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Effect of Impregnation Solution Ratio and Periods on Vacuum Impregnated Papaya

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Abstract

Papaya is a popular tropical fruit that is widely consumed in Thailand. In this study, fresh papaya fruit was subjected to vacuum impregnation to have a better understanding about the process parameters, including impregnation solution ratio, impregnation time and relaxation time. The fresh fruit was cut into pieces, added to impregnation solutions at ratios of 1:5 or 1:10, vacuum impregnated at 50 mbar for 5 or 10 min and left for another 10 or 30 min in the impregnation solution. After separating the fruit from the solution, it was analyzed for the fruit physicochemical properties, including real porosity (ε_r), volume of fruit impregnated with an external solution (X value), fruit volume deformation (γ value), effective porosity (ε_e), water loss and solid gain. Different factors investigated in this study significantly affected vacuum impregnated parameters of papaya pieces ($p<0.05$). The papaya treatment in the impregnation solution at 1:10 with 10 min vacuum time and 30 min relaxation time significantly produced the highest solid gain (3.36±0.37%), X value (0.24±0.01 m^3 liquid/m^3 sample), γ value (0.14±0.03 m^3/m^3 initial sample) and ε_e value (0.11±0.05%). At the same time, this particular papaya sample possessed the lowest water loss (–15.22±3.65%) and ε_r value (0.16±0.01%). Data in this study strongly indicated higher impregnation solution ratio with longer impregnation and relaxation periods produced better infusion of impregnation solution in papaya pieces.

Keywords : *Papaya, Ratio of Impregnation Solution, Vacuum Time, Relaxation Time, Physicochemical properties.*

1. Introduction

Carica papaya Linn. or generally known as papaya (Ikram et al., 2015) is an important commercial tropical fruit that can grow throughout Thailand (Fuggate et al., 2010; Subhadrabandhu and Nontaswatsri, 1997). The commodity is a climacteric tropical fruit and is recognized to have a very short postharvest life due to loss of weight, rapid pulp softening and the presence of microbial growth (Waghmare and Annapure, 2013). Fuggate et al. (2010) also stated that papaya softness increases rapidly during ripening. Beside its short shelf life, papaya is rich sources of antioxidant nutrients, minerals, digestive enzyme, fibers and vitamins A and C (Cheenkachorn et al., 2012; Fernandes et al., 2006; Udomkun et al., 2014). Most of the time, papaya production is mainly for the consumption of fresh fruit, juice, or jams (Dotto et al., 2015). When fresh papaya is processed to other form of products, the fruit can undergo degradation of desirable qualities (Udomkun et al., 2014).

Traditional impregnation processes have been carried out at atmospheric pressure. To speed up the process, the impregnation can now be done under vacuum pressure or accepted as vacuum impregnation (VI). In this method, the procedure consists of an application of a reduced pressure to a solid-liquid system, followed by restoration of atmospheric pressure (Mújica-Paz et al., 2003[a]). During a VI treatment, a sample is immersed in a container containing solution. When vacuum is applied to the system of the closed container, gas inside the sample pores is undergone expansion. Some of gas leaves the pores, taking with it some native liquid. After the pore gas pressure equals to the system pressure, capillary effects promote the penetration of outside solution into the pores. As atmospheric pressure is restored to the system, this leads to compression of the remaining gas volume inside the sample pores and brings an influx of external solution into the porous structure (Fito et al., 2001; Panarese et al., 2013; Zhao and Xie, 2004). The VI process causes an exchange of internal gas or free liquid in the sample pores for external solution and changes in the pore volume (Gras et al., 2003). The process allows a more rapid and controlled impregnation of desired solutes in food products (Mújica-Paz et al., 2003[a]). This treatment can be considered as a tool in the development of fruit or vegetable products without disrupting their cellular structure (Fito et al., 2001). The VI process and the quality of finished products are determined by processing conditions, including pre-treatment of the samples, composition, concentration of the VI solution, pressure, immersion time under vacuum, time to restore atmospheric pressure and solution/ sample ratio (Zhao and Xie, 2004).

Isotonic solution is a solution containing the same solute concentration both outside and inside the cell membrane (Zhao and Xie, 2004). The application of VI with isotonic solution for papaya had been carried out by Mújica-Paz et al. (2003[a]) for papaya slices using various vacuum pressures of 135-674 mbar at vacuum times of 3 to 45 min and a relaxation period of 25 min. Another work of Krasaekoopt and Suthanwong (2008) investigated VI treatments for papaya cylinder using fruit juices as external solution that were carried out at 50 mbar vacuum pressure for 5, 10 and 15 min and a relaxation time of 10 min. Since there was not any available information about the interaction between external solution ratio, vacuum times and relaxation periods on vacuum impregnated fruit, this study was dedicated to provide this data. The aim of this research was to understand the effect of external solution ratio and impregnation periods on the physicochemical properties of vacuum impregnated papaya cubes.

2. Materials and Methods

2.1. Papaya fruit

Ripen papaya fruit (variety Pluk Mai Lai) was purchased from a local producer in Chiang Mai province, Thailand.

The fruit was kept in a refrigerator at 4±1ºC until used in experiments. On the day of the experiment, papaya fruit was washed to remove any surface contaminants and hand peeled with a sharp knife. The fruit meat was then cut in cubes with a size of 1 cm × 1 cm × 1 cm.

2.2 Vacuum impregnation treatment

Impregnation processes were carried out with sucrose solution, mixing sugar with distilled water that had a similar a_w with the studied papaya fruit, which was 0.990±0.001. Papaya samples were weighed and submerged in the sucrose (impregnation) solution at ratios of 1:5 and 1:10 (w/w) for fruit and solution, respectively, in 1000 ml beaker. The solution with papaya inside it was then subjected to a vacuum pressure of 50 mbar for either 5 or 10 min, followed by a relaxation time of 10 or 30 min at atmospheric pressure. After removing the papaya pieces from the impregnation solution using a strainer, the fruit samples were analyzed for their physicochemical characteristics.

2.3 Physicochemical analyses

Apparent density (ρ_a) was measured in papaya pieces and real density (ρ_r) in papaya purees using a pycnometer method with toluene solution (Yan et al. 2008). Real porosity (ε_r) of vacuum impregnated papaya was calculated based on the apparent density and real density data according to Equation 1 (Mújica-Paz et al., 2003[a]).

$$\varepsilon_r = \frac{\rho_r - \rho_a}{\rho_a} \quad (1)$$

Volume of fruit impregnated with external solution (X value) was examined according to Rongkom et al. (2013) using Equation 2.

$$X = \frac{(M_f - M_i)}{\rho_s V_o} \quad (2)$$

where M_f and M_i are final mass and initial mass of fruit sample (kg), respectively. ρ_s is density of impregnation solution (kg/m^3) and Vo is initial volume of the sample (ml).

Sample volume deformation (γ value) was determined using Equation 3 (Rongkom et al., 2013).

$$\gamma = \frac{(Vt - Vo)}{Vo} \quad (3)$$

where Vo and Vt are initial volume (m^3) and final volume (m^3) of sample, respectively.

Effective porosity (ε_e) was calculated using X value, γ value and compression ratio (r) (atmospheric pressure/vacuum pressure) according to Equation 4 (Rongkom et al., 2013).

$$X - \gamma = \varepsilon_e \left(1 - \frac{1}{r}\right) - \frac{\gamma}{r} \quad (4)$$

Water loss (WL) and solids gain (SG) were determined using Equations 5 and 6, respectively, based on the method of Mújica-Paz et al. (2003[b]).

$$WL = \frac{(W_{wo}) - (W_t - W_{st})}{(W_{so} + W_{wo})} \, x \, 100 \quad (5)$$

$$SG = \frac{(W_{st} - W_{so})}{(W_{so} + W_{wo})} \, x \, 100 \quad (6)$$

where Wwo is weight of water and Wso is the weight of solid initially present in the fruit, while Wt and Wst are the weight of the fruit and the weight of solid at the end of treatment, respectively.

2.4 Statistical analysis

A complete randomized design (CRD) was used to study the effect of impregnation solution ratio and periods on parameters of vacuum impregnated papaya. Duncan's multiple range test was used to identify difference at 95% confidence level using SPSS for Windows version 17.0.

3. Results and Discussion

Table 1 displays that water loss (WL) and solids gain (SG) of vacuum impregnated papaya were significantly affected by solution ratios and impregnation and relaxation times studied in this work ($p<0.05$). Results of the WL were in negative values, this indicated that the papaya samples gained water in their tissues from the impregnation of external solution (Mujica-Paz et al., 2003[b]; Rongkom et al., 2013). The highest water gain in the papaya samples was found in the treatment with 1:10 water ratio and processed for 10 min impregnation time and 30 min relaxation time that had a value of -15.22±3.65%. Generally, it could be seen longer impregnation and relaxation periods led to lower WL values. This suggested that higher impregnation could occur at longer processing time.

VI is a process, where gas and native liquid inside sample pores are replaced with external solution (Zhao and Xie, 2004). The permeation of the external solution affects the amount of solid in the sample tissues. In this study, SG values of vacuum impregnated papaya were significantly increased with higher solution ratios and longer impregnation and relaxation periods ($p<0.05$; Table 1). Higher solid gain with extended vacuum and relaxation times for apple cylinders submitted to vacuum osmotic dehydration at 40 mbar had also been cited by Derossi et al. (2012). An increase in SG values could be attributed to deformation of sample structures by vacuum action (Mujica-Paz et al., 2003[b]). These researchers also explained that high vacuum pressure could help to open the fibrous structure of mango, producing spaces that could be filled with external solution.

Table 1. Water loss (%) and solids gain (%) values of vacuum impregnated papaya affected by solution ratio and impregnation periods

Papaya: solution ratio (w/w)	Impregnation time (min)	Relaxation time (min)	Water loss (%)	Solids gain (%)
1 : 5	5	10	-3.82±1.64c	0.19±0.59a
1 : 5	5	30	-12.72±2.31ab	1.24±0.49ab
1 : 5	10	10	-11.89±4.92ab	0.95±0.67ab
1 : 5	10	30	-14.13±3.76ab	1.70±1.09b
1 : 10	5	10	-14.78±3.97ab	2.01±0.70b
1 : 10	5	30	-14.84±2.67ab	1.84±0.41b
1 : 10	10	10	-8.09±4.20bc	2.08±0.36b
1 : 10	10	30	-15.22±3.65a	3.36±0.37c

[a-c] Values followed by different letters within the column are significantly different ($p<0.05$).

X and γ values of vacuum impregnated papaya affected by solution ratio and impregnation periods is shown in Table 2. X value was recognized as the volume of fruit impregnated with external solution (Fito et al., 2001; Gras et al., 2003), while γ value was deformation of sample volume after a VI process (Fito et al., 2001). The measurement results for both parameters can be seen in Table 2. The X value of vacuum impregnated papaya was varied between 0.102 and 0.241 m^3 liquid/m^3 sample. These values were slightly higher than those reported by Mújica-Paz et al. (2003[a]), which were 0.026 to 0.061 m^3 liquid/m^3 samples. Differences in the finding could be affected by different papaya varieties, dimension of papaya samples and vacuum impregnation conditions, including vacuum pressure and impregnation and relaxation periods. In this study, the highest X value was determined in the vacuum impregnated papaya that was processed with a solution ratio of 1:10 and had impregnation and relaxation times of 10 and 30 min, respectively. It could also be observed that the X value of the papaya samples increased with higher solution ratios and longer impregnation and relaxation periods. This finding was in an agreement with the result of Mújica-Paz et al. (2003[a]). The authors described that X value had a linear effect on papaya, in which the value increased with higher VI times between 3 and 25 min.

Table 2. X (m3 liquid/m3 sample) and γ (m3/m3 initial sample) values of vacuum impregnated papaya affected by solution ratio and impregnation periods

Papaya: solution ratio (w/w)	Impregnation time (min)	Relaxation time (min)	X value (m3 liquid/m3 sample)	γ value (m3/m3 initial sample)
1 : 5	5	10	0.102±0.010a	0.039±0.010a
1 : 5	5	30	0.131±0.011ab	0.045±0.017a
1 : 5	10	10	0.107±0.007a	0.042±0.031a
1 : 5	10	30	0.151±0.008b	0.041±0.008a
1 : 10	5	10	0.228±0.020c	0.079±0.056ab
1 : 10	5	30	0.233±0.020c	0.114±0.056ab
1 : 10	10	10	0.152±0.057b	0.086±0.058ab
1 : 10	10	30	0.241±0.007c	0.142±0.034c

a-c Values followed by different letters within the column are significantly different ($p<0.05$).

Sample volume deformation or γ value revealed the net volume changed at the end of VI process (Rongkom et al., 2013). The γ value of vacuum impregnated papaya was found to be increased between 0.039 and 0.142 m^3/m^3 initial sample at higher solution ratios and longer impregnation and relaxation times (Table 2). The result of relaxation time could be affected by the fact that at the last step of VI treatment, when atmospheric pressure was returned to the VI system, the residual gas inside sample tissues was compressed and external solution could flow into the sample pores as a function of the compression ratio (Ursachi et al., 2009; Zhao and Xie, 2004).

The highest γ value was determined in the vacuum impregnated papaya treated with a solution ratio of 1:10 and had 10 min vacuum time and 30 min relaxation time.

Table 3 show real and effective porosities of vacuum impregnated papaya affected by solution ratio and impregnation periods. Real porosity (ε_r) constituted a measure of the empty spaces in fruit tissue and represented the maximum space that could be

Table 3. Real (εr; %) and effective (εe; %) porosities of vacuum impregnated papaya affected by solution ratio and impregnation periods

Papaya: solution ratio (w/w)	Impregnation time (min)	Relaxation time (min)	εr value (%)ns	εe value (%)ns
1 : 5	5	10	0.247±0.094	0.077±0.001
1 : 5	5	30	0.233±0.056	0.090±0.025
1 : 5	10	10	0.253±0.123	0.081±0.011
1 : 5	10	30	0.265±0.061	0.092±0.030
1 : 10	5	10	0.243±0.021	0.098±0.014
1 : 10	5	30	0.178±0.025	0.098±0.018
1 : 10	10	10	0.189±0.093	0.070±0.012
1 : 10	10	30	0.163±0.012	0.106±0.045

ns Not significantly different.

Effective porosity (ε_e) determined the volume of samples that could be occupied by external solution in the sample tissue (Zhao and Xie, 2004). Collected data of the ε_e value of the vacuum impregnated papaya displayed that the parameter value was generally increased with longer vacuum and relaxation times (Table 3). This result was consistent with the finding of WL values, in which the values were decreased with extended VI periods (Table 1). Higher water gain (lower WL values) would increase the volume of papaya tissues that was impregnated with the external solution (ε_e value). However, a statistical analysis showed that there was not any significantly different between the ε_e values of different papaya treatments ($p \geq 0.05$). The ε_e values of the vacuum impregnated papaya were in the range of 0.077-0.106 %. Mújica-Paz et al. (2003[a]) also found that the ε_e value of papaya increased with an increase in VI time. The authors suggested that the VI time should be taken into account when applying VI methods into food products, since the processing time played an important role on ε_e value.

impregnated with an external solution (Paes et al., 2007). After VI processes, the ε_r values of different papaya samples impregnated with a solution ratio of 1:10 were reduced at longer vacuum and relaxation periods (Table 3). This was consistent with the result of ε_e value, indicating at extended period of VI processes, empty spaces in the papaya samples were decreased, replaced by the external solution. Zhao and Xie (2004) also reported that the volume of external solution impregnated into food samples significantly depended on VI time.

A comparison between ε_r and ε_e values of vacuum impregnated papaya displayed that the ε_r values were higher than those of the ε_e values (Table 3). This finding was similar to the report of Mújica-Paz et al. (2003[a]) for melon, papaya and peach. This indicated that there was still free volume in the fruit samples for impregnation. However, capillary effects or structure modifications might cause this free volume for not to be completely filled (Mújica-Paz et al., 2003[a])

4. Conclusions

This study clearly demonstrated that solution ratio and VI periods were important factors that affected the impregnation of external solution in papaya tissues. Applying a solution ratio of 1:10 with 10 min impregnation and 30 min relaxation times produced the highest impregnation of the external solution

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6. References

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