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Impact of pretreatment on colour and texture of watermelon rind

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A b s t r a c t. The effect of osmotic dehydration pretreatment on water loss, solid gain, colour and textural change was investigated. Watermelon rind 1 x 1 cm size was immersed in sucrose solution of 40, 50 and 60° Brix after pretreatment with microwave and conventional boiling in water for 1, 3, and 5 min, respectively. Water loss and solid gain increased with the time of cooking and sugar concentration. Microwave pretreated samples showed higher water loss and solid gain. Increase in the time of cooking decreased the brightness of all the samples. Microwave pretreated samples showed higher 'b' values than conventionally pretreated ones. There was no significant difference ($P \leq 0.05$) in texture profile analysis parameters except for hardness. Hardness decreased with increase in time of cooking and sugar concentration. Second order regression model was developed for water loss and solid gain of microwave and conventional pretreated watermelon rind.

K e y w o r d: osmotic dehydration, watermelon, rind, microwave, texture

INTRODUCTION

Watermelon is an important food crop in tropical countries. It has been in cultivation for a long time in India which is often considered as the secondary centre of its origin. It is a common summer crop and is grown from the lower Himalayan regions to South India. Watermelon is a natural and rich source of the non-essential amino acid citrulline. Citrulline is used in the nitric oxide system in humans and has potential antioxidant and vazodilatation roles. Rind contained more citrulline than flesh on a dry mass basis (24.7 and 16.7 mg g^{-1} d.m., respectively), but a little less on a fresh mass basis (1.3 and 1.9 mg g^{-1} f.m., respectively). Half of a watermelon fruit is edible while the other half, consisting of about 35% rind and 15% peel, goes to waste. Watermelon rind was higher in percent fresh mass dietary fibre and potassium than the flesh. Total sugar content was lower in the rind and sugars were primarily fructose and glucose, compared to flesh which had about 30% of its sugars as sucrose. The rind contains citrulline in high quantities and is a rich source of an important amino acid and may yield a useful product from an agricultural waste (Rimando *et al*., 2005). Most tropical fruits are highly perishable, showing a short shelf life post harvest at room temperature, which implies losses at the level of over 30% of production (Cardoso *et al*., 2007). Watermelon rind has a water content of about 95% making it susceptible to deterioration. Therefore, it is necessary to reduce the moisture content and produce shelf stable products from watermelon rind.

Osmotic dehydration is a water removal process involving soaking of foods, mostly fruits and vegetables, in a hypertonic solution such as concentrated sugar syrup (Anoar *et al*., 2006; Bahadur *et al.,* 2007; Kolawole *et al*., 2007; Rastogi *et al*., 2004; Sunjka and Raghavan, 2004). Osmotic dehydration is based on the principle that when cellular materials (such as fruits and vegetables) are immersed in a hypertonic aqueous solution, a driving force for water removal sets up because of the higher osmotic pressure (or lower water activity) of the hypertonic solution (Jokic *et al*., 2007; Erle and Scherbert, 2001; Rastogi *et al*., 2006; Bahadur *et al.*, 2010). In spite of the numerous studies that have been carried out on this subject, it is still difficult to establish general rules concerning the variables that affect osmotic dehydration. Water loss (*WL*) and solute gain depend both

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on operating conditions and cellular tissue type, as well as on the form in which the product was pretreated (Min Zhang *et al.*, 2012; Xin Li *et al.*, 2011). Hence, there, is a need to identify the optimum operating conditions that increase mass transfer rates without affecting quality significantly (Ispir and Togrul, 2009; Eren and Kaymak-Ertekin, 2007; Mercali *et al*., 2011). By using microwave pretreatment, physical properties of raw material may change, which could be a way to increase the process effectiveness.

The use of microwave heating as a pretreatment prior to osmo-air-drying was investigated. The influence of time of cooking (microwave) on the colour and textural properties of watermelon rind was examined and the results were compared with the conventional methods of pretreatment.

MATERIALS AND METHODS

Mature ripe watermelons were used for the experiment. The watermelons were stored in a ventilated room at 30± 3°C. The watermelons were washed and the outer green peel was hand peeled and the rind was cut into 1x1 cm cubes. Average moisture content of the watermelon rind was 94.5%. Commercial sucrose was purchased from local market.

Microwave treatment was performed in a domestic digital microwave oven, with technical features of approximately 230 V, 50 Hz and 2 650 W, and frequency of 2 450 MHz (wavelength of 12.24 cm). During microwave pretreatment experiments, 20 cubes of watermelon rind were put in a glass bowl, and placed at the centre of the oven. The microwave bowl with water was preheated for 1 min, uniformly before all the treatments. The water to fruit ratio was maintained at 5:1 (mass basis), which was also used in the osmotic dehydration experiments. Microwave pretreatment was performed by cooking the watermelon rind cubes in the microwave oven for 1, 2, and 3 min, respectively. Initial mass of the rind and the mass of the rind after microwave treatment were taken.

Conventional pretreatment was performed by cooking the watermelon rind in boiling water for 1, 2, and 3 min, respectively.

In the osmotic dehydration process, each experimental group consisting of 20 watermelon cubes (microwave pretreated) was immersed in the osmotic solution for 1, 2, 3, 4 or 5 h. The osmotic solution used in each experiment was prepared mixing food grade sucrose with distilled water to give a concentration of 40, 50 and 60° Brix. The osmotic solution to fruit ratio was maintained at 5:1 (mass basis). Previous studies have shown that the osmotic dehydration process should run under an osmotic solution to fruit ratio of at least 4:1 to maintain the operating conditions constant and to avoid excessive dilution of the osmotic solution (Fabiano *et al*., 2007). After removal from the solution, the dehydrated samples from each group were drained and blotted with absorbent paper to remove excess solution. Mass and moisture content were measured individually. The concentration of the solution was monitored during the runs determining the osmotic solution soluble solid content (°Brix) using an Abbe refractometer. Osmotic dehydration was conducted at 50°C. The same set of experiment was performed with conventionally pretreated watermelon rind.

Mass and moisture content of the samples were used to calculate the response variables of the experimental planning. From these data, water loss (*WL*) and solid gain (*SG*) were determined according to the methods of Panagiotou *et al*., 1999:

$$WL = (M_0 C_0 - MC) / M_0 100, \quad (1)$$

$$SG = [M_0 (C_0 - 1) - M(C - 1)] / M_0 100, \quad (2)$$

where: M_0 is the initial mass of the sample (t=0), M is the mass of the sample at time t, C_0 is the initial moisture of sample (wet basis), and C is the moisture of sample (wet basis) at time t.

Fresh, microwave pretreated osmosed and conventionally pretreated osmosed watermelon rind cubes were tested in a Hunter colorimeter to obtain a, b and L parameters as an average of three measurements. The equipment was calibrated with a white standard (L* = 97.71, a* = -0.59 and b* = 2.31) and each sample was scanned at three different locations. The L* value represents the lightness, a* – redness, -a* – greenness and b* – yellowness.

A TA-XT texture analyzer (Stable Microsystems Limited, UK) was used to conduct the texture profile analysis using a 75 mm cylindrical probe. The probe descended at a speed of 5 mm s^{-1} and compressed the sample at a speed of 2 mm s^{-1} up to a distance making 50% deformation. When the compression stroke was completed, the probe abruptly reversed its direction and started the upward stroke at 2 mm s^{-1}. Then a second down and up cycle was run on the same sample. A force-time curve was recorded by the instrument and four textured attributes including hardness, adhesiveness, cohesiveness and springiness were measured. Hardness (peak force of the first compression cycle in N), adhesiveness (negative area under the baseline between the compression cycles in Ns), cohesiveness (ratio of the area under the second cycle over the area under the first cycle) and springiness (ratio of the time duration of force input during the second compression to that obtained during the first compression, dimensionless (Segovia *et al*., 2008). The measurements of textural properties of fresh, conventional pretreatment osmosed and microwave pretreatment osmosed were conducted after an osmotic dehydration of 6 h.

The experiments were performed in triplicate and the resulting data were analyzed using a statistical analysis program AGRES. The differences between means were compared using Duncan multiple range test with the significance of $p<0.05$.

Essential regression computer software was used in developing the regression models and plotting the three-dimensional surface plots to study the effect of various independent variables on the dependent variable by employing multiple regression technique (Uddin *et al*., 2004).

RESULTS AND DISCUSSION

Fresh watermelon rind was subjected to the osmotic dehydration after pretreatment by microwave cooking and conventional cooking. Each treatment was replicated thrice and the osmotic dehydration was conducted for 6 h. The treated watermelon rind was assayed for water loss and solid gain during the treatment period and the results obtained are discussed below in detail.

Higher temperature during osmotic dehydration increased the water loss and solid gain due to increasing diffusion coefficients and decreasing viscosity of sucrose solution. There are limitations to using high temperature such as 60°C because of lower *WL*/*SG* ratio (and/or lower product quality) and the viscosity of the 70% solution at 50°C temperature was so high that its water loss curve was very close to the 60% curve. So the optimum temperature and concentration were found to be 50°C and 60%, respectively (Khoyi and Hesari, 2007). Hence in the present study osmotic dehydration was performed at 50ºC. High temperature caused swelling and plasticising of cell membrane and in that way the membrane became more permeable to water coming out of the product, and at the same time higher temperature reduced the viscosity of the osmotic medium, which resulted in better water transfer characteristics on the product surface (Simal *et al*., 1998; Jokic *et al*., 2007).

The analysis of fresh fruit showed that watermelon rind had an initial moisture content of 94.5% and soluble solid content of 5.8° Brix.

Data on the water loss and solid gain of watermelon rind as affected by different treatment period and immersion period in different concentrations of sugar solution are depicted in the form of surface plots in Figs 1 and 2. It is evident from the figures that the increase in immersion period and sugar concentration increased the water loss and solid gain of both the methods (microwave and conventional) of pretreatment of watermelon rind. Water loss and solid gain were higher in microwave pretreated watermelon rind than in conventionally treated watermelon rind.

An initial rapid increase in water loss and solid gain was observed, followed by a reduction in these flows close to the end of the osmotic process. Similar results are also reported by Kolawale *et al*. (2007). High level of water loss is reported for the microwave treated watermelon rind. This result can be attributed to an alteration in the structure of watermelon rind. This could be due to the tissues allowing more water movement from the tissue to the sugar solution with microwave treatments. The cellular tissue exposed to thermal or physical pretreatment loses cell wall rigidity, as well as inter cellular adhesion. Such changes in physical properties resulted in high solute uptake. Similar findings were reported by Leyva *et al*. (2007) who showed that ultrasonic treatment in bell pepper immersed in osmotic solution produced a significant water loss.

Water loss and solid gain increased with the higher concentration of osmotic solution concentration. Watermelon rind immersed in 60° Brix solution showed higher water loss and solid gain compared to those immersed in 50° Brix and 40° Brix solutions. The increase in solid gain and water loss with the solution concentration is due to the high concentration difference between the watermelon rind and osmotic solution, which increased the rate of diffusion of solute and water exchange with osmotic solution. Increased solution concentration resulted in increase in the osmotic pressure gradients and higher water loss (Kolawole *et al*., 2007).

The watermelon rind cooked for 1 min and immersed in 40° Brix solution for 6 h showed a water loss of 31 and 29% in microwave and conventional cooking, respectively. The watermelon rind cooked for 3 min and immersed in 60° Brix solution for 6 h showed a water loss of 77 and 69% in microwave and conventional cooking.

The rate of solid gain in microwave and conventional treatments was less than the water loss for the same treatments. The solid gain increased with the increase in the immersion period and sugar concentration. The higher the concentration of sugar, the higher is the rate of solid diffusion. Watermelon rind immersed in 60°Brix after treating in microwave for 3 min showed 15.6 and 30% increase in solid gain over the watermelon rind immersed in 50°Brix and 40 °Brix, respectively, after 6 h immersion period. Conventionally treated watermelon rind showed comparatively lesser gain in solid than microwave treated.

The solid gain increased rapidly with immersion time, whereas it increased slowly with sucrose solution.

A second order regression equation was fitted to the experimental data and the following second order regression models were obtained after deleting the non-significant terms using the software essential regression:

$$WL_{(Microwave)} = -26.96 + 0.281B + 0.246CT\,B + 6.2IT - 3.778CT^2 + 14.26CT \quad (R^2 = 0.98) \qquad (3)$$

$$WL_{(Conventional)} = -16.75 + 0.7CT\,IT + 0.304\,CT\,B - 5.028CT^2 + 6.999IT + 13.62CT \quad (R^2 = 0.98) \qquad (4)$$

$$SG_{(Microwave)} = -17.24 + 0.978\,CT\,IT + 4.056\,CT^2 + 0.052\,IT\,B - 20.21\,CT + 0.178\,CT\,B \quad (R^2 = 0.96) \qquad (5)$$

$$SG_{(Conventional)} = -16.66 + 2.115\,CT\,IT + 2.115\,B \quad (R^2 = 0.92), \qquad (6)$$

where: B is the sugar concentration (°Brix), CT is the cooking time (min), IT is the immersion time (h), WL is the mass loss (%), and SG is the solid gain (%).

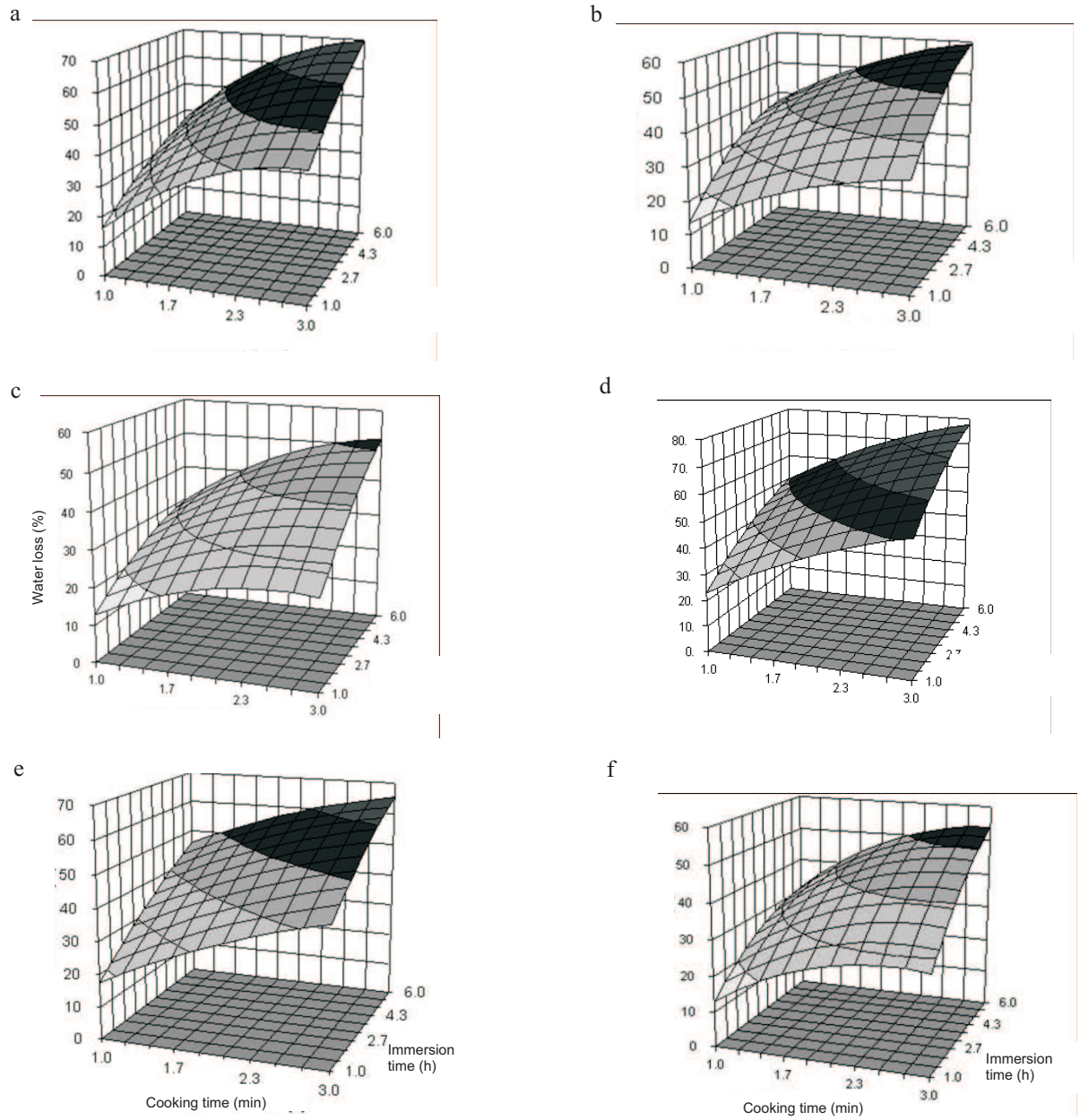

Fig. 1. Effect of conventional (a, b, c) and microwave(d, e, f) pretreatments on water loss of watermelon rind immersed in: 60, 50 and 40°Brix; ☐ 0-10, ☐ 10-20, ☐ 20-30, ☐ 30-40, ☐ 40-50, ■ 50-60, ■ 60-70.

The analysis of variance (ANOVA) was carried out for the second order regression models and it was found that the models were significant at 1% level. High values of R^2, obtained for water loss and solid gain for the microwave and conventional methods, indicate good fit of experimental data.

The F-test of the above models was found to be significant from the analysis. Hence the developed models were adequate to describe the relationship of various process parameters with respect to mass loss and solid gain in watermelon. The mean values of water loss and solid gain obtained for all the treatments were statistically analyzed and the ANOVA table is presented in Table 1.

Osmotic pretreatment, like conventional and microwave cooking, provoke small colour changes in the fruit surface. Table 2 shows the L*, a*, b* values of fresh and pretreated (microwave and conventional) osmosed watermelon rind. Significant differences ($p \leq 0.05$) were found between treatments regarding all colour values. Increase in the time of cooking decreased the brightness, both for convention and microwave pretreatment. There was not much difference in brightness upon cooking for 3 and 5 min, in both the methods of pretreatment. A significant difference ($p \leq 0.05$) in brightness was observed for the microwave pretreatment and conventional cooking. The values of

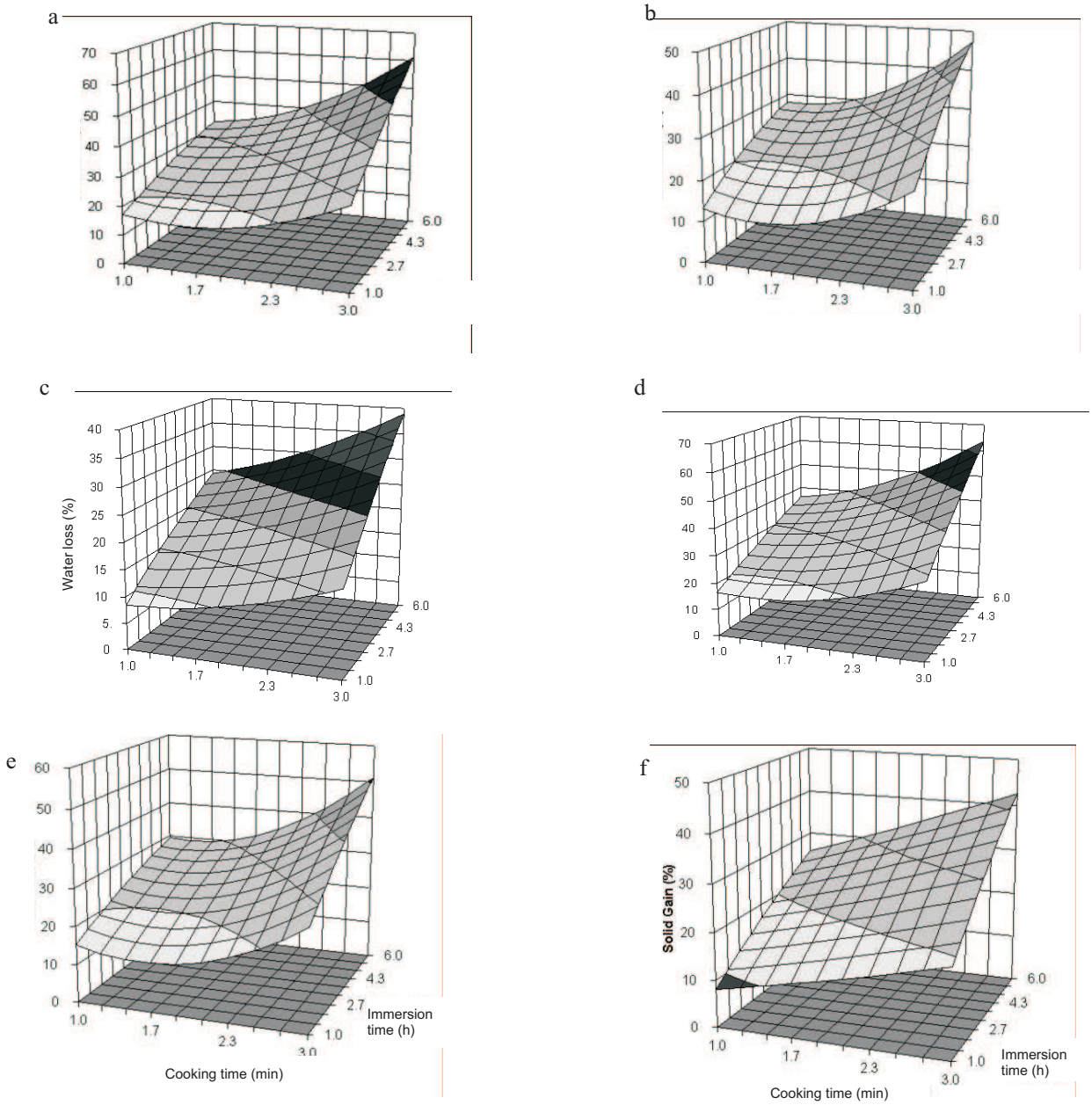

Fig. 2. Effect of conventional (a, b, c) and microwave(d, e, f) pretreatments on solid gain of watermelon rind immersed in 60, 50 and 40°Brix. Explanations as in Fig. 1.

T a b l e 1. Analysis of variance for water loss and solid gain of watermelon rind

Source of variation	Sum of squares	Degrees of freedom	Mean square	F-value
Water loss (microwave)	12 047.16	9	1 338.57	465.64
Water loss (conventional)	10 020.52	9	1 113.39	331.96
Solid gain (microwave)	7 201.30	9	800.14	139.76
Solid gain (conventional)	6 923.96	9	769.32	190.00

T a b l e 2. Colour parameters of fresh, osmosed (conventional pretreated and microwave pretreated) at 50°C watermelon rind

Cooking time (min)	°Brix	Lightness L*	Redness a*	Yellowness b*
			Fresh	
		73.42±0.068^{a}	-7.53±0.026^{o}	32.43±0.005^{q}
		Conventional pretreated		
1		46.41± 0.068^{g}	-3.94± 0.01^{n}	37.84± 0.010^{p}
3	40	40.63± 0.090^{h}	-2.93± 0.01^{i}	44.34± 0.005^{l}
5		38.84 ±0.026^{k}	-2.88± 0.005^{i}	47.89± 0.005^{f}
1		46.78± 0.066^{f}	-3.06± 0.005^{l}	39.78± 0.005^{o}
3	50	40.40± 0.037^{hi}	-2.85± 0.005^{h}	46.87± 0.005^{i}
5		37.56± 0.095^{n}	-2.53± 0.011^{e}	49.12± 0.01^{d}
1		50.18± 0.076^{c}	-2.88± 0.005^{i}	41.89± 0.005^{n}
3	60	39.94± 0.087^{l}	-2.43± 0.011^{d}	47.44± 0.010^{h}
5		37.78± 0.011^{m}	-2.33± 0.01^{b}	49.85± 0.020^{b}
		Microwave pretreated		
1		48.64 ±0.04^{e}	-3.87± 0.011^{m}	41.87± 0.005^{n}
3	40	38.71± 0.095^{k}	-2.76± 0.01^{g}	46.55± 0.015^{j}
5		38.16± 0.080^{l}	-2.41± 0.005^{c}	48.23 0.01^{e}
1		49.02± 0.035^{d}	-2.99± 0.011^{k}	43.56± 0.005^{m}
3	50	37.44± 0.066^{n}	-2.64± 0.005^{f}	47.67± 0.005^{g}
5		40.26± 0.090^{i}	-2.41± 0.005^{c}	49.44± 0.005^{c}
1		53.37± 0.040^{b}	-2.78± 0.005^{g}	44.45± 0.005^{k}
3	60	38.83± 0.026^{k}	-2.53± 0.005^{e}	48.23± 0.005^{e}
5		37.32± 0.072^{o}	-2.03± 0.005^{a}	50.32± 0.005^{a}

Means having different superscripts differ significantly in each column ($p \leq 0.05$), n=3.

conventional cooking were higher than those of the microwave pretreated watermelon rind. A significant decrease ($p \leq 0.05$) in brightness was observed with increase in sugar concentration for all the treatments. Fresh sample showed higher 'a' value, representing the product more greenish. A slight decrease in 'a' values was observed in samples that were osmotically pretreated (both microwave and conventional) and this decrease in 'a' value can be attributed to the heat-degradation of colour compounds that occur during osmotic pretreatment. A significant increase ($p \leq 0.05$) in 'b' was observed with increase in time of cooking and sugar concentration. This may suggest an influence of the high concentration of sucrose, giving more yellowish samples. Microwave pretreated sample showed higher 'b' value than conventional cooking; this increase in yellowness may be due to more infusion of sugar into the sample.

Texture profile analysis (TPA) was performed for each cooking treatment (3 replications). Table 3 shows the hardness, adhesiveness, springiness and cohesiveness values of fresh and pretreated (microwave and conventional) osmosed watermelon rind. For samples with better structural integrity and/or higher moisture content, a greater force was required to counteract the pressure generated by the water inside the cell vacuoles, thus giving a rise to the hardness. The hardness decreased with increase in the time of cooking, at particular temperatures and sugar concentrations. Increase in the time of cooking and Brix value decreased the hardness value. The conventional cooking showing higher hardness than microwave cooking for the same treatment conditions. The watermelon rind cooked for 5 min in microwave oven and soaked in 60ºBrix solution was very soft and showed the lowest hardness. The springiness of almost all the samples was the same as their springiness

T a b l e 3. Texture profile analysis of parameters of fresh, osmosed (conventional pretreated and microwave pretreated) at 50°C watermelon rind slices

Cooking time (min)	°Brix	Hardness	Adhesiveness	Springiness	Cohesiveness
			Fresh sample		
		58.56±0.44^{a}	-0.02^{b}	0.427±0.002^{a}	0.41±0.005^{e}
			Conventional pretreated		
1		29.18± 0.43^{b}	-0.02 ^{b}	0.4± 0.01^{b}	0.41± 0.005^{e}
3	40	24.45± 0.23^{d}	-0.01^{a}	0.38± 0.006^{cd}	0.42± 0.002^{d}
5		19± 0.27^{h}	-0.02 ^{b}	0.38± 0.006^{cd}	0.42± 0.002^{d}
1		25.75± 0.12^{c}	-0.01 ^{a}	0.4± 0.01^{b}	0.42± 0.002$_{d}$
3	50	22.33± 0.16^{f}	-0.02 ^{b}	0.37± 0.006^{de}	0.42± 0.002^{d}
5		17.45± 0.27^{i}	-0.01 ^{a}	0.36± 0.006^{ef}	0.43± 0.003^{c}
1		23.37± 0.33^{e}	-0.01 ^{a}	0.38± 0.006^{bd}	0.43± 0.003^{c}
3	60	19.36± 0.15^{h}	-0.02 ^{b}	0.35± 0.006^{fg}	0.43± 0.003^{c}
5		16.13± 0.15^{k}	-0.02 ^{b}	0.34± 0.006^{gh}	0.44± 0.003^{c}
			Microwave pretreated		
1		25.74± 0.13^{c}	-0.01 ^{a}	0.39± 0.006^{b}	0.41± 0.005^{e}
3	40	22.13± 0.16^{f}	-0.02 ^{b}	0.35± 0.006^{fg}	0.43± 0.003^{c}
5		18.32± 0.36^{i}	-0.01 ^{a}	0.34± 0.006^{gh}	0.43± 0.003^{c}
1		24± 0.32^{d}	-0.02 ^{b}	0.39± 0.006^{b}	0.44± 0.003^{b}
3	50	19.78± 0.69^{g}	-0.01 ^{a}	0.34 0.006^{gh}	0.44± 0.003^{b}
5		16.23± 0.39^{k}	-0.01 ^{a}	0.34± 0.006^{gh}	0.45± 0.004^{a}
1		24.35± 0.35^{d}	-0.01 ^{a}	0.37± 0.006^{de}	0.44± 0.003^{b}
3	60	17.12± 0.38^{j}	-0.02 ^{b}	0.33± 0.006^{hi}	0.45± 0.004^{a}
5		14.33± 0.34^{i}	-0.02 ^{b}	0.32± 0.006^{i}	0.45± 0.004^{a}

Explanations as in Table 2.

before the osmotic dehydration. There was no significant difference ($P \leq 0.05$) in springiness between the treatments, but there was a slight decrease in springiness with increase in time of cooking and Brix concentration. The reduction in the springiness was also a result of the loss of turgor, reducing the cells ability to regain their original form. There was no significant difference in adhesiveness between the treatments and the fresh sample. The cohesiveness of the treated and fresh samples was slightly different, but there was no significant differences between the treatments. Cell walls provide support to plant cells, as well as support the cohesiveness of the plant tissue. The cohesiveness of the plant tissue is determined by the amount of pectic substances at the middle lamella (Segovia *et al*., 2008). The cell membrane structure could have been altered during the osmotic dehydration process, causing the pectic substances to redistribute.

CONCLUSIONS

1. Increase in immersion period and sugar concentration increased the water loss and solid gain of both the methods of pretreatment on watermelon rind.

2. Water loss and solid gain were higher in microwave pretreated watermelon rind than in conventionally treated watermelon rind.

3. Increase in the time of cooking decreased the brightness of watermelon rind in all the treatments. A significant increase ($P \leq 0.05$) in 'b' value was observed with the increase in time of cooking and sugar concentration. Microwave pretreated sample showed higher 'b' value than the conventionally pretreated sample.

4. There was no significant difference in texture profile analysis parameters, except hardness. Hardness decreased with increase in the time of cooking and sugar concentration for all the treatments.

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