TURNITIN Biosilica forming by sol-gel extraction

by alfonsus oki

Submission date: 23-Jan-2024 09:06AM (UTC+0700)
Submission ID: 2206776484
File name: Biosilica_forming_by_sol-gel_extraction_method_of_rice_husk.pdf (2.73M)
Word count: 3718
Character count: 18168

RESEARCH ARTICLE | APRIL 25 2023

Biosilica forming by sol-gel extraction method of rice husk ash

Lydia Anggraini ✉; Putri Laila Anggraina; Temmy Wikaningrum

AIP Conference Proceedings 2630, 040008 (2023)
https://doi.org/10.1063/5.0125764

Biosilica Forming by Sol-Gel Extraction Method of Rice Husk Ash

Lydia Anggraini[1, a)], Putri Laila Anggraina[2, b)] and Temmy Wikaningrum[2, c)]

[1] Study Program of Mechanical Engineering, President University, Cikarang, Bekasi, West Java, Indonesia
[2] Study Program of Environmental Engineering, President University, Cikarang, Bekasi, West Java, Indonesia

[a)]Corresponding author: lydia.anggra@president.ac.id
[b)]putrianggraina@president.ac.id
[c)]temmy@president.ac.id

Abstract. Indonesia, as an agricultural country, produces much waste, especially from rice husk, which is a source of silica (SiO_2) production. Rice husk contains about 87% - 97% SiO_2 after complete combustion. SiO_2 extraction from ash of rice husk is carried out using an extraction process of solid-liquid with an alkaline as a solution solvent. The solid-liquid extraction process was done with 10 grams mass of rice husk ash added with 80 ml of potassium hydroxide (KOH) solution with a concentration of 10%, 15%, and 20% to extract the SiO_2 content with an operating time of 60 minutes. After the extraction process is complete, the solution is added with 1 N hydrochloric acid (HCl) to precipitate the SiO_2. The SiO_2 formed is then separated from the rest of the solution by filtration. The drying process is carried out to remove the moisture content of the resulting SiO_2. In this systematic study, HCl-washed rice husks were carried out in a muffle furnace for 60 minutes. The results showed that the samples produced SiO_2 with a polycrystalline structure, as confirmed by the results of analysis of the Energy-Dispersive X-ray Spectroscopy (EDS) that could be produced by solid-liquid extraction of KOH from rice husks ash. The amorphous SiO_2 has potential application as natural filler in rubber and environmentally friendly natural compounds.

INTRODUCTION

Recently, waste has become a new problem all over the world. Indonesia is one of the countries that face this problem. Many types of waste generate in Indonesia. As one agricultural countries, a rice husk as using a Silica (SiO_2) source is produced. Figure 1 shows the list of countries which produced milled rice in 2019/2020. Indonesia is in the third position to produce 34.7 million metric tons the milled rice after China and India. Meanwhile, more than 75% rice-growing countries, and more than 97% of husks are produced by developing countries [1, 10–17]. Rice is the basic staple food for Indonesians, which is also in line with the increase in staple food production in the other agricultural countries. The planted area expansion was measured with range from 11.786.400 to 14.116.600 ha in 2006 to 2015, respectively, with a 19.77% expansion rate, which is driven by increased rice production. Rice production was 54.459.900 and reached 75.397.800 tons in 2006 to 2015, with a 3.84% production rate per year [2]. On average, the top 10 rice producers from 2016 to 2019, Indonesia ranks third in the world as a rice-producing area, after China and India. China ranks first with an average rice production exceeding 211,378,225 tons, followed by India with 171,140,232.5 tons. Indonesia is in third place with increasing rice production, with annual rice production exceeding 58,156,641.75 tons in 2019 [3].

In addition to rice producing, rice husks also produced as a by-product. Dry milled rice is produced as 80 million tons in Indonesia per year in 2017, moreover, there are around 16 million weight tons of rice husks per year. The rice husks composition is controlled on the rice variety, situation of geographic and fertilizer type. Organic components can be converted into 20 percent of carbon dioxide, air, and ash via rice husks burn. The rice husk ash main component consists of 90-98 percent SiO_2, and Indonesia will produce 3.2 million tons of SiO_2 from rice husk ash per year [4].

Proceeding of International Conference on Energy, Manufacture, Advanced Material and Mechatronics 2021
AIP Conf. Proc. 2630, 040008-1–040008-7; https://doi.org/10.1063/5.0125764
Published by AIP Publishing. 978-0-7354-4453-9/$30.00

In all rice-producing countries, considered waste material is rice husk. Many husks of rice usually disposed of or burned in open fields. This can cause disturbance of the soil and pollution in environmental. Many attempts to utilize rice husks have been made, as well as SiO_2 [5]. After complete combustion, one of the primary sources of SiO_2 production is rice husk, 87–97%. SiO_2 ash is formed from ash of rice husk by controlled combustion at 500–600°C of high temperatures, which various chemical processes can be used [6]. SiO_2 is a compound of silicon dioxide that can be used in a variety of ways, is a significant standard material in the glass, ceramics, refractories industry, and for the manufacture of solutions of silicates, silicon, and their alloys is an essential raw material.

On the other hand, previous researchers (Kalapathy et al. in 2001, Pandiangan et al. in 2008, and Suka et al. in 2008) have researched SiO_2 extraction with alkaline solvents and SiO_2 deposition with acid [7–9]. Kalapathy et al. was examining the SiO_2 extraction from rice husks using sodium hydroxide (NaOH) for 1 N with an extraction method of two-cycle and yielded 91% yield at 2001 [7]. Pandiangan et al. was research the SiO_2 extraction from husks of rice using various concentrations of potassium hydroxide (KOH) solution and 10% nitric acid (HNO_3) solution as a trigger in 2008, and obtained from 50 grams of rice husk ash, the most enormous 1.8690 grams yield mass at a solution concentration of KOH, 1.5% for 30 minutes [8]. Another study conducted by Suka et al. was obtained the highest yield of 40.8% with the use of 5% KOH solvent with a reaction time of one hour in 2008 [9].

The purpose of this study was to confirm the conditions of the extraction process of rice husk ash into SiO_2 with different extraction times and concentrations of KOH and identify the formation of SiO_2 gel. The synthesis of SiO_2 gel by the extraction method is influenced by the concentration of the solvent, both acid and base. Generally, the acid solvents used such as sulfuric acid, hydrochloric acid, and nitric acid as inorganic acids. Furthermore, the reaction time and temperature also affect the microstructure and purity of the SiO_2 gel produced. The result of SiO_2 was confirmed through a sol-gel process with the influence of KOH concentration.

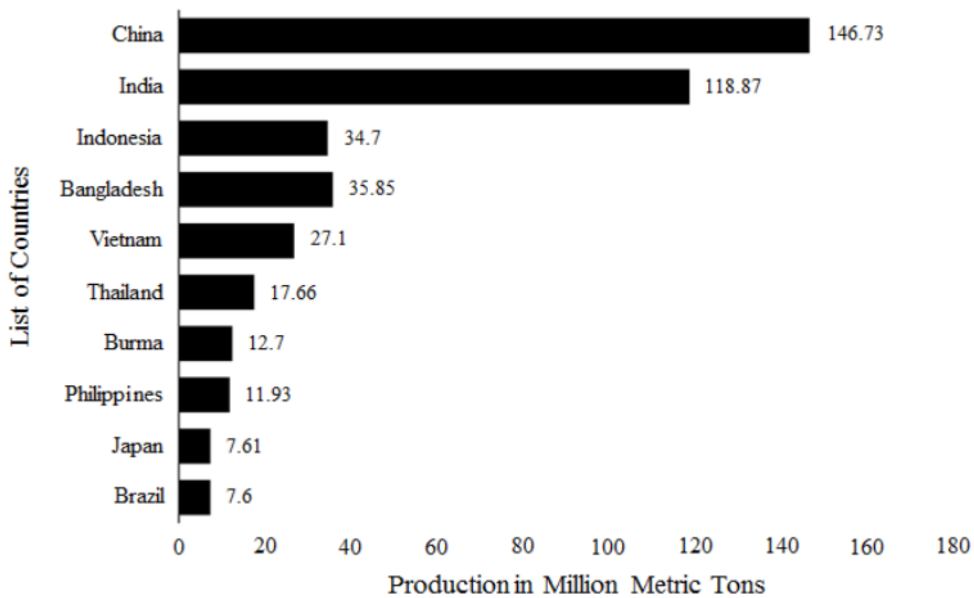

FIGURE 1. List of countries based on the production of milled rice in 2019/2020 [1].

EXPERIMENTAL PROCEDURES

Rice husk ash with a mass of 10 g is used in this study. Meanwhile, as a mixture in the manufacture of 1N Hydrochloric acid (HCl) and KOH solvents, the neutral acid of SiO_2 gel is using the aquadest (H_2O). Solid KOH is used itself, which is dissolved using H_2O in specific ratios into various concentrations of 10%, 15%, and 20%. HCl is used at a concentration of 37% for 1 N. The rice husk ash main components are shown in Table 1.

An Erlenmeyer tube is used in this study as a container for liquid chemicals in the form of laboratory glassware. In addition, this glass is also often used for the titration process to accommodate the solution to be used. Measuring cups are also used as a tool to measure the volume of a solution or liquid that looks like a funnel or glass that has a volume size that varies in milli litre (ml). To obtain the homogeneous solution, the hot plate magnetic stirrer is also used to heat and stir the solutions with a stirring rod. In the heating process, a furnace is used, which is a tool commonly used to extract metals from ores or smelters or in oil refineries and other chemical plants, as well as other applications as a heat source for fractional distillation pipes. Moreover, the oven is also used to heat or dry the sample. Meanwhile to dry glassware in the laboratory, chemicals and organic solvents can be used in the oven before the equipment is used, as well as for wet materials. In addition, the oven is also used for dry air sterilization. This sterilizer is used to sterilize glassware such as Erlenmeyer tubes, Petri-disks or Petri dishes, test tubes, and other glasses. To smooth or crush coarse particles is use a mortar and pestle. The mortar is the part of the container, while the pestle is the part of the stem held in place. The grinding duration depends on the type of material and the strength of the grinder. A digital scale is used for measuring the weight or mass of materials. The glass spatula is used to pick up solid or powder chemicals at the time of weighing. In addition to picking up chemicals, another function of the spatula is used to stir the mixture in a solution.

TABLE 1. The main component in the rice husks

Component	Content (% weight)
Water content	9.0
Crude protein	3.0
Fat	1.1
Crude fiber	32.6
Ash	20.3
Crude Carbohydrates	13.7
Carbon (Charcoal)	20.3

The various ratio of alkaline solvent KOH is used for 10%, 15%, and 30% with an extraction time of 60 minutes. The particle size is 100/80 mesh, the ash weight is 10 g, the extraction temperature is 90°C, the acid solvent type of HCl 1 N is chosen with the mixing speed of 100 rpm. The research procedure's step by step is as follows; first 5 kg of rice husk charcoal is used, followed by a pound with a pestle until smooth. The husk charcoal that has been pounded is followed by a filter using an iron sieve measuring 60 meshes. Rice husk charcoal with 500 g mass is put into the furnace. The heating process of the rice husk charcoal is carried out at 700°C furnace temperature for 4 hours, until the ash form. The ash result is pounded using a pestle, followed by filter using a 100-mesh sieve.

In addition, the SiO_2 Extraction Process is started by a 10 g mass of dry rice husk ash to be dissolved in 80 ml of KOH with concentrations (10%, 15%, and 20%). The heating process is carried out using a hot plate at a temperature of 85°C with a magnetic stirrer for a 60 min time. After cooling, filter paper is used to filtered the solution to separate the residue and filtrate. The resulting filtrate is taken.

The process of making SiO_2 gel is as follows first is 30 ml of potassium silicate solution is prepared into a breaker glass. The second is gently dropping the potassium SiO_2 solution with 1N HCl solution while magnetic stirrer used to stirring until a white gel with a neutral pH is formed. Let the gel that has formed at room temperature for 18 hours. The third is to filter, rinse the SiO_2 gel, and to remove excess acid with distilled water. Fourth, dry the SiO_2 gel in an oven at 120°C until the weight is constant, then crushed with a mortar. Last is filtering with 40 mesh, and SiO_2 gel was obtained. The basic characteristic of dry rice husks and husk ash available in some areas in Indonesia, are shown in Table 2 [10]. In this basic chemical compositions, some elements i.e. Al_2O_3 or ZnO are not detected at very old technology when it used.

TABLE 2. Chemical compositions of dry rice husk and husk ash basis (%) [10]

Content (origin)	Ash	SiO_2	CaO	MgO	Fe_2O_3
Rice Husk (Karawang)	25.486	22.785	1.24	1.02	0.40
Rice Husk (Tangerang)	20.359	17.559	0.141	0.033	0.091
Black Husk Ash (Karawang)	33.572	31.189	0.433	0.137	0.315
Black Husk Ash (Tangerang)	33.555	30.822	0.504	0.115	0.342
White Husk Ash (Karawang)	99.095	91.306	0.759	0.164	0.572
White Husk Ash (Tangerang)	98.097	90.703	0.914	0.190	0.571

RESULTS AND DISCUSSIONS

Extraction is the process of separating a mixture using solvents. Solid-liquid extraction is the type of extraction used in this research. Solid-liquid extraction is a process that involves a mass transfer in between the phases. In this case, the rice husk ash acts as the solid phase and the KOH as the extractant. In extraction of solid-liquid, when mixing the extractant with the extracted material, the solid will react with the extractant to form an extract. In the solid-liquid extraction process, a very long reaction between the extractant and the solid is required. SiO_2 contained in rice husk ash is recovered by dissolving it in an alkaline solution. The reaction that occurs is between SiO_2 contain in rice husk ash and an alkaline solution. In this case, the KOH solution is occur on the reaction (1).

$$SiO_2 + 2\ KOH \rightarrow K_2SiO_3 + H_2O \tag{1}$$

The SiO_2 compound formed is still in the form of a potassium silicate solution. Then the solution is added with 1 N HCl, which is used to bind potassium to produce SiO_2. The reaction that occur is described in the reaction (2). Figure 2 and 3 are shows the burning rice husk charcoal before and after entering into a furnace, respectively.

$$K_2SiO_3 + HCl \rightarrow SiO_2 + KCl + H_2O \tag{2}$$

The result of dried coarse SiO_2 which generated from the rice extraction using the hydrochloric acid solution is shown in Fig. 2. The function of HCl is as a precipitation agent. SiO_2 compounds are easy to solve in alkaline conditions and will settle in an acidic atmosphere [7]. Based on this, to create SiO_2 compounds easily extracted from rice husks, an alkaline solvent, KOH solution, is used, and after that, an acid solution, 1 N HCl, is used to precipitate it again. After the SiO_2 compound are-settled, by drying in an oven, can be removed, the H_2O levels which affect the product moisture. In this process, SiO_2 deposits produced still contain a lot of coprecipitation. The following figure shows the stages of forming the extracted SiO_2 gel as shown in Figure 2.

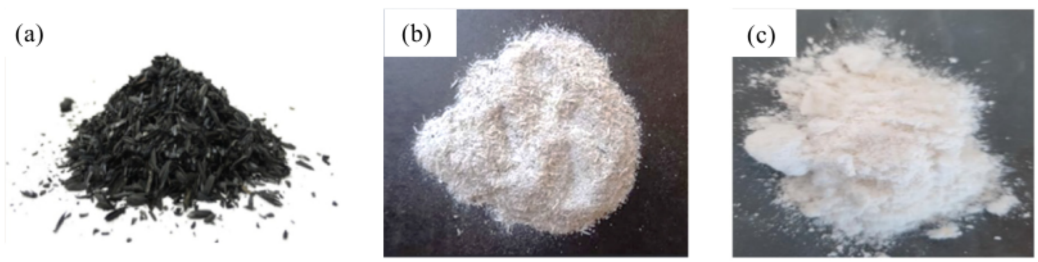

FIGURE 2. Step by step of SiO_2 forming. Burning rice husk charcoal (a) before furnace treatment, (b) after furnace treatment, and (c) dried coarse silica precipitate after sol-gel extraction

By various KOH concentrations and times are examined to obtain the sol-gel SiO2, through the husk ash extraction process. It was obtained that there is a slight difference the density of SiO_2 gel with various in extraction times and KOH concentrations, from the results of this study. Factors that affect the density is due to extraction include the size of the material particle. The smaller size results of the particle, has resulted in the contact area larger between the solvent and the solid. The extraction temperature is also has slight affects on the density yield. The solubility of the extracted material and its ability to diffuse will increase with increasing temperature. However, too high a temperature can damage the extracted material, so the optimum temperature is used.

Energy Dispersive X-ray Fluorescence (XRF) is used to identify the purity of SiO_2 and the chemical composition, which is produced from the rice husk ash. Table 3 shows that contains a small number of metallic impurities and SiO_2 is the main component. It notice that KOH extraction was effectively removed metal impurities in rice husk ash. The other elements is appear such as MgO, P_2O_5, SO_3, and K_2O due of the effect during the extraction process or the possible contamination. Therefore, more specific analysis is done using the Energy-Dispersive X-ray Spectroscopy (EDS).

TABLE 3. Elements of SiO_2 in the KOH sol-gel extraction result

Elements (%)	10% KOH	15% KOH	20% KOH
SiO_2	85.663	88.487	90.078
MgO	1.729	1.863	1.596
Al_2O_3	1.908	2.693	1.968
P_2O_5	1.583	2.058	1.971
SO_3	0.047	NA	NA
K_2O	0.350	0.011	0.045
CaO	0.063	0.061	NA
MnO	0.437	NA	0.545
Fe_2O_3	2.395	0.751	0.412
ZrO_2	1.543	1.271	0.645
C	0.500	0.338	0.543
CrO	3.782	2.467	2.197

Figure 3 and 4 show the EDS analysis data of polycrystalline SiO_2. The peak observed at 2θ around 45 eV indicates the formation of a non-crystalline SiO_2 phase in the sample. Under high-temperature conditions, the Si-O groups bond to give the low-temperature forms of crystobalite and tridymite crystalline [11, 12]. There is a versatile possibility of using heat-treated rice husks as a filler for elastomers, such as white ash is used as filler for polyethylene [13], polypropylene [14], and polystyrene [15]. SiO_2 with this amorphous crystalline structure contributes to tire durability, which measurable in terms of its efficiency factor [16]. The amorphous SiO_2 efficiency is confirmed as the additive dose ratio to the amount of rubber, which can be replaced to maintain the strength [17]. Thus, it is inevitable that by using a mixture of amorphous SiO_2, an eco-friendly tire filler can be produced in the future.

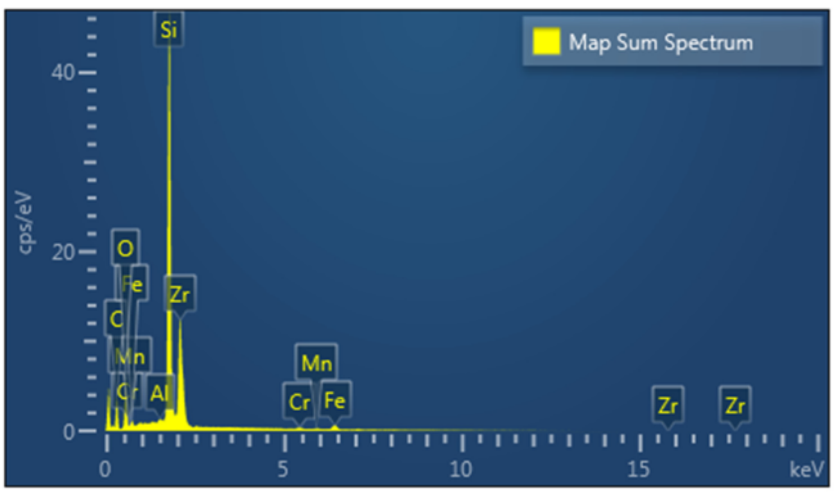

FIGURE 3. EDS image of amorphous SiO_2 as the sol-gel extraction result

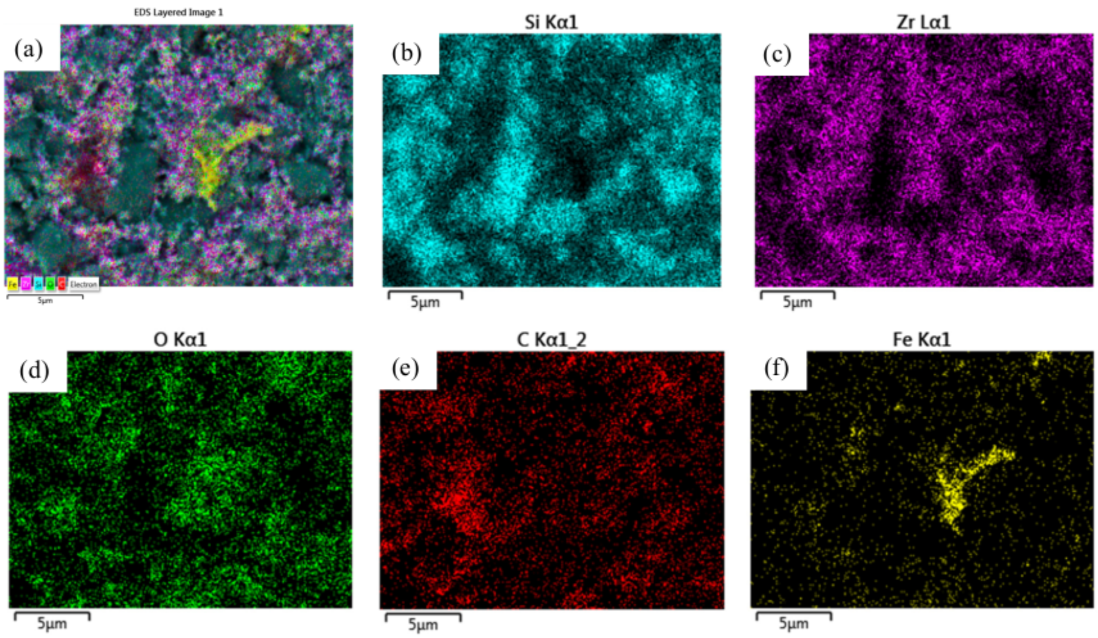

FIGURE 4. Scattering elements of (a) all, (b) Si, (c) Zr, (d) O, (e) C and (f) Fe elements

CONCLUSION

A polycrystalline SiO_2 was produced from rice husk by KOH solid-liquid extraction. By these process conditions, the SiO_2 was obtained and had potential application as in rubber filler as well as other types of compounding. In addition, the SiO_2 might be possible to applied as a catalyst support or adsorbent in the pure chemical synthesis.

ACKNOWLEDGMENTS

This research is fully funded by Direktorat Riset dan Pengabdian Masyarakat, Indonesian Ministry of Research and Technology Badan Riset dan Inovasi Nasional, based on the decree No. B/1176/E3/RA.00/2020 competitive grant of basic research.

REFERENCES

1. L. Armesto, A. Bahillo, K. Veijonen, A. Cabanillas, and J. Otero, "Combustion behaviour of rice husk in a bubbling fluidised bed," Biomass Bioenergy 23(3), 171–179 (2002).
2. H. Lubis, "Renewable Energy of Rice Husk for Reducing Fossil Energy in Indonesia," J. Adv. Res. Appl. Sci. Eng. Tech. 11(1),17–22 (2018).
3. T. Anggraeni, "A Comparative Study of Indonesian Estimated Rice Production and Consumption," J. Anal. Keb. Pel. Pub. 101–112 (2020).
4. N. Setyawan, and A. Wulanawati, "Simple extraction of silica nanoparticles from rice husk using technical grade solvent: effect of volume and concentration," In IOP Conf. Ser.: Earth Env. Sci. 309(1), 012032 (2019).
5. J.M. Wu, C.K. Chang, and Y.T. Chang, "High-output current density of the triboelectric nano generator made from recycling rice husks," Nano Energy 19, 39–47 (2016).
6. H. Moayedi, B. Aghel, H. Nguyen, and A.S.A Rashid, "Applications of rice husk ash as green and sustainable biomass," J. Cleaner Prod. 237, 117851 (2019).

7. U. Kalapathy, A. Proctor, and J. Shultz, "An improved method for production of silica from rice hull ash," Biores. Tech. 85(3), 285–289 (2002).
8. K.D. Pandiangan, I.G. Suka, M. Rilyanti, S. Widiarto, D. Anggraini, S. Arief, and N. Jamarun, "Characteristic of catalyst acidity of rice husk based silica obtained by sol-gel method." J. Sains Tek. Univ. Lampung (2008) [in Bahasa].
9. I.G. Suka, W. Simanjuntak, S. Sembiring, and E. Trisnawati, "Characteristic of Extracted Rice Husk Silica Originated from Lampung Province," MIPA Pemb. 37(1) (2009) [in Bahasa].
10. K. Soebijarso, "Rice Husk in Indonesia," J. Kim. Kemas. 3(11), 1–3 (1979).
11. E.T. Champagne, D.F. Wood, B.O. Juliano, and D.B. Bechtel, "The rice grain and its gross composition," Rice Chem. Tech. 3, 77–107 (2004).
12. I.B. Ugheoke, and O. Mamat, "A critical assessment and new research directions of rice husk silica processing methods and properties," Maejo Int. J. Sci. Tech. 6(3), 430–448 (2012).
13. Xiong, L., Sekiya, E.H., Sujaridworakun, P., Wada, S., and Saito, K., "Burning Temperature Dependence of Rice Husk Ashes in Structure and Property," J. Met. Mat. Min. 19(2), 95–99 (2009).
14. Della, V.P., Kühn, I., and Hotza, D., "Rice husk ash as an alternate source for active silica production," Mat. Letters 57(4), 818–821 (2002).
15. Hao, L., Gong, X., Xuan, S., Zhang, H., Gong, X., Jiang, W., and Chen, Z., "Controllable fabrication and characterization of biocompatible core-shell particles and hollow capsules as drug carrier," Appl. Surf. Sci. 252 (24), 8724–8733 (2006).
16. Permatasari, N., Sucahya, T.N., and Dani Nandiyanto, A.B., "Review: Agricultural Wastes as a Source of Silica Material," Indo. J. Sci. Tech. 1(1), 82 (2016).
17. Athinarayanan, J., Periasamy, V.S., Alhazmi, M., Alatiah, K.A., and Alshatwi, A.A., "Synthesis of biogenic silica nanoparticles from rice husks for biomedical applications," Ceram. Int. 41(1), 275–281 (2015).

TURNITIN Biosilica forming by sol-gel extraction

ORIGINALITY REPORT

5%	3%	3%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

1%

★ Lydia Anggraini, Hendra Jaya Tarigan, Joni Welman Simatupang. "Metamaterial and metasurface based emitters for solar thermal photovoltaic applications: analytical review", Bulletin of Electrical Engineering and Informatics, 2022

Publication

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		