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# Mass Transfer Behavior During Osmotic Dehydration And Vacuum Impregnation Of “Phulae” Pineapple and the Effects On Dried Fruit Quality

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**Abstract**

The influence of osmotic dehydration (OD) in combination with vacuum impregnation (VI) technique on the mass transfer behavior of “Phulae” pineapple was investigated. Pineapple slices of 10 mm thick were immersed in sucrose solution at concentrations of 55 and 65° Brix under atmospheric pressure or vacuum pressures at 250 mmHg (VOD-250) and 450 mmHg (VOD-450). The results deduced that 65° Brix of sucrose solution for 300 min and the vacuum pressure of VI at 450 mmHg were necessitated to increase solute uptake to 14.79 g/100 g when compared to other treatments. Surprisingly, the effect of OD and VI on water loss was not much different. Scanning electron microscope (SEM) showed that the pore sizes of pineapple slices were decreased when the impregnation period increased implying the higher adsorption of sucrose into the fruit structure. Subsequently, calcium lactate (Ca-L) at 2, 4 and 6% (w/w) was incorporated in sucrose solution prior to drying at 60°C in a conventional hot air dryer. It was observed that increasing concentration of Ca-L led to a significant decrease in moisture content (17.74 to 15.53%) and water activity (0.58 to 0.56) whereas calcium content was increased (24.472 to 676.317 mg/100g). However, it should be noted that high concentration of Ca-L had adverse effect on sensory property where overall actability decreased from 7.09 to 5.65 as well as total phenolic content (TPC) (17.74 to 15.53 gGAE/100g), DPPH (223.51 to 159.7 μmol Trolox/100g) and FRAP (380.65 to 291.57 μmol ascorbic acid/100g) values.

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## Introduction

Pineapple is one of tropical fruits that are most consumed worldwide. It holds the third most world production tropical fruit, after only bananas and mangoes.[1] Among various varieties, *Ananas comosus* (L.) Merr. or also known as "Phulae" pineapple is a Geographical Indication (GI) fruit which can grow only some areas in Chiang Rai, Thailand. Recently, this pineapple cultivar is becoming popular as fresh-cut product exported to other countries. However, short shelf life of fresh-cut fruits is the major problem that encountered by producers[2] where fermentation of sugar and enzymatic deterioration lead to discoloration and off-flavor of pineapple[3] which also raising the safety issue.[4] Drying is considered one of efficient methods that can extend shelf life and prevent postharvest loss. However, conventional hot air drying drastically causes negative changes in the sensory properties, nutritive values, chemical constituents and mechanical properties of products.[5]

Vacuum impregnation (VI) is the technique that applies pressure difference between the food samples and the environment so that solutes are introduced into the porous structures of food.[6] It has been used as a pretreatment step of freezing, canning and frying. Incorporation of VI with drying process is an effective option to render higher mass transfer and improve food composition in dried products. The process has an ability to modify the food formulation and to develop new products that both physicochemical and sensory properties are improved. Osmotic dehydration (OD) lowers the water activity by removal of water from fruits which contain lower concentration of solute to higher concentration of a hypertonic solution.[7] It could maintain good color, texture, and aroma as well as extend the shelf life by reduction of water activity while moisture content of products is relatively high. OD in combination with VI has been considered as the good solution to improve the rate of mass transfer and preserve physicochemical characteristics and nutritional values of dried fruit. Moreover, vacuum pressure also allows the absorption of specific ingredients directly into the porous structure of foods according to the hydrodynamic mechanism.[8]

Calcium is related to plant tissue firmness because of its interactions with pectin of cell wall[9] which the degree of uptake determines firmness of plant tissue.[10] It also has been reported to reduce microbial spoilage as well as total weight loss in fresh and frozen strawberry.[11] Therefore, the current study was aimed to investigate the effect of OD and VI treatments on mass transfer kinetic as well as physicochemical quality of dried "Phulae" pineapple. Moreover, Calcium lactate (Ca-L) was also introduced into the osmotic solution in order to investigate the effects on mineral supplement and dried pineapple quality.

## Materials and Methods

### Chemicals and Reagents

DPPH (2,2,1-diphenyl-1-picrylhydrazyl), Trolox, methanol (95% commercial grade), gallic acid, Folin-Ciocalteu reagent, sodium carbonate, potassium ferricyanide, trichloroacetic acid, sodium dihydrogen orthophosphate, disodium hydrogen orthophosphate and nitric acid were purchased from Sigma Company, Singapore. Ascorbic acid and ferric chloride were purchased from Ajax Finechem, Australia. Calcium lactate was supplied by Union Science Company (Chiang Mai, Thailand). All chemicals were of analytical grade.

### Sample Preparation

Fresh "Phulae" pineapple was purchased from local company in Chiang Rai, Thailand. The size of whole fruits was controlled at 200-250 g per fruit and a proper maturity level was yellow-gold color of the peel. After peeling, pineapples were washed thoroughly under running tap water to remove all undesirable components before cutting in spherical slices with thickness of 10 mm by slicing machine (GC Global Direct, Germany).

### Sucrose Solution Preparation

Sucrose solution at 55oBrix and 65oBrix were prepared in distilled water and brought to heat for well-dissolved. The solution was left to cool down to room temperature before using.

### OD and VI Treatment

'Phulae" pineapple slices were placed in vacuum chamber and covered with sucrose solution at the ratio of solution to fruit at 4:1. The vacuum chamber was equipped with water recirculating aspirator pump in order to generate three different vacuum pressures (0, 250 and 450 mmHg) at room temperature. Pineapple slices were collected after 30, 60, 90, 120, 150,180, 240 and 300 min impregnation and then they were taken out of solution, quickly rinsed with cool distilled water at $8^0$C and gently blotted dry with absorbing paper to remove adhering osmotic solution. The samples were weighed and analyzed for sugar gain, water loss and microstructure changes by using scanning electron microscope.[12]

### Mass Transfer Analysis

The pineapple slices were immersed in osmotic solution at 550Brix and 650Brix at room temperature at the sample/solution ratio of 1:4. The experiment was carried out at different pressure as described above. Pineapple slices were removed from the osmotic medium at 30, 60, 90, 120, 150 and 180 min and rinsed with distilled water prior to blot dry to remove osmotic medium and excess surface water, respectively.[12] Sugar gain, water loss, water activity and moisture content were determined.

### Scanning Electron Microscope (SEM)

SEM was carried out according to Aguilera and Lillford (2000)[13] to observe the effect of VI in introducing solutes into the pineapple pores. SEM was operated at 10 kV (LEO/1450 variable pressure) for investigating the microstructure of fresh and treated pineapple. Freeze-dried samples (Martin Christ, Beta 2-8 LSC Plus, Germany) were placed on aluminum stub. Conductive samples were prepared employing a mini-gold sputter (Leica EM SCD500, Leica Microsystems, Germany). The analysis was carried out in duplicate.

### Calcium Lactate Treatment

Hypertonic solution of sucrose at 65oBrix was fortified with calcium lactate at 0, 2, 4 and 6 % (w/w). The “Phulae” pineapple slices were immersed in impregnation solution under VI condition selected from the previous study. After that, atmospheric pressure was restored, and sample was kept for 150 min. At the end of immersion time, samples were taken out of solution, quickly rinsed with cool distilled water, blotted dry prior to dehydration using tray dryer at 60°C for 12 hours to get acceptable water activity level. The dried pineapple was stored in polyvinylidene chloride bag at room temperature under vacuum condition before the samples were determined for physical, chemical and sensory properties.

### Color Analysis

Color evaluation was conducted according to Kongsuwan (2009).[14] Three random sides of pineapple fruit were measured color by colorimeter (Color Quest XE Hunter Lab, USA) and the L*, a* and b* values represented lightness, red-green and yellow-blue, respectively, were recorded. All tests were performed in triplicate.

### Texture Analysis

Texture properties of samples were analyzed using TAXT2i texture analyzer (Stable Micro Systems, Surrey, England) employing Cylinder Probe, 36 mm Diameter. All samples were measured in triplicate.[12]

### Moisture Content and Water Activity Analysis

Moisture analysis was conducted according to AOAC (2000).[15] Approximately 3 g of sample was put into pre-dried dish, spread the sample to the uniformity and placed the dish with sample in the oven, dried for at least 16 hours at 105°C or until constant weight and moisture content was calculated. All tests were performed triplicate.

$$MC\ (\%) = (W_1 - W_2)/W_1$$

Where $W_1$: weight of sample before drying (g)
$W_2$: weight of sample after drying (g)

Water activity was measured employing Novasina water activity analyzer. The sample was cut into small pieces before putting into machine. Analysis was performed in triplicate.

### Calcium Content Analysis

The calcium content of dehydrated samples was determined by using flame atomic absorption spectrometer (Z-5000 series, Hitachi, Japan), according to AOAC (2000).[15] Three grams (±0.1) of dried pineapple was weighed, placed into cleaned crucible and dried at 105°C overnight in hot air oven. After that, crucibles were put into muffle furnace at 525°C for 5 hours. The crucible was removed from furnace and let cool. White ash was obtained without carbon and then dissolved into 5 ml of 1M Nitric acid. The mixture was added into 50 ml volumetric flask and the volume was adjusted by using 1M Nitric acid. Calcium stock solution (1000 ppm) was diluted into five different concentrations 2.5, 5, 10, 15 and

20 ppm to prepare calibration cure. The wavelength at 422.7 nm was employed. Calcium content was calculated and expressed as mg/ 100 g sample.

Calcium content = (a × V × F)/m

Where a: calcium concentration (µg/ml)
V: final volume (ml)
F: dilution factor
m: sample weight (g)

### Antioxidant Content and Antioxidant Activity Analysis

### Extraction of Sample

Sample was extracted for analysis of total phenolic content (TPC) and antioxidant activity according to the method described by Sari *et al*. (2016).[16] Pineapple (5.0±0.5 g) was blended with 20 ml of 95% methanol prior to centrifuged at 9000 rpm for 10 min while temperature was maintained at 4°C. The supernatant was filtered through Whatman filter paper No. 4 and the volume was adjusted to 25 ml employing 95% methanol.

### TPC Analysis

TPC was determined by using the Folin-Ciocalteu colorimetric assay using gallic acid as standard.[17] To 5 ml Folin-Ciocalteu reagent, one ml of the extract was added and 4 ml of 7.5% sodium carbonate solution was incorporated. The mixture was thoroughly mixed and the reaction was allowed to continue for one hour. The absorbance was measured by spectrophotometer ((UV-Vis spectrophotometer, Genesys 10S UV-Vis, Thermo Fisher Scientific, USA) at 765 nm. A blank sample consisting of water and reagents was used as a reference. The determination was performed in triplicates. Results were expressed as mg gallic acid equivalent (GAE) per 100 g dry basis of pineapple (mg GAE/100g dry weight).

### Dpph Radical Scavenging Activity Assay

DPPH radical scavenging assay was carried out as previously described by Blois (1958).[18] The pineapple extract (50 µl) was mixed with 1950 µl of 60 µM DPPH in methanol and left in the dark for 30 min. Standard solutions were prepared using Trolox at concentrations of 0-1000 µM. Absorbance was recorded at 517 nm using spectrophotometer and methanol was served as a blank. Results were expressed as µmol Trolox equivalent (TE) antioxidant capacity per 100 g dry weight of pineapple.

### Ferric Reducing Antioxidant Power (Frap) Assay

The FRAP assay was performed according to Benzie *et al*. (1996).[19] The extract (1 ml) was added to 2.5 ml of 0.2 M phosphate buffer (pH =6) and 2.5 ml of 1% trichloroacetic acid added. The mixture was mixed evenly by vortex mixer and then incubated at 50°C for 30 min. Subsequently, distilled water (2.5 ml) and 0.1% $FeCl_3$ (0.5 ml) were added. The reaction was allowed to take place in the dark for 30 min. Distilled water was used as control sample whereas 0-1000 µM ascorbic acid served as standard. The absorbance was recorded at 700 nm for Iron (III) reducing activity and reported as µmol equivalent of ascorbic acid per 100 g dry basis of pineapple.

### Sensory Evaluation

Sensory evaluation was conducted by 30 untrained panelists. The food preference on sensorial parameters including color, texture, aroma, taste, and overall acceptability was evaluated by the 9-point hedonic scale where 9 points category scale was labeled as '1=dislike extremely 5= neither like nor dislike, and 9= like extremely.[20]

### Statistical Analysis

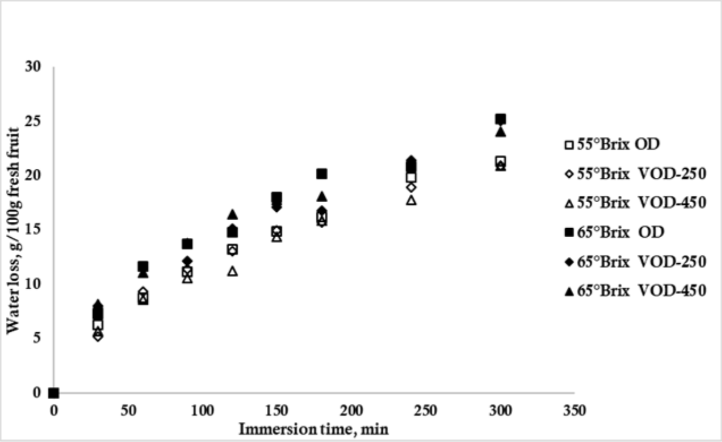
Data were expressed as means ± standard deviation. Statistical analysis was conducted using to SPSS 22.0 software program. Analysis of variance was performed and Duncan's multiple range tests were used to determine significant differences between the means. The significance level was reported at $p<0.05$.

## Results and Discussion

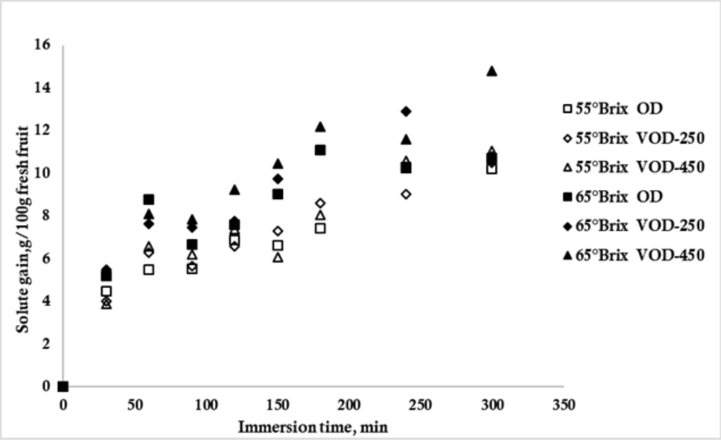
### Effect of Od And Vi Treatments on Mass Transfer Kinetics of "Phulae" Pineapple

The present study was undertaken to study the mass transfer kinetics during osmotic dehydration of pineapple slices at different vacuum pressures and osmotic solution concentrations. The osmotic agent used was aqueous solution of sucrose at concentrations of 55 and 65 °Brix. Different immersion periods were made to observe osmotic kinetics. At each osmotic time, the water loss and solute gain were calculated based on mass balance technique.

Water loss and solute gain in pineapple slices are shown in Figures 1a and 1b, respectively. As can be seen, water loss increased with increasing time as similarly reported.[21] Moreover, the water loss value (Figure 1a) was superior compared with solute gain (Figure 1b) when the same impregnation period was considered. In OD, a simultaneous flux of water and solutes from and into the material takes place. However, cell membranes allow water to pass through them more rapidly than sugar.[22] However, there was no significant difference ($p>0.05$) in water loss values between atmospheric and vacuum pressure treatment during 300 min of impregnation. Nonetheless, Figure 1a illustrates that 65 °Brix led to a non-statistical significance but higher in water loss compared to the treatment at 55 °Brix. In term of solute gain (ΔMS), an increase was observed but in a nonlinear correlation manner with time. Solute gain increased in the initial period of OD treatment and then rate decreased after 180 min.



(a) Water loss



(b) Solute gain

**Fig. 1: Water loss (a) and solute gain (b) in "Phulae" pineapple slices from different concentration of osmotic solution and vacuum pressure during osmotic dehydration. OD is osmotic dehydration at normal pressure where VOD-250 and VDO-450 are vacuumed osmotic dehydration at 250 and 450 mmHg, respectively**

Similar effect of vacuum pressure on water loss was noted; there was no significant difference of solute gain among different vacuum pressure during 0 to 240 min (Figure 1b). However, at 300 min impregnation, solute gain value of VOD-450 was significantly higher than lower vacuum pressured which the value was 14.79±1.1g/100g fresh fruit whereas those in VOD-250 and OD were 10.71±0.02 and 10.79±0.78 g/100g fresh fruit, respectively.

It is noteworthy that concentration of osmotic solution does not affect the solute gain at the longer impregnation time (> 240 min) indicating its equilibrium point. However, under vacuum pressure the much higher solute gain can be achieved at 300 min and the effect was observed only in high concentration treatment.

The results indicate that sucrose concentration was the main factor facilitating water loss and solute gain rate followed by immersion time, leading to the significant increase in water loss and solute gain at 65 °Brix compared to 55 °Brix. The highest value of water loss at 65°Brix and 55 °Brix were 25.25±0.6 and 21.31±0.42 g/100g fresh fruit, respectively. Similarly, the highest amount of solute gain was 14.79±1.1g/100g fresh fruit for 65 °Brix and 11.06±0.57g/100g fresh fruit for 55 °Brix which similar results have been reported in pineapple.[21] El-Aouar and colleagues (2006) also found that weight and water losses of fresh samples were affected by concentration of impregnation medium and soaking time, the former one played more important role.[23] As a result, it can be concluded that osmotic dehydration conditions under vacuum pressure (450 mmHg) at sucrose concentration (65 °Brix) for 300 min were found to be optimal.

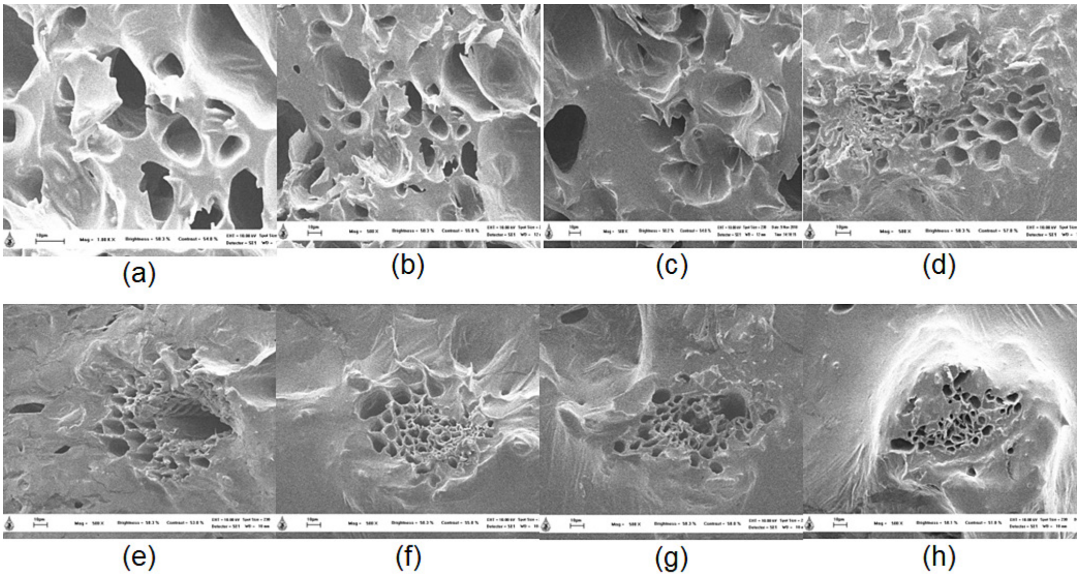


**Fig. 2: SEM porous structure micrograph (x500) of "Phulae" pineapple during osmotic dehydration at 450mmHg after: (a)0 min; (b)30 min; (c)90 min; (d)120 min; (e) 150 min; (f) 180 min; (g) 240 min; (h) 360 min**

### Effect of Od And Vi Treatments on Microstructure of "Phulae" Pineapple

Microstructure analysis was carried out using SEM technique. Figure 2 shows that for the fresh samples, there were many uniform pores contributed into porous structure in pineapple. Nonetheless, reduction of pore size was illustrated as a result of the higher concentration of sucrose solution.[24] Comparing to fresh state, the surface of immersed pineapple was smoother, less porosity, the size and distribution of pores decreased gradually with increased immersion time as shown in Figure 2. It has been established that cellular structure of foods involved the movement of water and nutrient.[25] Hence, the higher porosity structure of pineapple mostly affected water loss and solute gain rate during osmotic dehydration. It can be said that the soaking time can be predicted by examining microstructure of the sample.

However, the different effects of VI on mass transfer can be varying due to various factors including the VI conditions such as the applied vacuum pressure, the vacuum generation rate, the molecular weight of the solute as well as concentration of impregnated solution and the characteristics of sample such as cell porosity and the capillaries size and shape.[26] "Phulae" pineapple is well known for a crispy texture and hence less porosity in structure can be part of different findings as compared to previous works.

**Table 1: Effect of calcium lactate concentration on the physicochemical properties of dried "Phulae" pineapple**

| Level of Ca-L (%) | Moisture content (%) | Water activity | Color L* | b* |
|---|---|---|---|---|
| 0 | 17.74±0.28$^a$ | 0.58±0.00$^a$ | 68.72±3.40$^a$ | 46.27±1.82$^a$ |
| 2 | 16.77±0.05$^b$ | 0.58±0.01$^a$ | 61.42±4.07$^b$ | 42.08±2.33$^b$ |
| 4 | 16.05±0.12$^b$ | 0.56±0.00$^b$ | 54.32±0.76$^c$ | 36.50±2.18$^c$ |
| 6 | 15.53±0.38$^c$ | 0.56±0.00$^b$ | 56.07±1.27$^c$ | 35.93±2.07$^c$ |

Mean± standard deviation (SD), means in columns followed by different letters are significantly different ($p<0.05$)

### Effect of Calcium Lactate on Physicochemical Property of Dried "Phulae" Pineapple

Moisture content and water activity of dried "Phulae" pineapple are shown in Table 1. Significant reductions of moisture content and water activity were observed in all calcium-treated pineapple compared with the control where the lowest values were found in 4 and 6% Ca-L. Incorporation of calcium into sucrose solution led to superior dehydration rate as a result of elevation of osmotic pressure gradient during osmotic dehydration.[27] Moisture content (less than 18%) and water activity (less than 0.6) of the dried samples are considered to be low enough for high stability. According to Fellows (2009), the food product should be chemically and biologically stable when Aw is less than 0.6.[28] For the moisture content, it should be 20-25% for osmotically dried (sugar-treated fruits).

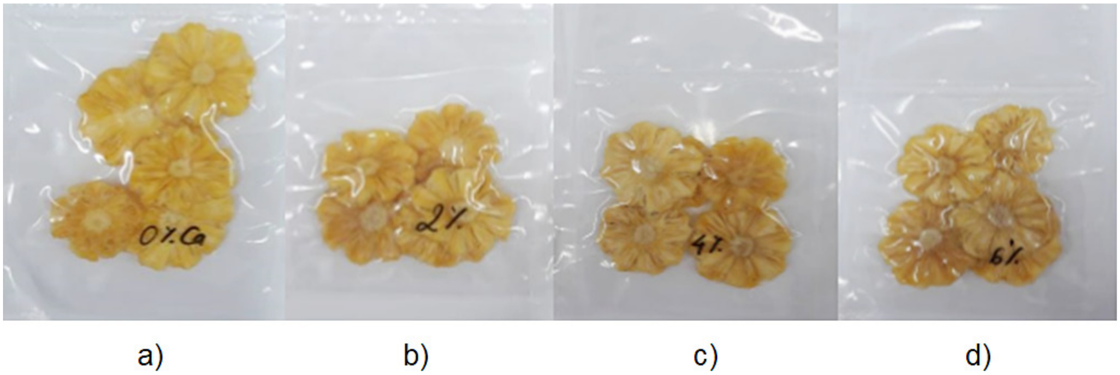


**Fig. 3: Effect of calcium lactate concentration a) 0% b) 2% c) 4% and d) 6% on dried "Phulae" pineapple color**

The Ca-L had significant influence on color parameter of dried "Phulae" pineapple. The increasing calcium concentration gave rise to a darker color of final product which illustrated through the decrease in L* (lightness) and b* (yellowness) values (Figure 3 and Table 1). The yellowish intensity has a strong correlation with carotenoid contents as they are responsible for yellow-orange color in many fruits and vegetables.[29] Similarly, the deeper yellow color of pineapple determines the higher carotenoid contents of the fruit.[30] However, it has been well established that oxidation can lead to degradation of carotenoid and resulting in a slight darker color in dried fruit.[31] Moreover, an addition of Ca-L may also contribute to the changes of color. This might be due to the fact that when calcium is added, the pH increases in the products and allows increasing in Maillard browning rate.[32]

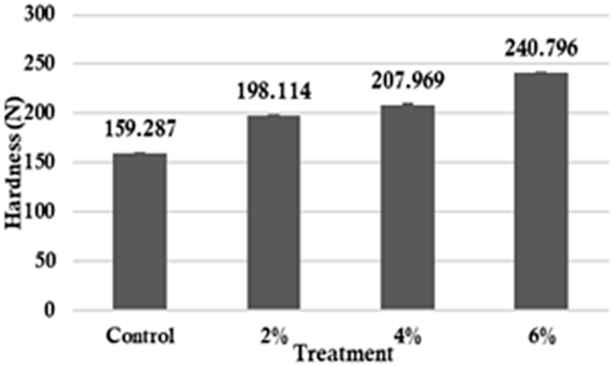


**Fig. 4: Effect of calcium lactate concentration (treatment) on the hardness of dried "Phulae" pineapple**

Hardness of dried pineapple was significantly affected ($p<0.05$) by Ca-L fortification. The higher Ca-L concentration was considerably raised the hardness degree compared to the control sample, as shown in Figure 4. This was due to an interaction between pectin molecules in the fruit structure and calcium salt where calcium pectate formation strengthen the firmness of texture. Moreover, the stronger cell membrane can be achieved by the binding of calcium ions to the negatively charged in the lipid parts of membrane.[33] Therefore, calcium salt can provide a more rigid structure in the middle lamella of the cell wall.

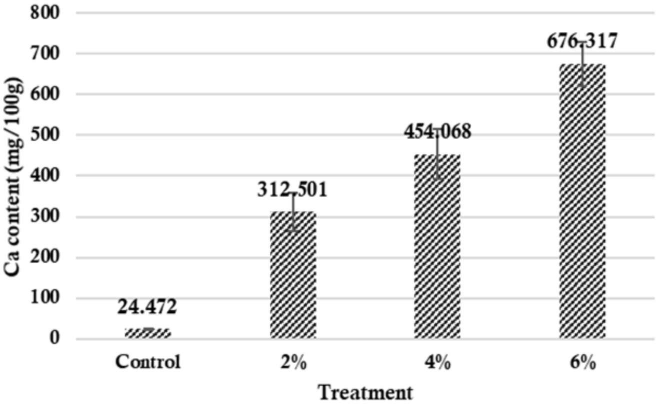


**Fig. 5: Effect of calcium lactate concentration (treatment) on calcium content of dried "Phulae" pineapple**

**Calcium Content**

The calcium content in the final dried "Phulae" pineapple was considerably influenced by the calcium incorporation level. Figure 5 presents the highest calcium intake under 6% calcium lactate fortification (676.317±54.706mg/100g) was 27 times higher than control without calcium supplement (24.472±0.324mg/100g). These results confirmed that the gain in calcium increased with an increase in the calcium lactate concentration.[12] The consumption of 100g of the final product when treated with 2%, 4% and 6% (w/w) Ca-L could provide an intake of approximately 31.25%, 45.41% and 67.63% of the daily calcium requirements (RDI), respectively. According to FAO's recommendation, the daily reference requirement for calcium consumption for adult is 1000 mg.[34]

**Table 2: Effect of calcium lactate concentration on antioxidant activity and bioactive compounds of dried "Phulae" pineapple**

| Level of Ca-L (%) | TPC (gGAE/100g DW) | DPPH (µmolTrolox/100g DW) | FRAP (µmol ascorbic acid/100g DW) |
|---|---|---|---|
| 0 | 17.74±0.28a | 223.51±5.28a | 380.65±28.15a |
| 2 | 16.77±0.05b | 162.23±0.89b | 283.13±9.62b |
| 4 | 16.05±0.12b | 161.22±0.94b | 298.19±23.42b |
| 6 | 15.53±0.38b | 159.7±1.92b | 291.57±18.02b |

Mean± standard deviation (SD), means in the same columns followed by different letters are significantly different (p<0.05).

### Total Phenolic Content (Tpc) and Antioxidant Capacity (Dpph and Frap)

The effect of Ca-L concentration on antioxidant activity and bioactive compounds of dried "Phulae" pineapple was evaluated. Table 2 illustrates that calcium fortification reduced significantly total phenolic compound and antioxidant activities compared to the control sample. However, there was no significantly different of these values noted in vary Ca-L incorporation levels. The highest amounts were found in control sample 0.1±0.01 g GAE/100 dry basis, 223.50±15.28 µmol TE/100g dry weight and 380.646±28.146 µmol ascorbic acid/ 100 dry weight for TPC, DPPH and FRAP value, respectively. No research has done before to prove the direct influence of Ca-L on TPC, DPPH and FRAP value in "Phulae" pineapple. Hypothesis may follow Giovanelli *et al*. (2012) who found that the osmotic agent applied in osmotic dehydration has direct influence on the retention of bioactive compounds and their antioxidant capacity where the higher sucrose gain led to reduction of those compounds.[35] According to Pereira and colleagues, calcium concentration limits the absorption of sucrose.[27] This was thought to be due to the action of pectinmethylesterase enzyme which releases during cutting of pineapple.[36] It hydrolyzes pectin to carboxyl groups and enhanced more calcium pectate generation.[37] The egg-box model formation reduces absorption of sucrose in the the cellular structure of fruits.[38] Moreover, Almeida *et al*. (2015) found that sucrose concentration had significant positive impact (p<0.05) on the retention of polyphenol compounds and antioxidant activity of osmotically dehydrated Bananas.[39] Therefore, high concentration of calcium and low sucrose intake might cause negative effect on TPC, DPPH and FRAP values retention of final product.

### Sensory evaluation

A sensorial test was conducted to evaluate the quality of dried "Phulae" pineapple in terms of color, texture, aroma, taste and overall acceptability. The results showed that there was a gradual decrease (p<0.05) in color score with increased level of calcium concentration which correlated well with the darker color of the dried products. Table 3 shows that dried "Phulae" pineapple with 0% Ca-L scored the highest (7.957±0.638) followed by 2% Ca-L (7.130±0.626), 4% Ca-L (6.087±0.949) and 6% Ca-L (5.304±0.765). In the control sample, the typical yellow color of pineapple remained unchanged and brighter as compared to the treated samples. The higher level of Ca-L fortified, the higher intensity of darkness color of sample. The texture acceptance score of samples incorporated with 4% and 6% CaL and control were significantly lower (p<0.05) than that of 2% incorporation. At 4% and 6% Ca-L, the texture was extremely hard and chewy, whereas the texture of control sample without calcium fortification was quite sticky and soft, only 2% Ca-L got the balance in hardness, softness and chewiness. The taste score of the product incorporated with 4% and 6% calcium lactate was significantly lower (p<0.05) compared to the control and other fortified calcium sample. Overall acceptability scores of dried "Phulae" pineapple slightly decreased with an increase in Ca-L concentrations. The effects were more pronounce at 4% and 6% Ca-L. The results suggest that sensory acceptability can limit the level of calcium fortification in dried pineapple even though the high Ca-L application can enhance more daily intake of calcium.

**Table 3 Effect of calcium lactate concentration on the sensory attributes of dried "Phulae" pineapple**

| Sensory attribute | Control | Level of Calcium Lactate | | |
|---|---|---|---|---|
| | | 2% | 4% | 6% |
| Color | 7.96±0.64a | 7.13±0.63b | 6.09±0.95c | 5.30±0.77d |
| Texture | 5.54±0.74b | 6.98±0.73a | 5.61±0.72b | 5.00±0.95c |
| Aroma | 7.30±0.47a | 7.09±0.73a | 5.19±0.79b | 5.52±0.73b |
| Taste | 6.80±1.10a | 6.78±1.35a | 6.02±1.08b | 5.87±1.29b |
| Overall acceptability | 7.09±1.00a | 6.86±1.08a | 5.79±1.08b | 5.65±1.03b |

Mean± standard deviation (SD), means in the same row followed by different letters are significantly different (p<0.05)

## Conclusion

OD incorporation with VI efficiently improved mass transfer kinetic by interrupting the equilibrium state of the process. Solute gain was significantly increased under high vacuum pressure whereas no significant effect was noted in case of water loss. The sucrose uptake was demonstrated by the image of porous structure by SEM. Incorporation of Ca-L increased hardness of dried "Phulae" pineapple but only acceptable by panelists at the low level (2% Ca-L). Moreover, Ca-L paid role in reduction of yellow color and color acceptability, TPC and the correlated antioxidant activities. However, calcium content of dried "Phulae" pineapple increased with increasing concentration of Ca-L. Finally, the use of 2% Ca-L provided the best acceptance scores in most of sensorial parameters as well as acceptable calcium content in the dried "Phula" pineapple which reached up to 31.25% of the daily calcium requirements.

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## Conflict of interest

Authors declare no conflict of interest.

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