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Extraction and Equipment Design of Silica using Rice Husk

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Abstract

Rice is one of the most widely produced crops in the world, and the kernel (hull) of the rice is separated from the remaining grain after the paddy has been removed. Rice husk is a common agricultural by-product in nations that produce rice, and India produces 12 million metric tons of rice husk each year. Rice husk is often not advised as cow feed due to its poor cellulose and other sugar levels. Furfural and rice bran oil are produced from rice husk, and industries burn rice husk to generate electricity and as a fuel for boilers. Silica, which makes up 85% to 95% of rice husk ash, is its main component. Silica, additionally called silicon dioxide, is a naturally occurring compound which is observed in diverse minerals, rocks, and soils. It is a chemical compound which includes silicon and oxygen atoms and has quite exclusive physical and chemical properties which make it beneficial in lots of unique industries. Silica is valued for its hardness, chemical and thermal stability, and capacity to take in moisture, making it a crucial material for an extensive variety of engineering applications. Some of the common applications of silica consist of the manufacturing of glass, ceramics, cement, and digital components. Silica is likewise used as a filler in diverse materials, inclusive of plastics, rubbers, and adhesives, to enhance their mechanical properties, including power and durability. This project aims to present a straightforward method for producing silica from this used rice husk, making husk disposal easier and a useful product may be made from it, which has a high silica content but a low ash level. It is more cost-effective to extract silica from the ash, which has a broad market and also takes care of ash disposal. Experimental results demonstrate improved performance and practical use of the method along with equipment designs of ball mill and CSTR for understanding of the process on an industrial level.

Keywords: *Rice husk; Agricultural by-product; Cellulose; Silica; Rice husk ash; Cost-effective; High silica content*

1. INTRODUCTION

1.1 General

Silica, additionally called silicon dioxide, is a naturally occurring compound which is observed in diverse minerals, rocks, and soils. It is a chemical compound which includes silicon and oxygen atoms and has quite exclusive physical and chemical properties which make it beneficial in lots of unique industries.

Silica is valued for its hardness, chemical and thermal stability, and capacity to take in moisture, making it a crucial material for an extensive variety of engineering applications. Some of the common applications of silica include the manufacturing of glass, ceramics, cement, and digital components. It can also be used in anti-caking and anti-frothing agents. Silica is likewise used as a filler in diverse materials, inclusive of plastics, rubbers, and adhesives, to enhance their mechanical properties, including power and durability [1].

Table 1*: Chemical Composition of Rice Husk Ash*

Component	Weight %
Silica (SiO_2)	91.59
Carbon (C)	4.8
Calcium Oxide (CaO)	1.58
Magnesium Oxide (MgO)	0.53
Potassium Oxide (K_2O)	0.39
Hematite (Fe_2O_3)	0.21
Sodium (Na)	Trace
Titanium Oxide (TiO_2)	0.20

From Table 1, we can understand the chemical composition of rice husk ash and how much amount of each chemical elements are present in rice husk ash in weight percentage.

1.2 History and Background

Silica, also known as silicon dioxide (SiO_2), is a compound found widely in nature and has a rich history dating back many centuries. Its unique properties and abundance have made it an essential material in many different fields, from industry to technology and even in the realm of art and culture.

The geological origin of silica goes back to its formation by natural processes. It usually occurs as a mineral in the earth's crust and is a major component of rocks such as granite, quartzite, and sandstone. Silica minerals are formed by the cooling and solidification of magma, resulting in the crystallization of silica-rich magma. Quartz, one of the most abundant minerals on Earth, is composed of silica and has many applications due to its superior physical and chemical properties [3].

The study of silica and its properties received considerable attention in the 19th century. Thomas Graham, a Scottish chemist, made significant contributions to the understanding of colloids and was a one of the pioneers in silica gel research. His work laid the foundation for later advances in the field. In 1919, Samuel Kistler developed the first industrially viable process to make air gel, a highly porous form of silica. This breakthrough has opened up new possibilities for the practical application of silica in various industries [4].

Throughout the 20th century, the study of silica continued to evolve thanks to the efforts of scientists and researchers around the world. Donald W. Iler, an American chemist, made important contributions to the understanding of silica particles and colloidal systems. His book

"The Chemistry of Silica" published in 1979 became a fundamental reference in the field. Iler's work not only enhanced the understanding of silica, but also influenced the study of other inorganic colloidal systems, expanding the knowledge base of scientists working in related disciplines [4].

The importance of silica extends beyond its geological and chemical properties. Its unique characteristics, such as high heat resistance, electrical insulating properties, and optical transparency, have made it a valuable material in various industries. Silica is used in the manufacture of glass, ceramics, semiconductors, and optical fibers. It is also used in the manufacture of rubber, paints, coatings, and cosmetics, among many other products [2].

In summary, the history and context of silica reveal a fascinating journey of discovery and innovation. From its geological origins to the pioneering research of scientists like Graham and Iler, silica has become a versatile and indispensable material in many fields. Its diverse range of applications and unique attributes continue to drive progress and create new possibilities in all industries [2][4].

1.3 Extraction of Silica

The extraction of silica from various sources has received considerable attention in recent years due to its potential as a sustainable and valuable resource for various industries. Silica can be obtained from minerals, rocks, and plants, and researchers have explored alternative extraction techniques to overcome the complexity, cost, and environmental impact associated with conventional methods.

Silica deposition in plants performs important biological and biochemical functions, contributing to stress reduction, defense mechanisms and overall plant health. Silica acts as a defense system, reducing lipid peroxidation, supporting metal detoxification, and improving drought tolerance. It also forms a physical barrier against pathogens [5].

The structure of silica varies among plant families and interacts with the cell wall. Environmental factors affect silica polymerization and the association between silica and organic compounds affects silica nucleation. Research involving biomolecules and model systems provides information on silica formation. To understand the function of silica in higher plants requires further research, which may help improve crop yield and disease resistance [5].

Extracting silica from natural sources, including quartz sand and agricultural wastes, has been extensively studied for its potential applications as a support material for antimicrobial photocatalysts. The extraction processes involve thermal, biological, and chemical methods.

Chemical methods using acids and bases are commonly used due to their simplicity. Silicon nanoparticles obtained from different sources showed variation in particle size and yield. The size of silica particles affects their photocatalytic activity and antibacterial properties. Silica can enhance the surface area and semiconductor activity of photocatalysts, acting as a green filler. Incorporating silica into the photocatalyst improves adsorption, photocatalytic reactivity, and stability [6].

Silica-supported nanoparticles have demonstrated significant bactericidal effects and have found applications in textiles and coatings. Many studies including synthesis, characterization, and application of silica, explore the potential of silica nanoparticles from waste in different fields [6].

In addition to plant and mineral sources, lignin-silica hybrids can be obtained from biomass sources by alkaline fractionation and pH adjustment. The binding mechanism between lignin and silica has been studied and the resulting hybrids have applications in biotechnology, energy storage and environmental remediation [7].

Pyrolysis of hybrids under inert gas conditions yields carbon-silica materials with various applications. The quality of the obtained material depends on the extraction method used, and alkaline treatment combined with acid pH adjustment has been proposed for efficient recovery. Advanced stabilization of lignin and silica materials shows great promise in conductive and electrochemical materials to contribute to zero-waste production processes and the use of agricultural by-products [7].

Ongoing research and development on techniques to extract silica from a variety of sources, including plants, minerals, and rocks, offers the potential for sustainable use in various industries. The discovery of innovative mining methods will further improve silica applications and contribute to sustainable development [5][6][7].

Acid filtration involves treating the husks with hydrochloric acid or sulfuric acid to dissolve the silica, followed by filtration and purification. The use of acid filtration for silica extraction has been explored in several studies, highlighting its effectiveness in obtaining high purity silica. Acid filtration is a less complicated and more environmentally friendly alternative to conventional techniques for extracting silica from minerals and rocks [8][11].

Another method to extract silica from rice husks is alkaline extraction using sodium hydroxide. Alkali treatment dissolves the silica, which is then filtered and purified to obtain a high-purity silica product [8].
Efficient rice husk treatment using alkaline peroxide treatment, acid precipitation and ethanol extraction has been studied, demonstrating the potential to convert waste biomass into valuable components, including silica. [9].

Heat treatment is also used to extract silica from rice husks. In this method, the rice husks are burned at high temperatures to remove organic matter, leaving behind a silicon-rich residue. The silica residue is then treated with an acid or alkaline solution to remove impurities and produce a high-purity silica product [8].

Heat treatment provides an alternative method to extract silica from rice husks and its effectiveness has been demonstrated in various studies. Silica extracted from rice husk has many uses in commercial industries, including ceramics, glass, cement, plastics, rubber, and adhesives. Silica extracted from rice husks has been used in refractory insulating materials, producing glass, white ceramics, and oxide ceramics such as mullite and cordierite [8][11].

It has also been used in the synthesis of lithium alumino-silicate, forsterite, and silicon carbide. The use of husk-derived silica offers a sustainable and cost-effective alternative to traditional silica sources, contributing to sustainability [8].

The literature review shows that the extraction of silica from rice husks is a promising area of research and development. Various techniques, including acid filtration, alkaline extraction, and heat treatment, have been explored and optimized for efficient silica extraction [8][11][12].

The extracted silica has been characterized for its purity and surface properties, and its potential applications in various industries have been investigated. Using rice husks as a source of silica offers environmental benefits, is cost-effective, and the opportunity to turn waste into a valuable resource. Further research and improved extraction techniques will improve the use of husk-derived silica in various applications and contribute to environmentally friendly and sustainable technologies [8][13].

1.4 Need for the Project

Sustainable use of resources: Rice husk is a derivative of rice milling, and it is usually taken into consideration as waste and is both burnt or discarded. By extracting silica from rice husk, we are able to convert this waste material right into a valuable and useful resource that may be utilized in numerous commercial applications, which can lead to sustainable use of resources.

Environmental benefits: Burning or discarding rice husk can result in environmental pollutants, along with air pollutants and water pollutants. Extracting silica from rice husk can help lessen the quantity of waste, which is burned or discarded, which provides advantages to environmental benefits.

Cost financial savings: Silica is a vital commercial and industrial material, and its manufacturing from conventional sources including quartz or sand may be expensive. Extracting silica from rice husk offers a possibility to attain a low-fee opportunity production of silica, which can lead to financial savings for industries that use silica.

Wide variety of applications: Silica has variety of applications in numerous industries, which include electronics, construction, healthcare, and automotive. By extracting silica from rice husk, we are able to attain a sustainable supply of silica that may be utilized in numerous applications, contributing to the improvement of technologies which are sustainable and environmentally friendly.

Reduced carbon footprint: The manufacturing of silica from conventional sources including quartz or sand calls for substantial consumption of energy, which leads to an excessive carbon footprint. Extracting silica from rice husk offers a possibility to attain a sustainable supply of silica that can lead to a decrease in carbon footprint in comparison to conventional sources, which are important in increasing environmental benefits.

1.5 Aims and Objectives

The objectives and goals for a test at the extraction of silica from rice husk may include:

- To decide the ideal situations for extracting the most yield of silica from rice husk
- To signify the extracted silica in relation to its particle size distribution, surface morphology, and purity.
- To evaluate the performance and yield of the silica extracted with different strategies along with different concentrations of acid, alkaline at different temperatures.
- To check the environmental effect of the extraction technique through examining the acid waste generated for the duration of the extraction technique.
- To examine the possible applications of the extracted silica, for example the manufacturing of ceramics, glass, cement, and different substances.
- To make a contribution to the improvement of sustainable and green procedures for the extraction of silica from agricultural waste.
- To offer valuable and useful data for industries that use silica as an uncooked material, and for researchers operating on developing new substances with better and enhanced properties.
- To make a contribution to the technical data and information of the chemical and physical properties of silica extracted from rice husk.

Overall, the extraction of silica from rice husk has the ability to offer diverse benefits, together with source utilization, environmental benefits, price savings, high-purity silica manufacturing, and the improvement of recent and modern strategies. The unique goals for the extraction of silica from rice husk can range relying at the wants and requirements of the industries and its application.

2. PROBLEM DEFINITION

The problem statement describes the current situation where the demand for silica is constantly increasing, while traditional extraction methods involve the use of hazardous and energy-intensive chemicals, leading to degradation. environmental degradation and health risks. To address this issue, a study is proposed to explore a sustainable and eco-friendly method to extract silica from rice husks, which can meet the growing demand for silica while reducing pollution. environmental contamination [9].

Rice husk, an agricultural waste generated during rice processing, is a rich source of silica. However, most of the rice husks are discarded or burned, leading to air pollution and environmental degradation. The proposed study aims to solve this problem by developing a sustainable method to extract silica from rice husks, which offers various benefits for environmental, economic, and social aspects [9].

Extraction of silica from rice husk involves a bio-refining process using alkaline peroxide treatment, acid precipitation and ethanol extraction. This process can separate valuable components such as cellulose, hemicellulose, lignin, and amorphous silica from rice husk [9].

Another method involves heat treatment to extract high purity silica from rice husks, which can be used in various applications, such as catalyst support for acid steam reforming acetic [14].

The use of silica extracted from rice husks has the potential to contribute to the development of a circular economy. Silica can be used in the production of durable materials, such as poly(lactic acid) bio-composites, which exhibit improved properties and reduced oxygen permeability [15].

In addition, silica husk can be converted into nanomaterials with applications in energy, environmental functional materials, and ceramics [8][16].

The extraction and use of silica from rice husks also offers potential benefits to local communities. This includes creating jobs and improving environmental conditions by reducing air pollution and greenhouse gas emissions associated with rice husk burning [9].

In summary, the proposed study aims to develop a sustainable and environmentally friendly method for the extraction of silica from rice husks. This method helps to meet the growing demand for silica while reducing environmental pollution and offers various benefits in terms of environmental, economic, and social aspects [9].

3. METHODOLOGY

There are various methodological processes to extract silica using rice husk which are sol–gel method, lye method, precipitation method and heat treatment method. In this project we will be utilizing a mixture of precipitation and heat treatment methods.

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Procedure for extracting silica from rice husk:

3.1 Extraction of Silica

Procedure for extracting silica from rice husk:

3.1.1 Materials and Instrumentation:

- Rice husk
- Mortar and pestle
- Filter paper
- Glass beakers
- Distilled water
- Bunsen burner
- Safety goggles
- Gloves

3.1.2 Chemicals Required:

- Hydrochloric acid (HCl)
- Sodium hydroxide (NaOH)

Table 2*: Experimental Conditions*

Experiment Variables	Value
Type of acid or alkali	6%, 8% and 12% NaOH
Temperature	850°C
Duration for Heating	1.5 hours
Duration for Extraction	4-6 hours

From Table 2, we can understand the different variables of the experimental conditions which are required in the methodology process in order to get the desired results.

3.1.3 Procedure

1. Collect enough quantity of rice husk, which is a by-product of rice milling, and remove any foreign material, substances, or particles from it.
2. Grind the rice husk with the help of a mortar and pestle to create a fine powder. The finer the powder, the less difficult it'll be to extract silica.
3. Weigh out 80 grams of the powdered rice husk and add it into a container.
4. This container is placed inside the furnace and heated to 850 C for 1.5 hours.
5. The resultant is ash formed after heating, ash is then weighed and found to be approximately 14 grams.
6. 100 ml of 5%, 6%, 8% and 12% sodium hydroxide (NaOH) are prepared and added with the ash in a glass beaker. This will cause the silica to precipitate out of the solution. A strong base like sodium hydroxide (NaOH) can help to neutralize and cause the silica to shape a gel-like precipitate.
7. Ratio of 1:7 is followed for ash and NaOH i.e., 10 grams ash and 70 ml of NaOH.
8. Heat the beaker on a Bunsen burner at a low flame, while the mixture is stirred occasionally. Continue heating for 2-3 hours till the rice husk is absolutely dissolved. Heating the mixture facilitates boosting the reaction and dissolve the rice husk in a much more efficient manner.
9. Heating takes place in a round bottom flask with simultaneous distillation process.
10. After the rice husk is absolutely dissolved, mixture is filtered with the help of filter paper/activated charcoal to remove off any solids or impurities. Filtrate is then collected in a clean glass beaker.

$$\underset{\textit{Ash}}{SiO_2} + \underset{\textit{Caustic Soda}}{2NaOH} \longrightarrow \underset{\textit{Sodium Silicate}}{Na_2SiO_3} + H_2O$$

11. After the rice husk is absolutely dissolved, mixture is filtered with the help of filter paper to remove off any solids or impurities. Filtrate is then collected in a clean glass beaker.
12. Precipitate is then collected on filter paper and washed with distilled water to remove any impurities which remain.
13. Filtrate collected is added into a fresh beaker along with 1 N HCl and heated for 1-2 hours which will help to precipitate the silica.
14. After heating solution formed is filtered again and filtrate collected is resultant silica obtained.
15. Dry the silica precipitate in an oven for 4-6 hours. This will take off any residual water and moisture from the precipitate.
16. Weigh the dried silica precipitate to decide the yield. The yield of silica will depend upon the quality and amount of rice husk used.

$$Na_2SiO_3 + 2HCl \longrightarrow \underset{\textit{Silica}}{SiO_2} + \underset{\textit{By-product}}{2NaCl + H_2O}$$

Fig 1*: Extracted Silica*

[17][18][19][20][21][22][23]

3.2 Process Design

In chemical and process engineering, a process flow diagram (PFD) is a diagram that is frequently used to show the general flow of plant operations and equipment. It provides a visual representation of the sequence steps and relationships between the main plant equipment, without including minor details such as piping symbols and specifications.

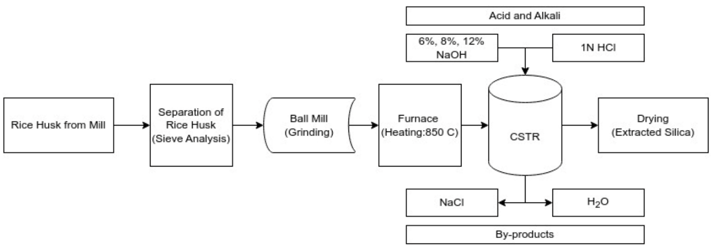

Fig 2*: Process Flow Design Diagram*

Sieve Analysis: Sieve analysis, also known as hierarchical testing, is a method used in civil engineering and chemical engineering to evaluate the particle size distribution (gradation) of materials. granulated. This analysis involves passing the material through a series of progressively smaller mesh sieves and measuring the amount of material retained on each sieve. Sieve analysis results provide information on the particle size distribution of a material, which is important for various applications such as determining the suitability of a material for construction purposes or understanding the behavior of a material. it in chemical processes. [24][25][26]

Ball mill: A ball mill is a type of mill used to crush and mix raw materials for use in mineral processing, pharmaceuticals, ceramics, and other industries. It works on the principle of impact and attrition: the grinding elements (balls) in the rotating cylinder exert force on the material being ground, causing them to break into smaller particles. The critical speed of a ball mill is the speed at which the grinding balls experience an effective centrifugal force that is equivalent to the gravitational force. Ball mills can operate in batch or continuous mode and can be adapted to different applications and materials. They are widely used in the production of cement, silicate products, new building materials and other materials. [27][28][29]

Furnace: A furnace is a device used for heating purposes, usually involving high temperatures. It is commonly used in various industries and applications including metallurgy, material handling, heat treatment and scientific research. Ovens are designed to generate and maintain high temperatures for processes such as smelting, melting, annealing and heat testing. They can be powered by a variety of sources such as natural gas, electricity, or solid fuel. Ovens come in a variety of types and configurations, including electric, gas, muffler, and vacuum furnaces, each suited to specific applications and temperature ranges. [30]

CSTR: CSTR stands for Continuous Stirred Tank Reactor. It is a type of chemical reactor commonly used in industrial processes to carry out chemical reactions. In CSTR, the reactants are continuously fed into a stirred barrel reactor, where they undergo a chemical reaction. Simultaneously, an outflow is extracted from the reactor at the same rate as the inlet to maintain a constant volume inside the reactor. Continuous reactor stirring ensures even mixing and even distribution of reactants, which promotes efficient reaction kinetics. CSTR is widely used due to its simplicity, flexibility, and ability to achieve steady state of operation. They find applications in industries as diverse as pharmaceuticals, petrochemicals, and food processing. [31]

Continuous stirring in a continuously stirred tank reactor (CSTR) denotes a regular alteration of the conditions for stirring or mixing in a reactor. In CSTR, the reactants are fed into the reactor continuously, where they engage in a chemical reaction. To accomplish effective mass transfer, homogenous temperature distribution, and efficient reaction kinetics, it is crucial to stir or mix the reactants.

The CSTR's stirring conditions are frequently modified during intermittent stirring. This may be accomplished by altering the stirring speed, shifting the stirring direction, or even briefly pausing the stirring operation. Intermittent stirring is used to change the mixing environment, which may have an impact on the reaction's course and the performance of the reactor.

4. Experimental Results and Analysis

S. No	Weight of Rice Husk (grams)	Concentration of NaOH (%)	Concentration of HCl (%)	Weight of Extracted Silica (grams)	Yield of Extracted Silica (%)
1.	10	6	1	0.528	**5.28**
2.	10	8	1	0.648	**6.48**
3.	10	12	1	1.002	**10.02**

Table 3*: Results of Extracted Silica according to different concentrations*

From Table 3, we can understand that the weight of rice husk remains constant along with the concentration of HCl which remains constant as well. The concentration of NaOH changes with every sample as to find the result with the highest yield possible.

4.1 Extraction of Silica Calculations

4.1.1 Preliminary Calculations

Acid and Alkali Concentration Calculations

NaOH Concentration Calculations
3 samples for concentration of NaOH
6%, 8% and 12% NaOH
For 6% NaOH = 6 grams of NaOH in 100 ml of water
For 8% NaOH = 8 grams of NaOH in 100 ml of water
For 12% NaOH = 12 grams of NaOH in 100 ml of water

HCl Concentration Calculations
1N HCl will be used.
Using the formula $N_1V_1 = N_2V_2$ (1)
Basis of 100ml water is used.
$V_1 = 8.33$ml

Using formula 1 we can calculate the volume of HCl to be used in the methodology process.

4.1.2 Yield Calculations

$$\text{Yield \%} = \frac{\text{Weight of Extracted Silica}}{\text{Weight of Rice Husk}} * 100 \quad (2)$$

Using formula 2 we can calculate the yield percentage, the values for analysis of the calculated yield percentages are present in Table 3.

4.1.3 Results Comparison

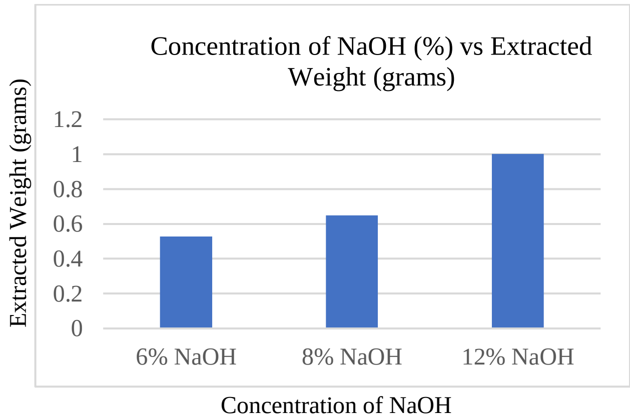

Fig 3*: Graph comparison between Concentration of NaOH (%) vs Extracted Weight (grams)*

From this figure we can understand that there is an increase in yield percentage across the 3 samples. The yield increases as the concentration of the alkali i.e., NaOH increases. We have taken 3 samples in concentration of NaOH respectively, 6%, 8% and 12% NaOH.

For 6% NaOH, we get yield % as **5.28%**
For 8% NaOH, we get yield % as **6.48%**
For 12% NaOH, we get yield % as **10.02%**

4.2 Equipment Design Calculations

4.2.1 Ball Mill Design Calculations

Assuming ball mill volume = 3.375 m^3
Diameter = 1.5 m
Length = 1.5 m
Material weight (Rice Husk) = 10 kg
Assuming steel balls are used
Density of steel balls = 7.8 g/cm^3
Assuming steel ball diameter = 20 mm
Therefore, approximate volume of steel ball = 0.008 m^3/kg

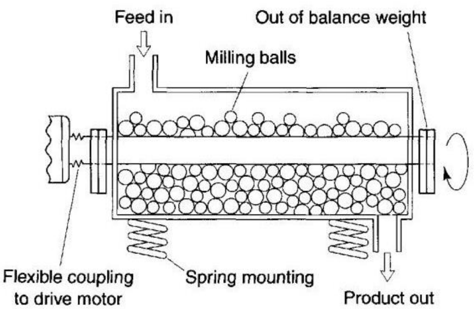

***Fig 4**: Schematic Representation of a Ball Mill*

***Table 4**: Results of Ball Mill Design Calculations*

Milling Media Size	50 kg
Volume of Milling Media (N_c)	0.00641 m^3
Critical Speed	35.5 rpm
Mill Drive Power (P)	0.612 W

Milling Media Size

Total weight of the milling media = Ball to powder ratio * Material weight (3)

Total weight of the milling media = 50 kg

Using formula 3 we can get the milling media size using the ball to powder ratio of 5:1.

The value for analysis of the calculated milling media size is present in Table 4.

Volume of Milling Media

$$\text{Volume of Milling Media} = \frac{\text{Total weight of the Milling Media}}{\text{Density of the Milling Media}} \quad (4)$$

Volume of Milling Media = 0.00641 m^3

Using formula 4 we can get the volume of milling media.

The value for analysis of the calculated volume of milling media is present in Table 4.

Critical Speed

$$N_c = \frac{1}{2\pi\sqrt{\frac{Rc}{g}}} \quad (5)$$

N_c = 35.5 rpm

Using formula 5 we can get the critical speed.

The value for analysis of the critical speed is present in Table 4.

Mill Drive Power

$$P = (0.6 * W * \frac{(Rc+r)}{(Nc)}) \quad (6)$$

P = 0.612 W

Using formula 5 we can get the mill drive power.

The value for analysis of the mill drive power is present in Table 4.

4.2.2 CSTR Design Calculations

Input of Rice Husk (m_{in}) = 10 kg
Desired reaction temperature (T) = 400 K
Reaction time (t) = 2 hours = 7200 seconds
Specific heat capacity (Cp) = 1500 J/Kg.K
Density of Rice Husk (ρ) = 120 kg/cm^3

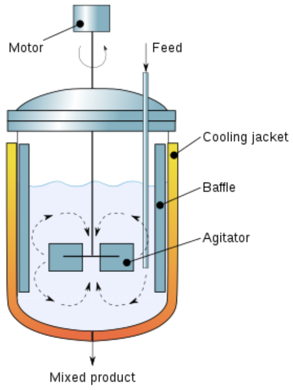

***Fig 5** : Schematic Representation of a CSTR*

***Table 5**: Results of CSTR Design Calculations*

Volume of CSTR (L)	85 L
Diameter (m)	0.5 m
Height (m)	1 m
Energy required to heat the rice husk to the desired reaction temperature (Q_{in})	1530000 J
Stirring Duration (N)	30 cycles of 1 min. stirring and 1 min. resting to complete reaction time in 2 hours
Stirring Power (P_{stir})	850 W

$$\textbf{Volume of CSTR} = \frac{\text{Mass}}{\text{Density}} \quad (7)$$

Volume of CSTR = 83.3 L

Approximate Volume of CSTR = 85 L

Using formula 7 we can get the volume of CSTR

The value for analysis of the volume of CSTR is present in Table 5.

$$\textbf{Diameter} = (4 * \frac{Volume\ of\ CSTR}{\pi})^{1/3} \quad (8)$$

Diameter = 0.47 m ~ 0.5 m

Using formula 8 we can get the diameter of CSTR

The value for analysis of the diameter of CSTR is present in Table 5.

Height = Diameter * 2 (9)

Height = 1 m

Using formula 9 we can get the height of CSTR

The value for analysis of the height of CSTR is present in Table 5.

Energy required to heat the rice husk to the desired reaction temperature.

Qin = Min * Cp * (T-T_0) (10)

Qin = 1530000 J

Using formula 10 we can get the energy required to heat the rice husk to the desired reaction temperature of the CSTR

The value for analysis of the energy required to heat the rice husk to the desired reaction temperature of the CSTR is present in Table 5.

Stirring Duration

$$N = \frac{t}{tstir + trest} \quad (11)$$

N = 30 cycles of 1 min. stirring and 1 min. resting to complete reaction time in 2 hours

Using formula 11 we can get the stirring duration of the CSTR

The value for analysis of the stirring duration of the CSTR is present in Table 5.

Stirring Power

$$P_{stir} = \frac{Qin}{N * tstir} \quad (12)$$

P_{stir} = 850 W

Using formula 12 we can get the stirring power of the CSTR

The value for analysis of the stirring power of the CSTR is present in Table 5.

4.2.3 Adiabatic Flame Temperature Calculation

$$C_6H_{10}O_5 + 6O_2 \longrightarrow 6CO_2 + 5H_2O$$

Reactants = $C_6H_{10}O_5$ = (6 *12 + 10 * 1 + 5 * 16) = **162.16 g/mol**

Products = CO_2 = (1 * 12 + 2 *16) = **44 g/mol**

Products = H_2O = (2 * 1 + 1 * 16) = **18 g/mol**

Table 6: Results of Adiabatic Flame Temperature Calculations

ΔHr	-1.682 mJ/Kg
Cp	32.5 J/mol K
Tf	1123 K

Calculating ΔHr using ΔHf for each species

$$\Delta Hr = [(m * \Delta Hf)_{C_6H_{10}O_5} + (m * \Delta Hf)_{CO_2} + (m * \Delta Hf)_{H_2O}] \quad (13)$$

ΔHr = -16824.7 = -1.682 mJ/Kg

Using formula 13 we can get ΔHr using assumed ΔHf values for each species

The value for analysis for ΔHr is present in Table 6.

C_p: Specific Heat

C_p for each species

$$C_p = \frac{(m * Cp)_{C_6H_{10}O_5} + (m * Cp)_{CO_2} + (m * Cp)_{H_2O}}{(m)} \quad (14)$$

C_p = 32.5 J/mol K

Using formula 14 we can get Cp using Cp values for each species

The value for analysis for Cp is present in Table 6.

T_f: Adiabatic Flame Temperature

$$T_f = \left(\frac{\Delta Hr}{m * Cp}\right) + T_0 \quad (15)$$

T_f = 1122.9 K ~ 1123 K

Using formula 15 we can get T_f value

The value for analysis for T_f is present in Table 6.

5. Conclusion

In conclusion, the extraction of silica from rice husk is a promising area of studies, research, development and has the capability to offer a sustainable and useful resource for diverse applications in various industries. The improvement of recent and state-of-the-art techniques for extracting silica from rice husk is predicted to boost the usage of silica in diverse applications and contribute to sustainable development.

Gathering data from various parameters performed in the experimental procedure can help us to optimize and select the most sustainable and cost-effective way of extracting silica with the highest yield possible.

5.1 Merits

Rice husk is an abundant and renewable source of silica. It can be obtained at low or no cost in rice mills or agricultural facilities, and can be used to produce high-quality silica gel, silica nanoparticles and silica-based materials. It can also be used to produce energy by combustion or gasification.

Overall, extracting silica from rice husk has several merits, including abundance, cost-effectiveness, environmental sustainability, high purity, versatility in applications, and potential for generation. additional value-added products.

5.2 Future Scope

- Sustainable resource utilization and waste management.
- Economic benefits through cost-effective production and new revenue streams.
- Advancements in extraction techniques for improved efficiency and productivity.
- Diversified applications of silica in various industries.
- Environmental benefits by reducing waste and minimizing environmental hazards.
- Opportunities for collaboration and innovation among researchers, industry experts, and policymakers.

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7. REFERENCES

[1] Gao, Y., Zhang, Y., Hong, Y. et al. Multifunctional Role of Silica in Pharmaceutical Formulations. AAPS PharmSciTech 23, 90 (2022).

[2] Britannica, The Editors of Encyclopaedia. "silica". Encyclopedia Britannica, 13 May. 2023.

[3] Stewart, David B. and Simmons, William B. "silica mineral". Encyclopedia Britannica, 31 Jul. 2018.

[4] Sánchez, M. G. "Development of Silica Gels and Impact of Silica Research on Studies of Other Colloidal Systems." 1994. 470-479.

[5] Heather A. Currie , Carole C. Perry, Silica in Plants: Biological, Biochemical and Chemical Studies, Annals of Botany, Volume 100, Issue 7, December 2007, Pages 1383–1389.

[6] Luthfiah, Annisa, et al. "Silica from Natural Sources: a Review on the Extraction and Potential Application as a Supporting Photocatalytic Material for Antibacterial Activity." Science and Technology Indonesia 6.3 (2021): 144-155.

[7] Pham, Co D., et al. "A review of the extraction methods and advanced applications of lignin-silica hybrids derived from natural sources." International Journal of Biological Macromolecules (2023): 123175.

[8] Hossain, SK S., Lakshya Mathur, and P. K. Roy. "Rice husk/rice husk ash as an alternative source of silica in ceramics: A review." Journal of Asian Ceramic Societies 6.4 (2018): 299-313.

[9] Nguyen, Ngoc Thuy, et al. "The extraction of lignocelluloses and silica from rice husk using a single biorefinery process and their characteristics." Journal of Industrial and Engineering Chemistry 108 (2022): 150-158.

[10] Gun, Melis, et al. "Optimization of silica extraction from rice husk using response surface methodology and adsorption of safranin dye." International Journal of Environmental Research 16.2 (2022): 20.

[11] Fernandes, Iara Janaína, et al. "Characterization of silica produced from rice husk ash: comparison of purification and processing methods." Materials Research 20 (2017): 512-518.

[12] Park, Ji Yeon, et al. "Two-stage continuous process for the extraction of silica from rice husk using attrition ball milling and alkaline leaching methods." Sustainability 13.13 (2021): 7350.

[13] Tyagi, Varee, et al. "Extraction and characterization of silica from rice husk for use in food industries." Extraction 2.4 (2017).

[14] Guo, Wenwen, et al. "Nano-silica extracted from rice husk and its application in acetic acid steam reforming." RSC advances 11.55 (2021): 34915-34922.

[15] Battegazzore, Daniele, et al. "Rice husk as bio-source of silica: preparation and characterization of PLA–silica bio-composites." RSC Advances 4.97 (2014): 54703-54712.

[16] Shen, Yafei. "Rice husk silica derived nanomaterials for sustainable applications." Renewable and sustainable energy reviews 80 (2017): 453-466.

[17] Selvakumar, K. V., Umesh, A., Ezhilkumar, P., Gayatri, S., Vinith, P., & Vignesh, V. (2014). Extraction of silica from burnt paddy husk. International Journal of ChemTech Research, 6(9), 4455-4459.

[18] Todkar, B. S., Deorukhkar, O. A., & Deshmukh, S. M. (2016). Extraction of silica from rice husk. Int J Eng Res Dev, 12(3), 69-74.

[19] Azat, Seitkhan, et al. "Extraction of high-purity silica from rice husk via hydrochloric acid leaching treatment." Turkish Journal of Chemistry 43.5 (2019): 1258-1269.

[20] Steven, Soen, et al. "An appropriate acid leaching sequence in rice husk ash extraction to enhance the produced green silica quality for sustainable industrial silica gel purpose." Journal of the Taiwan Institute of Chemical Engineers 122 (2021): 51-57.

[21] Setyawan, N., H., & Wulanawati, A. (2019, September 1). Simple extraction of silica nanoparticles from rice husk using technical grade solvent: effect of volume and concentration - IOPscience. Simple Extraction of Silica Nanoparticles from Rice Husk Using Technical Grade Solvent: Effect of Volume and Concentration - IOPscience.

[22] Park, Ji Yeon, et al. "Two-stage continuous process for the extraction of silica from rice husk using attrition ball milling and alkaline leaching methods." Sustainability 13.13 (2021): 7350.

[23] Daulay, A., Andriayani, Marpongahtun, & Gea, S. (2021). EXTRACTION SILICA FROM RICE HUSK WITH NaOH LEACHING AGENT WITH TEMPERATURE VARIATION BURNING RICE HUSK. Rasayan Journal of Chemistry, 03, 2125–2128.

[24] Sieve analysis - Wikipedia. (2018, May 1). Sieve Analysis - Wikipedia.

[25] Sieving methods of sieve analysis - RETSCH. (n.d.). Sieving Methods of Sieve Analysis – RETSCH

[26] Lucka, Mike & Hanke, Tanja. (2016). Sieve Analysis Different sieving methods for a variety of applications.

[27] Gupta, V. K., and Shivani Sharma. "Analysis of ball mill grinding operation using mill power specific kinetic parameters." Advanced Powder Technology 25.2 (2014): 625-634.

[28] Mohanty, Satish, Karunesh K. Gupta, and Kota Solomon Raju. "Vibration feature extraction and analysis of industrial ball mill using MEMS accelerometer sensor and synchronized data analysis technique." Procedia Computer Science 58 (2015): 217-224.

[29] Ball Mill - an overview | ScienceDirect Topics. (n.d.). Ball Mill - an Overview | ScienceDirect Topics

[30] Studocu. (n.d.). EXP 3 Size Reduction Using Ball Mill and Screen Analysis Using Sieve Shaker - i) To demonstrate a - Studocu. .

[31] 1.23: Continuously stirred tank reactors. (2016, March 9). Chemistry LibreTexts.