Softening in pistachio kernels during ultrasonic desiccation

Ahmad Kouchakzadeh

(Department of Biosystems Engineering, Ilam University, Ilam, Iran)

Abstract: Changes in Young's modulus of pistachio kernels after ultrasonic desiccation were examined. Young's modulus in ultrasonic dried nuts (6.3% to 8.0% d.b.) rises from 27 to 35 MPa within 150 W to 300 W ultrasonic powers. The sun dried modulus values were roughly greater than 70 MPa and a consistent trend like acoustic dried could not be observed. These results showed the acoustic softening is accrued when the pistachio kernels are exposed to ultrasonic vibration. Kernels could not maintain its hardness so the Young's modulus decreased rather than sun dried.

Keywords: ultrasonic softening, young's modulus, desiccation, pistachios

Citation: Kouchakzadeh, A. 2016. Softening in pistachio kernels during ultrasonic desiccation. Agricultural Engineering International: CIGR Journal, 18 (2):185-189.

1 Introduction

In recent years, the uses of ultrasound technology as thermal processing in food industries have been known. Many benefits of applying high power ultrasound in food processes have been reported (Knorr et al., 2004). It was established that acoustic vibration assisted drying can result in a significant reduction in drying time; by a combination of convective air, microwave and infrared or solar radiation. The effect of ultrasonic oscillation on loss of water in foodstuff was investigated by Chandrapala et al. (2012). It was reported that reduced drying time could be obtained when the oscillation is combined with the conventional methods. Many high power ultrasonic waves cause rises in surface temperature with insignificant bulk heating of the foods (Yao et al., 2011), but some ultrasounds waves cause changes in the structures of foods which is an important determinant of their quality. When a high-intensity ultrasonic wave is directed to the foodstuff, it moves through the solid medium and makes a rapid series of alternative compressions and expansions, in a similar way to a sponge when it is squeezed and released repeatedly. The forces involved by this mechanical mechanism can be higher than the surface tension that maintains the moisture inside the capillaries of the material creating microscopic channels that may remove the moisture easily. An acoustic softening can be accrued from this process (Kouchakzadeh, 2013). It has shown that when ultrasonic vibration is applied at the levels of stress faced during deformation, acoustic softening response is nearly linear to vibration amplitude (Yao et al., 2012).

The acoustic softening term is given by Siddiq and Sayed (2011) as:

$$U_{soft} = (1 - d_{ut}.I_{ultrasonic})^{e_{ut}} \quad (1)$$

Where, d_{ut} and e_{ut} are ultrasonic (acoustic) softening parameters, which must be found from experiments, while $I_{ultrasonic}$ is the ultrasonic intensity that is an observable variable computed using the following relation as given by Siddiq and Sayed (2011):

$$I_{ultrasonic} = \frac{\sigma^2_{acoustic}}{\rho c} \quad (2)$$

Where, $\sigma_{acoustic}$ is the acoustic power, ρ is the density of material and c is the velocity of sound in the medium.

The elastic properties of foodstuffs are one of the primary attributes to evaluate in characterizing product rheological attributes. Young's modulus is a measure of elastic properties of a material, which might be used as a limit to assess food quality (Sahin and Sumnu, 2006). Most of the research that work on simulating ultrasonic

Received date: 2014-11-07 **Accepted date:** 2016-01-10

***Corresponding author: Ahmad Kouchakzadeh,** Department of Biosystems Engineering, Ilam University, Ilam, Iran. Email: akouchakzadeh@mail.ilam.ac.ir. Phone: 00989124532128. Fax: 00988412227015.

assisted drying processes have concentrated on varying the moisture contents to reduce the surface and volume effects (shrinkage) to explain the application of ultrasonic energy (Chandrapala et al., 2012), but internal effects caused by ultrasonic energy (acoustic softening) were not explicit in the used models. To perform simulations of ultrasonic processes, both volume or surface effects (shrinkage) and rheology effect (acoustic softening) must be incorporated in the ultrasonic food process.

High intensity ultrasound has been considered to enhance mass transfer for different products and processes such as: drying apple and red bell pepper (Schössler et al., 2012), orange peel during air drying (Garcia-Perez et al., 2012); and in many food and vegetables applications, such as sterilizing, extracting, degassing, filtrating, drying and enhancing oxidation (Knorr et al., 2013), drying of pistachios with convective-ultrasonic technique (Kouchakzadeh and Ghobadi, 2012) and combination of solar and acoustic energy for drying of pistachios nuts (Kouchakzadeh, 2013). However, not many studies about changing in rheological properties when a foodstuff exposes in high power ultrasound were found.

In this study, changes in Young's modulus for cylindrical tissue samples of pistachio kernel at different ultrasound powers were examined by using precious testing device on individual samples after ultrasonic fication and sun drying.

2 Materials and Methods

Akbari pistachios (*Pistachio Vera L*), one of the major varieties of Iranian pistachios were used for consideration of ultrasonic fication. The samples were obtained from an orchard in Iran, Qom province. The unshelled pistachios kernels were used in this research. The moisture contents of samples were determined by oven drying at temperature of 130℃ for 6 h following standard methods ASAE (ASAE, 2005).

2.1 Sample preparation

The unshelled pistachios kernels were placed in an ultrasonic-convective dryer (Figure 1). The constructional and operational details of the drying system can be found elsewhere from previous research by Kouchakzadeh and Ghobadi (2012). After drying process, the surface of pistachio kernel tissues was collapsed or distorted for measurement. A 5 mm diameter and 8 mm height cylindrical piece of kernel tissue was cut out from the kernel center. Same removal was performed with the sun-dried pistachio's kernels. Samples were excised using a precious cutting apparatus.

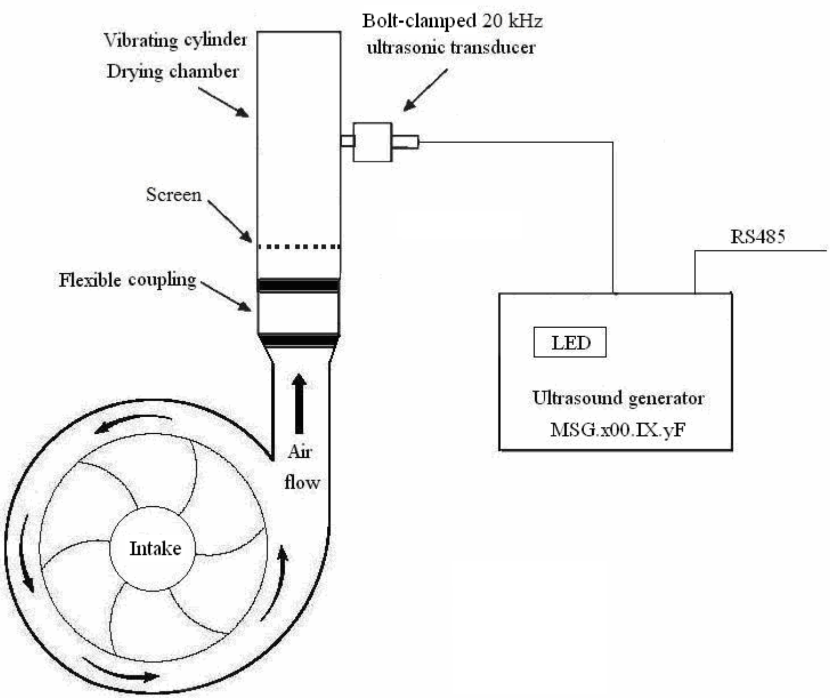

Figure 1 Schematic diagram of acoustic dryer

2.2 Measurement procedures

A universal 100 kN testing machine (ZWICK ROELL, Germany) was used to compress the formed cylindrical samples. The testing machine also measured normal stress against compression and compressive strain. Compression rate was set to 0.1 mm/min, and the apparatus start force was set at 0.1 N. The first contact point between sample and plunger, which is regarded as the sample height, was set at 0% compression level.

Young's modulus (E) was calculated from normal stress (σ) values divided by compressive strain (ε) as given by Dill (2006) as:

$$E = \frac{\sigma}{\varepsilon} \quad (3)$$

Such as previously investigation by Kouchakzadeh and Ghobadi (2012), ultrasonicfication experiments were carried out with 150 W for about 100 min and 300 W acoustic powers for about 55 min at 1 m/s airflow. A fixed room temperature of 25℃±2℃ was used during tests. Stress-strain curves were derived from formed cylindrical of sun dried and acoustic dried pistachio kernels. Kernels with moisture contents ranging between 6.3% to 8.0% d.b. were selected for tests and experiments were performed in triplicates. Young's modulus is strictly defined for an elastic object or an elastic region of compressive strain. The modulus is the slope value at an elastic range which appears as a linear region in the stress-strain curve as mentioned above and it is regarded as the apparent Young's modulus (Kouchakzadeh, 2012).

3 Results and discussion

The average variation of stress vs. strain from formed cylindrical samples in acoustic dried and sun dried kernels are depicted in Figure 2. Young's modulus for individual samples for each condition was calculated as a slope of the linear part of stress-strain curve.

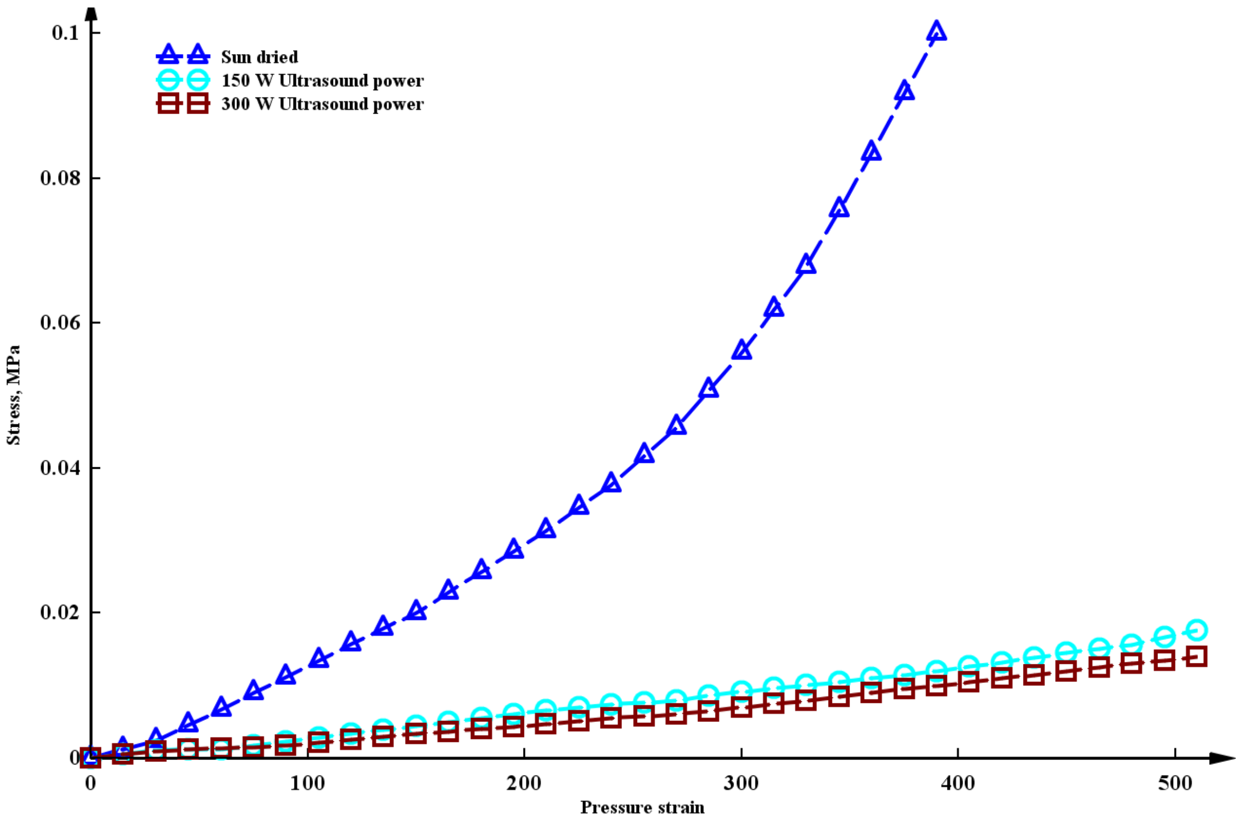

Figure 2 Stress-strain curves for sun dried and ultrasonic dried pistachio kernels

In acoustic dried kernels, when stress varied from zero to 0.18 MPa, strain did not succeed over 0.005. However, for sun dried kernels, stress rapidly increased approximately to 1.00 MPa when strain was 0.004. Research shows that upon removal of vibration during acoustic softening, force builds up at a rate determined by Young's modulus, much like a typical sample undergoing plastic deformation that is unloaded and reloaded. Figure 3 shows the differences between acoustic and sun dried kernels.

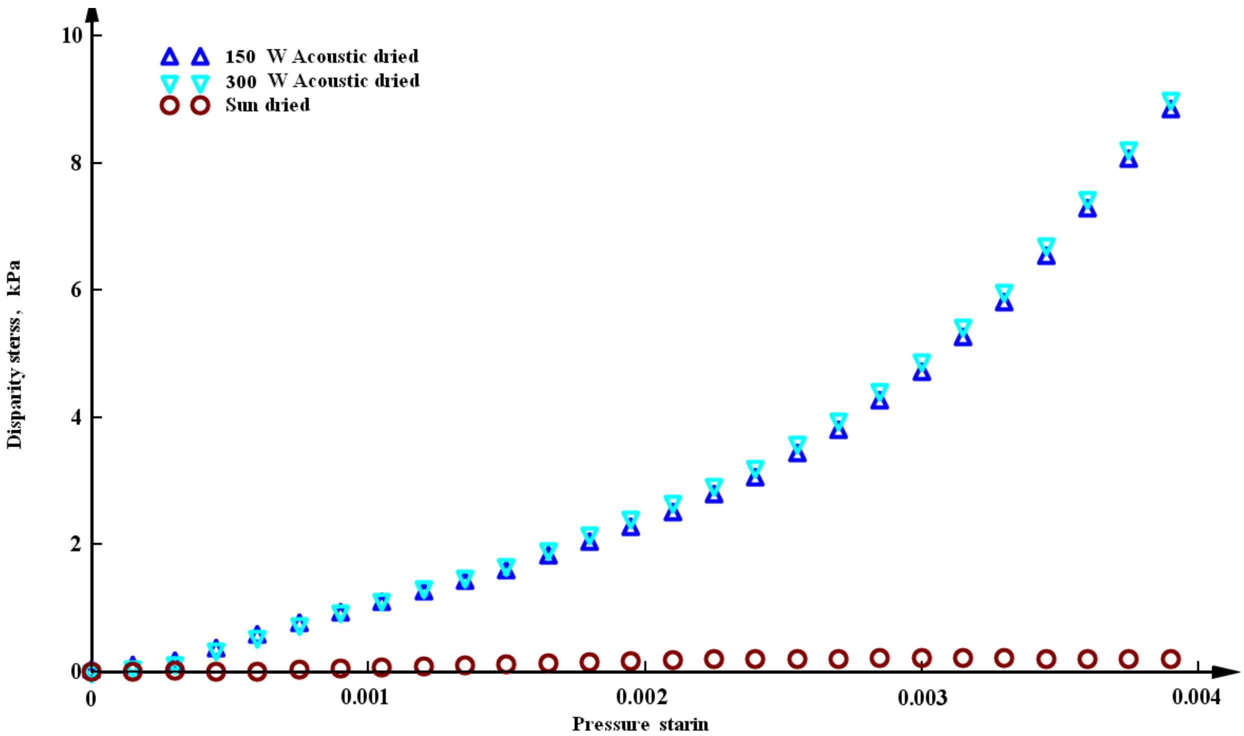

Figure 3 Differences between acoustic and sun dried pistachio kernels

This result indicated the volume reduction in sun dried pistachio kernel tissue against compression was greater than in acoustic dried kernel. This is showing that by drying of pistachio, not only texture strength but also textural conduct (in terms of elastic or viscous domination) is subject to change. Capillary voids filled with moisture can be the cause of cohesiveness increase by moisture increase during rehydration. When food biopolymers absorb water, it appears that they become more elastic. The springiness of rehydrated cells can decrease due to reduction in ability of cells to recover their initial form (Farahnaky and Kamali, 2015).

As shown in Figure 3, the maximum stress difference in two acoustic powers 150 and 300 W were measured 0.21 kPa within strain 0.002, while maximum differences in sun dried and acoustic dried were measured 0.87 and 0.90 kPa in 150 and 300 W within strain 0.004, respectively. Young's modulus in acoustic dried nuts rises from 27 to 35 MPa within 150 W to 300 W ultrasonic powers. The sun dried modulus values was approximately greater than 70 MPa and a consistent trend like acoustic dried could not be observed. Reduction of extra and intracellular spaces, canals and cavities, rapid loss of moisture content and case hardening have been referred to as the reasons of hardness increase with moisture decrease (Deng et al., 2014). The results of this study indicated the acoustic dried pistachio kernels were softer than the sun dried kernels at the same moisture content. It was established that acoustic dried kernels should be more easily chewed than sun dried kernels under the same moisture conditions.

4 Conclusions

Acoustic softening is apparent in the test data, indicating a need to add this effect to the foodstuffs drying in future revisions. A study that couples the vibration behaviour of the forming tissues with forming stress will allow the design of methods that are better acoustically tuned for high-frequency vibration dehydration interfaces. The forming stress of the sample could then be modified to include the effects of the actual amplitude experienced at the tissues surface and how they propagate through the sample during drying. Experimental data for test cylinders show that applying ultrasonic pulse to the kernel reduces the mean stress in upsetting. The outcome of this research is clearly showing that significant texture declines or changes can occur when fruits are sun dried and ultrasonically dried to the same moisture level. Further research is suggested to evaluate the effect of ultrasonic dehydration processes and storage on textural properties of other food materials.

References

ASAE. 2005. Standard for measurement of moisture in grin and seed. *Agricultural Engineers Yearbook,* 564-565.

Deng, Y., Y. Luo, Y. Wanga, J. Yue, Z. Liu, Y. Zhong, Y. Zhao, and H. Yang. 2014. Drying induced protein and microstructure damages of squid fillets affected moisture distribution and rehydration ability during rehydration. *Journal of Food Engineering,* 123(2): 23–31.

Chandrapala, J., C. Oliver, S. Kentish, and M. Ashokkumar. 2012. Ultrasonics in food processing–Food quality assurance and food safety. *Trends in Food Science & Technology*, 26(2): 88-98.

Dill, E. H. 2006. *Continuum Mechanics: Elasticity, Plasticity, Viscoelasticity*. Germany: CRC Press.

Farahnaky, A., and E. Kamali. 2015. Texture hysteresis of pistachio kernels on drying and rehydration. *Journal of Food Engineering*, 166(12): 335-341.

Garcia-Perez, J. V., C. Ortuño, A. Puig, J. A. Carcel, and I. Perez-Munuera. 2012. Enhancement of water transport and microstructural changes induced by high-intensity ultrasound application on orange peel drying. *Food and Bioprocess Technology*, 5(6): 2256-2265.

Knorr, D., A. Froehling, H. Jaeger, K. Reineke, O. Schlueter, and K. Schoessler. 2013. Emerging Technologies for Targeted Food Processing. In *Advances in Food Process Engineering Research and Applications*, 341-374. US: Springer.

Knorr, D., M. Zenker, V. Heinz, and D. U. Lee. 2004. Applications and potential of ultrasonics in food processing. *Trends in Food Science & Technology*, 15(5): 261-266.

Kouchakzadeh, A. 2012. Bulk modulus of five major varieties of Iranian pistachios. *Agricultural Engineering International: CIGR Journal*, 14(2): 35-39.

Kouchakzadeh, A. 2013. The effect of acoustic and solar energy on drying process of pistachios. *Energy Conversion and Management*, 67(3): 351-356.

Kouchakzadeh, A., and P. Ghobadi. 2012. Modeling of ultrasonic-convective drying of pistachios. *Agricultural Engineering International: CIGR Journal*, 14(4): 144-149.

Sahin, S., and S. G. Sumnu. 2006. *Physical properties of foods*, 38-39. New York: Springer.

Schössler, K., H. Jäger, and D. Knorr. 2012. Effect of continuous and intermittent ultrasound on drying time and effective diffusivity during convective drying of apple and red bell pepper. *Journal of Food Engineering*, 108(1): 103-110.

Siddiq, A., and T. E. Sayed. 2011. Acoustic softening in metals during ultrasonic assisted deformation via CP-FEM. *Journal of material letters*, 65(2): 356-359.

Yao, Y., W. Zhang, and B. He. 2011. Investigation on the kinetic models for the regeneration of silica gel by hot air combined with power ultrasonic. *Energy Conversion and Management*, 52(10): 3319–26.

Yao, Z., G. Y. Kim, Z. Wang, L. Faidley, Q. Zou, D. Mei, and Z. Chen. 2012. Acoustic softening and residual hardening in aluminum: modeling and experiments. *International Journal of Plasticity*, 39(12): 75-87.