados mostraram que o branqueamento por etapas por 40 minutos com tempo de espera de 30 minutos resultou em amostras com módulo de elasticidade de equilíbrio maior que o do controle. Estes parâmetros foram utilizados como pré-tratamentos à secagem com ar aquecido a 60 °C e velocidade do ar de 1,5 m/s por diferentes tempos. As amostras branqueadas por etapas apresentaram tecido mais firme que o do controle após a secagem. Não houve diferença significativa nos parâmetros de cor *L** e *a** das amostras branqueadas e dos controles durante a secagem.

PALAVRAS-CHAVE: *BRANQUEAMENTO POR ETAPAS, SECAGEM, TEXTURA, COR, MODELO DE MAXWELL.*

REFERENCES

1 BARRETT, D.M.; THEERAKULKAIT, C. Quality indicators in blanched, frozen, stored vegetables. **Food Technology**, v. 49, p. 62–65, 1995.

2 BARTOLOME, L.G.; HOOFF, J.E. Firming of potatoes: Biochemical effects of preheating. **Journal of Agriculture and Food Chemistry**, v. 20, n. 2, p. 266-270, 1972.

3 BOURNE, M.C. Effect of blanch temperature on kinetics of thermal softening of carrots and green beans. **Journal of Food Science**, v. 52, p. 667-668, 1987.

4 DEL NOBILE, M.A.; CHILLO, S.; MENTANA, A.; BAIANO, A. Use of the generalized Maxwell model for describing the stress relaxation behavior of solid-like foods. **Journal of Food Engineering**, v. 78, p. 978–983, 2007.

5 DOYMAZ, I.; GÖL, E. Convective drying characteristics of egg plant slices. **Journal of Food Process Engineering,** v. 34, p. 1234-1252, 2011.

6 DUTTA, D.; CHAUDHURI, U.R.; CHAKRABORTY, R. Effect of thermal treatment on the β-carotene content, colour and textural properties of pumpkin. **Journal of Food Science Technology**, v. 43, n. 6, p. 607-611, 2006.

7 GABAS, A.L.; MENEGALLI, F.C.; FERRARI, F.; TELIS-ROMERO, J. Influence of drying conditions on the rheological properties of prunes. **Drying Technology**, v. 20, n. 7, p. 1485–1502, 2002.

8 GABAS, A.L.; TELIS-ROMERO, J.; GUIZZO-SILVA, L.K.; TELIS, V.R.N. Rheological properties of rehydrated papaya. **Brazilian Journal of Food Technology**, v. 6, n. 2, p. 221-227, 2003.

9 GARCIA, C.C.; CAETANO, L.C.; SILVA, K.S.; MAURO, M.A. Influence of edible coating on the drying and quality of papaya (*Carica papaya*). **Food and Bioprocess Technology**, v. 7, p. 2828-2839, 2014.

10 GARCIA, C.C.; CANIZARES, D.; SILVA, K.S.; DARROS-BARBOSA, R.; MAURO, M.A. Utilização de métodos combinados para obtenção de mamão Formosa (*Carica papaya*) seco. **B. CEPPA**, v. 30, n. 2, jul/ dez, 2012.

11 GARCÍA-REVERTER, J.; BOURNE, M.C.; MULET, A. Low temperature blanching affects firmness and re-hydration of dried cauliflower florets. **Journal of Food Science**, v. 6 n. 59, p. 1181-1183, 1994.C.

12 JAISWAL, A.K.; GUPTA, S.; ABU-GHANNAM, N. Kinetic evaluation of color, texture, poliphenols and antioxidant capacity of Irish York cabbage after blanching treatment. **Food Chemistry,** v. 131, p. 63-72, 2012.

13 KROKIDA, M.K.; MAROULIS, Z.B.; MARINOS-KOURIS, D. Visco-elastic behavior of dehydrated carrot and potato. **Drying Technology**, v. 16, n. 3-5, p. 687-703, 1998.

14 LEE, C.Y.; BOURNE, M.C.; VAN BUREN, J.P. Effect of blanching treatments on the firmness of carrots. **Journal of Food Technology**, n. 44, p. 615-616, 1979.

15 LOMAURO, C.J.; BAKSHI, A.S.; LABUZA, T.P. **Evaluation of food moisture sorption isotherm equations part I: Fruit, vegetable and meat products**. LWT - Food Science and Technology, v. 18, n. 2, p. 111-117, 1985.

16 LUZURIAGA, D.A.; BALABAN, M.O.; YERALAN, S. Analysis of visual quality attributes of white shrimp by machine vision. **Journal of Food Science**, v. 62, n. 1, p. 113-118 e 130, 1997.

17 MOHSENIN, N. Physical Properties of Plant and Animal Materials, 2° Ed., London, London: Gordon and Breach, 1986.

18 MORENO-PEREZ, L.F.; GASSON-LARA, J.H.; ORTEGA-RIVAS, E. Effect of low temperature-long time blanching on quality of dried sweet potato. **Drying Technology**, v. 14, n. 7 and 8, p. 1839-1857, 1996.

19 NICOLETI, J.F.; SILVEIRA-JR, V.; TELIS-ROMERO, J.; TELIS, V.R.N. Viscoelastic behavior of persimmons dried at constant air temperature. **LWT**, v. 38, p. 143-150, 2005.

20 PÉREZ-ALEMÁN, R.; MÁRQUEZ-MELÉNDEZ, R.; MENDOZA-GUZMÁN, V.; JIMÉNEZ-CASTRO, J.; DE LA TORRE, L.; RODRÍGUEZ-TERRAZAS, B.; BARNARD, J.; QUINTERO-RAMOS; A. Improving textural quality in frozen jalapeño pepper by low temperature blanching in calcium chloride solution. **International Journal of Food Science and Technology**, v. 40, p. 401–410, 2005.

21 QUINTERO-RAMOS, A.; BOURNE, M.C.; ANZALDÚA-MORALES, A.. Texture and rehydration of dehydrated carrots as affected by low temperature blanching. **Journal of Food Science**, v. 57, p. 1127-1139, 1992.

22 QUINTERO-RAMOS, A.; SÁNCHEZ DE LA PAZ, A.L.; MEZA-VELÁZQUEZ, J.A.; JIMÉNEZ, J.A.; BARBOSA-CÁNOVAS, G.; ANZALDÚA-MORALES, A. Optimización del escaldado de calabacita criolla (*Cucurbita pepo*) deshidratada a temperaturas bajas y tiempos largos / Optimization of stepwise blanching of dehydrated zucchini (*Cucurbita pepo*). **Food Science and Technology International**, v. 4, p. 159-167, 1998.

23 RODRIGUEZ-AMAYA, D.B.; KIMURA, M.; GODOY, H.T. Updated Brazilian database on food carotenoids: Factors affecting carotenoid composition. **Journal of Food Composition and Analysis**, v. 21, p. 445-463, 2008.

24 SANJUÁN, N.; CLEMENTE, G.; BON, J.; MULET, A. The effect of blanching on the quality of dehydrated broccoli florets. **European Food Research Technology**, v. 213, p. 474-479, 2001.

25 SILVA, K. S.; CAETANO, L. C.; GARCIA, C. C.; ROMERO, J. T.; SANTOS, A. B.; MAURO, M. A. Osmotic dehydration process for low temperature blanched pumpkin. **Journal of Food Engineering,** v. 105, p. 56–64, 2011.

26 SILVA, K.S.; GARCIA, C.C.; AMADO, L.R.; MAURO, M.A. Effects of Edible Coatings on Convective Drying and Characteristics of the Dried Pineapple. **Food and Bioprocess Technology**, v. 8, p. 1465-1475, 2015.

27 STEFFE, J.F. **Rheological methods in food process engineering**. East Lansing, Michigan, USA.: Freeman Press, 1992. 418 p.

28 STEFFE, J.F. Visco-elasticity. In STEFFE, J.F. **Rheological methods in food process engineering**. East Lansing, Michigan: Freeman Press., 1996. p. 294-348.

29 VAN BUREN, J.P. Function of pectin in plant tissue structure and firmness. In Walter, R.A (Ed.) **The Chemistry and Technology of Pectin.** San Diego, California: Academic Press Inc.,1991. p. 1-22.

30 VAN BUREN, J.P. The Chemistry of Texture in Fruits and Vegetables. **Journal of Texture Studies**, v. 10, n. 1, p. 1-23, 1979.

31 VLIET. T.V. Rheological classification of foods and instrumental techniques for their study. In ROSENTHAL, A.J. (Ed.), **Food Texture** — measurement and perception. Gaithersburg, Maryland: Aspen Publishers, Inc, 1999. p. 65-97.

ACKNOWLEDGMENT

The authors would like to thank FAPESP (Proc. 2007/01879-5 and Process 2007/07586-0) for the financial support.