International Food Research Journal 19(2): 547-552 (2012)

Application of ultrasound to pineapple mash treatment in juice processing

Nguyen, T. P. and *Le, V. V. M.

Department of Food Technology, Ho Chi Minh City University of Technology, 268 Ly Thuong Kiet, District 10, Ho Chi Minh City, Vietnam

Abstract: This study focused on application of ultrasound to pineapple mash treatment in juice processing. The effect of ultrasonic power, treatment time and sonication temperature on the juice yield was investigated. Sonication of pineapple mash in juice processing increased extraction yield 10.8% in comparison with the control without ultrasonic treatment. In addition, use of ultrasound in the treatment of pineapple mash highly improved the level of sugars, total acids, phenolics and vitamin C in the obtained pineapple juice.

Keywords: ***Ananas comosus*, juice, mash, treatment, ultrasound**

Introduction

Pineapple (*Ananas cosmosus*) is one of the most important tropical fruits. This fruit can be consumed fresh or processed in various forms; and pineapple juice is a popular product due to its pleasant flavor (Rattanathanalerk *et al*., 2005). In juice processing, extraction yield is a critical technological parameter (McLellan and Padilla-Zakour, 2005). This is the ratio between the content of soluble extract in the obtained pineapple juice and the content of total solids in the plant material used in the production. In principle, the higher the extraction yield, the lower the loss during the processing, and the higher the economic efficiency of the production line.

Soluble extract in juice are mainly located in the cytoplasm of fruit flesh cells (Rutledge, 1996). The juicing process starts with the crushing step to break down the fruit tissue and cell wall. Then juice extraction can be performed by pressing (McLellan and Padilla-Zakour, 2005). It was reported that enzymatic treatment of fruit mash enhanced disintegration of the fruit tissue and that led to an improvement in juice yield (Kashyap *et al*., 2001). However, enzymatic treatment of fruit mash might not be used for the production of high quality, single-strength, cloudy and clear juices, where the preservation of the fresh flavor is imperative (McLellan and Padilla-Zakour, 2005).

During the last decades, application of ultrasound to extraction has found increasing attention. Ultrasound was used in extraction of plant materials thanks to enhancement of extraction yield and reduction in extraction time (Toma *et al*., 2001; Kamaljit *et al*., 2008). There are a lot of studies on ultrasound-assisted extraction, however the authors were only interested in certain valuable components in the plant extract such as saponin (Wu *et al*., 2001), anthocyanins (Chen *et al*., 2007), rutin (Paniwynk *et al*., 2001), isoflavones (Lee and Lin, 2007), lycopene (Zhang and Liu, 2008), carvone and limonene (Chemat *et al*., 2004), oil (Sharma and Gupta, 2006), xyloglucan (Caili *et al*., 2006). In juice processing, water-soluble components in the fruit flesh must be completely recovered for improvement in extraction yield. Recently, a study showed that sonication of grape mash pronouncedly increased the juice yield due to simultaneous extraction of many water-soluble compounds from vegetal cells (Lieu and Le, 2010).

Until present, there have been no studies on application of sonication to the production of pineapple juice for improvement in extraction operation. The objective of this study was to investigate the effects of different technological variables of sonication on the extraction yield in pineapple juice processing as well as to determine maximum extraction yield and some physico-chemical characteristics of the juice obtained by the ultrasound-assisted extraction.

Materials and methods

Materials

Pineapple (*Ananas comusus*, Cayen variety) used in this study was originated from a farm in Ben Luc, Vietnam. Pineapple was destemmed, washed and crushed in a blender (National, T1GN, Ho Chi Minh city, Vietnam). The obtained pineapple mash was then used for ultrasonic treatment.

Experimental methods

Samples of 100 g pineapple mash were used in each assay. The samples were placed into 250 mL

*Corresponding author.
Email: *ivvman@hcmut.edu.vn*
Tel: 00 84 8 38 64 62 51; Fax: 00 84 8 38 63 75 04

beakers. Ultrasonic treatment was carried out by a horn type ultrasonic probe (Sonics & Materials Inc., VC 750, Newtown, USA). This equipment operated at frequency of 20 kHz with the maximum ultrasonic power of 750 W. The sonication temperature was adjusted by placing the beakers containing the samples in a thermostatic water bath (Memmert, WNB 45, Yogyakarta, Indonesia).

Impact of technological variables of ultrasonic treatment on extraction yield in pineapple juice processing

This experimental section consisted of three series:

First series: The ultrasonic power was varied from 0 to 300 W. The treatment was carried out at the ambient temperature. The treatment time was fixed at 1 min.

Second series: The treatment time was changed from 0 to 5 min. The ultrasonic power was fixed at 225 W. The sonication was carried out at ambient temperature.

Third series: The sonication temperature was ranged from 30 to 80 ^oC. The ultrasonic power and treatment time were 225 W and 2 min, respectively.

At the end of the ultrasonic treatment, the obtained suspension was centrifuged at 6,500 rpm for 10 min by a refrigerated centrifuge (Sartorius, Sigma 3K30, Geneva, Switzerland) and the supernatant was collected for further analysis. For all series, a control without ultrasonic treatment was carried out. 100g of pineapple mash was pressed in a screw press (Oekotec, CA59G, Monchengladbatch, Germany) for juice release. The obtained juice was then centrifuged at 6,500 rpm for 10 min by a refrigerated centrifuge and the supernatant was also collected for further analysis.

Determination of maximum extraction yield in pineapple juice processing with ultrasound-assisted extraction by response surface methodology

The response surface methodology was implemented to estimate the maximum extraction yield in the pineapple juice processing with ultrasound-assisted extraction. A randomized, quadratic central composite circumscribed response surface design was used to determine suitable ultrasonic power and treatment time for maximizing the extraction yield. Five levels of the independent variables and the software Modde version 5.0 were used to generate the experimental planning and to process data. The complete experimental design (Table 1) consisted of 11 experimental points including 4 factorial points, 4 axial points and 3 center points.

In this experimental section, the temperature of ultrasonic treatment was fixed at 40^{o}C. At the end of the sonication, the following steps were similar to those in the previous experimental section. A control was also carried out in the same way of the previous experimental section for comparing the juice yield in the pineapple juice processing with and without ultrasonic extraction.

Table 1. Experimental planning and results of extraction yield in the pineapple juice processing with ultrasound-assisted extraction

Run	X_1 - Ultrasound power (W)	X_2 - Treatment time (min)	Y - Yield (%)
1	187.5	1	78.6
2	262.5	1	81.3
3	187.5	3	82.9
4	262.5	3	84.9
5	171.975	2	79.6
6	278.025	2	84.9
7	225	0.59	79.2
8	225	3.41	84.6
9	225	2	84.5
10	225	2	84.5
11	225	2	84.6

Evaluation of some physico-chemical characteristics of pineapple juice obtained by ultrasound-assisted extraction

In this experimental section, the sonication conditions of pineapple mash were as follows: ultrasonic power of 247.4 W, treatment temperature of 40^{o}C, and sonication time of 2.7 min. After ultrasonic treatment, the suspension was centrifuged in the same way of the previous experimental section. The obtained samples were further analyzed in total sugars, total acids, total phenolics and vitamin C. A control without ultrasonic treatment was simultaneously realized in the same way of the previous experimental section.

Analytical methods

Extraction yield of the non-ultrasonic and ultrasonic extraction (Y, %w/w) was evaluated according to the following formula:

$$Y = \frac{m_2 \times C}{m_1 \times (100 - W)} \times 100$$

Where m_1 was the mass (g) of the initial pineapple mash; W was the moisture (%) of the initial pineapple mash; m_2 was the mass (g) of the obtained pineapple juice after centrifugation, and C was the content of soluble extract (g) in the obtained pineapple juice after centrifugation.

Moisture and soluble extract were quantified by drying method (Bradley, 2003). Total sugar content of pineapple juice was determined by spectrophotometric method, using 3,5-dinitrosalicylic acid reagent (BeMiller, 2003). The total acids were expressed in equivalent of citric acid content (g/L), and determined by method of titration, using 0.1 N NaOH solution (Cliff *et al*., 2007). Total phenolics were evaluated by spectrophotometric method, using Folin-Ciocalteu reagent (Luque-Rodrıguez *et al*., 2007). Vitamin C in juice was quantified by method of titration with iodine solution (Suntornsuk *et al*., 2002).

Statistical analysis

All experiments were performed in triplicate. Means were compared by Multiple range tests with $p<0.05$. Analysis of variance was done using the software Statgraphics plus, version 3.2.

Results and Discussion

Impact of technological variables of ultrasonic treatment on extraction yield in pineapple juice processing

The influence of ultrasonic power on extraction yield in the pineapple juice processing with ultrasound-assisted extraction is shown in Figure 1. The extraction yield in all samples treated by ultrasound was significantly higher than that in the control. During sonication treatment, the formation, growth and collapse of many small bubbles in liquid appeared thanks to pressure fluctuation. Cavitation promoted intensive breakdown of fruit tissue and cell wall structure, enhanced mass transfer within the system (Toma *et al*., 2001; Wu *et al*., 2001). As a result, water-soluble extract in the cytoplasm of pineapple flesh cells could be released easily and rapidly. Similar observation was recently reported in ultrasound-assisted extraction in grape juice processing (Lieu and Le, 2010).

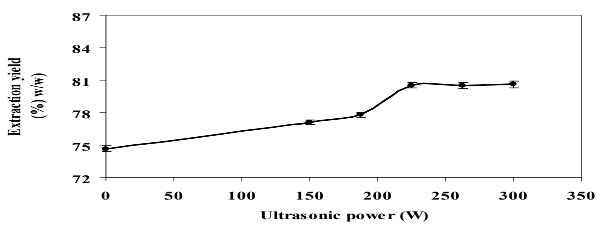

Figure 1. Effect of ultrasonic power on extraction yield in pineapple mash treatment

Increase in ultrasonic power from 0 to 225 W for 100 g of pineapple mash augmented the extraction yield 5.9%. Theoretically, high ultrasonic power intensifies acoustic cavitation (Li *et al*., 2007). This phenomenon leads to a more disintegration of fruit flesh cells and a higher rate of mass transfer. Many researchers demonstrated that a higher ultrasonic power meant the enhancement of extraction efficiency of different components from vegetal cells (Wang and Zhang, 2006; Sivakumar *et al*., 2007). Nevertheless in this study, when the sonication power was higher than 225 W, the analysis of variance showed that increase in extraction yield became insignificant. It can be noted that too high ultrasonic power could not increase more the juice yield but augmented energy cost of the operation. Moreover, sonication of pineapple mash with high ultrasonic power facilitated extraction of macromolecules such as pectin and hemicellulose from the fruit tissue. This phenomenon led to an increase in viscosity of the obtained juice and decelerated the pressing operation. Consequently, suitable ultrasonic power for each fruit variety should be selected for improvement in economic efficiency of juice processing.

The impact of sonication time on the extraction yield in pineapple juice processing is visualized in Figure 2. After 2 minute treatment by ultrasound, the extraction yield in pineapple juice processing increased 9.8%. When the sonication prolonged more than 2 min, the juice yield changed insignificantly. The appropriate time of pineapple mash treatment by ultrasound in this study was therefore 2 min. Difference in ultrasound-assisted extraction time was recorded. In the extraction of hesperidin from Penggan (*Citrus reticulata*) peel, the suitable sonication time was 60 min (Ma *et al*. 2008). However, the ultrasonic treatment lasted only 15 min for maximizing anthraquinone yield from root of *Morinda citrifolia* (Hemwimol *et al*., 2006). The time for ultrasonic treatment of pineapple mash in this research was much lower than the findings of various authors. In fact, optimal sonication time depended on weight of plant material used in the experimentation, temperature, ultrasonic power (Wang *et al*., 2008; Lieu and Le, 2010). As a consequence, it can be varied in a large range.

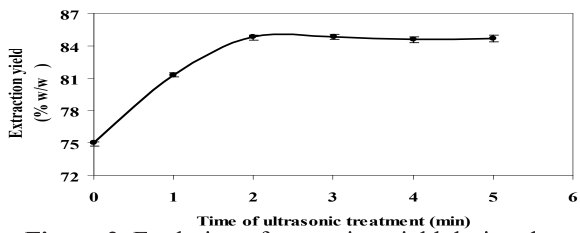

Figure 2. Evolution of extraction yield during the sonication treatment of pineapple mash

Figure 3 presents the effect of sonication temperature on the extraction yield in pineapple juice processing. When the treatment temperature augmented from 30 to 40^{o}C, the extraction yield just increased slightly, from 84.0 to 84.5%. In the temperature range of 40-60^{o}C, the analysis of variance demonstrated that the extraction yield was stable. On the contrary, sonication at higher temperature (70-80^{o}C) reduced slightly extraction

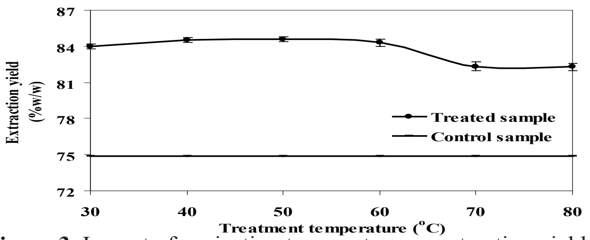

Figure 3. Impact of sonication temperature on extraction yield in pineapple mash treatment

efficiency. According to Patist and Bates (2008), high temperature weakens bubble collapse due to high vapor pressure. However, the higher the sonication temperature, the higher the number of cavitation bubbles, and the lower the viscosity in the system; that leads to a more violent collapse of bubbles in liquid. As a consequence, there is an appropriate temperature at which the viscosity is low enough to form enough violent cavitation bubbles, yet the temperature is low enough to prevent the dampening effect on collapse by a high vapor pressure. In this experiment, the extraction yield reached maximum when the temperature of ultrasonic treatment varied from 40 to 60°C. Hence, 40°C was considered as appropriate temperature of the treatment. Similar result was also observed in hesperidin extraction from Penggan (*Citrus reticulata*) peel (Ma *et al*., 2008). Nevertheless, this sonication temperature was much lower than that in the ultrasound-assisted extraction recommended by some researchers. For example, Wang and Zhang (2006) reported that the suitable sonication temperature of xylan extraction from corncobs was 60°C. With regards to grape juice processing, the optimum sonication temperature for maximizing juice yield was 74°C (Lieu and Le, 2010). It can be explained that the structure of plant tissue can be various in chemical composition and physical properties (McLellan and Padilla-Zakour, 2005). Accordingly, suitable temperature of ultrasonic treatment resulting in complete disintegration of plant tissue for extract release would be different. It can be noted that low sonication temperature obtained in this study exhibited many advantages thanks to low energy consumption and low loss of thermo-sensitive compounds in the pineapple juice. A little difference in the extraction yield was observed in Figure 3 when the ultrasonic temperature of pineapple mash fluctuated around 40°C. Hence, this variable was not selected in the subsequent experiment for estimating maximum extraction yield in the pineapple juice processing with ultrasound-assisted extraction.

Determination of maximum extraction yield in pineapple juice processing with ultrasound-assisted extraction by response surface methodology

Based on the results of the previous experimental section, an ultrasonic power of 225 W and a time of 2 min were selected as the central conditions of the central composite rotary design. Table 1 indicates extraction yield of each run according to the experimental planning. Multiple regression analysis was performed on the experimental data and the coefficients of the model were evaluated for significance with a Student t-test. The obtained results showed that the linear coefficients (X_1, X_2) and the pure quadratic coefficients (X_1^2, X_2^2) were significant ($P<0.05$). The crossproduct coefficient was eliminated in the refined equation as its effect was not significant.

Analysis of variance of the fitted model was performed. The coefficient of determination (R^2) of the model is 0.968 which indicated that the model had adequately represented the real relationship between the variables chosen. The final predictive equation (1) obtained is as given below:

$$Y = 84.533 + 1.525X_1 + 1.942\,X_2 - 1.179X_1^2 - 1.354\,X_2^2 \qquad (1)$$

Where Y, X_1, X_2 were the extraction yield in the pineapple juice processing with ultrasound-assisted extraction (%), the ultrasonic power (W) and the sonication time (min), respectively.

Surface response graph obtained by using the fitted model presented in equation (1) is showed in Figure 4.

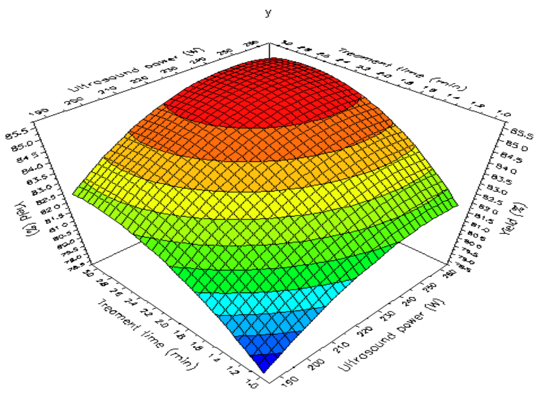

Figure 4. Response surface plot showing the effect of ultrasound power (W) and treatment time (min) on the extraction yield (%) in the pineapple juice processing with ultrasound-assisted extraction

According to equation (1), change in ultrasonic power or sonication time resulted in significant change in extraction yield. In addition, sonication time had stronger effect on extraction yield than ultrasonic power. From equation (1), the maximum extraction yield achieved 85.7% when the ultrasonic power and sonication time were 247.4 W and 2.7 min, respectively. In order to verify the accuracy of the model, three independent replicates were carried out for measuring extraction yield under the optimal conditions. The practical extraction yield was of 83.0 ± 1.8%. In the control, the extraction yield was 74.9%. Thus, the application of sonication to pineapple juice processing increased the extraction yield 10.8% in comparison with the control without ultrasonic treatment.

Evaluation of some physico-chemical characteristics of pineapple juice obtained by ultrasound-assisted extraction

Some physico-chemical characteristics of pineapple juice obtained from the processing with and without ultrasound-assisted extraction are visualized in Table 2. Sugars and organics acids are main components of fruit juice (McLellan and Padilla-Zakour, 2005). The content of sugars and organic acids in the sample treated by ultrasound was 9.9% and 14.3%, respectively higher than that in the control. Furthermore, the level of total phenolics and vitamin C in the pineapple juice obtained by ultrasound-assisted extraction increased 45.3% and 17.2%, respectively in comparison with that in the control. These results were in agreement with many previous studies which reported that ultrasonic treatment improved extractability of sugars (Lieu and Le, 2010), organic acids (Palma and Barroso, 2002) and phenolic compounds (Kamaljit *et al*., 2008). It can be explained that ultrasound exerts a mechanical effect, allowing greater penetration of solvent into the sample matrix, increasing the contact surface area between solid and liquid phase; as a result the solute easily diffuses from the material to the solvent (Rostagno *et al*., 2003). It can be concluded that the treatment of pineapple mash by ultrasound pronouncedly improved the nutritional quality of the obtained juice. Similar findings were also observed in sonication treatment in grape juice processing (Lieu and Le, 2010).

Table 2. Some physico-chemical characteristics of pineapple juice

	Sample treated by ultrasound	Control sample
Sugars (g/L)	74.2[a]	67.5[b]
Total acidity (g of citric acid/L)	0.72[a]	0.63[b]
Total phenolics (g/L)	1.09[a]	0.75[b]
Vitamin C (mg/L)	272[a]	232[b]

Values with various superscript letters in each row represent statistically significant difference at the level of p=0.05

Conclusion

Application of ultrasound to the treatment of pineapple mash increased significantly the extraction yield in juice processing. Moreover, the level of nutritional compounds of the obtained pineapple juice was significantly higher than that of the control without sonication treatment. The ultrasonic technique is simple and inexpensive. The use of sonication in pineapple juice production for enhancement of extraction yield and nutritional quality of the final product is therefore very hopeful.

References

BeMiller, J.M. 2003. Carbohydrate analysis. In Nielsen, S. S. (Ed.). Food analysis, p. 143-206. New York: Kluwer Academic.

Bradley, R.L. 2003. Moisture and total solids analysis. In Nielsen, S. S. (Ed.). Food analysis, p. 81-102. New York: Kluwer Academic.

Caili, F., Haijun, T., Quanhong, L., Tongyi, C. and Wenjuan, D. 2006. Ultrasound-assisted extraction of xyloglucan from apple pomace. Ultrasononics Sonochemistry 13 (6): 511−516.

Chemat, S., Lagha, A., AitAmar, H., Bartels, V. and Chemat, F. 2004. Comparison of conventional and ultrasound-assisted extraction of carvone and limonene from caraway seeds. Flavour and Fragrance Journal 19 (3): 188−195.

Chen, F., Sun, Y., Zhao, G., Liao, X., Hu, X., Wu, J. and Wang, Z. 2007. Optimization of ultrasound-assisted extraction of anthocyanins in red raspberries and identification of anthocyanins in extract using high-performance liquid chromatography-mass spectrometry Ultrasononics Sonochemistry 14 (6): 767–778.

Cliff, M. A., King, M. C. and Schlosser, J. 2007. Anthocyanin, phenolic composition, colour measurement and sensory analysis of BC commercial red wines. Food Research International 40 (1): 92–100.

Hemwimol, S., Pavasant, P. and Shotipruk, A. 2006. Ultrasound-assisted extraction of anthraquinones from roots of *Morinda citrifolia*. Ultrasononics Sonochemistry 13 (6): 543–548.

Kamaljit, V., Mawson, R., Simons, L. and Bates, D. 2008. Applications and opportunities for ultrasound assisted extraction in the food industry- a review. Innovative Food Science and Emerging Technologies 9 (2): 161–169.

Kashyap, D. R., Vohra, P. K., Chopra, S. and Tewari, R. 2001. Applications of pectinases in the commercial sector: a review. Bioresource Technology 77 (3): 215-227.

Lieu, N. L. and Le, V. V. M. 2010. Application of ultrasound in grape mash treatment in juice processing. Ultrasononics Sonochemistry 17 (1): 273-279.

Lee, M. H. and Lin, C. C. 2007. Comparison of techniques for extraction of isoflavones from the root of Radix Puerariae: Ultrasonic and pressurized solvent extractions. Food Chemistry 105 (1): 223–228.

Li, J. W., Ding, S. D. and Ding, X. L. 2007. Optimization of the ultrasonically assisted extraction of polysaccharides from *Zizyphus jujuba* cv. *jinsixiaozao*. Journal of Food Engineering 80 (1): 176–183.

Luque-Rodrıguez, J. M., Luque de Castro, M. D. and Pe´rez-Juan, P. 2007. Dynamic superheated liquid extraction of anthocyanins and other phenolics from red grape skins of winemaking residues. Bioresource Technology 98 (14): 2705–2713.

Ma, Y., Ye, X., Hao, Y., Xu, G., Xu, G. and Liu, D. 2008. Ultrasound-assisted extraction of hesperidin from Penggan *(Citrus reticulata)* peel. Ultrasononics Sonochemistry 15 (3): 227–232.

McLellan, M. R. and Padilla-Zakour, O. I. 2005. Juice processing. In Barrett, D. M., Somogyi, L. P. and Ramaswamy, H. (Eds). Processing fruits: Science and Technology, p. 72-95. Boca Raton: CRC Press.

Palma, M. and Barroso, C. G. 2002. Ultrasound-assisted extraction and determination of tartaric and malic acids from grapes and winemaking by-products. Analytica Chimica Acta 458 (1): 119–130.

Paniwynk, L., Beaufoy, E., Lorimer, P. and Mason, J. 2001. The extraction of rutin from flower buds of *Sophora japonica*. Ultrasononics Sonochemistry 8 (3): 299–301.

Patist, A. and Bates, D. 2008. Ultrasonic innovations in the food industry: From the laboratory to commercial production. Innovative Food Science & Emerging Technologies 9 (2): 147–154.

Rattanathanalerk, M., Chiewchan, N. and Srichumpoung, W. 2005. Effects of thermal processing on the quality loss of pineapple juice. Journal of Food Engineering 66 (2): 259-265.

Rostagno, M. A., Palma, M. and Barroso, C. G. 2003. Ultrasound-assisted extraction of soy isoflavones. Journal of Chromatography A 1012 (2): 119–128.

Rutledge, P. 1996. Fruit and juice processing. In: Arthey, D. and Ashurst, P. R. (Eds.). Production of non-fermented fruit products, p. 70-96. London: Blackie Academic & Professional.

Sharma, A. and Gupta, N. 2006. Ultrasonic pre-irradiation effect upon aqueous enzymatic oil extraction from alond and apricot seeds. Ultrasononics Sonochemistry 13 (6): 529–534.

Sivakumar, V., Ravi Verma, V., Rao, P. G. and Swaminathan, G. 2007. Studies on the use of power ultrasound in solid-liquid myrobalan extraction process. Journal of Cleaner Production 15 (18): 1813-1818.

Suntornsuk, L., Gritsanapun, W., Nilkamhank, S. and Paochom, A. 2002. Quantification of vitamin C content in herbal juice using direct titration. Journal of Pharmaceutical and Biomedical Analysis 28 (5): 849-855.

Toma, M., Vinatoru, M., Paniwnyk, L. and Mason, T. J. 2001. Investigation of the effects of ultrasound on vegetal tissues during solvent extraction. Ultrasononics Sonochemistry 8 (2): 137–142.

Wang, J., Sun, B., Cao, Y., Tian, Y. and Li, X. 2008. Optimisation of ultrasound-assisted extraction of phenolic compounds from wheat bran. Food Chemistry 106 (2): 804–810.

Wang, Y. and Zhang, J. 2006. A novel hybrid process, enhanced by ultrasonication, for xylan extraction from corncobs and hydrolysis of xylan to xylose by xylanase. Journal of Food Engineering 77 (1): 140-145.

Wu, J., Lin, L. and Chau, F. 2001. ultrasound-assisted extraction of ginseng saponins from ginseng roots and cultured ginseng cells. Ultrasononics Sonochemistry 8 (4): 347-352.

Zhang, L., and Liu, Z. 2008. Optimization and comparison of ultrasound/microwave assisted extraction (UMAE) and ultrasonic assisted extraction (UAE) of lycopene from tomatoes. Ultrasononics Sonochemistry 15 (5): 731–737.