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Ohmic heating/vacuum impregnation treatments on osmodehydrated apples enriched in polyphenols from concentrated pomegranate juice

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Abstract

The aim of this work was to study the combination of osmodehydration (OD), coupled with Ohmic Heating (OH) and Pulsed Vacuum (PV) and to introduce natural compounds from a cryoconcentrated pomegranate juice (47°Brix) at 30, 40 and 50 °C into apple matrix, during 180 min. PV was performed at 50 mbar for 5 min at the beginning of the process and OH generates an electric field of 6.6 V/cm. The results indicated that treatments reduced water content and increase polyphenol content of apples, evidencing that the osmotic treatment improve mass transfer, especially when they are applied together at higher temperatures.

Keywords: *Ohmic heating; pulsed vacuum; cryoconcentration; enriched; pomegranate.*

1. Introduction

As consequences in a change of lifestyle and eating habits diseases such as obesity, cardiovascular problems, diabetes type II, hypertension, cancer among others have increased (1). These adverse effects have developed the interest in healthy food and the consumption food functional food (2). Functional foods include bioactive compounds (BAC), which have health benefits as well as their nutritional value. Vitamins, polyphenols, and minerals are found in BAC (2).

Pomegranate (Punica granatum L.) has gain interest in the past few years for its nutritional and antioxidant activities (3). Pomegranate juice is a potential source of anthocyanins, flavonoids, organic acids, ellagic acid (4). Therefore, its health benefits are associated with those chemical characteristics. Therefore, its health benefits are associated with those chemical characteristics.

Freeze concentration (also called cryoconcentration) as mention before, is an emerging technology, which consists on entirely or partially freezing the liquid food solution for later separation of the ice fraction from the liquid. Vitamins as polyphenols are thermolabile compounds, by using FC the high nutritional value and organoleptic characteristics can be protected (5).

The ohmic heating (OH) is a thermal process, in which energy is generated by the passage of an alternating electrical current that diffuses through the food (2). The PV has been widely used to obtain a rapid penetration of compounds in vegetable tissues and enriches fruits and vegetables with antioxidants, vitamins, minerals, among others (6).

Osmotic dehydration (OD) is the process in which water is partially removed from the cellular material when it is exposed to a concentrated solution of solutes. The type of osmotic agent used and its molecular weight or ionic behavior affects the kinetics of water elimination and the gain of solids (7), during the OD mass transfer occurs through semipermeable cell membrane making substantial changes in the tissue structure (8).

The aim of this work was to study the combination of osmodehydration (OD), Pulsed Vacuum (PV), Ohmic Heating (OH) and to introduce natural compounds from a concentrated pomegranate juice at 30, 40 and 50 °C into an apple matrix, during 180 minutes.

2. Materials and Methods

2.1. Sample preparation

Pomegranate (cv. Wonderful) and apples (cv. Granny Smith) were acquired in the local market (Chillán, Chile) and stored under refrigeration (5 °C) until processing. The pomegranates were cut in half and removed the seeds manually for juice extraction and filtered to eliminate any residue.

2.2. Osmotic agent

To obtain the osmotic agent, freeze concentrated pomegranate juice, block freeze concentrated as described by (9) with modifications. Samples were frozen -20 °C for 12 h and place in a refrigerated centrifuge (Eppendorf 5430R) operated at 15 °C for 15 min for the first cycle and 10 min for the second and third cycle at a speed of 1878 RCF.

2.3. Osmodehydration treatments assisted by pulsed vacuum and ohmic heating.

Osmodehydration (OD) at atmospheric pressure and pulsed vacuum (PVOD) with conventional and ohmic heating (OH) at 30, 40, 50 °C, using a thermoregulated bath as described by (10). The freeze concentrated pomegranate juice was exposed to an alternating current at 60 Hz and 50 V, generating an electric field E of 6.66 V/cm.

2.4. Total phenolic content (TPC)

The total phenolic content was determined through a colorimetric method by Folin-Ciocalteu (FC) reagent (11) using gallic acid as standard. Treated samples extracts (100 µL) were mixed with 7900 µL distilled water, 500 µL FC reagent and 1500 µL sodium carbonate. The sample was incubated 120 min before measurement at 760 nm in a spectrophotometer (Shimadzu Scientific 1600 UV/VIS, USA). Results were expressed mg of gallic acid equivalents in 100 g of dry matter (mg GAE/ 100 g d.m.). 2.5. Compositional analysis

Soluble solids and moisture content were determined the effect of osmodehydration time over water loss, mass loss, solid gain and water activity (aw). Moisture content was determined according to the method defined by the AOAC, 2000 (12). The solute gain was determined as described by Moreno et al., (2016), the solid content was measured using a digital refractometer (Leica Mark II, Buffalo, NY, USA). The Xss and Xw content were determined for both fresh and treated, the compositional changes were calculated through the following equations. Samples water activity (aw) was determined using a dew point hygrometer (Aqua Lab Model 4TE, Pullman, USA). Measurements were executed in triplicate and the mean values are informed.

2.6. Physical properties

The firmness of the samples was evaluated with a Texture Analyzer TA-XT (Stable Microsystems, Haslemere, UK), using a slice shear blade the mechanical parameter was considered as maximum peak force and reported as N. Apple slices color, fresh and treated, was measured with a spectrocolorimeter (Konica Minolta CM-500). The CIE L* a* b* coordinates used a D_{65} illuminant and 10° observer as a system reference. The color was measured in triplicate.

3. Results and Discussion

3.1 Total phenolic content (TPC)

The phenolic content of the treated apple samples is expressed in mg gallic acid equivalent (GAE) in 100 g of dry matter. As Fig. 1 shows the apples treated with PVOD/OH at 30 °C had higher retention of TPC throughout the processing time (180 min), followed by PVOD/OH 50 °C; the samples with the lowest phenolic retention were the PVOD 40 °C OD/OH 50 °C.

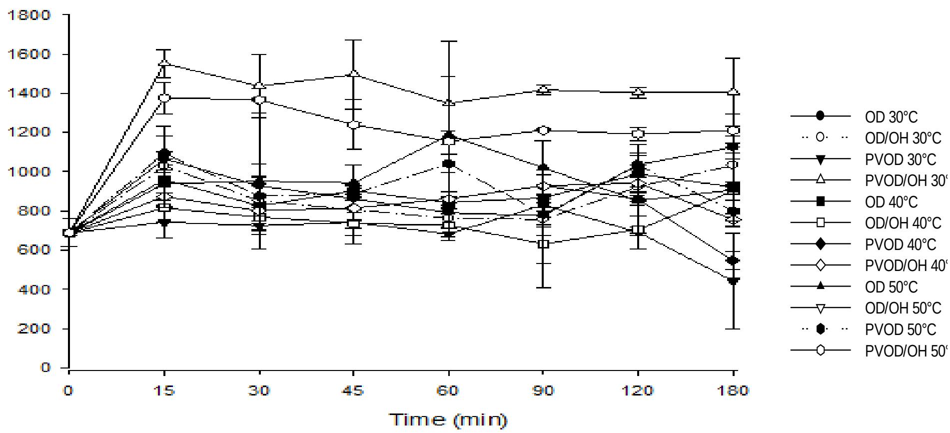

Fig. 1 Total phenolic content (TPC) kinetics of osmodehydrated apple using cryoconcentrated pomegranate juice for 180 min. OD: osmotic dehydration at atmospheric pressure, PVOD: osmotic dehydration with vacuum pulsed vacuum, OH: ohmic heating (OD/OH and PVOD/OH) at 6.66 V/cm

Furthermore, the total phenolic content decreases for all treated samples after 30 min of the process except PVOD/OH 30 °C; this may be due to the kind of treatment, temperature and time. Also after de processing time most of the treatments retained at least the same amount of TPC as in time 0, except PVOD 40 °C, such finding differs with (10); in which the fresh sample had a significant difference in the TPC compare to the treated.

3.2 Compositional changes and water activity

Table 1 shows the compositional changes between the fresh and different treatments of osmodehydration after 180 min of processing. According to previous findings, osmotic dehydration with concentrated juice is more significant compared to osmotic dehydration with sucrose (13). The combination of PVOD/OH 40 and 50 °C, and PVOD 30 °C had the highest solute gain had more significant water loss and solid gain, due to the diffusion and convection forces, both which facilitate the mass transfer process. Application of pulsed vacuum eases the osmotic agent into the matrix pores and facilitates the water loss and has a beneficial effect on the kinetics, reaching equilibrium easily (10). Also, the combination of OD/OH encouraged more substantial concentration levels in samples than OD.

Table 1. Composition parameters of fresh and processed samples (processing time: 180 min) water mass fraction (X_w), soluble solids mass fraction (X_{ss}), water loss (ΔM^w_t), solid gain (ΔM^{ss}_t) and water activity (a_w).

Treatments	X_w	X_{ss}	ΔM^w_t	ΔM^{ss}_t	a_w
Fresh	0.85 ± 0.01^{g}	0.22 ± 0.02^{a}	-	-	0.98 ± 0.09^{g}
OD 30°C	0.58 ± 0.01^{f}	0.33 ± 0.02^{b}	-0.32 ± 0.04^{c}	0.63 ± 0.12^{d}	$0.91 \pm 0.01^{d,e}$
OD/OH 30°C	$0.56 \pm 0.01^{d,e,f}$	0.77 ± 0.02^{d}	-0.85 ± 0.03^{c}	2.14 ± 0.15^{a}	$0.91 \pm 0.01^{e,f}$
PVOD 30°C	$0.56 \pm 0.01^{d,e,f}$	0.90 ± 0.12^{e}	-0.27 ± 0.01^{a}	$0.45 \pm 0.08^{d,e}$	$0.91 \pm 0.01^{c,d}$
PVOD/OH30°C	$0.55 \pm 0.05^{d,e,f}$	0.72 ± 0.03^{d}	-0.27 ± 0.01^{a}	$1.88 \pm 0.08^{a,b}$	0.92 ± 0.01^{f}
OD 40°C	$0.57 \pm 0.01^{e,f}$	0.47 ± 0.23^{c}	-0.66 ± 0.08^{b}	$1.50 \pm 0.06^{b,c}$	$0.91 \pm 0.01^{e,f}$
OD/OH 40°C	$0.52 \pm 0.01^{d,c,d}$	0.79 ± 0.04^{d}	-0.66 ± 0.05^{b}	1.35 ± 0.81^{c}	$0.90 \pm 0.01^{c,d}$
PVOD 40°C	$0.54 \pm 0.01^{b,c,d}$	$0.82 \pm 0.03^{d,e}$	-0.36 ± 0.16^{a}	$0.51 \pm 0.03^{d,e}$	$0.91 \pm 0.01^{d,e,f}$
PVOD/OH 40°C	$0.51 \pm 0.03^{a,b,c}$	0.78 ± 0.01^{d}	-0.31 ± 0.24^{a}	$1.27 \pm 0.22^{d,e}$	$0.90 \pm 0.01^{b,c}$
OD 50°C	$0.57 \pm 0.01^{e,f}$	0.76 ± 0.02^{d}	-1.15 ± 0.01^{d}	$2.08 \pm 0.45^{a,b}$	0.92 ± 0.01^{f}
OD/OH 50°C	$0.47 \pm 0.02^{a,b}$	$0.80 \pm 0.06^{d,e}$	-0.33 ± 0.09^{a}	$0.51 \pm 0.07^{d,e}$	0.89 ± 0.01^{b}
PVOD 50°C	$0.52 \pm 0.01^{c,d,e}$	$0.79 \pm 0.02^{d,e}$	-0.28 ± 0.07^{a}	0.52 ± 0.10^{d}	$0.92 \pm 0.01^{e,f}$
PVOD/OH 50°C	$0.49 \pm 0.01^{a,b}$	$0.81 \pm 0.01^{d,e}$	-0.35 ± 0.01^{a}	0.65 ± 0.03^{d}	0.87 ± 0.00^{a}

Different letters ($^{a, b, c,\dots g}$) in each column indicate significant differences at $p \leq 0.05$, according to a LSD test.

In this case, the mass transfer in PVOD and PVOD/OH in comparison to the OD is due to the unsteadiness of particles in the juice. Likewise, inadequate dissemination of the components may occur when gradients pressure in the vegetable tissue provoke the irregular flow of the osmotic agent through the structure and consequently accumulate bioactive components in some areas (14); making the mass transfer harder in OD.The most significant water activity reduction was in PVOD/OH 50 °C, followed by OD/OH 50 °C in contrast to the fresh sample. This difference is attributed to temperature, pH, and electroporation which promote the gain of freeze concentrated pomegranate juice and water loss (15).

3.4 Changes in physical properties

Table 2 shows the values obtained for the fresh and treated apple, the hue angle (h*ab), chrome (C*ab) and change in color (ΔE). Previous studies have demonstrated L increases with the osmotic treatments (15). However, samples with the combination of PVOD and PVOD/OH have reduced L, due to the concentration of anthocyanins from the pomegranate juice, this same effect reported by (9) treated sample had lower L than the fresh one. The ΔE was higher in the same treatments as the L, this due to the content of anthocyanin pigments present in the cryoconcentrated pomegranate juice. The firmness values acquired from the mechanical test (Table 2). A sample of PVOD 30 °C had the firmness highest value which indicates a higher resistance. Fresh sample differs significantly from the samples treated at 50 °C. Although, values from treatments at 40 °C had no difference with the fresh sample, as well as OD/OH and PVOD at 30 °C.

Table 2. Firmness and color determination in fresh and treated apples with three temperatures (30 C, 40 C, 50 °C).

Treatments	**Firmness (N)**	**Color**			
		L*	***C*ab***	***h*ab***	**Δ*E***
Fresh	12.75 ± 3.53^{c}	64.38 ± 5.53^{c}	16.80 ± 3.16^{d}	96.48 ± 3.06^{a}	---
OD 30°C	26.34 ± 3.83^{d,e}	29.27 ± 2.12^{b}	30.63 ± 2.14^{f}	199.88 ± 0.69^{g}	45.14 ± 2.97^{d}
OD/OH 30°C	15.99 ± 1.05^{c}	26.43 ± 1.79^{b}	23.96 ± 5.48^{e}	198.31 ± 2.10^{f,g}	45.80 ± 3.54^{d}
PVOD 30°C	29.35 ± 4.19^{e}	22.25 ± 3.19^{a,b}	15.58 ± 7.28^{c,d}	194.91 ± 3.38^{e,f}	39.85 ± 1.43^{b,c}
PVOD/OH30°C	10.87 ± 2.88^{b,c}	20.57 ± 1.18^{a,b}	3.84 ± 0.49^{a}	178.17 ± 2.80^{b}	48.91 ± 4.78^{e,f}
OD 40°C	14.61 ± 2.70^{b,c}	29.27 ± 2.12^{a,b}	30.63 ± 2.14^{f}	199.88 ± 0.69^{g}	47.89 ± 0.60^{d,e}
OD/OH 40°C	9.34 ± 0.61^{b,c}	24.70 ± 1.81^{a,b}	17.47 ± 3.30^{d}	197.50 ± 1.09^{f,g}	42.03 ± 2.63^{c}
PVOD 40°C	17.34 ± 2.97^{c,d}	21.63 ± 1.53^{a,b}	9.75 ± 3.12^{b}	191.83 ± 0.31^{d}	45.72 ± 0.76^{d}
PVOD/OH 40°C	8.57 ± 1.88^{b,c}	20.62 ± 0.51^{a}	3.45 ± 0.63^{a}	183.74 ± 1.49^{c}	51.82 ± 1.97^{f,g}
OD 50°C	2.88 ± 1.57^{a}	23.06 ± 1.14^{a}	13.97 ± 3.68^{b,c,}	197.59 ± 1.53^{f,g}	50.65 ± 1.91^{e,f}
OD/OH 50°C	2.70 ± 0.17^{a}	22.96 ± 2.03^{a}	10.99 ± 1.19^{b,c}	196.69 ± 0.15^{f,g}	38.25 ± 2.00^{b}
PVOD 50°C	5.34 ± 1.75^{b}	21.01 ± 0.16^{a}	3.92 ± 1.08^{a}	188.74 ± 2.81^{d}	51.69 ± 1.99^{f}
PVOD/OH 50°C	6.27 ± 0.87^{b}	20.67 ± 0.72^{a}	3.06 ± 0.96^{a}	189.30 ± 2.62^{d}	54.73 ± 2.47^{f}

Different letters ($^{a,\cdot\cdot g}$) in each column indicate significant differences at $p \leq 0.05$, according to a LSD test.

4. Conclusion

The combination of pulsed vacuum and ohmic heating in the osmodehydration of apple slices at 30 °C affected the retention of total phenolic content positively during processing time (180 min). Osmotic dehydration combined with pulsed vacuum and ohmic heating at 50 and 40 °C intensifies the solid gain and water loss due to the diffusion and convection forces which accelerated the mass transfer process. PVOD/OH and OD/OH 50 °C had the most significant water activity mainly cause by the electroporation and temperature. The changes in color were significant in C*ab (chrome) in L* (lightness), and values in treated apple slices with PVOD and PVOD/OH due to retention of anthocyanins from the freeze concentrated pomegranate juice. The highest firmness was observed in a sample of PVOD 30 °C. Therefore, our results suggest that PVOD/OH process at 50 °C by 180 min is the optimal treatment for osmodehydrated apples with freeze concentrated pomegranate juice.

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6. References

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