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FULL PAPER

Calcium-infused dehydrated pineapple

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Abstract

Mineral-infused dehydrated fruits could be an easy and most convenient way to healthy snacking for those who have mineral deficiencies. An attempt is made to impregnate selected minerals into fruit matrices by applying the vacuum impregnation process. Three-level factorial experiment designs with two factors were used in this study. In order to increase stability and assure fruit preservation, impregnated pineapple samples were dehydrated to a water content below 10%. Calcium-infused dehydrated pineapple was compared with commercially available dehydrated pineapple. The sample contains 10 times and 2 times more calcium than their fresh counterpart and commercial dehydrated pineapple respectively. Yellow colour (b* value) was equal to commercial. Moisture content was 6-7%, compatible with both samples. Firmness (g) was far less by 117-point when compared to commercial. The sample had a liking score of 6 (out of 7). Four attributes had a greater liking score than commercial, except for chewiness (compatible with commercial). The panellists accept this product, and it could be a healthy snacking to enhance daily calcium intake.

1. Introduction

Food is supposed to be the most significant factor contributing to health (Cathro and Hilliam, 1993). The development of foods that promote health and well-being is one of the key research priorities of the food industry (Klaenhammer and Kullen, 1999). This trend has favoured the consumption of foods enriched with physiologically active components such as prebiotics, probiotics, vitamins and minerals, dietary fibre, fish oils and plant sterols (Betoret *et al*., 2003).

Vacuum impregnation (VI) has been considered a useful way to force other soluble substances into the porous structure of foods. Physiologically active compounds may be introduced into fruit and vegetable products using this technique without modifying their integrity. This processing method is a key factor to distinguish it from other processing methods (Mavroudis *et al.* 1998a; Mavroudis *et al.* 1998b). Most VI experiments were using apples as the matrices. Assis *et al.* (2019) reported that the dried calcium-impregnated apple sliced had a higher amount of calcium with a rubbery and hard texture. Betoret *et al.* (2003) used the VI technique to impregnate *Lactobacillus rhamnosus* into apple matrices. The number of probiotics is similar to that in commercial dairy products.

Calcium is a mineral that is necessary for life. In addition to building bones and keeping them healthy, calcium enables our blood to clot, our muscles to contract, and our heart to beat. About 99% of the calcium in our bodies is in our bones and teeth. Dietary calcium plays an important role in disease prevention and health promotion. Deficiency of this nutrient has been demonstrated to occur in large segments of populations in developed and developing nations and has been epidemiologically linked to several chronic diseases, including osteoporosis, osteomalacia, hypertension and colon cancer (Goldberg, 2012).

Ananas comosus L. Merr (pineapple) is one of the

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most popular commercial fruit crops in the world. Pineapple is widely distributed in tropical regions such as the Philippines, Thailand, Malaysia and Indonesia. Pineapples are consumed or served fresh, cooked, juiced and can be preserved. Pineapple fruit exhibits high moisture, high sugars, soluble solid content, ascorbic acid and low crude fibre. Thus pineapples can be used as supplementary nutritional fruit for good personal health (Hemalatha and Anbuselvi, 2013). The main pineapple varieties grown in Malaysia are Moris, N36, Sarawak, Gandul, Yankee, Josapine, Maspine, and most recently MD2. Per capita consumption of pineapple among Malaysian is 7.6 kg/year, falls into third-ranking after coconut and banana (Department-of-Statistics, 2018). Among nine major pineapple varieties, MD2 has been identified as a key crop under the National Key Economic Area (Thalip *et al.*, 2015). This study was aimed to impregnate selected minerals (calcium) into pineapple matrices using the VI technique.

2. Materials and methods

2.1 Sample preparation, pre-treatment and vacuum impregnation-dehydration treatment

Pineapple was obtained from the Serdang soil plantation. Variety MD2 was chosen for availability throughout the study. The pineapple was cut to 1 cm thickness. Sliced pineapples were steam (steam blanching) to inactivate enzyme activity (enzymatic browning) for 10 mins.

VI treatments were carried out at 25-27°C in a vacuum desiccator. Hypotonic impregnation solution was prepared with 2% calcium and glucose syrup to reach 35°Bx. Sliced pineapples were immersed in the impregnation solution in a 1:3 (w/w) fruit/syrup ratio, then followed by vacuum pressure, and dehydration (70°C for 20 hrs) process. In the second part of the experiment, a dehydrated calcium-impregnated pineapple slice was cured/aged to achieve desired texture (at par or softer than commercial). Curing/ageing was done under atmospheric conditions (28-30°C; RH 60%) for 30 days. Each experimental unit evaluated its calcium content, colour (yellowness = b-value), water activity, dried recovery, weight loss, and firmness.

2.2 Experimental design, analytical methods and statistical analysis

The experimental design was factorial (2 independent factors × 3 levels) with 3 replications. The independent factors were vacuum time (min) and relax time (min). Levels of each factor were determined during the preliminary study (data was not shown). The levels were 0 min, 7 mins 30 s, and 15 mins. Thirteen experimental units were generated by the Design Expert program (9.0 Stat-Ease, Inc. Minneapolis, MN). The factorial models derived from the equation (via the software) were employed to visualize and identify the effect of independent factors and their interaction with the quality traits. Means were separated by Fisher's protected Least Significant Difference (LSD).

Calcium content was determined by the dry-ashing procedure according to the AOAC procedure 968.08 (AOAC, 2000). The mineral concentration was measured with a double-beam atomic absorption spectrometer (Analyst 300 Perkin–Elmer, USA) equipped with a deuterium lamp, background corrector and a hollow cathode lamp. The colour was measured with a CR-300 chroma meter (Minolta, Japan). Water activity was measured with the Aqualab Series 3TE water activity meter (Decagon, USA). Instrumental analysis of firmness was carried out with TA-TX 2 equipment (Stable Micro System Ltd. UK), with a probe of 2 mm diameter. The penetration depth was about 5 mm and the applied force used was 0.25 N. For each condition, firmness measurements were taken for five readings per sample and the results were expressed as a force in grams (g).

Soluble solids content (°Bx) was measured with an Atago Hand refractometer (Atago Co., Osaka, Japan). The percentage of weight loss and dried recovery were calculated by differences in weight between dehydrated and fresh products. Sensory evaluation was done with 40 -consumer panellists using a 7-inch hedonic scale form.

3. Results and discussion

3.1 Impact of vacuum time and relax time on product quality

The effects of independent factors and their interaction on calcium content were demonstrated in factorial model plots (Figure 1A). There was no trend plotted indicating impregnation of calcium into pineapple matrices does not reflect via vacuum time and relax time. However, the calcium content of the impregnated product was greater than freshly cut pineapple (Table 1). Assis *et al.* (2019) have reported the same phenomena in apple slices.

Product recovery has been viewed as an economic indicator towards new product manufacturing (Lindahl *et al.*, 2006). A higher number is preferred. The product recovery per cent was impacted by both independent factors, relax time and vacuum time (Figure 1B). As vacuum time increased (from 0 min to 15 mins), the percentage of product recovery was increasing from 7.3 to 14.9%. The combination of these two independent factors resulted in a greater dried product recovery percentage up to 17.4%.

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Table 1. Characteristics of commercial product vs. developed dehydrated pineapple.

Product	Color (b-value)	Water activity (a_w)	Firmness (g)	
Commercial	41.10^{ab}	0.62^{b}	173.66^{b}	
Freshly cut	40.19^{bc}	0.73^{a}	2,171.11^{a}	
Developed product	43.11^{a}	0.49^{c}	55.87^{c}	
	Overall Acceptability	After Taste (bitter)	Calcium (mg/100g)	% NRN*
Commercial	4.70^{a}	5.00^{b}	18.00^{b}	2.25
Freshly cut	3.50^{c}	3.00^{c}	5.83^{c}	0.73
Developed product	5.60^{b}	5.70^{a}	27.68^{a}	46.82

* Nutrient Reference Value (NRN = Nilai Rujukan Nutrien) for Calcium is 800 mg (by Peraturan-Peraturan Makanan 1985, Bahagian IV, Perkara 18B(11)).
Values with different superscripts within the same column are significantly different ($p < 0.05$).

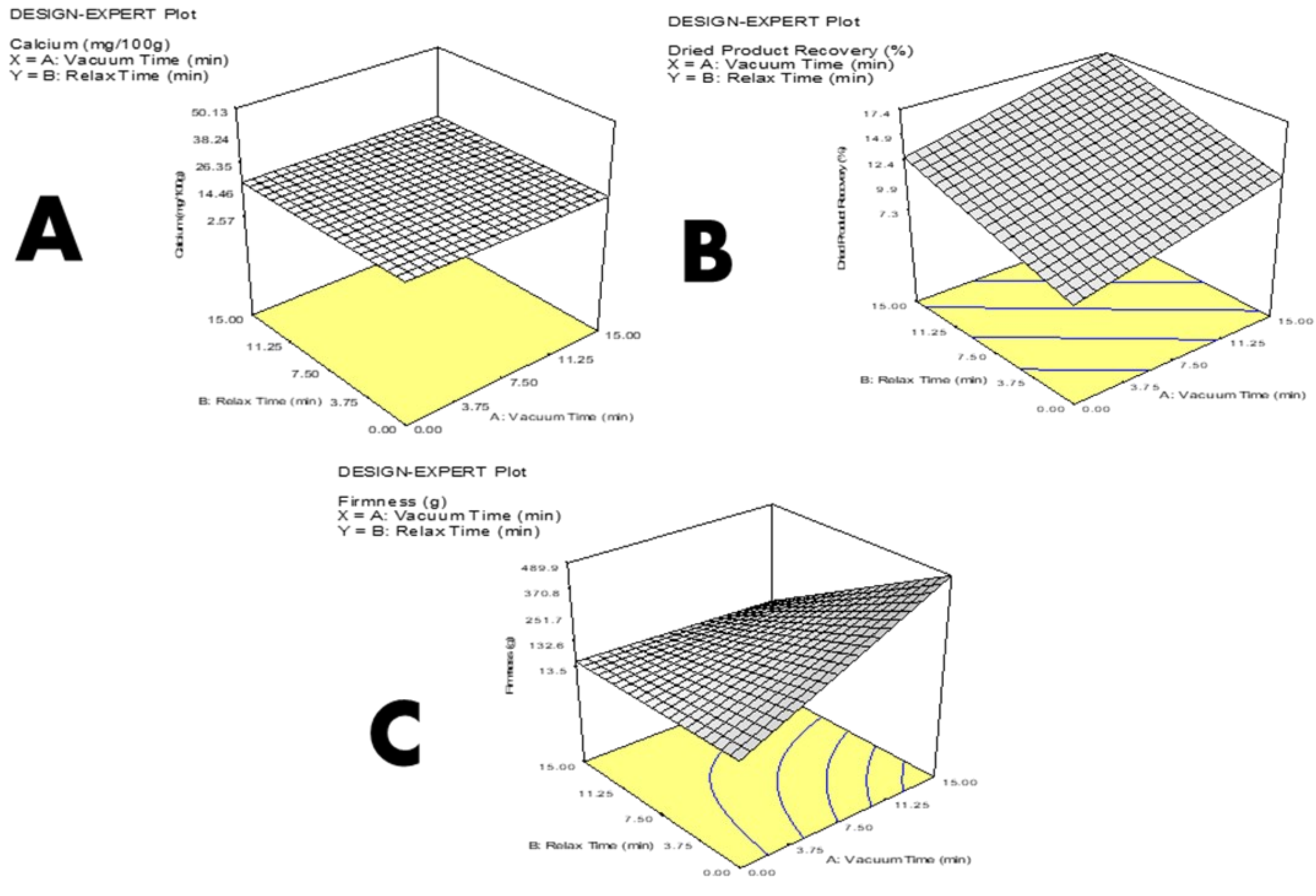

Figure 1. 3D contour plot for calcium response (A); Dried product recovery response (B); Firmness responses (C).

The fruits' texture was probably affected by the compositions of external liquid, which penetrated into the extracellular space of the tissue (Guillemin *et al.*, 2008). Fruit texture is closely related to calcium levels (Mao *et al.*, 2017). However, our study found that the fruit's firmness was affected by vacuum time rather than relax time (Figure 1C). Firmness was greater by 36-fold from 0 min to 15 mins of vacuum time. The end product was hard, chewy and had a rubber-like texture, making it unpalatable to eat.

3.2 Quality comparison with commercial product

Seven min and 30 s of vacuum time and relax time were used as final VI parameters for this part of the study. Those parameters were chosen for their highest calcium content (28 mg/100 g) in the final product. After dehydration for 20 hrs, the samples were cured/aged for 30 days to achieve desired texture (comparable with commercial).

Table 1 shows quality traits of dehydrated calcium-impregnated pineapple slices, commercially dehydrated pineapple slices, and freshly cut pineapple slices. The first quality judgement made by a consumer is visual appearance and colour is one of the most important appearance attributes (Nourian *et al.*, 2003). Yellowness (showed as b-value) for those three products was at par (Table 1). Steam blanching was successfully inhibiting browning enzyme activity. Blanching is an excellent tool for inactivating enzymes, causing enzymatic browning/

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Maillard reaction (Deliza *et al.*, 2005; Baron, *et al.*, 2006).

Water activity (a_w) is a measure of how much water is free (unbound), and thus available to microorganisms to use for growth. Freshly cut pineapple slices had the a_w of 0.73, while commercially dehydrated pineapple slices had 0.62 of a_w. We successfully developed a dehydrated calcium-impregnated pineapple slice with a lower a_w, which is 0.49. In some cases, a_w is the main factor accountable for food stability and controlling microbial growth in food (Rockland and Beuchat, 2017).

Curing/ageing under atmospheric conditions (28-30°C) for 30 days, has remarkably improved the texture of the developed product. Developed products had the lowest firmness number, indicating it was the softest among all. However, it may seem not economical to the manufacturer, as they have to cure the products for up to 30 days. Future study is to include and consider the use of a climatic chamber to shorten the curing time. The sensory evaluation score is shown in Figure 2. The developed product exceeded the commercial product in all five attributes, indicating the developed product is accepted by the consumer.

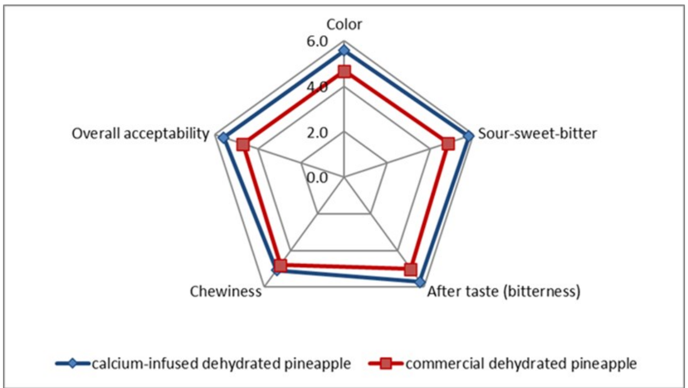

Figure 2. Spider web of sensory attributes.

4. Conclusion

Ten times more calcium was successfully impregnated into pineapple matrices via the VI process. The optimum parameters of 7 mins and 30 s were needed for both vacuum and relax time. However, the dehydration process led to a harder, chewy, and rubber-like texture to the end product. The additional process of curing/ageing had been a successful way to improve the texture and acceptability of the final products. A future study might be needed to improve or find other techniques to soften the texture of dehydrated products.

Conflict of interest

The authors declare no conflict of interest.

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