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The influence of osmotic pretreatments on melon (*Cucumis melo L.*) quality during frozen storage

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Abstract

The aim of work was to evaluate the influence of using osmotic dehydration (OD) on drip loss (DL), volume (V), total color change (ΔE), and firmness of *Cucumis melo L*. samples (Cantaloupe variety), stored under freezing conditions. The samples were dehydrated up to two humidity levels (75 and 85%, w.b.), using an osmotic sucrose solution with 55ºBrix, at 27± 0.2ºC. The dehydrated samples were frozen at -40ºC and then stored at -18ºC for 1, 15 and 30 days. Fresh fruit samples (non-osmotic treatment) were used as control duringthe frozen storage time. The results showed that the treated samples had significantly (p<0.05) lower DL, V, and ΔE, compared to the untreated ones along the freezing process. The firmness was significantly (p<0.05) greater in treated samples. The quality of osmotic-treated samples was higher than non-treated ones. However, treated samples with a lower content of humidity (75%, w.b.) showed greater firmness and lower loss in color and volume.

Keywords: Freezing, Osmotic dehydration; Cantaloupe melon; osmodehydrofreezing.

Influencia de pretratamientos osmóticos sobre la calidad de muestras de melón (*Cucumis melo L.*) durante almacenamiento en congelación

Resumen

El objetivo de este trabajo fue evaluar la influencia de la aplicación de deshidratación osmótica (OD) previa a la congelación sobre la pérdida de fase líquida (DL), volumen (V), cambio total de color (ΔE) y firmeza de muestras de melón (variedad *Cantaloupe*) almacenado en congelación. Las muestras fueron deshidratadas hasta dos niveles de humedad (85 y 75%, w.b) empleando solución osmótica de sacarosa con 55ºBrix a 27±0.2ºC. Las muestras deshidratadas fueron congeladas a -40ºC y posteriormente almacenadas a -18ºC durante 1, 15 y 30 días. Fruta fresca (no tratada osmóticamente) fue empleada como muestra control durante el almacenamiento en congelación. Los resultados mostraron significativamente (p<0.05) que las muestras tratadas presentaron menores DL, V y ΔE respecto a las muestras no tratadas durante el almacenamiento en congelación. La firmeza fue significativamente (p<0.05) mayor en las muestras tratadas. Sin embargo, las muestras tratadas hasta el menor contenido de humedad (75%. w.b.) presentaron mayor firmeza y menor pérdida de color y de volumen.

Palabras clave: Congelación; deshidratación osmótica; melón Cantaloupe; osmocongelación.

1. Introduction

Melon (*Cucumis melo L.*) is a creeping-stem herbaceous plant, whose fruit can have an oval, elliptical, or round shape. It bears a rough skin with orange, sweet pulp. This fruit basically is composed of water, at its maturity has a soluble solids content between 7 and 12ºBrix. Several varieties exist, including the Spanish, the Yellow, the Written or Reticular, the Frog-like skin, and the Cantaloupe varieties, among others. The most representative variety in Colombia, in terms of production and commercialization (national and international), is Cantaloupe [1]. Cantaloupe melon production is growing in national and international markets; in Colombia the production has increased from 20.1 tonnes in 2001 to 43.8 tonnes in 2011, while international production grew in 2100 tonnes during this period [2].

Like any other fruit, melon is highly perishable, due to its high moisture content (MC). Therefore, it is important to seek alternative ways to preserve and store it. Freezing is one the most commonly used food preservation processes and it is considered one of the best food conservation methods. According to Wu *et al.*, [3] freezing helps keep food taste, and nutritional value, better than any other conservation technology. However, after freezing-thawing, food presents some drastic changes and cumulative, gradual, and irreversible quality loss, mainly shown in drip loss (which is due to cell damage) [4], texture alteration (loss of turgor during thawing, thus resulting in flaccidity and shrinking) [5,6], lower volume [7] and, in some cases, change in color [4], taste and aroma [8]. During freezing, part of the aqueous content is frozen, thus creating ice crystals which damage cell tissues. As a result, the structure of the cell membrane weakens causing the cells to lose their osmotic state and their semi-permeability [9].

Osmodehydrofreezing (ODF) is considered an alternative technique to avoid substantial quality loss in fruit and vegetables during frozen storage. It minimizes texture loss [6], structural collapse, and drip loss [10], among other benefits. ODF consists in osmotic dehydration (OD) of the product, prior to the freezing process [9]. This technique has been reported as a tool in fruit conservation, mainly due to the reduction of freezable water content [11]. Partial reduction of the product's freezable water results in fewer ice crystals duringthe freezing time [8]. Therefore, using OD reduces the content of freezable water in the product, a process consisting in the extraction of water in the product, by submerging it in a hyper-tonic osmotic solution (OS), along a specific time period and temperature rate [12]. This OS must be a highly-concentrated solute, like salt or sugar [4].

OD has been used with different fruits and vegetables, including apples [4, 9], kiwis [4,6], pears [4], eggplant [3], and carrots [13]. Research on melon is scarce [14,15], with a few studies on varieties others than Cantaloupe, using sucrose concentrations different from the ones reported here (55ºBrix).

The objective of this work was to study the effect of osmotic pre-treatment on the drip loss (DL), volume change (ΔV), total color change (ΔE), and texture of melon (Cucumismelo L.) tissue, stored under freezing for 1, 15 and 30 days.

2. Materials and methods

2.1. Sample preparation

Melons having similar ripeness degree 7.75±0.7ºBrix, moisture content (MC) of 92.5±0.5% (w.b), and bearing the *extra* category, according to NTC 5207 standards [16] were used. The fruit was purchased at a local store in Cali, Colombia. Fruits were washed, peeled (using a stainless steel knife) and cut in halves, in order to remove these eds. Each half was cut into 20mm-high and 15mm-diameter cylinders, using a stainless cylindrical steel hollow punch.

2.2. Osmotic pretreatment

The samples were submerged in a commercial sucrose OS at 55% w/w, in a plastic container. The OS was kept at 27.0±0.2ºC and constantly stirred at 1000 rpm, using a mechanical stirrer (Kika Labor Technik Pol Col, US), in order to avoid crusting resulting from the presence of sugar on the samples' surface.

The OS to fruit ratio was 1:20 (w/w), in order to guarantee the OS concentration along OD [17-20] and avoid reduction of the impulse force during the process [21]. At two time periods of OD 35 and 98 min, samples were taken out of the OS so as to achieve two MC levels of 85.00±0.18 and 75.00±0.21% (w.b.) respectively. The times required to reach MC levels were previously calculated in melon OD kinetics [22]. These MC levels were chosen in order to reduce the content of freezable water melon. The osmo-dehydrated samples were placed on humid paper towels to eliminate OS excess on their surface. The MC of the treated and non-treated samples was determined by using the 934.06 Method of the AOAC [23] and the MC of the soluble solids (°Brix) was calculated by means of a refractometer (Abbe Atago 1T, Zeiss, thermostated at 20ºC).

2.3. Freezing, storage and thawing

Both the treated and non-treated samples were stored in resealable plastic bag sin a commercial freezer at 8ºC for 12 hours, in order to enhance the internal equilibrium of the concentration [6, 24]. Then, the samples were frozen at –40ºC (Revco, USA) at a rate of 1.3ºC/min and stored in a commercial freezer at -18ºC, along 1, 15 and 30 days. For each storage time, the samples were thawed at 8ºC in a commercial freezer, for 14 hours to ensure complete thawing [8,25,26]. The physical properties (DL, V, color, and texture) of the samples were measured after thawing.

2.4. Physical properties

DL was calculated considering the weight differences of the samples before and after the freezing-thawing process [6, 26], using an analytic balance (Mettler Toledo AE200, Switzerland), with a 0.001g precision. DL was calculated using eq. (1).

$$DL = \frac{m_f - m_o}{m_o} \qquad (1)$$

Where m_o and m_f correspond to the weight of the sample before and after freezing-thawing respectively.

The volume of each sample before and after freezing-thawing was calculated by measuring its diameter and height at three 120º separate points on one of the cylinder's circular sides, using a digital caliper (Bull Tols, USA). The ΔV or shrinking was calculated with eq. (2).

Where V_o *and* V_f are volume of the sample before and after freezing, respectively.

The color coordinates CIEL*a*b* were calculated between 400-700 nm, based on the reflexion spectra of the samples, using a spectrocolorimeter (Hunterlab Reston, Virginia USA). Illuminant D65 and Observer 10º were used as referents. Total color change (ΔE) was calculated with eq. (3).

$$\Delta E = \sqrt{\Delta L*^2 + \Delta a*^2 + \Delta b*^2} \qquad (3)$$

Where:
L*: Lightness
a*: Green – red color axis
b*: Blue – yellow color axis
ΔL*, Δa* y Δb* were calculated following:
$\Delta L^* = L^*_{at} - L^*_{bf}$, $\Delta a^* = a^*_{at} - a^*_{bf}$, $\Delta b^* = b^*_{at} - b^*_{bf}$
Where:
at: after freezing-thawing
bf: before freezing

The texture (in terms of firmness, N) of the treated and non-treated samples was evaluated by using a uniaxial compression test. A texturometer (EZ-Test model, Shimadzu, Somerset, New Jersey), adapted with a 40mm diameter cylindrical plate was used for this purpose. The plate was lubricated, in order to avoid sample-plate friction [27]. The samples were compressed to 75% of their initial height, at 30mm/min speed. The firmness was calculated by means of the maximum force peak.

2.5. Experimental design

A factor 3x3 design was used, with two factors chosen at random:

Humidity content of the fruit at three levels: 92% (fresh), 85% (OD) and 75% (OD), and frozen storage time: 1, 15 and 30 days.

Each treatment was carried out in triplicate. The results were analyzed using analysis of variance (ANOVA), with a confidence level of 95%, using Minitab 16 (Minitab, Inc., State College, Pennsylvania, 2009).

3. Results and discussion

3.1. Drip loss evaluation

Drip loss of the treated and non-treated samples are shown in Fig.1.

It can be noticed that in all the treatments (treated and non-treated samples) DL of the samples increases as the storage time period increases, which may be due to ice re-crystallization during the storage period, thus resulting in loss of cell content and loss of cell water retention capacity [28]. Recrystallization is the change in size, shape and number of ice crystals during frozen storage [29,30]. These findings are similar to those reported for kiwi [29,30], strawberry [25], apple, and pear [4]. It can also be noticed that during frozen storage, treated samples show lower DL than non-treated samples. This is an indication of the cryoprotecting effect of osmotic treatment, previous to the freezing process. Similar findings have been reported for different fruits and vegetables [4,13]. As to the humidity levels in the treated samples, the treatment with lower MC level (75%) showed lower DL value in each storage time period (23.02+0.32, 26.68 + 0.13 and 30.36+0.14 % for 1, 15 and 30 days, respectively). This may be due to lower

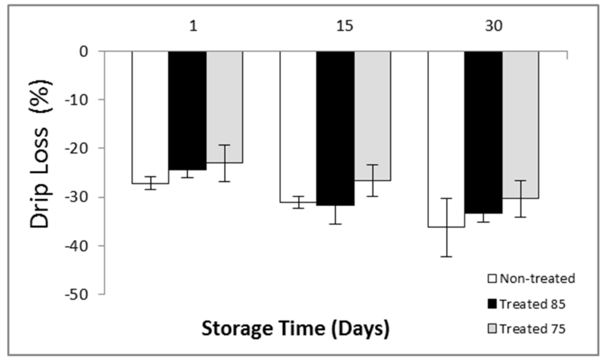

Figure 1. Drip Loss in treated and non-treated melon samples during the freezing – thawing process
Source: The authors

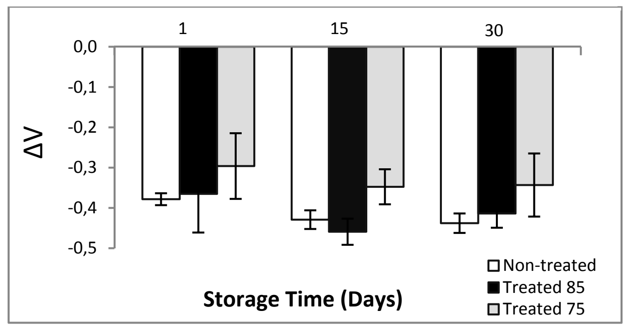

Figure 2.Volume change in osmo-dehydrofreezing treated and non-treated melon samples during frozenstorage
Source: The authors

ice recrystallization because of less freezable water content, which leads to less structural collapse. A similar behavior has been found for Kiwi [6]. ANOVA showed a significant ($p<0.05$) effect of the factors frozen storage time and WC level on the DL of cantaloupe samples.

3.2. Volume loss

Fig. 2 shows the volume loss (ΔV) for treated and non-treated samples during frozen storage. It can be noticed that in all the treatments there was ΔV along the freezing storing time period. However, the non-treated samples show higher ΔV, with 37.80±0.21, 42.90±0.43 and 43.80±0.29% for 1, 15 and 30 days, respectively. As to the treated samples, those with lower MC (75%) show lower ΔV, with 29.6+0.40, 34.8+0.18 and 37.3+0.26% for days 1, 15 and 30, respectively. These higher ΔV in non-treated samples are associated with higher drip loss in the freezing-thawing process, due to higher freezable water content. According to Koc and Eren[31], water loss in food leads to structural damage, which causes shrinking and microstructure changes in the product.

The statistical analysis (ANOVA) showed significant differences ($p<0.05$) for the storing time period and for the MC in connection with the volume of the samples.

3.2. Color change

Fig. 3 shows the total color change (ΔE) for the different treatments during frozen storage. High ΔE values indicate greater color changes. Total color change increased in all the treatments during the freezing time. However, the osmo-dehydrated samples show significantly ($p<0.05$) less color changes (values lower than 10). There were no significant ($p>0.05$) ΔE in the osmo-dehydrated samples in the two MC levels (75 and 85%). These ΔE were mainly influenced by L* coordinate, which indicates clarity or luminosity in the color space, and is indicative of the degree of browning of the food [3,32]. The non-treated samples showed greater ΔL* (%) during the storing time period (from day 1 to 30 day), varying from13.92±0.88 to 16.39±0.93%, while the osmo-dehydrated samples (75 y 85%) varied from 4.32±0.22 to 6.33±0.37% and from 8.53±0.39 to 10.15±0.76%, respectively. These results indicate that non-treated samples experienced greater brownness, compared to that of the osmo-dehydrated samples. These findings further explain the cryoprotecting effect of osmotic treatments in frozen fruit color. This effect may be due to lower freezable water content, which plays a role in the decrease of the number of reactions leading to the brownness of the fruit tissues [3]. Another explanation may be the presence of sugar on the surface of the treated samples,

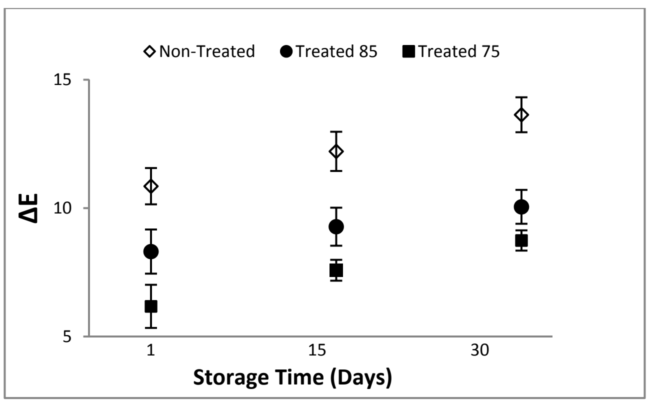

Figure 3. Color change in osmodehydrofreezing treated and non-treated melon samples during frozen storage
Source: The authors

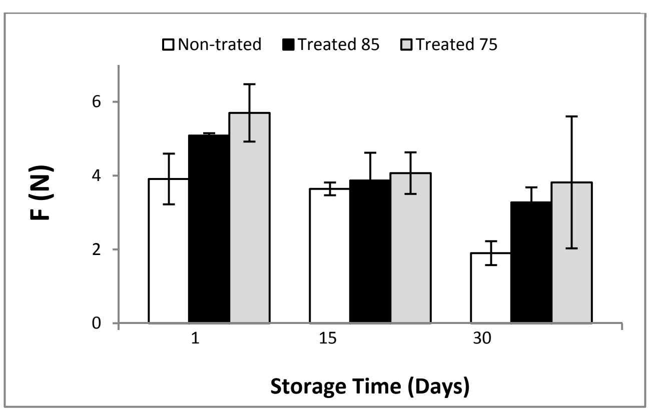

Figure 4. Firmness change of osmodehydrofreezing treated and non-treated melon samples during frozen storage
Source: The authors

which prevents oxygen transfer to the fruit, consequently reducing enzymatic brownness [33, 34]. These findings are similar to those reported in research studies dealing with kiwi, apple [4] and eggplant [3].

3.4. Firmness

Fig. 4 **s**hows the values for texture of treated and non-treated melon samples. It can be noticed that in both types of treatments the fruit's firmness significantly ($p<0.05$) decreased during the storage time period, possibly due to ice crystal formation during storage, which can cause structural cell damage in the fruit. However, the treated samples (75% and 85%) showed significantly ($p<0.05$) higher compression force values (higher firmness) when compared to the non-treated samples, which may be a result of less structural damage, since they contain less freezable water. This result is in accordance the ones found in mango [24] and tomato [35]. Thus, the cryoprotecting effect of OD on the fruit texture during frozen storage is evident.

When comparing the texture of the treated samples (75 y 85%), it was noticed that the treatment with lower water volume (75%) showed the highest firmness values, that is, 5.7±0.8, 4.1±0.6 y 3.8±1.8 N, for 1, 15 and 30 days, respectively. Similar results were found for papaya osmo-dehydrofreezing treatment [36]. A possible reason for this is that the most dehydrated cell structure (less freezable water content) was least affected, because of lower ice recrystallization [13]. According to Moncayo et al., [35], an OD time period increment (lower humidity content) results into greater firmness of the osmo-dehydrated product, a consequence of its solids gain and water loss.

4. Conclusions

The use of the osmo-dehydrofreezing technique, before the freezing of melon samples had a cryoprotecting effect (drip loss, color, volume and firmness reduction), compared to non-treated samples during frozen storage. In the first case, the treatment using lower humidity level (75%) showed lower quality loss (higher firmness, lower DL, ΔV and ΔE) than the non-treated samples, probably because of their lower freezable water content and, consequently, lower cell damage in the product. The frozen storage time period significantly ($p<0.05$) influenced the fruit's quality loss, perhaps because of ice recrystallization during storage, which led to cell content loss. These results show that the osmo-dehydrofreezing technique is effective in reducing quality loss in melon samples during frozen storage.

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