# The Effect Of Nanosilica Derived From Rice Husk As Coating Material On The Hydrophobicity Of Cotton Fabric

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**Abstract:** Cotton is the most cost effective and comfortable clothing material that is characterized as highly flammable and a good moisture absorbent. Introducing nanotechnology to the fabric is one of the most effective approaches in improving and developing its hydrophobicity. Nanosilica derived from rice husk was utilized in this study and showed that the percentage yield of nanosilica derived from rice husk is 23.19%. The produced nanosilica have particle diameters of less than 1 micrometer and exhibited non-spherical and irregular fiber-like structures. Three different concentrations of coating solution, that is, 0.10 g, 0.25 g and 0.50 g for every 100 mL of coating solution were produced to see the effect on the cotton fabric. The produced cotton-fabric after deep coating was subjected to characterization tests such as water contact angle, water absorption and surface morphology. The water contact angles of the samples were greater than 900 but the sample with 0.50 grams of nanosilica exhibited the highest value which is 112.7360 and 118.4710 on the left side and right side respectively therefore, the cotton fabrics were considered hydrophobic. When the samples were subjected to water absorption test, the cotton fabric that used 0.5g of nanosilica took 23.45 hours to absorb water which shows that the amount of nanosilica hinders the penetrability of the water on the cotton fabric. Based on the above properties, 0.50 g of nanosilica was considered as the best amount of coating material on cotton fabric. The surface morphology was taken at 15 000 magnifications and showed that the nanoparticles adhered to the surface of the cotton having sizes of 52 nm, 87 nm, 80 nm, 104 nm, 95 nm and 104 nm. The nanoparticles penetrated deeper and adhered strongly into the fabric matrix thus providing the fibers a rough surface.

**Keywords**: nanosilica, surface morphology, water contact angle, water absorption

## 1. Introduction

Nanotechnology is considered as a breakthrough in technology as it possesses new and improved ways to enhance the properties of some raw materials specifically on the layout and fabrication of structures, design and techniques by ensuring that its shape and size are in nanometer scale. Nanosilica, a hydrophobic chemical can be synthesized from rice husk. Rice husk is classified as a waste, but it can be used as materials of some environment friendly products and industrial sector. The projected production of rice husk is estimated to be one-fifth of the yearly gross production of rice all over the world, but the rice husk was limited to stock-breeding due to its contents [1]. Rice husk is characterized to have 70% of lignin-cellulose material and amorphous $SiO_2$ above 20% [2]. When burned, it can be considered as a good source of silica [3]. The application of silica nanoparticles has received wide attention in terms of providing hydrophobicity on fabrics. Hydrophobic surfaces are termed as surfaces that display a water contact angle higher than 90° which can be determined by measuring the water contact angle [4]. At present, cotton is considered as the topmost plant fiber crop globally. The production of cotton is noted in places such as USA, India, China, the Middle East and Australia because their climate is suited for its plant growth [5]. Cotton is the most cost effective and comfortable material although it is considered as highly flammable and a good moisture absorbent. Because of its usefulness and appearance, it can be considered as the nature's wonder fiber. Water contact angle, water absorbency and surface morphology are the important parameters to validate the effect of nanosilica drawn from rice husk on the hydrophobicity of the cotton fabric.

## 2. Objectives of the Study

This study aimed to verify the effect of nanosilica obtained from rice husk on the hydrophobicity of cotton fabric. To address this, the following specific objectives must be met:

**2.1.** To determine the percent yield of nanosilica obtained from rice husk.

**2.2.** To verify the surface morphology of the produced nanosilica used in the coating solution of cotton fabric.

**2.3.** To investigate the effect of using variable amounts of nanosilica (0.00g. 0.10 g, 0.25 g, 0.50 g) as coating material in terms of its water contact angle and water absorption.

**2.4.** To describe the surface morphology of the best amount of coating material on the cotton fabric based on the properties mentioned above.

## 3. Materials and Methodology

This study used the experimental design to determine the effect of the different amounts of nanosilica from rice husk on the hydrophobicity of cotton fabric. Properties such as contact angle and water absorption were determined and the surface morphology was examined using Scanning Electron Microscope (SEM)

### 3.1 Material Preparation

Rice husks were collected from Sariaya, Quezon. The rice husks were washed thoroughly using distilled water to get rid of adhering contaminants. then dried in the oven at 120 $^0$C. The polyvinyl alcohol and the cotton fabric were procured from the local market. The dimensions of the cotton used as samples were 8.5 inches x 1.5 inches.

### 3.2 Synthesis and Characterization of Nanosilica

Two liters of 1 M hydrochloric acid solution was prepared then 100 grams of the dried rice husk was immersed in the said solution with constant stirring for one hour. After an hour, the husks were filtered, washed three times using distilled water then dried at 120 $^0$C followed by burning at a temperature of 700 $^0$C for 3 hours in a furnace that resulted to white powder [6]. The yield of nanosilica can be computed using equation 1:

$$\text{yield} = \frac{\text{weight of nanosilica}}{\text{weight of rice husk}} \text{ x } 100\% \qquad (1)$$

The surface morphology of nanosilica derived from rice husk was verified using Scanning Electron Microscope. Also, the dimensions and shape of the nanosilica were identified

### 3.3. Preparation of Coating Solution

Three coating solutions containing nanosilica particles were prepared having 0.1 g, 0.25 g, and 0.5 g of nanosilica for every 100 mL of water with 10 g of polyvinyl. The resulting mixture was agitated with the use of a stirrer at 250 rpm for 30 minutes while the temperature is maintained at 60 °C [7].

### 3.4. Production of Hydrophobic Cotton Fabric

The cotton fabric was immersed in the coating solution for 10 minutes at room temperature, air-dried for 24 hours then it underwent curing at 120 °C for 10 minutes.

### 3.5. Characterization of the Ordinary Cotton Cloth and the Hydrophobic Cotton Fabric

The impact of nanosilica on the cotton fabric was verified with the use of scanning electron microscope instrument. On the other hand, the water contact angle was measured using ImageJ. This program helped to identify the hydrophobicity of the cotton fabric. If the measurement is 90° ≤ contact angle (θ) < 150°, it is considered hydrophobic. On the other hand, if θ measures greater than 150°, it is super hydrophobic. [8]. To check for water absorbency, a droplet of water was positioned on the cloth about 1.0 cm from the surface. During the process, time was recorded until the water drop is absorbed completely. This test was based on AATCC/ASTM Test Method TS-018, Procedure for Absorbency. The data gathered from all the tests done on the cotton fabric were used to verify the effect of varying the amount of nanosilica obtained from rice husk on the hydrophobicity of the cotton fabric.

## 4. Results and Discussion

### 4.1. Yield of Nanosilica Obtained from Rice Husk

Rice husk is a unique crop residue with uniform ash content of 25% with a silica content of 85-95% [ 9]. Thus, the range of the yield of nanosilica from rice husk is 21.25% to 23.75%. Synthesis of nanosilica from rice husk were done through the acid leaching and ashing in the furnace at a temperature of 700$^0$C for three hours. Acid leaching was done in order to remove the impurities in the rice husk [10]. The nanosilica yield was 23.19 g for every 100 g of rice husk. Therefore, the percentage yield of the nanosilica derived from rice husk is acceptable.

### 4.2. Characterization of the Produced Nanosilica

It was found out that the nanosilica were in nanoscale having particle diameters of less than 1 micrometer. Figure 1 shows the surface morphology of the nanoparticles synthesized as well as the sizes.

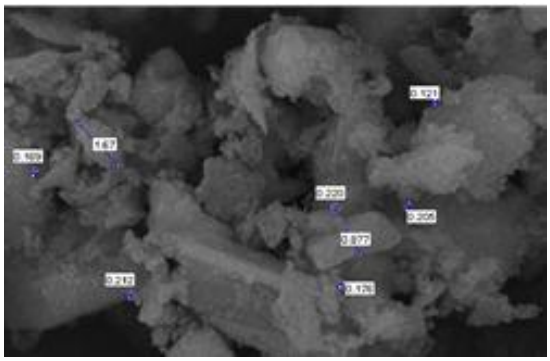

***Fig. 1****. Surface Morphology with Particle Sizes*

The particle sizes of the nanosilica derived from rice husk are 169 nm, 220 nm, 877 nm, 176 nm, 121 nm, 205 nm and 212 nm. Silica particles exhibit non -spherical and irregular fiber-like structures. This is due to the nonconductive nature of the silica that caused agglomeration in the particles [11].

### 4.3. Water Contact Angle

The table below shows the water contact angles of the different samples of cotton fabric.

***Table 1:*** *Water Contact Angle*

| Sample | Water Contact Angle | |
|---|---|---|
| | Left Side | Right Side |
| 1(with 0.00g nanosilica) | 0 | 0 |
| 2 (with 0.10g nanosilica) | 103.709 | 106.472 |
| 3((with 0.25g nanosilica) | 107.89 | 110.778 |
| 4 (with 0.50g nanosilica) | 112.736 | 118.471 |

All the water contact angles of the samples with nanosilica both at the left and right side are greater than 90, and therefore, the cotton fabric with nanoparticles were considered hydrophobic. Hydrophobic surfaces are formed by successful combination of low surface energy and high surface roughness. The nanosilica particles were able to roughen the surface of the fibers thus affecting the hydrophobicity of the fabric [12]. Surfaces having irregular structures tends to block the air beneath the water globules that create the water contact angle greater than 90 [13].

### 4.4. Water Absorption

Shown in Table 2 is the summary of water absorbency of the cotton fabrics with varying proportions of nanosilica particles in the coating solution.

***Table 2:*** *Water Absorbency of the Cotton Fabric*

| Sample | Water Absorbency (Time, hour) | | |
|---|---|---|---|
| | Trial 1 | Trial 2 | Average |
| 1 (with 0.00g nanosilica) | 0.0028 | 0.0028 | 0.0028 |
| 2 (with 0.10g nanosilica) | 20.3 | 20.5 | 20.4 |
| 3 (with 0.25g nanosilica) | 21.5 | 21.6 | 21.55 |
| 4 (with 0.50g nanosilica) | 23.4 | 23.5 | 23.45 |

All the cotton fabrics with different nanosilica concentration had a longer water absorbency time. As the concentration of the nanoparticles increased, there is also an increase in the time for the water to be absorbed. This is due to the clogging of the nanosilica particles on the spaces between the fibers of the cotton fabric thus, hindering the absorptivity of the fabric. Based on the results, if the concentration of the nanoparticles was increased it will further decrease the penetrability of water thus decreasing also its water absorbency time. Table 3 shows the differences in the properties of the cotton fabric with variable proportions of coating materials using One-Way Analysis of Variance.

***Table 3****.: Differences in the Properties of the Cotton Fabric Using Variable Proportions of Nanosilica*

| Properties | pvalues | Computed f-values | Decision on Ho | Verbal Interpretation |
|---|---|---|---|---|
| | | | | |
| Water Contact (right) | 0.039 | 11.55 | Do not accept Ho | Significant |
| Water Contact (left) | 0.002 | 102.43 | Do not accept Ho | Significant |
| Water Absorption | 0.000 | 474.50 | Do not accept Ho | Significant |

All the calculated p-values were lower than 0.05 level of significance indicating that varying the concentration of nanosilica in the coating solution had a significant effect on the property of the cotton fabric. There are significant effects between the varying proportions of nanosilica on the coating solution. As the amount of the nanoparticles were increased, the water contact angle also increased making the cotton more hydrophobic and thus, also affecting the water absorption of the modified fabric. Water was not easily absorbed as the concentration of the nanoparticles increases.

**4.5 Surface Morphology of the Cotton Cloth**

The surface morphology of the cotton cloth before coating with nanosilica at 500 magnification and 10 000 magnification are seen in figure 2 and figure 3 respectively.

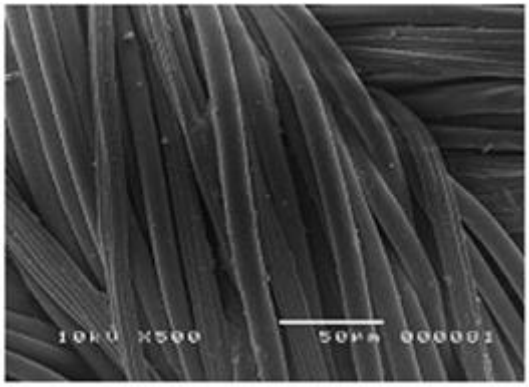


***Fig. 2.*** *SEM of cotton cloth at 500 magnifications*

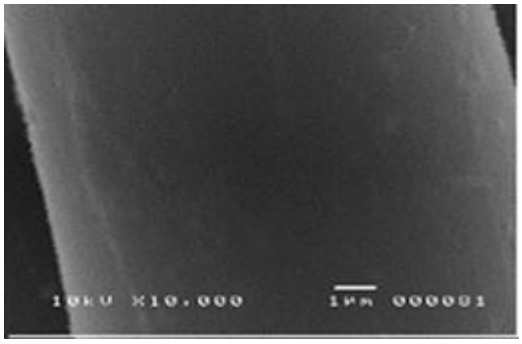


***Fig. 3.*** *SEM of cotton fabric at 10 000 magnifications*

As seen from the figures, the morphology of cotton fabric before deep coating with nanosilica showed that the fibers of the cotton fabrics all have smooth surfaces. On the other hand, a non-porous fabric was produced upon coating the fabric with the solution containing 0.5 g of nanosilica and the fibers were more bonded together creating a more solid fabric as seen in figure 4 and figure 5. The nanosilica particles closes the pores between the fibers thus covering the fibers surface

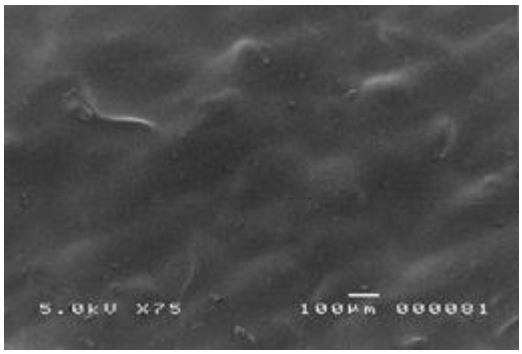


***Fig. 4****. SEM of cotton fabric with 0.5 g of nanosilica at 10 000 magnifications*

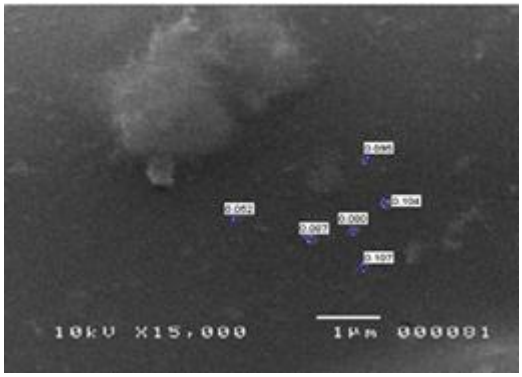


***Fig. 5****. SEM of cotton fabric with 0.5 g of nanosilica at 15 000 magnifications*

Reflected in the figure are the nanoparticles that adhered to the surface of the cotton fabric making the surface of the fabric rough. The sample sizes as seen in the figure are 52 nm, 87 nm, 80 nm, 104 nm, 95 nm and 104 nm. Accordingly, nanosilica were responsible for attaining the surface roughness of the fabric [14]. The surface morphology showed that the nanoparticles on the surface of the fibers were aggregated due to the binder. and the nanoparticles also tend to gather together thus coagulating it

on the surface. The coating covered the pores between the fibers and shielded the surface of the fiber [15].

## 5. Conclusion

Nanosilica can be produced from rice husk with 23.19% yield. The nanosilica obtained can be described as non-spherical and irregular fiber-like structure with a particle diameter having less than 1.0 micrometer. Different amounts of nanosilica when coated to the cotton cloth displayed a significant effect on the different properties of the cotton-fabric. All the water contact angles of the samples both at the left and right side are greater than 90, and therefore, the cotton fabric was considered hydrophobic. The computed p-values were 0.039 and 0.002 for left and right side respectively which were all less than 0.05 level of significance. It was determined that the third sample with 0.5 g of nanosilica in the coating solution displayed the most significant differences in terms of water contact angle and water absorption. It has a water contact angle of $112.736^0$ on the left-hand edge and $118.471^0$ on the right-hand edge which is greater as compared to other formulations. It also took 23.45 hours to absorb water which is longer than the water absorption of those having 0.10g and 0.25 g of nanosilica. The morphology of the cotton fabric with 0.5 g of nanosilica particles at 15 000 magnification indicates that the nanosilica penetrated deeper and adhered strongly into the fabric matrix thus providing the fibers a rough surface.

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