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The Extraction Process of Bamboo Silica for Halal Industries

Massitah Kipli[1,a)], Musfafikri Musa[2,b)], Rafidah Abu Nasir[1,c)], Budiah Karmilie[1,d)], Nurul Fariha Kamarul Rashid[1,e)] and Saiful Azhar Mahat@Kassim[1,f)]

[1]Politeknik Sultan Idris Shah, Sungai Air Tawar, Selangor, Malaysia
[2]Kolej Kemahiran Tinggi Mara Lenggong, Perak, Malaysia

[a)] Corresponding author: massitahkipli@psis.edu.my
[b)]musfafikiri@mara.edu.my
[c)]rafidah.abunasir@psis.edu.my
[d)]bkarmilie@psis.edu.my
[e)]nurul_fariha@psis.edu.my
[f)]saifulazhar@psis.edu.my

Abstract. The growing and persistent concern about halal requirements in the food, pharmaceutical, and cosmetic industries highlights the need for studies regarding alternative gelatine applications. Gelatine, a polymeric substance, is typically derived from animals such as pigs and cattle. Bamboo, on the other hand, is a readily available plants that has immense potential yet understudied. Thus, the impetus of this study is to understand the gelation mechanisms of bamboo parts, specifically silica from bamboo leaves via physiochemical properties, extraction conditions, and functional applications. The bamboo leaves were incinerated, and the ashes were examined. Fourier Transform Infrared Spectroscopy (FTIR) analysis and gravimetric analysis were conducted to detect functional groups related to substance properties. Results revealed the presence of carbonyl groups via FTIR, indicative of a polysaccharide-rich composition while the gravimetric analysis revealed that the extraction process achieved a notable silica yield of up to 71.49%. The findings are beneficial to the food, pharmaceutical, and cosmetic industries by providing a novel, plant-based gelling agent not only for halal, but kosher and vegan product development, and to researchers seeking a sustainable alternative for the halal industries.

Keywords: Bamboo, Silica, Halal, Physiochemical Properties, Applications

1. INTRODUCTION

Bamboo is a rapid-growing and self-sustaining type of grass from Poacea family plant that is predominantly available in the Asia region [1]. In China, 861 species were recorded, making it the largest bamboo producer in the world [1]. At the same time, in India, the second largest bamboo producer, bamboo production is estimated to be approximately 3.23 million tons [2]. In Malaysia alone, there are 69 numbers of species recorded with projected RM53 billions of export earnings in 2025 [3]. However, the bamboo industry is still untapped, producing insignificant products despite continuous action plans by the government [3]. Likewise, [4] share the same sentiment by declaring that, despite the abundance of potential, studies about bamboo are still mainly overlooked.

Undeniably, the physicochemical properties of bamboo are discussed by researchers worldwide. Silica particularly, the biggest amount of the properties in bamboo leaves [5], is widely used in several industries, including construction materials as well as the biomedical and rubber industries [2]. Similarly, other authors such as [6] experimented with silica as an alternative material for lithium-ion battery, while [7] suggest that silica from bamboo can be turned into invaluable chemicals, heat, and biofuels. [8] on the other hand, claim that bamboo silica is a significant source of fertilizer.

Interestingly, the same silica from bamboo is found to be beneficial in biomedicine too. For example, [9] describe that silica from bamboo can be used as a dietary supplement. In a similar vein, [10] posit that bamboo silica is viscous in nature and largely present in collagen that keeps the skin supple and repairs and renew cells and connective tissues. [11] concur by stating that silica from bamboo has ayurvedic benefits such as anti-inflammation, antioxidants, and rejuvenating cells, among others. Similarly, [12] highlight the utilization of silica in Chinese traditional remedy. In the food industry, silica has been used as additives in edible oil, meat, seafood, and is considered as a superfood due to its highly nutritious and wealth of bioactive compound [13]. Evidently, there is endless potential for bamboo silica in different industries.

While there is an abundance of studies regarding plant-based gelatine, only a small number of studies have been conducted to unravel the potential of bamboo in providing such [3], making the potential of bamboo silica as a gelatinous substance remains unexplored, with unknown physicochemical properties, extraction conditions, and functional applications. Hence, this study aims to understand the physicochemical properties and optimize the extraction process of silica and its functional application.

3. Research Methodology

The bamboo used in this study was collected from the northern part of Malaysia, specifically in the state of Perak. Few bamboo species were used, including *buluh kuning* or Sacred Bali bamboo (*Schizostachyum brachycladum* 'Yellow') and *buluh Semantan* (*Gigantochloa scortechinii*). In this study, only the bamboo leaves were used to extract the silica. The methods, objectives and parameters of the extraction process are shown in Table 1 and the steps in the bamboo silica extraction process as illustrated in Figure 1.

Table 1: The methods, objectives and parameters of the extraction process

Term	Objective	Parameter
Separation and Purification		
Centrifuge	1.To separate gelatine from other components such as fibre and residual lignin 2. Supernatant collected	5000 rpm
Rotary Evaporator	Concentrate supernatant	40-60-degree Celsius
Vacuum Filtration System	1. To remove small solid waste 2. Filter with filter paper	-
Ultrafiltration membrane	To separate molecule based in size	pore size 10kda
Characterization		
FTIR	1. To identify chemical bond and functional group 2. To be used to identify main protein structure	Standard ATR
Differential Scanning Calorimetry	To measure thermal stability and heating properties	-

Figure 1: The extraction process

Step 1 – The bamboo leaves were weighed and crushed
Step 2 – The bamboo leaves were incinerated in a furnace
Step 3 – The ashes from the bamboo leaves were treated with the sol-gel method and filtered.
Step 4 – The ashes were then dried in a universal oven for 24 hours.

Methods Used:

Sample Preparation: Thermal-chemical extraction was conducted to extract silica from the bamboo leaves as shown in Table 2.

Table 2: Bamboo silica criteria and extraction characteristics

Criteria	Silica Extraction
Source	Leaves
Extracted Compound	Silicon Dioxide (SiO2)
Extraction Method	Thermal-Chemical
Halal Compliance	Inorganic origin, halal-compliant
Sustainability	Agricultural waste

Analysis Tool:

FTIR Spectroscopy was selected as the screening method due to its rapid functional group identification and its ability to detect polysaccharide (pectin) and Si–O–Si (silica) functional bands while gravimetric analysis was chosen due to its ability to determine the ash content of the bamboo leaves via thermal analysis. Besides, these methods are cost-effectiveness and requires minimal sample preparation. Figure 2 outlines the methods used in silica extractions and the analysis tool.

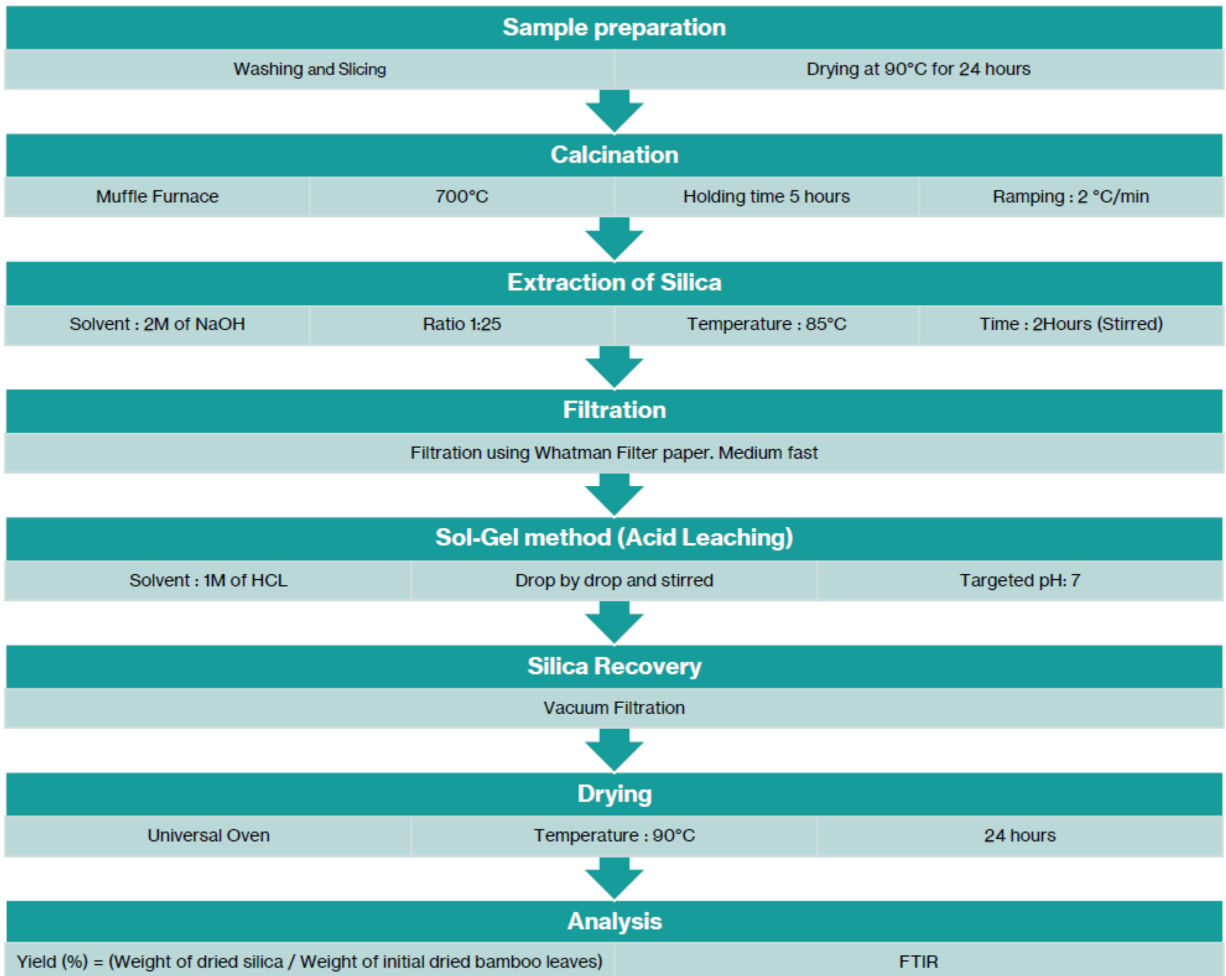

Figure 2: Methods used in silica extraction

Justification:

While FTIR cannot determine purity or yield, it is suitable for functional group detection in early screening. It has allowed us to differentiate between silica-rich extracts, enabling selection for further optimization. Also, through gravimetric analysis, the parameters used in this study represent a significant advancement toward an optimized extraction process.

4. RESULTS

Fourier-transform infrared (FTIR) spectroscopy confirmed the successful synthesis of amorphous silica. As illustrated in Figure 3, the FTIR spectrum of the extracted sample shows characteristic absorption peaks for the Si-O-Si network at 1014 cm^{-1}, 798 cm^{-1}, and approximately 470 cm^{-1}. These spectral features are consistent with standard reference spectra for amorphous silica and are comparable to those of commercial silicon dioxide, indicating a high degree of structural similarity and purity. The excellent correlation between the spectra confirms the successful synthesis of amorphous silica as depicted in Figure 3.

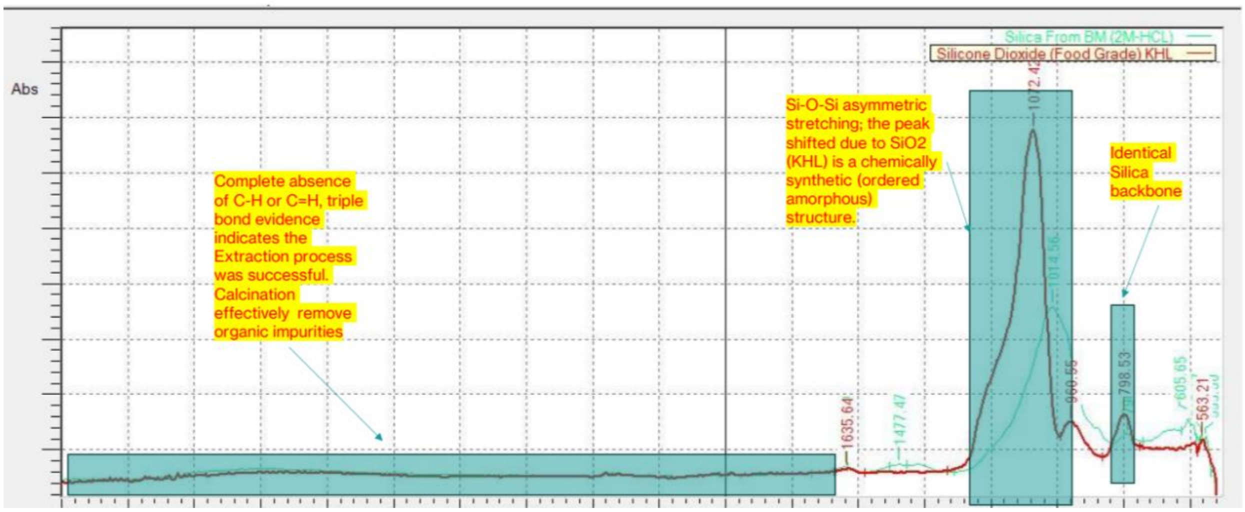

Figure 3: The results of analysis

Figure 4 shows the results of the sol-gel method process using acid leaching. As the pH level nearing 7, the bio silica from the bamboo leaves will form. The formation of a cloudy substance indicates the presence of silica.

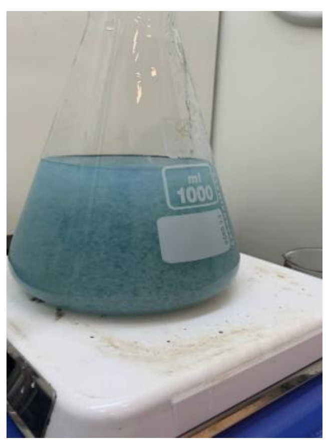

Figure 4: The sol-gel method using acid leaching.

The silica was then dried in the universal oven at 90 degrees Celsius for 24 hours. Figure 5 shows the form of dried silica.

Figure 5: Dried silica from bamboo leaves

5. DISCUSSION

This study aimed to develop an optimized, eco-friendly extraction process for producing a plant-based gelatinous substance from bamboo silica. The gravimetric analysis revealed that the extraction process achieved a notable silica yield of up to 71.49%. This result is highly competitive when compared with previous studies. For instance, the yield surpasses the 38.88% to 65.17% range reported by [14] using acid leaching methods. While it is lower than the near-complete 98.86% yield achieved by [2] under different alkaline conditions, it nonetheless confirms that the parameters used in this study represent a significant advancement toward an optimized extraction process. The successful synthesis of high-purity amorphous silica was further validated by FTIR analysis, which confirmed the presence of the characteristic Si-O-Si network.

That said, plant-based alternatives are not made from collagen. Instead, they are typically composed of different types of polysaccharides (carbohydrates) or gums. As a result, they are often low in protein, very much unlike the animal gelatine. But bamboo silica helps in the production of collagen, so further testing could be conducted to determine if bamboo silica could have almost equal characteristics or consistency as animal-based gelatine.

Indisputably, there are plant-based gelatines available such as pectin, agar-agar, konjac and a few others. While the characteristics of animal-based gelatine greatly differ from the plant-based gelatine, the latter has exponentially gained significant attention from researchers. This is observable through various works of previous studies such as [15] and [16] who showed interest in studying the structural characteristics and gel properties of pectin in citrus and its application while [17] and [18] studied about agar and its use in pharmaceuticals and the food industry among others. Besides, [19], [20], and [21] observed konjac structural properties, benefits, and its application in biomedical and pharmaceutical fields as well. In that regard, this paper brings the attention to the possibility of silica being treated as a gelatinous substance that can be used in the food, cosmetic, and pharmaceutical industries as an alternative to gelatine.

For future research, it is recommended to improve the extraction process that includes acid leaching, optimization, and purity improvement. The silica then could be treated with solvent to form a gelatinous like substance. The characterization of silica can be investigated by using multiple testing methods such as FTIR; Thermogravimetric analysis (TGA) a method used to determine the weight change of a substance as a function of temperature (or time), X-Ray diffraction analysis (XRD) a non-destructive technique that provides detailed information about the crystallographic structure, chemical composition, and physical properties of a material; XRF (X-ray Fluorescence) to determine the elemental composition of materials, Scanning Electron Microscopy (SEM), to scan a sample's surface, generating detailed images of its topography, composition, and other properties, and BET analysis, to determine the particle size, and Zeta potential. Apart from that, the application potential can be further determined by studying the gel strength and moisture absorption.

6. Conclusion

The findings of this study confirm that silica extracted from bamboo leaves possesses significant potential as a plant-based gelling agent. Its robust physicochemical properties, and favourable thermal stability make it a viable alternative to conventional animal-based gelatine. The use of FTIR and a high silica yields up as compared to previous studies proves that the parameters used in this study embodies a considerable prospect towards an improved extraction process. This research successfully demonstrates that optimized extraction conditions yield a silica substance with strength and viscosity comparable to those currently used in the halal, particularly food, pharmaceutical, and cosmetic industries.

Regardless, bamboo silica has a promising potential to be exploited as an anti-caking agent in food additives, scrub and filler in cosmetics, and encapsulation in the pharmaceutical industries. The results not only benefit various industries by offering a novel ingredient for product development but also pave the way for further research into the untapped potential of bamboo in halal food alternatives and other plant-based biomaterials.

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