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# Salt Diffusion Enhancement in the Salt Pickled Lime Processing by Ultrasonic Treatment Technique

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**Abstract**

In the present study, effect of ultrasonic treatments on the sodium chloride diffusion in the pickled lime processing is investigated. The ultrasonic treatment is continuously performed by the ultrasonic generator system with constant frequency of 40 kHz. The experiments are done with various input ultrasonic powers at the constant curing temperature of 30°C. The salt pickled limes obtained from the ultrasonic treatment method are verified with those from the conventional salt soaking method. For the same final salty of the salt pickled lime, the diffusion rate for the ultrasonic treatment method is higher than that for the conventional method. The results of this study are expected to lead to guidelines that will allow the developing a curing technique in the pickled lime processing which increasing quality/quantity of the products and reducing curing time.

**Keywords**: Ultrasonic treatment; salt pickled lime; diffusion

## INTRODUCTION

In general, the curing technology is based on the addition of salt which diffuses through the material matrix. The curing method is often complemented with a mechanical treatment on the material which causes cellular disruption of the material tissue. The distribution of salt in the material can be promoted by the modified structure. Ultrasound, the term used to describe sounds ranging from 20 kHz to 1 GHz, is usually generated by a transducer which converts mechanical or electrical energy into high frequency vibrations. The enhancement of extraction efficiency of organic compounds using ultrasound is attributed to a phenomenon called cavitation produced in the solvent by the passage of an ultrasonic wave. The works reported on the application of high power ultrasonic waves on the properties of meat (Jayasooriya et al., [1]). Most of the previous studies on this topic have been carried out within the use of ultrasonic on the meat tissue (Fox, [2]; Djelveh and Gros, [3]). Ultrasonic radiation has significant effect on the physical characteristics of breast muscle (Dickens et al., [4]), however, there was paper reported on the application of ultrasonic to determine the fish and meat composition (Ghaedian et al., [5]). In additional, ultrasonic treatment tests were undertaken on frozen meat and fish samples (Miles, [6]; Genaro et al., [7]). Some study showed the effects of high-intensity and high-frequency ultrasound on the ageing rate (Got et al., [8]). The low-frequency ultrasonic technique was used for monitoring of milk gelation (Nassar et al., [9]; Ay and Gunasekaran, [10]). The ultrasonic assisted curing technique can be improved the diffusion of sodium chloride in the meat (Graiver et al., [11]; Carcel et al., [12]; Siro et al., [13]). Some of studies reporting the role of ultrasonic-assisted extraction on the natural products were investigated by Lionetto et al., [14]; Xia et al., [15]; Valero et al., [16]. In additional, the ultrasonic technique has been applied for drying processing of the fruits, textiles or et al. Some infrared experimental drying combined with convective drying of food stuffs have been continuously reported by Kiyoshi et al., [17]; Garcia-Perez et al., [18]; De la Fuente-Blanco et al., [19]; Fernandes et al., [20]; Fabiano et al., [21].

As discussed above, there is no paper reported on the applicability of ultrasonic technique on the pickled lime processing. The conventional salt pickled lime processing is the soaking lime in the sodium solution. However, this method has a long curing time, great consumption of salt solutions, and lower curing efficiency. Therefore, developing a fast and efficient curing method has become an issue of concern in the food industries. The objective of this work is to present the applicability of ultrasonic assisted curing technique for improving the diffusion rate of sodium in the salt pickled lime processing. Effects of relevant parameters on the diffusion rate of sodium chloride into the lemons are investigated. The results obtained from the ultrasonic treatment method are compared with those from the conventional method.

## MATERIAL AND METHOD

### Material

In the present study, twenty fresh lemons with size homogeneity are used for the ultrasonic treatment method and 20 lemons for the conventional soaking in the sodium chloride methods. Before soaking in the salt solution, the lemons scratched outer surface in order to avoid the taste bitter must be boiled and then drying with daylight for a day. This process begins with the heating the water up to help the process of dissolution of salt. The preparation of the solution is done for the common salt-water ratio of $1:2\frac{3}{4}$.

### Salt pickled lime processing with the salt solution

For this method, the sodium chloride concentration is similar to the one used for the ultrasonic treatment method. The lemons are submerged in the container filled with the prepared sodium chloride solution. The immerged lemons in the sodium chloride

solution are stored at the room temperature (30ºC). The salts uniformly diffuse into the soaked lemons. For each period time, the salt pickled lime sample is taken out of the container to measure the pH with the pH meter and observed the physical characteristics. The pH of the salt pickled lime at each period time is recorded in three times. In general, before consumption or cooked various dishes, the common curing time in the salt pickled lime processing is a month. Therefore, the pH and physical properties of the salt pickled lime at this curing time are used to verify those from the ultrasonic treatment method as will be mentioned in the next section.

**Salt pickled lime processing with ultrasonic treatment**

The experimental curing system with ultrasonic system is shown in Fig. 1.

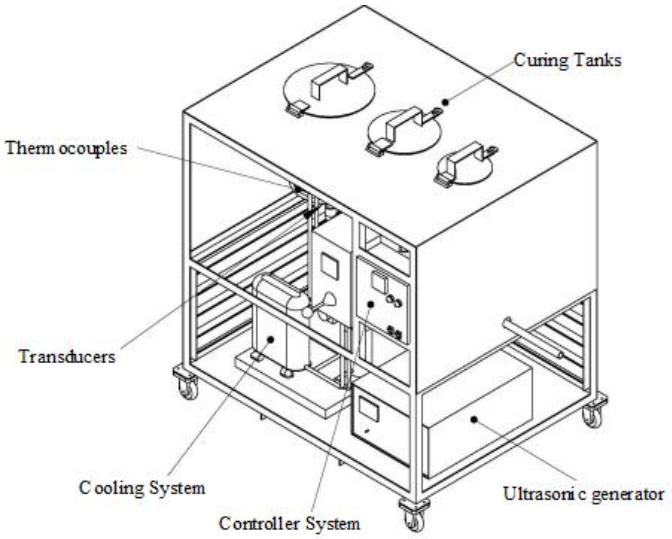



**Figure 1.** Experimental curing system with ultrasonic treatment system

The test loop consists of an ultrasonic treatment system, refrigerant loop, curing tank system and data acquisition system. The curing tank system consists of the curing tanks with different three ultrasonic input powers, temperature sensor, a wound cooling coil around the curing tank, and the insulation layer. The ultrasonic treatment is continuously performed by the ultrasonic generator system with constant frequency of 40 kHz. The experiments are done at constant curing temperature of 30ºC with input ultrasonic powers ($P_{in}$) of 200, 280 watts. The salt solution temperature in the curing tank is chilled by the refrigeration system. The head ultrasonic transducers are attached on the outside surface with the special glue at the bottom of curing tank.

Each experiment was conducted with soaking 20 lemons into the curing tank. As mentioned above, the outer surface of the lemons must be scratched with brush grate in order to avoid the taste bitter and then drying with daylight for a day. The lemons must be submerged in the sodium chloride solution. The curing temperatures were adjusted to achieve the desired level by using refrigeration system controlled by temperature controllers. For each period time, the pH of pickled lime is measured in three times with the pH meter with an accuracy of ±0.05% of full scale and observed the physical characteristics.

**pH analysis**

The pH meter (827 pH Lab, Metrohm Ltd., Thailand) consisted of calomel–glass membrane electrode is used to pH analysis of salt pickled lime. The calomel–glass membrane electrode is calibrated at pH 4 and 7 before analyzed pH of salt pickled lime. In this experiment, the ultrasonic treatment is continuously preformed until the pH of salt pickled lime close to these from the conventional method.

**RESULTS AND DISCUSSION**

Salt pickled lime in the salt solution has been traditionally performed in Thailand for preserving lemons. However, the salty of the lemons obtained from this conventional method has a long curing time, great consumption of solution. Therefore, the ultrasonic treatment technique is used to approve the diffusion rate of the sodium chloride in the salt pickled lime processing.

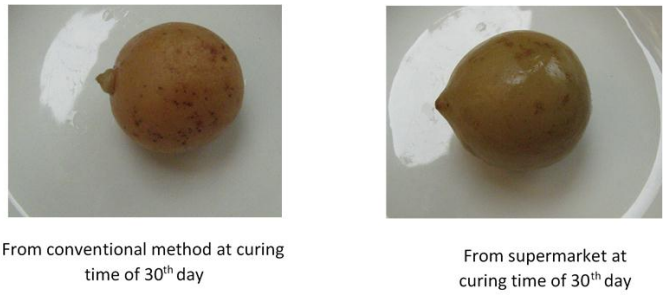
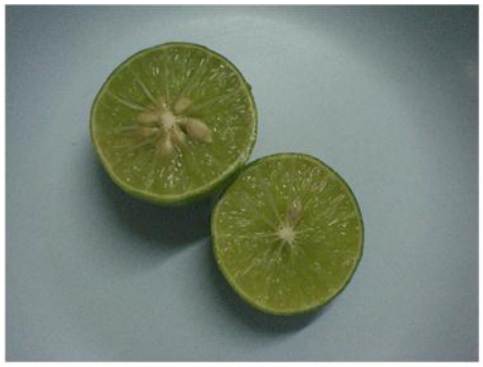



**Figure 2.** Outer surface characteristics of the salt pickled lime obtained from the conventional method

Figure 2 shows the outer surface characteristics of the salt pickled lime obtained from the present experiment and from the supermarket at the water:salt ratio of 1:$2\frac{3}{4}$. As mentioned above, the curing time of salt pickled lime for the conventional method is 30 days. It can be seen that the pH of the salt pickled lime obtained from two conventional methods are similarly with pH of 3.50-3.52. The colour and physical characteristics of salt pickled lime obtained from these methods will be used to verify the salt pickled lime obtained from the ultrasonic treatment method. The changing of the inside colour, and pH of the salt pickled lime in the same salt-water ratio obtained from the ultrasonic treatment method with various conditions is shown in Fig. 3. It can be seen that for the same final salty, the colour of salt pickled lime obtained from various conditions change from the green colour to the brown-yellow colour. The pH is increased from 3.05 to 3.51. In addition, the salt pickled lime obtained from the input ultrasonic power of 280 watts gives the shortest curing time.



Fresh lime (pH=3.05)

From conventional method at curing time of 30th day (pH=3.51)

From ultrasonic method at curing time of 14th day at $P_{in}$ = 200 watts (pH=3.50)

From ultrasonic method at curing time of 9th day at $P_{in}$ = 280 watts (pH=3.50)

**Figure 3.** Comparison between the fresh lime and the salt pickled lime obtained from various conditions

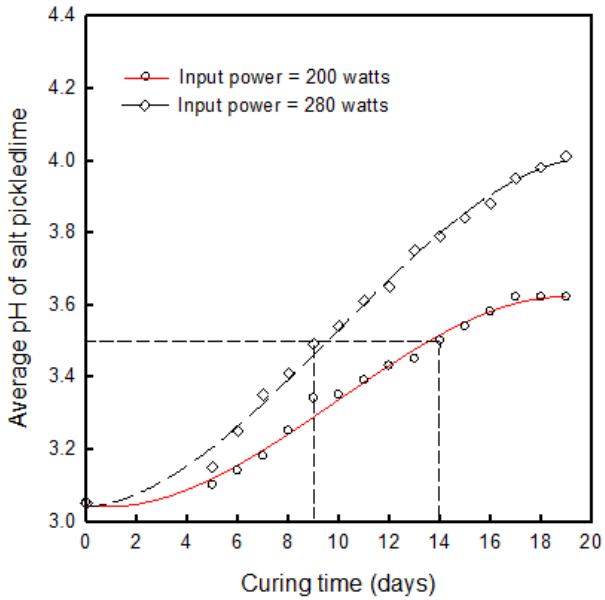



**Figure 4.** Effect of input power on the variation of pH in the salt pickled lime

Figure 4 shows effect of input ultrasonic power on the variation of pH. The greater penetration of salt solution into the cellular material is promoted by the generated energy from the collapsing cavitational bubbles. The diffusion rate increases rapidly with the curing time for the first 16 days. However, this effect becomes relatively less as the curing time increases > 16 days. Considering Fig. 4 which shows effects of input ultrasonic power on the salt diffusion into the salt pickled lime, it can be seen from figure that the salt diffusion tends to increase as the input power of the ultrasonic treatment increases. However, the increase of salt diffusion becomes relatively smaller as curing time decreases. For the final pH of the salt pickled lime similar to the one conventional method, the curing time of the input ultrasonic power of 200 watts case is 14 days and 9 days for the input ultrasonic power of 280 watts case.

Figure 5 shows the comparison between the pH obtained from the ultrasonic method at input power of 200 watts and the conventional method. It can be seen that the pH rapidly increases with increasing curing time. For the conventional method, however, this effect tends to diminish as the curing time increases > 30 days. Considering the salt pickled lime obtained from the ultrasonic treatment method, it can be seen that the trends of the curve are similar to those of the pH curves from the conventional method. The ultrasonic treatment has significant effect on the cellular disruption of the lemon wall. Therefore, the migration of salts into the lemons is excited by the modified structure. This means that the salt diffusion rate obtained from the ultrasonic treatment method is higher than these from the conventional method. For the same final pH and the colour, the curing time of the ultrasonic treatment method at input power of 200 and 280 watts as compared with those of the conventional method decreases 53.3% and 70.0%, respectively.

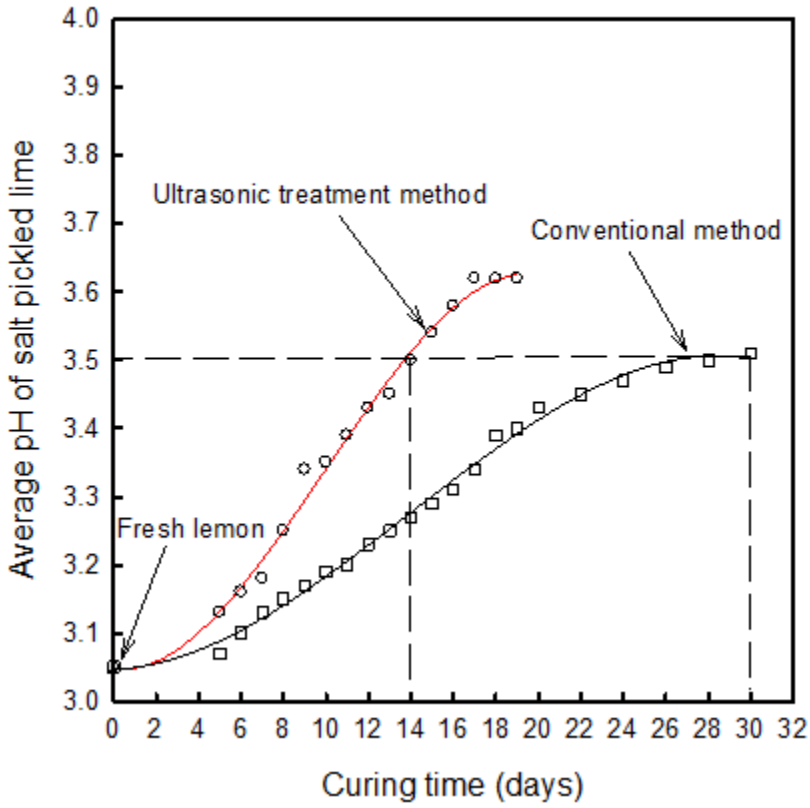



**Figure 5.** Comparison between average pH obtained from ultrasonic method at input power of 200 watts and conventional method

## CONCLUSION

The applicability of an ultrasonic assisted curing technology in the salt pickled lime processing is investigated. The ultrasonic system generates standing waves resulting in mechanical effects rather than temperature effects. Sodium diffusion in the lemon is accelerated by ultrasonic treatment. This means that the diffusion rate from ultrasonic treatment method is higher than these from the conventional method. In additional, as one of the more advanced food technologies, it can be applied not only to improve the quality and food safety but also offers the potential for developing new products with unique functionality as well.

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