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EFFECT OF IMPREGNATION OF OSMOTICALLY DEHYDRATED PINEAPPLE WITH CALCIUM SALTS BY BLANCHING AND FREEZING TREATMENTS

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Abstract

This study investigates the effect of calcium chloride ($CaCl_2$) and calcium lactate (CaL) impregnation on osmotically dehydrated (OD) pineapple. Pineapple samples treated with 2.5% w/v $CaCl_2$ and CaL, followed by blanching and freezing, showed consistent functional group and water holding capacity results without any significant differences. Color analysis revealed increased L^* and h^* values and decreased a^* values in all treated-OD pineapple samples. The $CaCl_2$-treated-OD pineapple samples exhibited higher b^* and C^* values than the CaL-treated-OD pineapple samples, which declined post-blanching and freezing. Sensory analysis indicated significant differences ($P<0.05$) in overall acceptance influenced by appearance, texture, taste, and odor. Hardness varied significantly ($P<0.05$) among treated OD samples. However, the blanching and freezing had little adverse effect, indicating no significant difference in the OD pineapple samples. Overall, $CaCl_2$ proved more effective than CaL in preserving the physicochemical and sensory qualities of OD pineapple, suggesting its potential as a superior preservative.

Keywords: Blanching, calcium chloride, calcium lactate, osmotic dehydration, pineapple

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Introduction

Pineapples are well-known tropical fruits that can be grown and consumed throughout the year in any part of the world. According to statistics compiled by the Department of Statistics of Malaysia, pineapple is the second most popular fruit consumed by Malaysians, accounting for 7.6 kg per year. There is a huge variety of pineapple food products on the market, such as processed, fresh cut, dried, canned, juice, chips, and jam (Silva *et al*., 2014). Conversely, pineapple fruits cannot be stored for extended periods because the chemical components of the fruits have begun to degrade, resulting in a loss of quality in terms of nutrients, texture, colour, aroma, and flavour of the fruits due to processing, ripening, senescence, and microbial growth (Silva *et al*., 2014). However, consumers have a high demand for good quality products that maintain the freshness of the pineapple. Therefore, numerous types of physical preservation methods, such as drying, freezing, dehydration, irradiation, and pasteurization, considered mild heat treatments, are used to prevent or minimise postharvest loss of pineapples (Pereira *et al*., 2007). However, these methods result in significant unintended changes and damage to texture, colour, and aroma, as well as sensorial and nutritional value discrimination, which may discourage consumers from consuming more nutritious food products in their daily lives (Pereira *et al*., 2007).

To support these physical preservation methods, osmotic dehydration (OD) is one of the alternative additional preservative methods that can be applied to sustain the final quality and shelf life of minimally processed pineapples. OD partially eliminates moisture from the fruit and vegetable using a hypertonic solution without any thermal treatments, primarily employed in several traditional physical preservation methods. Previous research showed that pre-treatments, such as calcium salt treatments, blanching, and freezing methods prior to OD, enhanced cell permeabilization and precluded browning on the fruits (Silva *et al*., 2014). Additionally, calcium chloride ($CaCl_2$) and calcium lactate (CaL) act as suitable preservatives and firming agents. These salts are employed to preserve the cellular structure and maintain the structural integrity of the fruit and vegetable (Pereira *et al*., 2007).

To the greatest of our knowledge, just a few research have detailed the use of calcium salts for preservation in the literature namely Ngamchuachit *et al*., 2014 and Udomkun *et al*., 2014. Both of these studies reported on the preservation of papaya and mango using calcium salts with various concentrations. The present study differs from previous work, as it explores a preservation method of the impregnation of osmotically dehydrated (OD) pineapple with $CaCl_2$ and calcium lactate (CaL) treatments, along with blanching and freezing methods. This study also examines the physicochemical properties and conducts a sensory analysis.

Methods

Sample Preparation

Fresh pineapple (*Ananas comosus L. Merr*) was purchased at a market near Pagoh, Johor, Malaysia. Pineapples were met commercial degree of ripeness by having a weight of 1.2 kg with 13° Brix and 14° Brix (Silva *et al*., 2014). The pineapple skin was peeled off after the tops and tails had been removed. After peeling the skin from the pineapple, the remaining flesh was cut into 1.5 cm × 1.5 cm × 1.5 cm cubes (Ngamchuachit *et al*., 2014). About 75 pineapple samples were required for each analysis. The pineapple samples were submerged individually in a 2.5% (w/v) $CaCl_2$ and CaL solution at chilling temperature (Udomkun *et al*., 2014). Then, the pineapple samples were subjected to blanching and freezing. Blanching was performed on the calcium salts treated pineapple samples in hot water for 1 min at 80 °C, followed by the cooling process in cold water for 5 s at 10 °C to prevent the pineapple samples from being overcooked. For the freezing process, the calcium salts-treated pineapple samples were frozen at -18 ± 1 °C for 30 minutes (Kowalska & Lenart, 2003).

Osmotic Dehydration

After blanching and freezing, calcium salts-treated pineapple samples were osmotically dehydrated in a solution that combined distilled water with food-grade sucrose to achieve the required concentration (Kowalska & Lenart, 2003). The sample to 30% w/w OD solution ratio was 1:4. The samples were placed in a 30° Brix sucrose solution at 60°C and were left at room temperature for 4 hours without agitation (Udomkun *et al*., 2014). The samples were then rinsed with distilled water for 2 seconds before being filtered through filter paper to eliminate excess moisture (Udomkun *et al*., 2014). The entire samples that were then subjected to further physicochemical and sensory analysis immediately after the osmotic dehydration process over one week. The names of the samples are displayed in Table 1.

Table 1. List and names of all pineapple samples

Sample	Name of samples
S1	Fresh pineapple sample (as control sample)
S2	$CaCl_2$-treated-OD pineapple sample
S3	$CaCl_2$-treated-blanched-OD pineapple sample
S4	$CaCl_2$-treated-frozen-OD pineapple sample
S5	CaL-treated-OD pineapple sample
S6	CaL-treated-blanched-OD pineapple sample
S7	CaL-treated-frozen-OD pineapple sample

Functional Group Analysis

The spectra of all samples were recorded using the Fourier Transform Infrared-Attenuated Total Reflectance (FTIR-ATR) spectroscopy (Cary 630 FTIR spectrometer, Agilent Technologies, USA) in transmittance mode over a frequency range of 400 – 4000 cm^{-1} with a resolution of 4 cm^{-1} (Abdul Aziz *et al*., 2018).

Water Holding Capacity Analysis
About 250 mg of dried samples, obtained over one week on days 1, 3, 5, and 7, were placed in a centrifuge tube containing 25 ml of distilled water and left at room temperature for one hour. After 1 hour, the sample residues were weighed, and the WHC was determined using Equation 1. W_1, W_2, and W_3 denote the weights of the initial fresh samples (g), the centrifuge tube (g), and the sample and centrifuge tube (g), respectively (Felli *et al*., 2018).

$$\mathrm{WHC} = \frac{[(W_3 - W_2) - W_1]}{W_1} \quad (1)$$

Colour Analysis
The colour analysis was carried out on a smartphone with a mobile software app (Color Name AR) to measure colour changes in the sample. The CIE $L^*a^*b^*$ was used, where the L^*, a^*, and b^* indicated lightness, redness, and yellowness, respectively (Udomkun *et al*., 2014). These values were used to determine the hue angle (h^*) and chroma (C^*) using Equations 2 and 3.

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$h^* = tan^{-1}\,(b^*/a^*) \quad (3)$$

Sensorial Analysis
Sensory evaluation was done on all samples using a 9-point hedonic scale, where 1 means “dislike extremely,” 5 means “neither like nor dislike,” and 9 means “like extremely” to evaluate consumer acceptance. Twenty semi-trained panelists who already have knowledge regarding the sensory, undergone training in sensory testing, and were able to evaluate the sensory attributes performed a sensory evaluation. Several sensory attributes, such as appearance, texture, taste, odour, and overall acceptability, were evaluated (Ngamchuachit *et al*., 2014).

Textural Analysis
The hardness of samples was examined using a texture analyser (TA. XTplus C Stable Micro System Ltd., Godalming, United Kingdom). Before beginning the evaluation, several adjustments were performed to the texture analyzer, which was equipped with a 50 kg load cell and a 5 mm diameter cylindrical aluminium probe (Kowalska & Lenart, 2003). In a two-cycle test, the probe compressed the samples until a maximum strain of 75% was attained. The pre-test, test, and post-test speeds were 5.0 mm s^{-1}, 10.0 mm s^{-1}, and 5.0 mm s^{-1}, respectively (Udomkun *et al*., 2014). The texture analyser’s software was used to collect and record the data.

Statistical Analysis
All the analysis results were triplicated. The findings were presented as means ± standard deviation. The one-way analysis of variance (ONE-WAY ANOVA) and post-hoc analysis was used to identify the significant difference ($P<0.05$) by using Microsoft Excel 16.0 (Excel 2019, United States) and Minitab 19.0 software (Minitab, State College, PA).

Result and Discussion

Functional Group Analysis
All pineapple samples’ spectra revealed a strong and broad peak of O-H stretching between 3200 – 3550 cm^{-1}, while medium peak for C-H stretching between 2840 – 3000 cm^{-1}. Pineapple is typically high in insoluble fibre, which is known as cellulose (Asim *et al*., 2015). All pineapple samples revealed a noticeable medium C=C symmetric stretching between 1600 – 1670 cm^{-1}. There is medium C-O stretching of esters at 1000 – 1330 cm^{-1}, contributing to the pleasant and fruity flavour and odour of all pineapple samples. Peaks in the 1120 – 995 cm^{-1} band (coupled C-O and C-C stretching vibration) are primarily caused by sugars and organic acids. Peaks at 1180 – 1056 cm^{-1} are largely produced by the C-O and C-C of sugars and organic acids (Di Egidio *et al*., 2009).

Table 2 summarises the functional groups associated with the FTIR spectra of all pineapple samples. It is supported by a research study conducted by Kowalska *et al.* (2008), where pre-treatments such as calcium salt treatments, blanching, and freezing have a less significant effect on the functional groups and volatile compounds because most pre-treatments may preserve the textural and sensorial quality of pineapple samples rather than changing the functional groups in pineapple compositions.

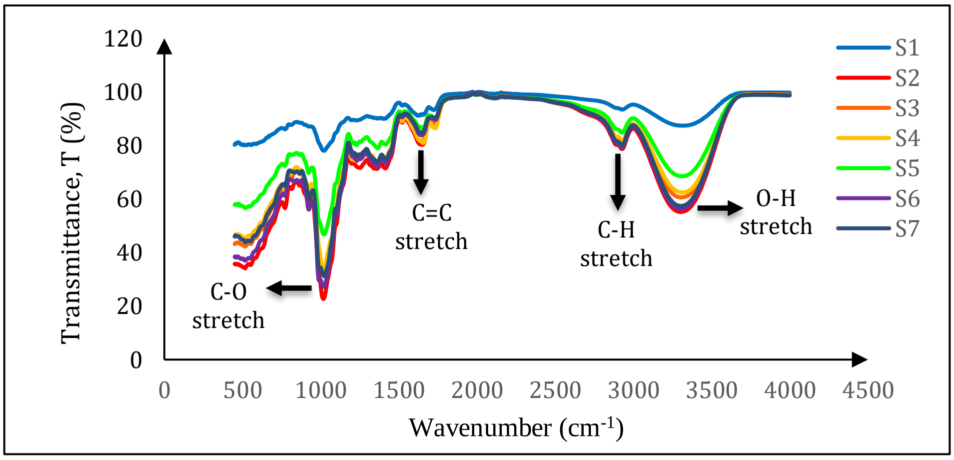

Figure 2. FTIR spectra of all pineapple samples

Table 2. FTIR significant peaks for all pineapple samples

Wavenumber (cm^{-1})	Functional group	Interpretation
3200 – 3550	O-H stretch	Indicates cellulose
2840 – 3000	C-H stretch	Represents aliphatic acids
1600 – 1670	C=C stretch	Represents aromatic rings
1000 – 1330	C-O stretch	Indicates the fruity flavour and odour of pineapple

Notes- Functional groups have been chosen based on FTIR peaks in all pineapple samples, including the control sample (S1).

Water Holding Capacity Analysis

The water holding capacity (WHC) of all treated-OD pineapple samples was measured over a week and found to be a non-significant difference ($P>0.05$) since the average WHC values are relatively identical (Table 3). Pineapple samples produce less pectin, which could affect its WHC. The WHC of fruits depends on how much pectin they have (Muhammad *et al.*, 2020). The fiber content in the calcium salts-treated-blanched-OD pineapple samples declined promptly due to exposure to high temperatures during blanching. It is proven that blanching at 80 °C affects the pineapple fiber structure, thus reducing the WHC of pineapple samples. A similar finding obtained by Borchani *et al.* (2012) demonstrated that the high drying temperature affected the WHC by decreasing the WHC of fiber in dates.

Table 3. Water holding capacity (WHC) of all pineapple samples

	S1	S2	S3	S4	S5	S6	S7
1	5.18 ± 0.08^{a}	5.17 ± 0.07^{a}	5.46 ± 0.16^{a}	5.29 ± 0.15^{a}	5.40 ± 0.09^{a}	5.26 ± 0.18^{a}	5.34 ± 0.05^{a}
3	5.21 ± 0.03^{a}	5.32 ± 0.03^{a}	5.15 ± 0.06^{a}	5.14 ± 0.17^{a}	5.34 ± 0.07^{a}	5.24 ± 0.18^{a}	5.25 ± 0.10^{a}
5	5.24 ± 0.10^{a}	5.31 ± 0.17^{a}	5.12 ± 0.01^{a}	5.25 ± 0.07^{a}	5.20 ± 0.05^{a}	5.17 ± 0.05^{a}	5.22 ± 0.12^{a}
7	5.19 ± 0.02^{a}	5.27 ± 0.16^{a}	5.28 ± 0.19^{a}	5.33 ± 0.06^{a}	5.16 ± 0.03^{a}	5.25 ± 0.13^{a}	5.24 ± 0.13^{a}

Notes- Values are represented as mean ± standard deviation for each sample (S1-S7) over one week.

The water holding capacity (WHC) has been expressed as grams of water retained per gram of dried pineapple sample.

Colour Analysis

Table 4 displays the *L** (lightness), *a** (redness), *b** (yellowness), *C** (chroma), and *h** (hue angle) values of all pineapple samples over one week (since day 1 until day 7). S1 (fresh pineapple) demonstrated that the *L**, *a**, *b**, and *C** values are decreased. The *h** value increased on day 5 but began to fall on day 7. The findings demonstrated that the colour of fresh pineapple began to deteriorate when the samples were held for an extended period without any pre-treatments (the fruit ripening process) (Rashima *et al.*, 2019). For the $CaCl_2$ and CaL-treated-OD pineapple samples (S2 and S5), *L** and *a** values of both samples exhibited an increase and decrease, respectively, while the *b**, *C**, and *h** values for S2 are increased and S5 are decreased. For calcium salts-treated-blanched-OD pineapple samples, the values of *L**, *a**, *b**, *C**, and *h** for S3 and S6 followed the S2 and S5 trend results, respectively. It can be seen that the *L** and *h** values of S3 and S6, which were subjected to blanching, are higher than those of S2 and S5, which were not blanched. The *a** values of both S3 and S6 declined with increased *b** and *C** values for S3, and the *b** and *C** values for S6 decreased over one week. For calcium salts-treated-frozen-OD pineapple samples, the *L**, *a**, *b**, *C**, and *h** values of the S4 and S7 showed the same pattern as the S3 and S6, respectively. The *L** values of S4 and S7 were much greater than the other samples. The *a** values of S4 and S7 declined somewhat after one week. During the one week, S4's *b** and *C** values increased, whereas S7's values decreased. Similarly, after one week, the *h** values of S4 and S7 increased.

Table 4. Colour measurement values (*L**, *a**, *b**, *C**, and *h**) of all pineapple samples

Sample	Days	*L**	*a**	*b**	*C**	*h**
S1	1	65.36 ± 1.42^{fg}	2.26 ± 0.17^{a}	44.80 ± 0.58^{cdefg}	44.85 ± 0.57^{a}	87.11 ± 0.24^{a}
	3	65.60 ± 0.86^{fg}	2.01 ± 0.24^{a}	42.98 ± 1.08^{defg}	43.03 ± 1.07^{ab}	87.32 ± 0.36^{a}
	5	68.12 ± 0.92^{cdefg}	1.97 ± 0.09^{a}	41.81 ± 1.95^{defg}	41.84 ± 1.97^{ab}	87.40 ± 0.28^{a}
	7	69.55 ± 0.50^{abcdefg}	1.90 ± 0.18^{a}	39.10 ± 4.09^{fgh}	39.15 ± 4.08^{ab}	87.10 ± 0.32^{a}
S2	1	68.82 ± 0.41^{cdefg}	-3.27 ± 0.48^{a}	43.67 ± 0.65^{cdefg}	43.79 ± 0.62^{ab}	-85.71 ± 0.66^{fg}
	3	71.11 ± 0.24^{abcde}	-3.55 ± 0.40^{a}	58.66 ± 1.39^{b}	58.43 ± 1.09^{a}	-86.54 ± 0.32^{g}
	5	72.14 ± 0.31^{abcd}	-5.32 ± 0.52^{a}	60.83 ± 1.47^{ab}	61.07 ± 1.50^{a}	-85.01 ± 0.42^{efg}
	7	71.73 ± 1.10^{abcde}	-5.35 ± 0.54^{a}	65.75 ± 1.78^{ab}	65.96 ± 1.75^{a}	-85.34 ± 0.55^{fg}
S3	1	69.22 ± 0.75^{bcdefg}	-3.26 ± 0.92^{a}	50.77 ± 3.72^{cde}	50.88 ± 3.71^{a}	-86.31 ± 1.05^{g}
	3	71.69 ± 0.33^{abcde}	-3.38 ± 1.28^{a}	63.98 ± 0.73^{ab}	64.08 ± 0.80^{a}	-86.99 ± 1.10^{g}
	5	72.37 ± 0.32^{abcd}	-5.94 ± 0.06^{a}	64.83 ± 0.55^{ab}	65.11 ± 0.54^{a}	-84.76 ± 0.09^{defg}
	7	72.87 ± 2.93^{abc}	-5.11 ± 0.24^{a}	66.20 ± 0.92^{ab}	66.39 ± 0.92^{a}	-85.58 ± 0.22^{fg}
S4	1	70.68 ± 0.91^{abcdef}	-4.50 ± 0.88^{a}	49.55 ± 8.09^{cd}	49.76 ± 8.05^{a}	-85.55 ± 0.64^{fg}
	3	73.24 ± 0.42^{abc}	-4.39 ± 1.20^{a}	67.01 ± 1.29^{a}	67.16 ± 1.30^{a}	-86.25 ± 1.02^{g}
	5	74.30 ± 0.19^{ab}	-5.30 ± 0.42^{a}	67.76 ± 0.48^{a}	68.00 ± 0.38^{a}	-85.53 ± 0.39^{fg}
	7	74.68 ± 7.13^{a}	-5.16 ± 0.68^{a}	66.42 ± 1.08^{ab}	66.62 ± 1.03^{a}	-84.71 ± 1.43^{cdefg}
S5	1	64.96 ± 0.73^{g}	0.88 ± 0.05^{a}	42.87 ± 0.74^{defg}	42.88 ± 0.74^{ab}	88.82 ± 0.05^{a}
	3	65.60 ± 0.84^{fg}	-5.33 ± 0.28^{a}	36.64 ± 1.53^{g}	37.03 ± 1.53^{ab}	-81.71 ± 0.41^{b}
	5	68.12 ± 0.92^{cdefg}	-4.98 ± 0.52^{a}	37.62 ± 0.48^{g}	37.95 ± 0.54^{ab}	-82.46 ± 0.69^{bcd}
	7	69.55 ± 0.50^{abcdefg}	-5.12 ± 0.31^{a}	38.85 ± 0.20^{fg}	39.18 ± 0.21^{ab}	-82.50 ± 0.44^{bcd}
S6	1	68.96 ± 0.60^{fg}	-3.30 ± 0.47^{a}	45.71 ± 6.77^{cdef}	45.83 ± 6.73^{a}	-85.77 ± 1.17^{fg}
	3	67.29 ± 1.71^{defg}	-5.01 ± 1.09^{a}	36.07 ± 0.58^{g}	36.43 ± 0.57^{ab}	-82.09 ± 1.74^{b}
	5	68.96 ± 0.60^{bcdefg}	-5.53 ± 0.40^{a}	38.63 ± 0.22^{fg}	39.03 ± 0.26^{ab}	-81.86 ± 0.55^{b}
	7	70.60 ± 0.42^{abcdef}	-5.35 ± 0.44^{a}	39.81 ± 0.47^{fg}	40.17 ± 0.41^{ab}	-82.34 ± 0.71^{bc}
S7	1	66.52 ± 1.51^{efg}	-4.39 ± 0.46^{a}	47.76 ± 1.24^{cde}	47.97 ± 1.22^{a}	-84.75 ± 0.61^{defg}
	3	67.96 ± 1.79^{cdefg}	-4.47 ± 0.72^{a}	39.90 ± 0.77^{fg}	40.15 ± 0.81^{ab}	-83.62 ± 0.95^{bcdef}
	5	70.06 ± 0.32^{abcdefg}	-5.28 ± 0.56^{a}	39.97 ± 0.48^{fg}	40.32 ± 0.51^{ab}	-82.48 ± 0.75^{bcd}
	7	71.72 ± 0.33^{abcde}	-5.34 ± 0.34^{a}	41.59 ± 0.39^{efg}	41.93 ± 0.35^{b}	-82.69 ± 0.52^{bcde}

Notes- Values are represented as mean ± standard deviation for each sample (S1-S7) over one week. Colour analysis has been measured *L** (lightness), *a** (redness), *b** (yellowness), *C** (chroma), and *h** (hue angle) values of all pineapple samples over one week.

Based on the findings, calcium salts treatment, blanching, and freezing help to preserve the colour of the OD pineapple samples from deterioration. All pineapple samples, including the control sample (S1), differed significantly ($P<0.05$). All calcium salts-treated OD pineapple samples had greater L^* values, whereas the a^* values are reduced in all pineapple samples after one week. Similar to the findings from Udomkum *et al*. (2014), the colour attributes of dried papaya are strongly impacted by calcium salts treatments, with L^* values of calcium salts-treated papaya being greater than those of the control. Meanwhile, $CaCl_2$-treated-OD pineapple samples have higher L^* values than the CaL-treated-OD pineapple samples because $CaCl_2$ is more efficient at retaining colour than CaL.

There is a comparison between the $CaCl_2$-treated-OD pineapple samples along the CaL-treated-OD pineapple samples. The a^* values of both calcium salts-treated-OD pineapple samples declined. However, the $CaCl_2$-treated-OD pineapple samples have higher b^*, C^*, and h^* values than the CaL-treated-OD pineapple samples because the $CaCl_2$-treated-OD pineapple samples become more yellowish, which improves the various colour attributes. The b^*, C^*, and h^* values of pineapple samples were significantly impacted by the sample's colour and maturity stage since each pineapple has a varied range of yellowish colour (Rashima *et al*., 2019). Similar findings were observed by Cháfer *et al*. (2003) and Zhao *et al*. (2014). Different findings from Udomkum *et al*. (2014), the researchers found that the a^*, b^*, C^*, and h^* values of calcium salts-treated papaya were not significant, using a high calcium concentration where L^* values increased with decreasing b^*, C^*, and h^* values. It is summarised that the types and physicochemical properties of fruits influenced their colour attributes. Blanching and freezing also altered the colour of calcium salts-treated OD pineapple samples, where these pre-treatments inhibit browning, which is accelerated by polyphenol oxidase (PPO).

Sensorial Analysis

Table 5 depicts the sensory attributes of all the pineapple samples, including the appearance, texture, taste, odour, and overall acceptability, where there is a significant difference ($P<0.05$). The S1 is considered a control sample. The S1 received the highest scores for all sensory attributes since it was fresh pineapple samples. The average appearance scores of the treated-OD pineapple samples were varied. The $CaCl_2$-treated-OD pineapple samples (S2) received the highest scores of roughly 5.88 ± 0.45, while the CaL-treated-frozen-OD pineapple samples (S7) received the lowest score of 4.86 ± 0.86, where $CaCl_2$ improved the appearance of the OD pineapple samples. A similar observation was found by Udomkum *et al*. (2014), which indicated that the colour of the dried papaya samples varied significantly. The dried papaya samples treated with both calcium salts obtained higher scores than the control samples. The blanching and freezing pre-treatments also had a substantial impact on the appearance of the samples, with both pre-treatments significantly improving the colour and appearance of the pineapple samples. Jariyawaranugoon (2015) also observed a similar result for pre-treated osmotically dehydrated bananas.

In terms of texture, the average sensory score for S2 is about 5.83 ± 0.43 higher than the S7, roughly about 4.80 ± 0.65. The results indicated that the texture scores for S7 decreased due to freezing, which contributed to the loss of their hardness and textural quality. The pineapple samples naturally have a firm texture, and the texture characteristics of the pineapple began to degrade as the maturity stages increased (Rashima *et al*., 2019). As the pineapple samples were treated with pre-treatments, their texture lost firmness and became watery. In comparison to the CaL-treated-OD pineapple samples, the $CaCl_2$-treated-OD pineapple samples (S2, S3, and S4) have the highest score. It has been similarly evidenced by Ngamchuachit *et al*. (2014). The taste scores began to decline as the storage period was prolonged. The S2 received the highest score, 5.95 ± 0.32 since the panellists were impressed with the sweet flavour. While the S7 had the lowest score, approximately 4.09 ± 0.49, the flavour was less pleasant to consume. The blanching had little impact on the taste of treated-OD pineapple samples because volatile components were vaporised during heat treatments (blanching), lowering sensory ratings (Stone *et al*., 1986). The freezing pre-treatment also lowered the sensory scores of the pineapple samples for flavour (Jariyawaranugoon, 2015).

The aroma is always associated with flavour, making the food product more delicious and pleasant. The most volatile chemicals, such as ester and ether, are responsible for the fruits' distinct aroma (Deng *et al*., 2019). As the pineapple matured, the amount of aroma increased (Rashima *et al*., 2019). The S2 has the greatest aroma score (5.63 ± 0.43), while the S7 has the lowest aroma score (4.56 ± 0.52). It is proven that the aroma of the treated-OD pineapple samples began to deteriorate throughout the numerous pre-treatments and prolonged storage periods. Similarly, Udomkun *et al*. (2014) demonstrated that the impact of $CaCl_2$ and CaL treatments on the dried papaya obtained the lowest score for the aroma. The findings indicated that the blanching and freezing had a minor adverse impact on the aroma of OD pineapple samples. It is inferred that various sensory aspects influenced the overall acceptance of all treated-OD pineapple samples. The $CaCl_2$-treated-OD pineapple samples (S2, S3, and S4) get the best score, while the CaL-treated-OD pineapple samples (S5, S6, and S7) have the lowest overall acceptability score. Briefly, $CaCl_2$ is considered an effective preservative agent compared with CaL. It has been similarly evidenced by Ngamchuachit et al. (2014). The researchers reported that the mango cubes treated with $CaCl_2$ scored higher on textural features and other sensory attributes than those treated with CaL.

Table 5. Average sensory scores of each sensory attribute for all pineapple samples

Sensory attributes	S1	S2	S3	S4	S5	S6	S7
Appearance	6.34 ± 0.31^{a}	5.88 ± 0.45^{ab}	5.65 ± 0.35^{ab}	5.75 ± 0.41^{ab}	4.89 ± 0.74^{b}	5.23 ± 0.29^{ab}	4.86 ± 0.86^{b}
Texture	6.15 ± 0.28^{a}	5.83 ± 0.43^{ab}	5.16 ± 0.36^{ab}	5.36 ± 0.34^{ab}	5.15 ± 0.73^{ab}	5.05 ± 0.44^{ab}	4.80 ± 0.65^{b}
Taste	5.78 ± 0.26^{ab}	5.95 ± 0.32^{a}	4.96 ± 0.27^{bc}	5.41 ± 0.30^{ab}	4.33 ± 0.49^{cd}	4.41 ± 0.25^{cd}	4.09 ± 0.49^{d}
Odour	6.01 ± 0.17^{a}	5.63 ± 0.43^{ab}	5.25 ± 0.32^{abc}	5.50 ± 0.29^{ab}	4.85 ± 0.53^{bc}	4.94 ± 0.29^{bc}	4.56 ± 0.52^{c}
Overall acceptability	6.34 ± 0.21^{a}	6.04 ± 0.48^{a}	4.80 ± 0.46^{bc}	5.46 ± 0.39^{ab}	4.29 ± 0.78^{bc}	4.34 ± 0.46^{bc}	4.05 ± 0.58c

Notes- Values are presented as mean ± standard deviation for each sample (S1-S7) throughout one week. Sensory analysis was conducted to evaluate the sensory attributes of the pineapple samples, including appearance, texture, taste, odor, and overall acceptability.

Textural Analysis

Table 6 summarises the findings of hardness for all the pineapple samples. The hardness of S1 is reduced over a week. These findings indicated that the hardness of S1 started to deteriorate and decline along with the increased storage period, where the force required to compress the pineapple samples decreased. Fresh-cut fruit textural features are connected to the distortion and disintegration of the food under stress. The reduction in intermolecular bonding among cell wall polymers results from a decrease in hardness. As a result, the solubilization of the wall constituents, particularly pectin, tends to increase, resulting in softening (Defilippi *et al*., 2018). For the calcium salts-treated-OD pineapple samples, the hardness of S2 ($CaCl_2$-treated-OD pineapple samples) and S5 (CaL-treated-OD pineapple samples) increased from day 1 to day 7. There is a significant difference between the calcium salts-treated-OD pineapple samples ($P<0.05$). Supported by Pereira *et al.*(2007) for guava samples, the researchers indicated that CaL is a more effective chemical agent than $CaCl_2$ in retaining the hardness of fruits samples for a longer storage period, demonstrating the formation of connections among Ca^{2+} ions and pectin located within the cell membrane and middle lamella of guava tissue.

For calcium salts-treated-blanched-OD pineapple samples, the hardness of S3 and S6 is quite varied. The hardness of S3 and S6 decreased from day 1 to day 7. The findings proved that significant differences are found in the hardness among the S3 and S6 ($P<0.05$). These findings indicated that the hardness of calcium salts-treated-blanched-OD pineapple samples began to decline during heat treatment. A similar observation was researched by Inam-ur-Raheem *et al*. (2013). The calcium salts treatment can preserve the hardness of pineapple samples even after the blanching pre-treatment. For calcium salts-treated-frozen-OD pineapple samples, the findings discovered through the S4 and S7 followed the same trends as the S3 and S6, where the hardness of the S4 and S7 are decreased. The findings revealed a significant difference (P<0.05), with the samples requiring more compression forces on day 1 and fewer forces on day 7. According to Lovera *et al.* (2018), calcium-impregnated samples exhibited greater stress levels prior to freezing than fresh fruit, depending on the types of calcium salts being used and the impregnation duration. Although freezing reduced the hardness of both fresh and treated fruit, CaL impregnation treatments increased firmness.

Table 6. Texture profile analysis of the hardness for all pineapple samples

Days	S1	S2	S3	S4	S5	S6	S7
1	263.44 ± 3.49^{ab}	283.14 ± 3.22^{ab}	275.22 ± 4.22^{ab}	277.98 ± 1.89^{ab}	290.75 ± 4.31^{a}	283.45 ± 3.63^{ab}	288.94 ± 3.24^{ab}
3	256.71 ± 3.40^{ab}	290.55 ± 3.94^{ab}	263.54 ± 4.01^{ab}	266.02 ± 4.44^{ab}	324.87 ± 3.31^{a}	274.03 ± 1.63^{ab}	282.72 ± 2.77^{ab}
5	248.65 ± 3.26^{b}	293.83 ± 4.96^{ab}	258.63 ± 0.96^{ab}	261.17 ± 4.62^{ab}	327.85 ± 1.75^{ab}	267.43 ± 2.45^{ab}	273.10 ± 3.13^{ab}
7	235.08 ± 2.43^{b}	295.06 ± 4.41^{ab}	249.45 ± 2.91^{ab}	252.41 ± 3.50^{ab}	332.99 ± 2.83^{ab}	258.81 ± 5.18^{ab}	268.66 ± 3.07^{ab}

Notes- Values are presented as mean ± standard deviation for each sample (S1–S7) across various days (1, 3, 5, and 7) during one week. Texture profile analysis was conducted to examine the hardness of all pineapple samples over one week.

Conclusion

The impregnation of OD pineapple with $CaCl_2$ and CaL by blanching and freezing treatments was successfully studied. The functional group analysis revealed that all pineapple compositions were identical, even after pre-treatments. There is no significant variation in WHC between all pineapple samples (P>0.05). All treated-OD pineapple samples differed significantly for all colour attributes (P<0.05). The *L** and *h** values of all treated-OD pineapple samples were increased, but the *a** values were decreased. The $CaCl_2$-treated-OD pineapple samples had higher *b** and *C** values than the CaL-treated-OD pineapple samples, but these values decreased after blanching and freezing. The sensory analysis also revealed a significant difference between all pineapple samples (P<0.05). The $CaCl_2$-treated-OD pineapple samples had higher sensory scores than the CaL-treated-OD pineapple samples. The texture analysis indicated a significant difference between all the treated-OD pineapple samples (P<0.05). The hardness of the CaL-treated-OD pineapple samples was higher than that of the $CaCl_2$-treated-OD pineapple samples. The hardness of treated-OD pineapple samples subjected to freezing and blanching pre-treatments decreased. The results proved that $CaCl_2$ is a more efficient preservative than CaL in maintaining the qualities of the OD pineapple samples instead of pre-treatments, blanching, and freezing because the $CaCl_2$ helps preserve the color of pineapple samples, as evidenced by significant differences in *L**, *a**, *b**, *C**, and *h** values. $CaCl_2$ reduces browning by suppressing polyphenol oxidase activity through chloride ions. $CaCl_2$ preserves color while improving sensory attributes such as appearance, texture, taste, aroma, and overall acceptability. This is shown by the fact that OD pineapple samples treated with $CaCl_2$ received higher sensory scores than those treated with CaL. $CaCl_2$ also helps maintain the textural integrity and firmness of the pineapple samples under proper storage conditions, outperforming CaL in this aspect.

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Author Contribution

Shalini Raja: collecting data, analysis, writing, and editing. Saliza Asman: conceptualization, review, and editing

Conflict of Interest

Authors declare no conflict of interest.

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