ESTA JOURNAL
Energy Storage Technology and Applications
Article
jurnal.uns.ac.id/esta

Agriculture waste-based silica for enhancing the preservation of ruminant feed

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Received:05-11-2023; Revised: 30-11-2023; Accepted: 21-12-2023; Published: 16-02-2024

ABSTRACT: Indonesia, the third largest global producer of rice, has yet to fully optimize the utilization of rice husk ash, which is generated as a waste byproduct. The silica content of rice husk ash ranges from 15% to 20%, indicating its potential suitability as a viable source material for silica production. The acid leaching procedure employing hydrochloric acid was utilized in this study. The present investigation resulted in the acquisition of silica with a yield of 42.55%. The morphological examinations conducted using a digital microscope yielded black silica powder particles measuring between 0.03 and 0.08 mm in size. The SEM-EDX characterization findings indicate that the predominant constituents of silica are silicon (Si) and oxygen (O), accounting for approximately 73.14% ± 1.59% and 26.86% ± 1.64% of the composition, respectively. The experimental results of the water adsorption test indicate that silica exhibited an average adsorption velocity of 0.021 g/h and an average adsorption capacity of 11.23%. Silica can effectively maintain the moisture content of animal feed at levels below 10%, thereby impeding the proliferation of mold inside the spread.

Keywords: Silica, Rice husk, Acid leaching, Ruminant feed.

1. Introduction

Indonesia ranks as the third most prominent global producer of rice, following Republic of China and India. In 2005, Indonesia's rice production amounted to 54 million tons. The productivity discussed in this context represents around 9% of the overall global production and has exhibited a consistent upward trend, culminating in a total output of 66 million tons by 2010 [1]. As Smart agriculture continues to advance, farmers are more compelled to adopt an integrated agricultural system to mitigate adverse environmental effects. One potential approach for the implementation of this system is the integration of agricultural and livestock systems. The concept of an agricultural and livestock integration system pertains to a methodology amalgamating agricultural and livestock practices, establishing a more sustainable, efficient, and environmentally beneficial agricultural and livestock system. Agricultural and livestock activities might be integrated by exchanging organic waste materials. The utilization of livestock waste as organic fertilizer in farming practices and the repurposing of agrarian waste as animal feed are viable strategies.

High-quality animal feed must be provided to support livestock's physiological needs and growth. The storage method is a significant factor that impacts the quality of animal feed Fields[2]. Inadequate storage practices can result in degrading essential nutrients inside animal feed. The oxidation and destruction of nutrients, such as vitamins, amino acids, and lipids, can be initiated by environmental factors such as dampness and high temperatures [3]. According to a study conducted by Min, Attwood, McNabb, Molan, and Barry (2005), moisture in feed provides optimal circumstances for the proliferation of bacteria and fungi, which subsequently generate heat [4]. The degradation of feed quality, alteration of scent, and synthesis of detrimental chemicals can be attributed to the effects of heating and spoiling in animal feed.

Currently, the predominant utilization of agricultural waste entails its conversion into animal feed. This study uses rice husks, an agricultural waste, to produce high-value products. Rice husks comprise approximately 50% cellulose, 25 to 30% lignin, and 15 to 20% silica, thereby indicating their potential suitability as viable sources for silica production [5]. Silica is a group of minerals composed of a single silicon atom (Si) and two oxygen atoms (O_2). Silica exhibits non-conductive properties and favorable resistance to oxidation and thermal degradation [6]. Silica displays a range of distinctive characteristics that distinguish it from other inorganic compounds. Notably, it possesses commendable adsorption and ion exchange properties, owing to the presence of silanol groups (Si-OH) and siloxane groups (Si-O-Si) [7]. This study focuses on implementing innovation in amalgamating agricultural and livestock systems using silica derived from rice husks. The primary objective is to mitigate excessive moisture in animal feed, enhancing its durability and longevity.

The leaching method is a viable approach for extracting silica from rice husks. Leaching refers to the scientific procedure of extracting substances from solid materials through the dissolution of said substances in a liquid solution. The present study involves the synthesis of silica through the acid leaching method, utilizing the residual ash derived from the combustion of rice husks. Hydrochloric acid (HCl) is employed as the acid of choice due to its non-reactivity with SiO_2, thereby facilitating the production of high-purity silica [8]. This method was selected based on its ease of implementation, low-temperature requirements, and ability to yield silica with exceptional purity and uniformity [9]. The synthesized silica was characterized using a Digital Microscope and Scanning Electron Microscope-Energy Dispersive X-ray (SEM-EDX) to ascertain its size and composition. In addition, a water absorption test was conducted to determine the water absorption capacity.

2. Experimental Method

2.1 Material

The materials used in this research were rice husk ash, HCl, and distilled water. The tools used are analytical balances, volumetric flasks, volume pipettes, measuring pipettes, clamps, states, beakers, thermometers, Petri dishes, porcelain dishes, filter paper, ovens, glass funnels, and desiccators. A digital microscope and SEM-EDX were used to characterize the silica products.

2.2 Methodology

As depicted in Figure 1, the leaching procedure involves the chemical reaction between 250 grams of rice husk ash and 1000 ml of a 4 M HCl solution. The experiment is conducted within a beaker equipped with a stirrer heater, with the temperature set to 80°C [10]. After 60 minutes, the solution underwent filtration using filter paper and subsequent rinsing with distilled water until achieving a neutral pH level. The solid that had undergone filtration was subsequently transferred into a porcelain cup and subjected to a drying process in an oven set at a temperature of 80^{o}C. The outcome is the production of powdered silica.

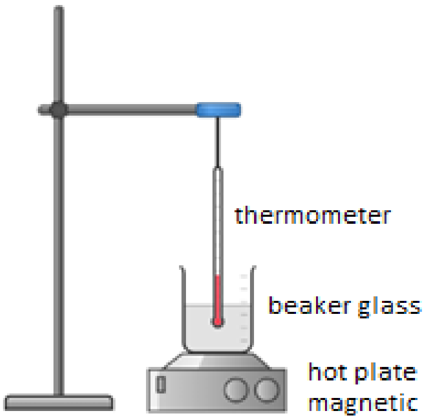


Figure 1. Leaching Process

2.3 Characterization

This study involved the evaluation of silica products through the implementation of four distinct testing methodologies. These methodologies encompassed morphology assessments utilizing a digital microscope and morphology and composition analyses employing SEM-EDX. Additionally, water adsorption capacity tests and water adsorption experiments on animal feed were conducted as part of the investigation.

2.3.1 Morphology Test with a Digital Microscope

This test used a digital microscope to observe silica powder's color, shape, and size characteristics. As depicted in Figure 2, the silica particles are initially subjected to a sieving process using a 100-mesh sieve. Subsequently, the specimen was examined utilizing a digital microscope featuring a magnification power of 1600x.

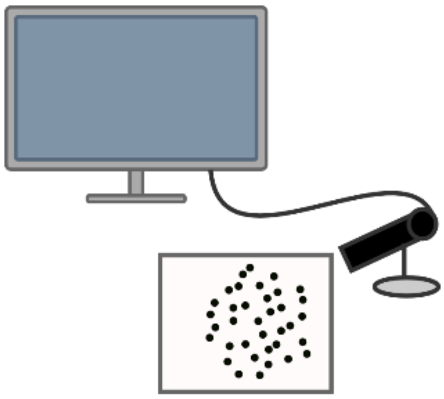


Figure 2. Morphology Test with a Digital Microscope

2.3.2 Morphology and Composition Test with SEM-EDX

This test aims to analyze silica particles' surface characteristics and chemical composition at either the micro-scale or nano-scale level. The silica particles are initially separated using a sieve with a mesh size of 100. Subsequently, the specimen was subjected to scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDX) analysis at magnifications of 500x and 2500x.

2.3.3 Water Adsorption Capacity Test

The purpose of this experiment was to assess the water absorption capacity of silica. The water adsorption capacity is quantified as the quantity of water adsorbed in silica within a specific timeframe relative to the initial mass of silica. The silica sample was first measured using a precision analytical balance and subsequently transferred into a glass jar containing a beaker. Pour 100 milliliters of distilled water into the beaker. Following 24 hours, the silica substance was subjected to weighing to ascertain the quantity of water that the silica had absorbed.

Figure 3. Water Adsorption Capacity Test

2.3.4 Water Adsorption Test on Animal Feed

This test aimed to assess silica adsorption's efficacy in mitigating water absorption in animal feed. The process involves the measurement of silica powder followed by its encapsulation within filter paper. Subsequently, transfer the substance above into a receptacle specifically designed to store animal nourishment and allow it to undergo a period of seven-day maturation.

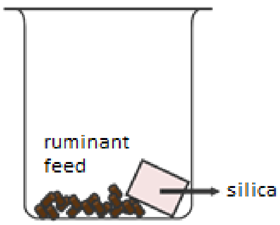


Figure 4. Water Adsorption Test on Animal Feed

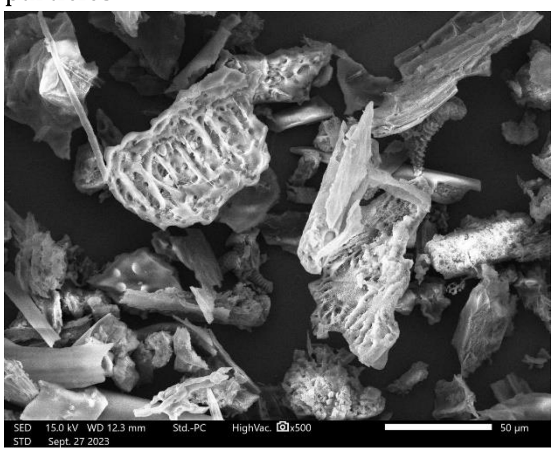
3. Results and Discussion

3.1 Morphological Test Results with a Digital Microscope

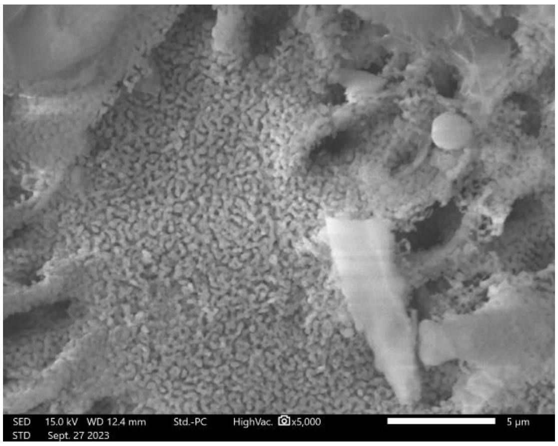
Using a digital microscope yielded findings of silica powder exhibiting a coarse texture and a dark hue, potentially indicating the presence of residual impurities. The present study successfully acquired silica powder within a relatively narrow size range of 0.03 - 0.08 mm, as depicted in Figures 5a and 5b. Figure 5. Observation Results with a Digital Microscope: (a) Minimum Size of Silica, (b) Maximum Size of Silica.

3.2 Morphology and Composition Test Results using SEM-EDX

The presence of silica particles, depicted in Figure 6, is characterized by an uneven distribution and a white coloration. These particles are observed to form lumps or clusters, with microcracks present between them, resulting in the separation of the nodes [11]. This observation suggests that the particles exhibit an uneven distribution and possess diverse sizes, ranging from 1 μ to 92 μ. Consequently, silica has a sufficiently large surface area to facilitate adsorption. Silica exhibits a coral-like morphology in larger dimensions, whereas, in its most petite sizes, it adopts a granular structure resembling sand particles.



(a)



(b)

Figure 6. SEM Test Results: (a) 500x magnification, (b) 5000x magnification

According to the EDX analysis depicted in Figure 7, the predominant constituents of silica derived from rice husk ash are silicon (Si) and oxygen (O), comprising approximately 73.14 ± 1.59 % wt and 26.86 ± 1.64 % wt, respectively. The results suggest that the acid-leaching method was effective in achieving a high level of purity in the extracted silica.

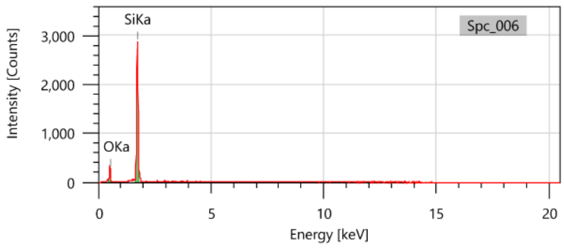


Figure 7. EDX Spectrum of Synthesized Silica

3.3 Water Adsorption Capacity Test Results

During the experiment, it was determined that the mass of silica exhibited an increase after the implementation of an adsorption test, thereby substantiating the silica's capacity to absorb water. Table 1 presents the data obtained from four leaching experiments, including information on silica yield, mass of water absorbed, adsorption capacity, and average adsorption velocity. The greater the silica yield, the higher the adsorption capacity and velocity value.

Table 1. Water Adsorption Test Results

Sample/ Variable	Silica yield	Adsorption Capacity	Adsorption Velocity (gram/h)
Experiment -1	35.90%	10.03%	0.015
Experiment -2	43.90%	12.98%	0.024
Experiment -3	49.50%	17.17%	0.035
Experiment -4	40.90%	5.00%	0.009
Average	42.55%	11.23%	0.021

3.4 Results of Water Absorption in Animal Feed

Water or moisture absorption tests for animal feed are conducted by altering the weight ratio of feed with silica within the range of 4:1 to 2:1. According to the data presented in Table 2, there is a direct relationship between the size of the ratio and the amount of water absorbed, whereby a smaller ratio corresponds to more excellent water absorption. Silica has demonstrated the capacity to effectively decrease the moisture content of animal feed at a ratio of 3.3:1. The moisture content of animal feed typically exhibits a consistent range of 2.8:1 to 2:1. The test results revealed that the optimal conditions for adsorption were observed at a ratio of 2.8:1.

Table 2. Water Adsorption Test Results in Animal Feed

Animal feed weight (gram)	Silica weight (gram)	The water content of feed before adsorption	The water content of feed after adsorption
100	25	10.11%	10.11%
100	30	10.11%	10.01%
100	35	10.11%	9.91%
100	40	10.11%	9.92%
100	45	10.11%	9.91%

4. Conclusion

Based on the study, it can be concluded that rice husk ash exhibits promising potential as a viable raw material for producing natural silica. High-purity silica can be obtained using the acid-leaching method. The silica generated exhibits the capability to mitigate excessive moisture levels in animal feed during storage to create a sustainable agricultural and livestock integration system.

Acknowledgment

This study was supported by the Universitas Sebelas Maret, Surakarta, Indonesia, under Research Grant No. 229/UN27.22/PM.01.01/2023.

Conflict of Interest

We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere. In addition, all authors have agreed to publish this article. We also have no conflicts of interest to disclose.

Author Contributions

The experiment was carried out by Firman Asto Putro, Cornelius Satria Yudha, Dyah Ayu Mutiara Anggraeni, and Fadhilah Nurayuni Priyaningsih. The report was written and revised by Firman Asto Putro, Cornelius Satria Yudha and Windhu Griyasti Suci, Esa Nur Shohih, Muhammad Iqbal Al Fuady, Himmah Sekar Eka Ayu Gustiana. All contributors committed to the final report.

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