American Journal of Animal and Veterinary Sciences

Original Research Paper

Particle Size Determination in Rice Bran Testing with Various Levels of Rice Husks Using Ultrasonic Waves

[1]Urip Rosani, [1]Iman Hernaman, [1]Rahmat Hidayat and [2]Darmawan Hidayat

[1]Department of Animal Nutrition and Feed Technology, Universitas Padjadjaran, Indonesia
[2]Department of Electrical Engineering, Universitas Padjadjaran, Indonesia

Article history
Received: 08-07-2024
Revised: 02-9-2024
Accepted: 12-09-2024

Corresponding Author:
Urip Rosani
Department of Animal Nutrition and Feed Technology, Universitas Padjadjaran, Indonesia
Email: urip@unpad.ac.id

Abstract: The principle of ultrasonic waves in detecting materials is based on their physical properties. The size of particles has an impact on various aspects of their composition and function. The limited information that reports the particle size of RH-contaminated RB samples tested using ultrasonic waves is the basis for this study. This study aims to determine the optimal sample particle size for testing RB contaminated with RHs in order to obtain the most accurate and consistent results when reading with ultrasonic waves based on attenuation. The research method used Completely Factorial Random Design (CFRD) with factor levels of RH (0, 20, 40, 60, 80, and 100%) and different particle sizes (10, 20, 30, 40, and 50 mesh). The test principle is to transmit ultrasonic waves with a frequency of 50 kHz through the sample. The results of statistical analysis showed that the RH level was very real ($p<0.01$) affecting the damping and speed. The higher the RH content, the higher the damping value. The particle size of RB is very real ($p<0.01$) affects the attenuation and velocity, the smaller the particle size, the higher the damping value. Conclusion of this study are the level of RHs and the particle size of the sample affect the accuracy of ultrasonic wave readings on RB contaminated with RHs. The optimal particle size for testing RB contaminated with RHs using ultrasonic waves with attenuation parameters is mesh 30, resulting in a linear regression pattern with a 91.30% r-square value. More research needs to be done on these results to find out what affects the transmission (amplitude) of ultrasonic waves when measuring samples.

Keywords: Amplitude, Correlation, Frequency, Mesh, Particle Size, Testing

Introduction

The principle of ultrasonic waves in detecting materials is based on their physical properties. One of the physical properties is particle size. Different particle sizes will give different results (Rosani *et al*., 2024). The quality of Rice Bran (RB) varies greatly depending on the type of machine, tuning, and destination. This will result in varied, fine, medium, or coarse RB it will affect the quality of RB. The Rice Husk (RH) content in RB results in lower crude protein of RB and higher crude fiber and lignin (Hernaman *et al*., 2024). In the practice of counterfeiting RB with RHs, RHs are usually added and finely ground. Based on the properties of ultrasonic waves and the physical properties of RB, it is necessary to establish a test standard for the sample size of RB contaminated with RHs.

The size of the particle has an impact on various aspects of its composition and function. Research has found that smaller particle sizes can enhance certain benefits of peppermint, such as antioxidant activity and nutritional availability. Examples: Particle size RB with a range of 0.73-1.67 mm show significant inhibition potential against the free radical DPPH at IC50 values of 6.63 µg/mL (Massarolo *et al*., 2017). Smaller particle sizes, such as about 38 µm, result in increases in moisture content, protein percentage, soluble dietary fiber, water-holding capacity, and development capacity when compared to larger particle sizes, such as 150 µm (Mukprasirt *et al*., 2023). Reducing the particle size from 150 to 38 µm also resulted in nearly double the surface area, improved nutrient and phytochemical extraction capabilities, and improved the nutrient properties and overall function of RB (Mukprasirt *et al*., 2023). Processing by reducing the particle size of RB will produce greater benefits for health.

Reducing the size of RB is carried out by milling and sieving methods. Sieving is carried out using a ball mill vibrator using a sieve of various density levels (for example, meshes 4, 8, 16, 30, 50, 100, and 400) (Bhatnagar *et al*., 2014; Mukprasirt *et al*., 2023). Research was conducted on different RB particle sizes between 0.18-0.39 mm and particle sizes of 53, 125, and 210 µm (Majzoobi *et al.*, 2013; Schmidt and Furlong, 2012). With this study, researchers can find out the nature and distribution of RB particles. So, it can help understand how this particle size works to affect certain uses and purposes.

Ultrasonic particle sizing is a method used to test the distribution of particles in samples. This technique can test the distribution of particles in a certain area with a particle size of 10 nm to 1 mm (Povey, 2013). In liquid media, ultrasonic waves will interact with the sample particles, so we will be able to know the particle size distribution and be able to measure the speed, flow, and layer limits.

Ultrasonic vibrations are applied to the particle-containing sample, causing the particles to interact. Understanding how ultrasonic waves interact with different particle sizes can assist in determining the size of the particles in a sample. The velocity and attenuation are found using the amplitude spectrum versus the received signal's frequency and the particle size distribution can be explained by the geometric mean and standard deviation of the particle radius. Ultrasonic particle meters can detect particles over a wide range, from 10 nm to 1 mm, for opaque and optically undiluted materials (McClements, 2000; Povey, 2013). There are no reports on the application of ultrasonic waves for evaluating various items and mediums, or for testing solid, liquid, gas, or powder media. Research indicates that in husk-adulterated RB, there is a strong association between the content of the husk and the acoustic attenuation of propagating ultrasonic waves (Bhagaspati *et al.*, 2021). Ultrasonic waves propagating through a powder medium are unique (Al-Lashi *et al*., 2018).

Previous research showing ultrasonic waves (attenuation) are accurately used to detect the physical properties of materials has been informed (Rosani *et al.*, 2024). There is no information that has reported the particle size of RB samples contaminated with RHs tested using ultrasonic waves. This study aims to determine the best particle size of RB samples contaminated with RHs in order to obtain the most accurate and consistent results when tested using ultrasonic waves. The benefit of this study is to produce a consistent and accurate RB testing method for RH contamination. We believe that particle size determination for testing RB contaminated with husk has never been studied. We hope to produce accurate and consistent testing procedures in the future.

Materials and Methods

Experimental Design

The Completely Factorial Random Design (CFRD) was used in this study. The first factor (RB) was the level of RB and RH (6 levels) and the second factor (M) was the particle size based on the mesh (5 sizes), with repeated readings of 3 times. The research design is as follows: RB1 = 100% RB + 0% RH, RB2 = 80% RB + 20% RH, RB3 = 60% RB + 40% RH, RB4 = 40% RB + 60% RH, RB5 = 20% RB + 80% RH, RB6 = 0% RB + 100% RH and paticle size M1 = 10 mesh, M2 = 20 mesh, M3 = 30 mesh, M4 = 40 mesh, M5 = 50 mesh.

Sample Preparation

RB comes from a local rice mill in sindangsari village, Sumedang. Sample preparation follows the procedures carried out in previous studies (Rosani *et al*., 2024).

Ultrasonic Measurement

The parameters measured were the attenuation coefficient and velocity following the procedure carried out in the previous study (Rosani *et al*., 2024).

Statistical Analysis

The General Linear Model (ANOVA) was used to analyze the research data if there were any significant differences. Duncan's test and Pearson correlation analysis were used to determine the differences and relationships between factors.

Results and Discussion

This research begins by testing the ability of ultrasonic waves on RB mixed with RHs based on treatment, then on various particle sizes based on mesh, then on the combination of percentage with particle size, and finally determining the best particle size for testing RB using ultrasonic waves based on regression coefficients.

This research is not directly related to research ethics that use living objects. This study uses inanimate objects as samples such as RB and RHs. The special treatment applied is caution so that the sample does not mix with the contaminants. However, we obtained research ethics approval from Padjadjaran University for the overall research with number 572/UN6. KEP/EC/2024.

Ultrasonic Wave Response to RH Level

The results of statistical analysis of RH level are very real ($p<0.01$) affect attenuation and velocity. Table (1) shows that the higher the RH content, the higher the attenuation value. The attenuation value (dB) in RB1 is 0.09589, RB2 is 0.10832, RB3 is 0.11620, RB4 is 0.12287, RB5 is 0.12650 and RB6 is 0.13109. This means RHs cause a decrease in ultrasonic waves when passed.

DOI: 10.3844/ajavsp.2024.371.376

Table 1: Attenuation (dB) and velocity (m/s) of RB contaminated with RHs at various percentages

Parameters	Treatment					
	RB1	RB2	RB3	RB4	RB5	RB6
Attenuation, α (dB)	0.09589[a]	0.10832[b]	0.11620[c]	0.12287[d]	0.12650[d]	0.13109[e]
Velocity (m/s)	0.27837[b]	0.26769[a]	0.26656[a]	0.26576[a]	0.26558[a]	0.26341[a]

Significancy ($p<0.01$) is indicated by different superscripts on the line. RB1 = 100% RB + 0% RH, RB2 = 80% RB + 20% RH, RB3 = 60% RB + 40% RH, RB4 = 40% RB + 60% RH, RB5 = 20% RB + 80% RH, RB6 = 0% RB + 100% RH

In contrast to attenuation, the velocity value tends not to differ with the higher the RH content. The velocity value (m/s) in RB1 is 0.27837, RB2 is 0.26769, RB3 is 0.26656, RB4 is 0.26576, RB5 is 0.26558 and RB6 is 0.26341. This means that the resistance of ultrasonic waves is low when passing through the material. These results support previous research, which stated that the attenuation coefficient occurs due to the presence of ultrasonic wave energy absorbed when passing through the medium; the absorption strength is influenced by the density of the medium particles. The energy absorbed and dissipated will get smaller as the density gets smaller (Bhagaspati *et al*., 2021).

Ultrasonic Wave Response to Particle Size

The results of the statistical analysis of RB particle size are very real ($p<0.01$) and affect attenuation and velocity. Table (2) shows that the smaller the particle size, the higher the attenuation value. The attenuation value (dB) in mesh 10 particle size is 0.05991, mesh 20 is 0.07968, mesh 30 is 0.12515, mesh 40 is 0.13367, and mesh 50 is 0.18565. This means that the greater the energy loss of ultrasonic waves as they pass through the material.

In contrast to attenuation, the velocity value decreases with the smaller the particle size of RB. The velocity value (m/s) in mesh 10 particle size is 0.29607, mesh 20 is 0.28176, mesh 30 is 0.27052, mesh 40 is 0.25757, and mesh 50 is 0.23356. This means that the ultrasonic waves have greater resistance when passing through the smaller particle size of the material.

This is due to the smaller RB particles, the higher the density; in other words, the density increases. The high density of the material will inhibit the propagation of ultrasonic waves, so the time needed is higher. The particle size causes a pattern of relationships between the particle size and the attenuation of the waves that pass through it. Attenuation parameters in sample measurements using ultrasonic waves can determine the particle size distribution of the sample (Alarab *et al*., 2020; Falola *et al*., 2021; Jia *et al*., 2019). The study measured the particle size of concrete aggregates using ultrasonic waves, showing that amplitude attenuation, energy density, and frequency are positively correlated with particle size (Wu *et al*., 2021). Particle size and concentration greatly affect the velocity propagation and attenuation coefficient of ultrasonic waves.

Table 2: Attenuation (dB) and velocity (m/s) of RB with different levels of RH at various particle sizes based on the mesh

Parameters	Treatment				
	M1	M2	M3	M4	M5
Attenuation, α (dB)	0.05991[a]	0.07968[b]	0.12515[c]	0.13367[d]	0.18565[e]
Velocity (m/s)	0.29607[e]	0.28176[d]	0.27052[c]	0.25757[b]	0.23356[a]

Significancy ($p<0.01$) is indicated by different superscripts on the line. M1 = 10 mesh, M2 = 20 mesh, M3 = 30 mesh, M4 = 40 mesh, M5 = 50 mesh

This is seen when measuring particle size and dispersion phase concentration in samples in suspensions and emulsions (McClements, 2000).

There is a not always linear relationship between particle size and ultrasonic waves. For instance, in the synthesis of metal nanoparticles, Ultrasonic power up to 0.395 power is proportional to particle size. This means that the particle size decreases with increasing ultrasonic power, but the rate of decrease slows down as the ultrasonic power increases and a further increase in power can lead to an increase in particle size (Yang *et al*., 2021).

Ultrasonic spectrometry can measure particle sizes between approx. 10 nm (nanometers) and 1000 μm (micrometers) (McClements, 2000; Povey, 2013). Ultrasonic particle measuring devices perform measurements in the range of 1 to 200 MHz, which can analyze particle sizes of 10 nm and 1000 μm (McClements, 2000). This range can be expanded by using tailor-made techniques to take measurements at higher or lower frequencies (McClements, 2000).

Ultrasonic particle size analysis is particularly useful for materials with high concentrations, such as mineral slurries, pitch-black crude oil suspensions, viscous pastes, and crystal slurries, where other methods may not be effective. Measurements using ultrasonic waves have many advantages, but there are technical obstacles that need to be noted and overcome before the technique finds more widespread use. For example, in colloid sample measurements, air bubbles will scatter waves, so the measurement results are not accurate (McClements, 2000), frequency of waves used, dimensions and configuration of particles in the sample, presence of air bubbles or contaminants in the sample (Hornowski *et al*., 2008; Riebel and Löffler, 1989) and temperature (Chanamai *et al*., 1998; Cherepanov *et al*., 2015; Xu *et al*., 2019).

Table 3: Attenuation (dB) of RB with RH level at various particle sizes based on mesh and percentage of RH

Mesh	RB (%)					
	RB1	RB2	RB3	RB4	RB5	RB6
M10	0.04217[a]	0.05763[b]	0.06044[b]	0.06154 [b]	0.06847[c]	0.06920[c]
M20	0.06453[a]	0.07155[b]	0.08135[c]	0.08135[d]	0.08719[d]	0.08809[d]
M 30	0.10012[a]	0.11130[b]	0.12001[b]	0.13410[c]	0.14101[cd]	0.14434[d]
M 40	0.11198[a]	0.12641[b]	0.12922[bc]	0.13573[c]	0.14423[d]	0.15447[e]
M 50	0.16065[a]	0.17471[b]	0.18999[c]	0.19344[cd]	0.19487[cd]	0.20023[e]

Significancy ($p<0.01$) is indicated by different superscripts on the line. RB1 = 100% RB + 0% RH, RB2 = 80% RB + 20% RH, RB3 = 60% RB + 40% RH l, RB4 = 40% RB + 60% RH, RB5 = 20% RB + 80% RH, RB6 = 0% RB + 100% RH. M1 = 10 mesh, M2 = 20 mesh, M3 = 30 mesh, M4 = 40 mesh, M5 = 50 mesh

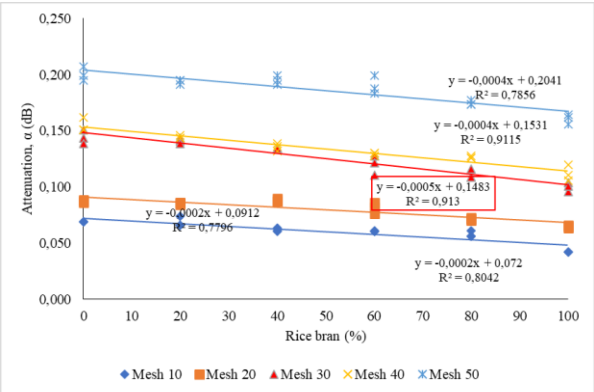

Fig. 1: R-squared value of RB attenuation with different RH levels at various particle sizes based on the mesh

After knowing the response of RB levels and the overall particle size of the research data, we want to know how the attenuation response in various meshes with different RB levels is described next.

Ultrasonic Wave Response to RH Level and Particle Size

The results of the statistical analysis of RB level and very real particle size ($p<0.01$) affect attenuation, as presented in Table (3). Based on Table (3), the attenuation response at different RB levels based on particle size has different responses.

The smaller the particle size of the sample, the greater the attenuation, and the higher the level of RH, the greater the attenuation value. This is due to the higher density of the sample. RHs have a low density when the particle size is normal from the rice milling process, but when the particle size is reduced (up to 50 mesh), the density will increase because RHs consist of lignin and silica, which are high, so they become heavy. To determine the regression pattern of the influence of RH levels in RB based on particle size, regression analysis was then carried out, which is presented in Fig. (1).

Based on the figure, the regression pattern of the influence of RH level in RB based on particle size is linear with variations in r-square values. At mesh 10 r-square 80.42%, mesh 20 r-square 77.96%, mesh 30 r-square 91.30%, mesh 40 r-square 91.15% and mesh 50 r-square 78.56%. Mesh 30 has the highest r-square of 91.30%, meaning that the measurement results have very high accuracy. In contrast to previous studies that produced exponential regression with an r-square of 88.27% (Bhagaspati *et al*., 2021). This is due to the difference between the transducer and the sample preparation technique at the time of measurement. Ultrasonic waves are very sensitive to differences in the physical properties of materials. So, it can be concluded that the measurement of RB polluted with RHs is based on the best attenuation at particle size based on mesh 30.

In measuring ultrasonic waves, RB has problems, namely the propagation of waves through the medium where the sample is, the tool structure, room temperature, changes in electric current voltage, contaminants, and the certainty that the sample has been mixed evenly. The challenge in the future is to standardize this ultrasonic tool by minimizing these factors so that measurements are more accurate and consistent.

Conclusion

The level of RHs and the particle size of the sample affect the accuracy of ultrasonic wave readings on RB contaminated with RHs. The optimal particle size for testing RB contaminated with RHs using ultrasonic waves with attenuation parameters is mesh 30, resulting in a linear regression pattern with a 91.30% r-square value. More research needs to be done on these results to find out what affects the transmission (amplitude) of ultrasonic waves when measuring samples. Also, a set of small ultrasonic test systems needs to be made so that they can be used in industry or in the field.

Novelty Statement

Effective particle size information in testing the counterfeiting of RB with RHs, namely on mesh 30 with a particle size of 0.595 mm. These results are a reference for testing the contamination of RB with RHs.

Acknowledgment

The author expresses gratitude to the Rector for granting permission to pursue studies in the Doctoral

Study Program in Animal Science at the Faculty of Animal Science, Universitas Padjadjaran. The Electrical Power, Electrotechnical and Communication Technology Laboratory, Department of Electrical Engineering, FMIPA UNPAD, provided the necessary equipment for this research.

Funding Information

Universitas Padjadjaran has financed this research through the RDDU scheme, with the number 1549/UN631/PT00/2023.

Author's Contributions

Every author made an equal contribution.

Ethics

This research was conducted to solve the problem of counterfeiting rice bran as animal feed. This is a request from feed business actors who feel economically disadvantaged. The test was carried out using a method developed by the Laboratory of Electrical Power, Electrotechnology, and Communication Technology, Department of Electrical Engineering, FMIPA UNPAD.

Conflict of Interest Statement

The results of this study were not influenced by financial interests and personal relationships among the authors.

References

Alarab, M., Augereau, F., Laux, D., & Lapierre, L. (2020). Estimation of Particle Size in Turbid Water Using Ultrasonic Attenuation - Application for Immersed Cave Exploration. *Forum Acusticum*, 2303–2306. https://doi.org/10.48465/fa.2020.0078

Al-Lashi, R. S., Povey, M. J. W., & Watson, N. J. (2018). Ultrasonic Wave Propagation in Powders. *Journal of Physics: Conference Series*, *1017*(1), 012001. https://doi.org/10.1088/1742-6596/1017/1/012001

Bhagaspati, D. D., Syafei, N. S., & Hidayat, D. (2021). Investigation of Husk-Adulterated Rice Bran Using Ultrasonic Wave. *2021 International Conference on Artificial Intelligence and Mechatronics Systems (AIMS)*, 1–5. https://doi.org/10.1109/aims52415.2021.9466011

Bhatnagar, A. S., Prabhakar, D. S., Prasanth Kumar, P. K., Raja Rajan, R. G., & Gopala Krishna, A. G. G. (2014). Processing of Commercial Rice Bran for the Production of Fat and Nutraceutical Rich Rice Brokens, Rice Germ and Pure Bran. *LWT - Food Science and Technology*, *58*(1), 306–311. https://doi.org/10.1016/j.lwt.2014.03.011

Chanamai, R., Coupland, J. N., & McClements, D. J. (1998). Effect of Temperature on the Ultrasonic Properties of Oil-in-Water Emulsions. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *139*(2), 241–250. https://doi.org/10.1016/s0927-7757(98)00335-5

Cherepanov, P. V., Kollath, A., & Andreeva, D. V. (2015). Up to Which Temperature Ultrasound can Heat the Particle? *Ultrasonics Sonochemistry*, *26*, 9–14. https://doi.org/10.1016/j.ultsonch.2015.03.002

Falola, A. A., Huang, M. X., Zou, X. W., & Wang, X. (2021). Characterization of Particle Size Distribution in Slurries Using Ultrasonic Attenuation Spectroscopy: Addressing Challenges of Unknown Physical Properties. *Powder Technology*, *392*, 394–401. https://doi.org/10.1016/j.powtec.2021.05.040

Hornowski, T., Józefczak, A., Łabowski, M., & Skumiel, A. (2008). Ultrasonic Determination of the Particle Size Distribution in Water-Based Magnetic Liquid. *Ultrasonics*, *48*(6–7), 594–597. https://doi.org/10.1016/j.ultras.2008.06.006

Hernaman, I., Rosani, U., Dhalika, T., Tanuwiria, U. H., & Ayuningsih, B. (2024). Red-Green-Blue Color Analysis Concerning Rice Husk Incorporation in Rice Bran. *American Journal of Animal and Veterinary Sciences*, *19*(2), 193–199. https://doi.org/10.3844/ajavsp.2024.193.199

Jia, N., Su, M., & Cai, X. (2019). Particle Size Distribution Measurement Based on Ultrasonic Attenuation Spectra Using Burst Superposed Wave. *Results in Physics*, *13*, 102273. https://doi.org/10.1016/j.rinp.2019.102273

Majzoobi, M., Sharifi, S., Imani, B., & Farahnaky, A. (2013). The Effect of Particle Size and Level of Rice Bran on the Batter and Sponge Cake Properties. *Journal of Agricultural Science and Technology*, *15*, 1175–1184.

Massarolo, K. C., Ribeiro, A. C., Furlong, E. B., & de Souza Soares, L. A. (2017). Effect of Particle Size of Rice Bran on Gamma-Oryzanol Content and Compounds. *Journal of Cereal Science*, *75*, 54–60. https://doi.org/10.1016/j.jcs.2017.03.012

McClements, D. J. (2000). Ultrasonic Measurements in Particle Size Analysis. *Encyclopedia of Analytical Chemistry*, 5581–5588. https://doi.org/10.1002/9780470027318.a1518

Mukprasirt, A., Domrongpokkaphan, V., Akkarachaneeyakorn, S., & Sumonsiri, N. (2023). Effect of Particle Size and Concentration of Defatted Rice Bran Supplemented in Tomato Salad Dressing. *Food Science and Technology*, *43*, e063422. https://doi.org/10.1590/fst.063422

Povey, M. J. W. (2013). Ultrasound Particle Sizing: A Review. *Particuology*, *11*(2), 135–147. https://doi.org/10.1016/j.partic.2012.05.010

Riebel, U., & Löffler, F. (1989). The Fundamentals of Particle Size Analysis by Means of Ultrasonic Spectrometry. *Particle and Particle Systems Characterization*, *6*(1–4), 135–143. https://doi.org/10.1002/ppsc.19890060124

Rosani, U., Hernaman, I., Hidayat, R., & Hidayat, D. (2024). The Relationship of Lignin and Crude Fiber in Rice Bran with Ultrasonic Wave Parameters. *Advances in Animal and Veterinary Sciences*, *12*(4), 586–801. https://doi.org/10.17582/journal.aavs/2024/12.4.791.801

Schmidt, C. G., & Furlong, E. B. (2012). Effect of Particle Size and Ammonium Sulfate Concentration on Rice Bran Fermentation with the Fungus Rhizopus Oryzae. *Bioresource Technology*, *123*, 36–41. https://doi.org/10.1016/j.biortech.2012.07.081

Wu, X., Yan, Q., Hedayat, A., & Wang, X. (2021). The Influence Law of Concrete Aggregate Particle Size on Acoustic Emission Wave Attenuation. *Scientific Reports*, *11*(1), 22685. https://doi.org/10.1038/s41598-021-02234-x

Xu, B.-W., Shen, Y., Zhang, Q.-A., Zhao, W.-Q., & Yi, X. (2019). Effect of Ultrasound Irradiation on the Particle Size Distribution and Rheological Properties of Red Wine. *CyTA - Journal of Food*, *17*(1), 180–188. https://doi.org/10.1080/19476337.2019.1569167

Yang, G., Lin, W., Lai, H., Tong, J., Lei, J., Yuan, M., Zhang, Y., & Cui, C. (2021). Understanding the Relationship Between Particle Size and Ultrasonic Treatment During the Synthesis of Metal Nanoparticles. *Ultrasonics Sonochemistry*, *73*, 105497. https://doi.org/10.1016/j.ultsonch.2021.105497