Journal of Science and Technology, Vol. 9 No. 4 (2017) p. 102-108

Effect of Combining Ultrasound with Osmotic Pre-treatment on Osmotic Characteristics of Pomelo Peel

Navis Ryan Xavier[1], Norazlin Abdullah[1*], Norhayati Muhammad[1] and Norazatul Hanim Mohd Rozalli[2]

[1]Department of Technology and Natural Resources, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Educational Hub, 84600 Pagoh, Johor, Malaysia.
[2]School of Industrial Technology, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia.

Received 30 September 2017; accepted 30 November 2017; available online 28 December 2017

Abstract: Pre-treatment of food greatly manipulates the food processing applications and techniques that enhance the quality characteristics of food thus producing a wide array of preserved foods. This research aims to investigate the effect of application of radiating ultrasound waves, coupled with the presence osmotic dehydration as pre-treatment, on water loss (%) and solid gain (%) in pomelo (*Citrus grandis)* fruit peels. Pomelo peels were immersed in three different osmotic concentrations (0%, 50% and 100%) of food grade sucrose solutions, in the presence of ultrasound waves with three varying ultrasound bath temperatures (30°C, 50°C and 70°C) at two different immersion times (10 minutes and 30 minutes). The values for water loss and solid gains were calculated from the values of moisture content (initial and final) and weight (initial and final). At constant lowest immersion time (10 minutes), decreasing ultrasound bath temperature and increasing osmotic concentration resulted in greater water loss (%), at the same time, resulted in the lesser solid gain (%). This result dictated that solid gain fluctuations are not affected by the percentage of osmotic concentration. Pre-treatment with 10 minutes immersion time, 30°C ultrasound bath temperature and 100% osmotic concentration employed the ideal value of both water loss and solid gain. This indicates that low immersion time and temperature with greatest osmotic concentration dehydrates the pomelo peels to preserve the fruit via ultrasound assisted osmotic dehydration process.

Keyword: Osmotic dehydration; peel; pomelo; sucrose; ultrasound.

1. Introduction

The food industry prospects at this current time is a tricky business as it revolves on the new innovation of food processing applications and techniques to enhance the quality characteristics of food and to produce a wide array of preserved foods. For this research study, applications of radiating waves with osmotic pre-treatment which pretty much shows its significance towards the food industry are applied.

This research topic binds the application of ultrasound with osmotic concentration to assemble the effects of ultrasound waves on the osmotic characteristics that contributes to the osmotic dehydration mechanism. In order for osmotic dehydration to occur, the specimens must obviously be exposed to a specific osmotic concentration. For this research study, a concoction of sucrose solution with distilled water at different ratios controls the osmotic concentrations.

Influence of osmotic concentration plays an important role in treating foods at a specific level. Osmotic concentration, before dehydration, has a shielding action on the structural component of the dehydrated material, which enables it to be springy and less impenetrable [1]. Fruits that are concentrated osmotically are more acceptable with the expulsion of fruit acids, gain in sugar composition and minimal deterioration in fresh flavour [2]. It involves the expulsion of water using an osmotic agent where moisture content is further reduced to make the product shelf stable.

During osmotic dehydration, the water and readily solutes are displaced from fruit to the solution and the solutes are displaced from the osmotic solution to the fruit in a counter current

*Corresponding author: norazlinh@uthm.edu.my

penerbit.uthm.edu.my/ojs/index.php/jst

manner [3]. The assistance of ultrasound would enhance the net movement of mass of the osmosis process. Net movement of mass during osmosis depends on concentration and solute type of the dehydration solution, temperature and period of process [4]. For fruit slices, the application of osmosis process has the potential to affect solids concentration.

When it comes to ultrasound technology, no retail food merchandise is currently marketed. However, Welti-Chanes et al. [5] did mention that there is existence about ultrasound facilitated technology for product adjustment or procedure improvement. Therefore, this research would show the potential effects of ultrasound technology wave application in the food industry in terms of food processing. The mechanism of ultrasound clearly relates well to the characteristics of the wave energy itself, the compression of the nodes and antinodes and its recurrent effects to the application involved. Leighton [6] agreed that it is pivotal to acknowledge thermal emission due to ultrasound applications when it comes to the food processing purposes. A motion will be triggered as a waveform that is produced when sound waves enters or penetrates the food medium. Longitudinal waves will be developed that creates an agitation of alternative compression and rarefaction of particles [7]. At the same time, micro-channels are produced that reconstructs pathways for the flow of gas and moisture away from the medium.

The ultrasound application in the food industry has been multiplying in recent years. Wide array of ultrasound wave application have been investigated which correlates directly to the process or product [8]. Mason [9] did mention that power ultrasound has a physicochemical effect on the processes or products upon application.

Past studies have experimented on various post-harvest fruits such as strawberries, bananas and papayas but little research was done on citrus fruits primarily due to the high concentration of the fruits' acidity [10]. Therefore, the opportunity was taken to expand the research and experimentation plus to study the osmotic characteristics of a citrus fruit, in this case, the pomelo fruit. A pomelo fruit which goes by the name *Citrus grandis* appears to be the largest citrus fruits [11]. This type of fruit belongs to the Rutaceae family and is a native fruit to Southeastern Asia [11]. The description and grading of the pomelo fruit are widely affected by its physical attributes. The pomelo fruit has a capability to grow around 25 to 30 cm in width and have a maturity weight around 3 kg [12]. The peel of the pomelo fruit has a dense and thick layer; however its softness enables it to be peeled with ease. In Malaysia, pomelo fruits are cultivated in the states of Perak, Kedah, Melaka, Kelantan and Johor. The PO52 (Tambun), PO51 (Sha Thing), KK2 (Melomas) and Ledang (PO55) are among the well-known species of pomelo in Malaysia. The characterisation of these fruit varieties are primarily based on its colour, size, shape and after taste. Table 1 below reflects on these characteristics.

Table 1 The characteristics of four different pomelo fruit varieties [13].

Variety	PO52 (Tambun)	PO51 (Sha Thing)	KK2 (Melomas)	Ledang (PO55)
Size	Small to medium	Medium-large	Large	Medium-large
Shape	Round and circular	Obovoid to pyriform	Oblate	Round
Colour	Light green to lemon yellow	Light yellow	Lime green with slight yellow base	Greenish shade
Taste	Sweet	Sweet with a hinge of sourness with a mild bitter aftertaste	Mild sweetness with slight acid flavour and faintly bitter	Sweeter and reduced bitter aftertaste

Another variation of this experiment is the utilisation of the pomelo peels instead of the fruit pulp. This choice of utilising the peel would be ideal for the selected pre-treatment, which is the ultrasound wave as the penetration of radiating waves would be rapid and efficient when accommodated to the thin and dry layer of the peel instead of the thick and watery sacked layer of the pulp [14]. The skin nature of the fruit is a pivotal factor as the outcome of the experiment that greatly relies on the characterisation of the treatment.

Application of ultrasounds would be the form of the pre-treatment which is bounded by the osmotic concentration part of the experimentation which supplies great significance to the experimentation results. This processing method has a recurrent effect to the food industry as dehydration processing has become a norm to the society [15]. The aim of this study was to determine the osmotic characteristics such as water loss and solid gain of ultrasonically pre-osmotic treated pomelo peel.

2. Materials and methods

Sample preparation

Pomelo fruit (*Citrus grandis*) was bought from Seri Muda Jaya Sdn. Bhd at R&R Rest Area Pagoh (South Bound) supplier in Pagoh, Johor. The Tambun (PO52) species was used for this research study since it is abundantly found in Malaysia. The sample components such as the size, shape and the green skin to white flesh ratio were very important to be kept constant for consistent experiment outcome.

The pomelo peel samples were cut using a sharp knife in a radial orientation height of 0.02 meters, the thickness of 0.02 meters and the width of the peel was at 0.015 meters [16]. The measurement of the height, thickness and width was aided with a Vernier caliper. The overall dimensions of the pomelo peel were rectangular in shape which would ease the osmotic dehydration [17]. Each pomelo peel samples were weighed within a range between 5 and 10 grams [18]. For the sample preparation stage, the initial moisture content of the pomelo peels were determined by using the moisture analyser (MX-50, AnD, USA). The application of this instrument was straightforward with the requirement of the pomelo peel sample insertion into the device with a setting of 105°C [19].

Preparation of osmotic concentration solution as ultrasound bath medium

The three different osmotic solution concentrations were distilled water and two osmotic concentrations (0 % (w/w) osmotic solution for distilled water, 50 % (w/w) osmotic solution and 100% (w/w) osmotic solution). Each experiment run, the pomelo peel samples were placed in numerous separate 400 ml beakers filled with 300 ml of pre-treatment solution. The osmotically concentrated solutions were concocted by combining food-grade sucrose with distilled water, until concentrations of 50% w/w sucrose in water (150 ml distilled water, 150 ml sucrose solution). For the 100%, it was fully sucrose solution (300 ml). The ratio of 1:4 between the weight of fruit and the pre-treatment fluid medium was set to overcome any dilution consequences [20].

Pre-treatment

The ultrasound pre-treatments were accomplished via the ultrasound bath equipment (FB15055, FISHERBRAND, India) at a standard frequency of 37 kHz. This equipment allowed the manipulation of immersion time and immersion temperature. The pre-treatment runs were set up in sequences of two time settings (10 minutes and 30 minutes). Since the reaction of ultrasound dictated to be irrelevant at lower times, the ultrasound wave application was applied for at least 10 min [21]. The ultrasound bath temperature had a 30°C, 50°C and 70°C variation [22].

Table 2 shows the set up perimeter for the immersion time, ultrasound bath temperature and osmotic concentration. For every ultrasound pre-treatment run, flasks were filled with the osmotic concentration solution (with shaped pomelo peel inside) and placed in the ultrasound bath. After the pre-treatment runs, the pomelo peels were pulled out from the flasks, filtered, and absorbed with absorptive paper to soak up any unwanted solution.

Weights after each run for the ultrasound-assisted osmotic dehydration process were measured by an electronic scale (GR-120, AnD, USA). The final moisture content of the pomelo peel was measured using the moisture analyser as mentioned in the section earlier.

Table 2 The set up perimeter for the immersion time, ultrasound bath temperature and osmotic concentration prior to optimisation.

Immersion time (mins)	Ultrasound bath temperature (°C)	Osmotic concentration of solution (%)
10	70	0
10	50	50
10	30	100
30	70	0
30	50	50
30	30	100

Upon the measurement of the weights and the quantification of moisture content of the pomelo peel after the ultrasound application pre-treatment, two response variables were quantified with the respected values. The response factors of water loss (WL) and solid gain (SG) together with moisture content were calculated via the pomelo peels weight before and after the pre-treatment rounds. Water loss and solid gain were calculated based on the equations (1) and (2) [20].

$$Water\ Loss\ (\%) = \frac{\{(wi \times Xi) - (wf \times Xf)\}}{wi} \times 100 \quad (1)$$

$$Solid\ Gain\ (\%) = \frac{\{(wf \times (1 - Xf)) - (wi \times (1 - Xi))\}}{wi} \times 100 \quad (2)$$

Where,

wi was the initial fruit mass (g) prior pre-treatment;

wf was the final fruit mass (g) after pre-treatment;

Xi was the initial fruit moisture content on a wet basis (g water/g total fruit mass) prior pre-treatment;

Xf was the final fruit moisture content on a wet basis (g water/g total fruit mass) after pre-treatment.

3. Results and Discussion

Water loss and solid gain in the pomelo peels, as part of its osmotic characteristics, when exposed to ultrasound wave application and osmotic concentration pre-treatment are displayed in Table 3. The pomelo peels for all 6 runs have observed a decrease in moisture content after subjected to ultrasound and osmotic pre-treatment.

Table 3 Water loss and sugar gain during ultrasound and osmotic pre-treatment of pomelo peels.

Number of runs	Immersion time (mins)	Ultrasound bath temperature (°C)	Osmotic concentration of solution (%)	Water loss (%)	Solid gain (%)
1	10	70	0	-8.4016	3.1495
2	10	50	50	1.5686	2.0050
3	10	30	100	2.4831	0.5159
4	30	70	0	19.2310	-2.7620
5	30	50	50	-3.7179	3.1786
6	30	30	100	1.5718	4.4600

At lowest immersion time of 10 minutes (runs 1, 2 and 3), there was a rise in water loss and gradual decline in solid gain, with the manipulation of both ultrasound bath temperature and osmotic concentration solution. Highest ultrasound temperature with 0% concentration at 10 minutes (run 1) reported to have significant water gain (8.4016%) and a high solid gain (3.1495%) as compared to run 2 and 3. Run 3 at 100% osmotic concentration with the lowest ultrasound bath temperature (30°C) at 10 minutes, gave a low solid gain (0.5159%) which contradicts with the report by Fernandes et al. [23]. It was reported that the solid gain is directly proportional to the concentration of osmotic solution [23]. In this research, at lowest immersion time (10 minutes), solid gain decreased with increasing osmotic concentration and decreasing ultrasound bath temperature. This showed that ultrasound bath temperature has a vital counter role in the change of osmotic pressure [24], as low ultrasound bath temperature with high osmotic concentration produces a low solid gain value. These patterns are shown in Fig. 1.

Runs 4 and 6 clearly showed the significance of increasing ultrasound bath temperature at constant long immersion time (30 minutes). These set of data greatly affected the values of water loss and solid gain. With the incline of ultrasound bath temperature by 40°C, the water loss value rocketed from 1.5718% (run 6) to 19.231% (run 4). At the same time, the solid gain decreased from 4.46% (run 6) to -2.762% (run 4). The differences in these values indicated that high ultrasound temperature efficiently increases water loss and decreases solid gain at long immersion times.

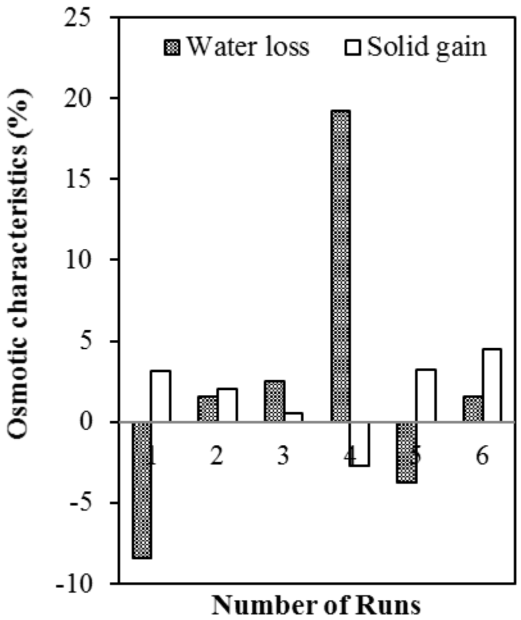

Fig. 1 Water loss and solid gain as osmotic characteristics that correspond to the number of runs.

Pomelo peel subjected to high immersion time and ultrasound bath temperature in 0% osmotic concentration solution (run 4) lost its solids to the bath medium at 2.7620%. However, the same settings in run 1, excluding its immersion time, showed a gain in solids at 3.1495%. This indicated that a prolonged immersion time under ultrasound treatment would affect the osmotic characteristics of the pomelo peel. This loss of solids occurred as it favoured a net movement of solid mass from the pomelo peel to be transported into the ultrasound bath medium [24]. At the same time, there was a significant increase in water loss from -8.4016% (run 1) to 19.231% (run 4) with the increase in immersion time. This is correlated with the high solid loss from the pomelo peel to the ultrasound bath medium after a prolonged immersion time [24]. Fernandes & Rodrigues [24] explained that longer immersion time would diminish the solid concentration gradient between the pomelo peel and the bath medium which causes small quantity of water to penetrate the peel, in order to regulate the gradient of osmotic pressure [24]. Therefore, greater immersion time at constant ultrasound bath temperature and osmotic concentration would decrease solid gain and increase water loss in pomelo peels.

Based on the results, the water loss was directly proportional to the osmotic solution concentration as observed in run 1 and run 3. With constant immersion time (10 minutes), there was a significant amount of water loss from -8.4016% to 2.4831% with an increase of 100% osmotic concentration. This was due to the difference in concentration gradient [25]. Garcia-Noguera et al. [25] reported that there was a rise in water loss with a boost of osmotic solution concentration due to the rise in gradient between the concentration of soluble solids in the fruit and in the osmotic solution. Run 5 with 30 minutes immersion time and 50°C ultrasound bath temperature at 50% osmotic concentration did record a low solid gain value (3.1786%). The development of microscopic pathways and the disintegration of tissue molecules may have correlation to this pattern [25]. The development of micro-channel [25] would enable greater rise in solid gain, as seen in run 1 with immersion time (10 minutes), 0% osmotic concentration and high ultrasound bath temperature (70°C). In contrast, prolong pre-treatment with greater osmotic concentration may impede the microchannel opening with soluble solids thus causing a lower solid gain, which is noticed in run 5.

4. Conclusion

The presence of the ultrasound application and osmotic pre-treatment had induced significant changes on the osmotic characteristics of pomelo peel. From the research, the outcome on solid gain did not necessarily correspond to the water loss value. Therefore, it can be said that solid gain fluctuations are not affected by the percentage of osmotic concentration. The application of ultrasound and osmotic pressure generated by the osmotic concentration solution played an important role yielding high soluble gain. Ultrasound bath temperature factor did play an inverse role towards the other factor, which is the osmotic concentration solution, as it was able to decrease solid gain with the increasing osmotic concentration. In other words, the manipulation of ultrasound bath temperature has an effect on the pomelo peel osmotic pressure. This research gave a perspective on the solid loss as a relation to immersion time with the presence of radiating ultrasound application. Greater immersion time at constant ultrasound bath temperature and osmotic concentration would decrease solid gain and increase water loss in pomelo peels. Therefore, it can be concluded that upon unit operations at high scale in the food industry, significant processing time have the ability to extract sufficient amounts of water content from dehydrated foods. High osmotic concentration solution used in the ultrasound and osmotic pre-treatment had a great impact on the water loss as it managed to increase the water loss at a desirable level. Ideally, a shorter processing time with high osmotic concentration would be best suited for the food industry. This setting would be beneficial to the food industry as the unit operation for the food processing would be energy efficient.

Acknowledgment

This research was supported by Universiti Tun Hussein Onn Malaysia.

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