

Comparative study of SiO₂ in biomass ashes at different temperatures

Watcharin Rachniyom^{1,2,*}, Nattapon Srisittipokakun^{1,2}, and Jakrapong Kaewkhao²

¹Industrial Physic Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University,
Nakhon Pathom, 73000, Thailand

²Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University,
Nakhon Pathom, 73000, Thailand

Abstract

In this work a range of biomass ashes were investigated in order to understand their chemical compositions. Ashes were calcined at different temperatures from 400-1,000 °C for 2 hours. The SiO₂ content of the samples was compared before and after calcination. Rice husk and rice straw were found to show the highest SiO₂ content of between 92.10 and 85.00 wt.% when calcined at 1,000 °C. The other biomass samples tested were found to produce ash with an SiO₂ content ranging from 9.54–67.90 wt.%. It was found that running the calcining process at high temperature can lead to an increase in the SiO₂ concentration of some biomass ashes. In this research it was found that SiO₂ concentration of sugar cane, eucalyptus, stubble corn and rubber ashes was not affected by calcination temperature.

Keywords: Ash, Biomass, SiO₂

Article history: Received 14 January 2019, Accepted 21 June 2019

1. Introduction

Biomass ashes are by product of burning biomass at thermal power plants in Thailand. There are four major sources of biomass. These are sugar cane, rice, oil palm and waste wood. In total there is nearly 80 million tons of biomass available for producing power each year [1]. The burning process produces a significant amount of waste ash. The ash-forming elements in the biomass include Al, Ca, Cl, Fe, K, Mg, P, Na, S, Mn, Si, and Ti. The exact composition of the ash depends on the technological and environmental sources of the biomass [2]. If the ash was disposed of in land-fill then it may cause groundwater and surface water contaminations and issues in the food supply chain. It is therefore an urgent necessity to find sustainable uses for biomass ash.

Recently, there have been many studies for use of biomass ash in the production of concrete, glass and ceramics [3–5]. Biomass ashes are considered to be useful in these industries if it has a silica content of more than 50 wt.%. The silica content of biomass ash, however, is dependent on its source (plant or part of plant). In Thailand, there are many types of biomass ash but there is limited data to show which

ash could be used for which purposes. In this research an investigation was undertaken into different biomass ashes produced in Thailand. These were ashes that resulted from the burning of rich husk, sugar cane, rice straw, eucalyptus, suburban sugarcane, rod palm, palm bunch, coconut shell, stubble corn, cassava and rubber. Analysis was first carried out using an X-ray Fluorescence (XRF) machine. Following this biomass ash samples were calcined at different temperatures from 400-1,000°C and their chemical composition was analysed again. This research was focused mainly on the SiO₂ component in biomass ashes

2. Materials and methods

In this research dry biomass ashes from Rich husk (A1), sugar cane (A2), rice straw (A3), eucalyptus (A4), suburban sugarcane (A5), rod palm (A6), palm bunch (A7), coconut shell (A8), stubble corn (A9), cassava (A10) and rubber (A11) were investigated. Analysis was carried out using an Energy Dispersive X-ray Fluorescence machine (Panalytical model minipal-4). Samples of all 11 different biomass ashes were calcined in an electrical furnace at 200, 400, 600, 800, and 1,000 °C for 2 hours. The heating process was operated under normal atmospheric pressure. The effect of this calcination on SiO₂ concentration was

*Corresponding author; email: watcharinratniyom601@hotmail.com

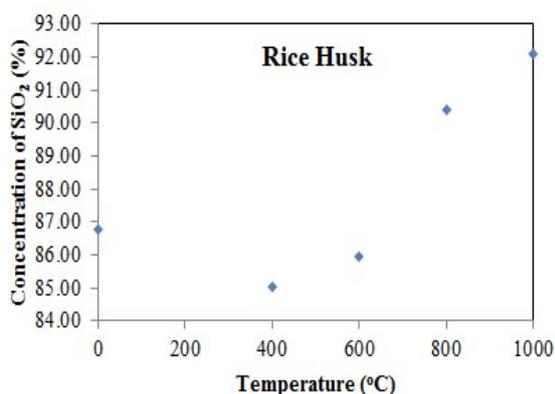
Table 1. The chemical compositions of biomass ashes.

Compound(wt.%)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
MgO	0.60	2.00	2.80	12.00	5.00	4.80	7.50	-	3.90	6.20	12.00
Al ₂ O ₃	-	1.40	-	0.30	-	0.96	-	-	-	-	-
SiO ₂	86.80	69.60	66.60	1.40	52.00	64.50	42.40	14.60	39.10	5.02	11.90
P ₂ O ₅	5.04	2.15	1.47	12.10	5.77	3.07	5.29	6.41	6.16	4.81	4.21
SO ₃	0.40	2.64	1.26	3.05	9.25	2.58	2.26	4.61	3.68	3.53	5.24
K ₂ O	4.98	4.43	11.30	17.80	16.50	5.95	24.20	58.83	30.36	29.89	15.00
CaO	1.47	17.06	3.92	53.17	10.80	16.40	16.30	11.50	12.80	48.22	48.80
TiO ₂	0.02	0.07	-	0.06	0.03	0.09	0.10	0.34	0.33	0.15	0.24
MnO	0.48	0.08	0.24	0.10	0.26	1.08	1.03	0.21	0.21	0.23	0.81
Fe ₂ O ₃	0.10	0.54	0.14	0.36	0.30	0.49	0.63	2.83	2.94	1.83	1.43
CuO	0.05	0.02	0.02	0.03	0.05	0.04	0.10	0.30	0.05	0.08	0.05
ZnO	0.03	0.01	0.02	-	0.07	-	0.11	0.33	0.38	0.06	0.20

Table 2. The SiO₂ concentration of biomass ashes at different temperature.

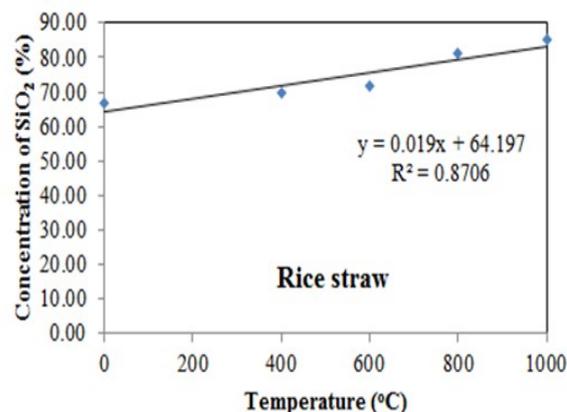
Temperature	SiO ₂ (wt.%)										
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
No sintered	86.80	69.60	66.60	1.40	52.00	64.50	42.40	14.60	39.10	5.02	11.90
400	85.04	68.00	69.90	2.10	47.30	65.70	46.80	12.10	34.60	1.40	10.90
600	85.94	69.70	71.60	1.50	49.70	67.70	47.70	9.30	34.10	0.92	8.07
800	90.40	65.60	81.22	1.70	53.10	60.30	44.40	12.90	33.60	5.26	7.69
1,000	92.10	67.90	85.00	1.50	63.70	65.20	48.00	25.40	39.80	9.54	5.44

measured using an Energy Dispersive X-ray Fluorescence machine.

**Figure 1:** The SiO₂ concentration of Rice husk at different temperature.

3. Results and discussion

The chemical composition of all dry biomass ashes used for the study (A1-11) are shown in Table 1. For the major composition, they could be classified in to 3 main groups based on their major component. The first group which was found to contain large amounts SiO₂, the second group which was found to contain a large amount of CaO and the third group which was found to contain a large amount of CaO. The results

**Figure 2:** The SiO₂ concentration of Rice straw at different temperature.

of the analysis of each sample can be found in the following tables.

This research was focused on the impact on SiO₂ content in biomass ashes following calcinations at different temperatures. The results are shown in table 2. Calcination was carried out using temperatures from 400 to 1,000 °C. It was thought that this would eliminate organic substances and increase the amount of SiO₂ in the ash. It was found that, rice husk had the highest SiO₂ content when it was calcined at 1,000 °C. It was found to be 92.10 wt.%. The SiO₂ content was found to fit the same trend identified by previous researchers [4]. It is thought that the removal of

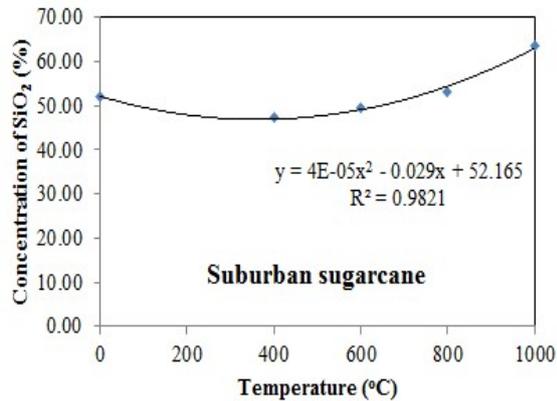


Figure 3: The SiO₂ concentration of Suburban sugarcane after calcinations at different temperatures.

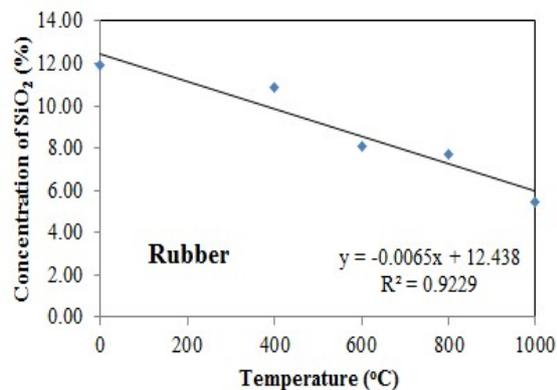


Figure 4: The SiO₂ concentration of Rubber after calcination at different temperatures.

organic compounds at high sintering temperature led to the percentage of SiO₂ increasing. The higher the calcination temperature the greater the removal of organic compounds and hence the higher the SiO₂ concentration. Fig. 1. shows that the overall trend was for SiO₂ content to decrease for calcination temperatures between 400 and 600 °C then to increased for calcinations temperatures between 800 and 1,000 °C. The SiO₂ content of rice straw and suburban sugarcane was increased the most through calcination. At a calcination temperature of 1,000 °C the rice straw ash sample increased to 85.00 wt.% SiO₂ and the suburban sugarcane ash sample was increased to 63.70 wt.%. In Figures 1-4 the relationship between SiO₂ content and calcination temperature for the samples is shown.

It can be seen that the starting percentage of SiO₂ in the rice straw was much lower than that in the rice husk. The calcination process had a large impact on the SiO₂ content of the rice straw but much less of an impact on the rice husk. The calcination process had a much more limited impact when it was carried out on the other biomass ashes. In one case, the rubber tree

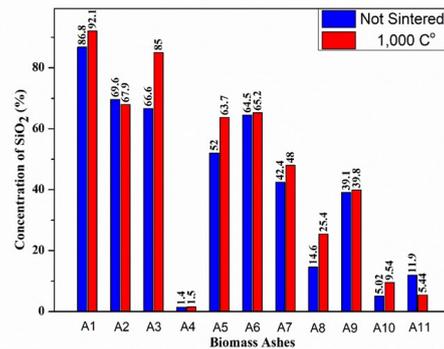


Figure 5: The comparison of SiO₂ concentration between before and after calcined at 1,000 °C.

ash, it actually led to a reduction in SiO₂ content.

The results show that biomass ash from different parts of rice plants are the richest in SiO₂ content. The SiO₂ content of rice husk and rice straw was found to be increased by calcination at high temperature. Figure 5 shows the the SiO₂ concentration of dry biomass ashes and biomass ashes that have been calcined at 1,000 °C. The process of calcining rice husk and rice straw ashes led to increases in SiO₂ content of 6.11 and 28.52% respectively. In addition to this it can be seen that even though some biomass ashes have medium-low of SiO₂ concentrations they still benefit from calcinations at 1,000 °C. Calcining only had a negative impact on SiO₂ concentration in the rubber tree ash sample. In this case the concentration of SiO₂ was reduced by more than half.

4. Conclusions

SiO₂ is a major component of most of the biomass samples analyzed. Samples with the highest levels were rice husk ash, sugar cane ash, rice straw ash, suburban sugarcane ash, rod palm ash, palm bunch ash and stubble corn ash.

The SiO₂ concentration of some biomass ashes can be increased by calcining at high temperature. This has the most dramatic impact in the case of rice straw ash. Calcining at a low temperature can lead to a reduction in SiO₂ content. Calcining rubber tree ashes appears to lead to a reduction of SiO₂ content at low or high temperature.

It was also concluded that the calcining of some biomass ashes at high temperature is a good technique to activate SiO₂ content on rich husk, rice straw, suburban sugarcane, palm bunch, coconut shell.

Acknowledgement

This work was supported by the National Council of Thailand (NRCT)

References

- [1] Y. Rueangtaweep, N. Srisittipokakun, K. Boonin, P. Yasaka, J. Kaewkhao, Characterization of Rice Straw and Utilization in Glass Production, *Adv Mat Res.* 748 (2013) 304–308.
- [2] V. Steven, M. Mikko, D. Olli, A review of biomass ash properties towards treatment and recycling, *Renew Sust Energ Rev.* 96 (2018) 479–486.
- [3] V. V. Stanislav, B. David, K. A. Lars, G. V. Christina, An overview of the composition and application of biomass ash. Part 2. Potential utilisation, technological and ecological advantages and challenges. *Fuel.* 105 (2013) 19–39.
- [4] M. M. Younes, H. A. Abdel-Rahman, M. M. Khattab, Utilization of rice husk ash and waste glass in the production of ternary. *J Bridge Eng.* 20 (2018) 42–50.
- [5] N. Srisittipokakun, Y. Ruangtaweep, W. Rachniyom, K. Boonin, J. Kaewkhao. CuO, MnO₂ and Fe₂O₃ doped biomass ash as silica source for glass production in Thailand. *Results Phys.* 7 (2017) 3449–3454.
- [6] X. Weiting, Y. L. Tommy, A. M. Shazim, Microstructure and reactivity of rich husk ash. *Constr Build Mater.* 29 (2012) 541–547.