

Electronic Supplementary Material

Autohydrolysis treatment of bamboo and potassium oxalate ($K_2C_2O_4$) activation of bamboo product for CO_2 capture utilization

Dang Duc Viet^{1,2}, Doan Thi Thao^{1,2}, Khuong Duy Anh¹, Toshiki Tsubota (✉)^{1,3}

1 Department of Materials Science, Faculty of Engineering, Kyushu Institute of Technology, Fukuoka 804-8550, Japan

2 Vietnamese Academy of Forest Sciences, Hanoi 10000, Vietnam

3 Collaborative Research Centre for Green Materials on Environmental Technology, Kyushu Institute of Technology, Fukuoka 808-0196, Japan

E-mail: tsubota@che.kyutech.ac.jp

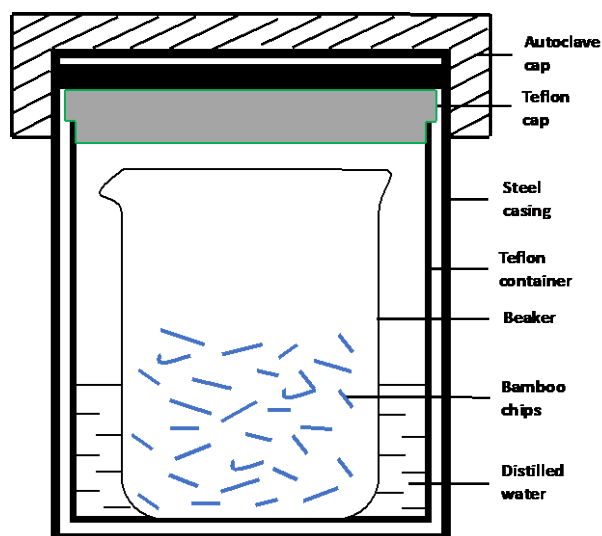


Figure S1: Schematic diagram of autoclave for autohydrolysis treatment of bamboo

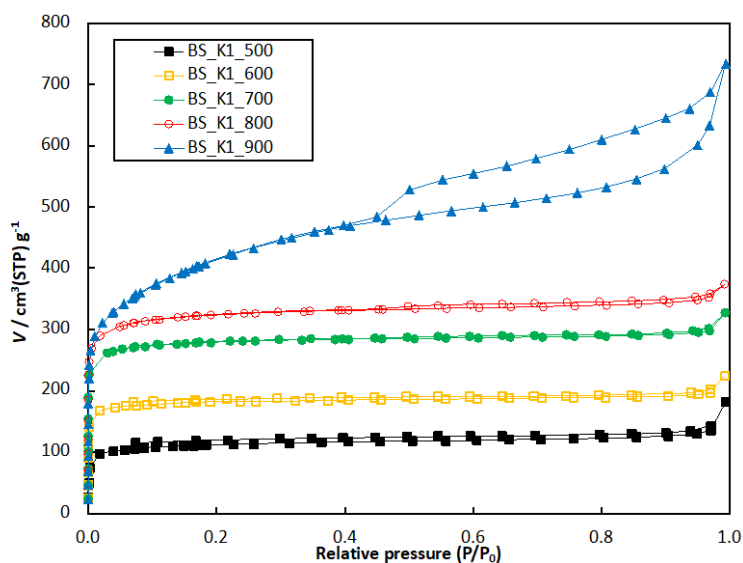


Figure S2: N_2 sorption isotherm at 77K of activated carbon from solid residue at different temperature

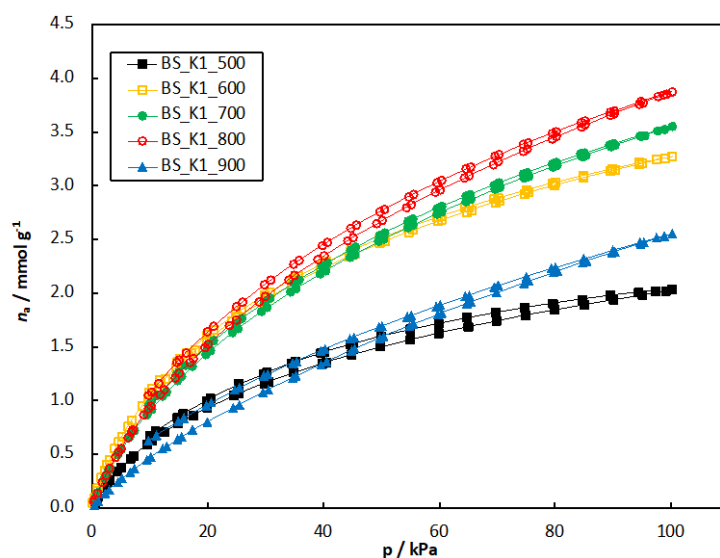


Figure S3: CO₂ sorption isotherm at 25 °C and 1atm of activated carbon from solid residue at different temperature

Table S1: Textural properties and CO₂ uptake for activated carbons from solid residue prepared under different temperature

Sample	S _{BET} ^a (m ² g ⁻¹)	V _{total} ^b (cm ³ g ⁻¹)	S _{micro} ^c (m ² g ⁻¹)	V _{micro} ^d (cm ³ g ⁻¹)	CO ₂ uptake (mmol g ⁻¹)
BS_K1_500	432.1	0.28	464.9	0.18	2.0
BS_K1_600	723.95	0.35	806.4	0.30	3.3
BS_K1_700	1121.2	0.51	1243.7	0.46	3.6
BS_K1_800	1262	0.58	1403.5	0.54	3.9
BS_K1_900	1458.5	1.14	1381	0.67	2.6

^aBET specific surface area; ^bTotal pore volume; ^cMicro pore surface area; ^dMicro pore volume

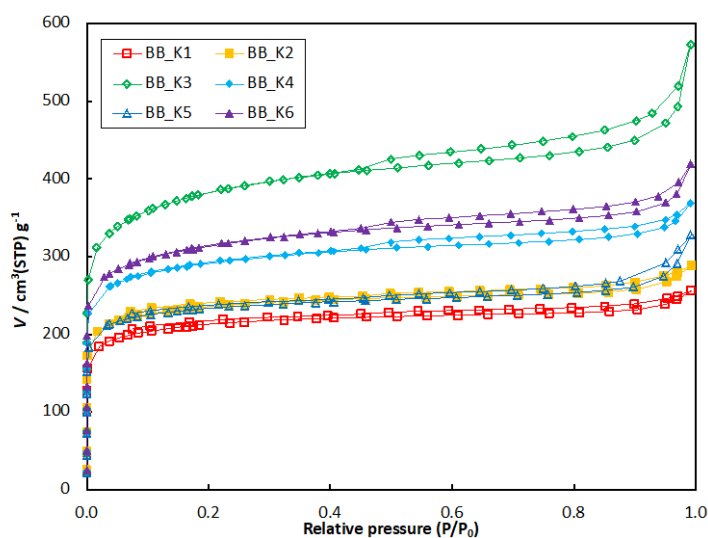


Figure S4: N₂ sorption isotherm at 77K of activated carbon from bamboo raw material

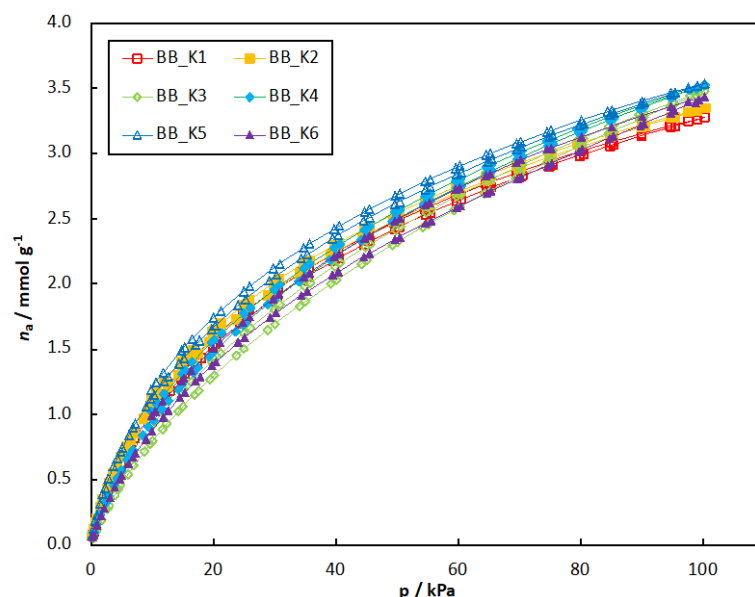


Figure S5: CO₂ sorption isotherm at 25 °C and 1atm of activated carbon from bamboo raw material

Table S2: Textural properties, yield and CO₂ uptake for activated carbons prepared under different ratios of K₂C₂O₄/bamboo

Sample	Yield (%)	S _{BET} ^a (m ² g ⁻¹)	V _{total} ^b (cm ³ g ⁻¹)	S _{micro} ^c (m ² g ⁻¹)	V _{micro} ^d (cm ³ g ⁻¹)	CO ₂ uptake (mmol g ⁻¹)
BB_K_1	12.92	809.1	0.40	895.5	0.36	3.3
BB_K_2	12.54	905.78	0.45	995.6	0.39	3.4
BB_K_3	10.11	1412.7	0.89	1493.7	0.63	3.5
BB_K_4	13.35	1101.3	0.57	1205.8	0.49	3.5
BB_K_5	13.88	897.14	0.51	976.9	0.38	3.5
BB_K_6	10.83	1178.6	0.65	1278	0.53	3.4

^aBET specific surface area; ^bTotal pore volume; ^cMicropore surface area; ^dMicropore volume

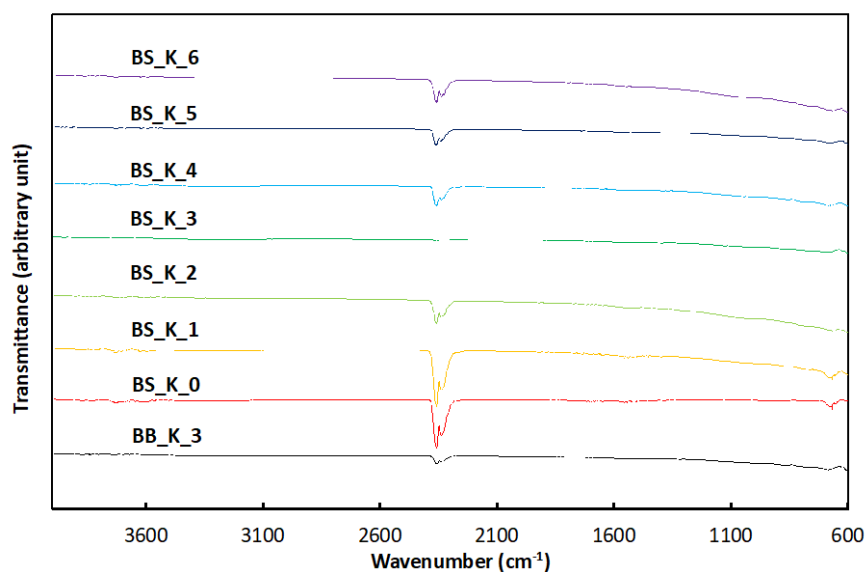


Figure S6: FT-IR spectra of activated carbons and biochar from bamboo and solid residue

*** Cost estimation for activated carbon from bamboo solid residue and bamboo with different activator at laboratory scale**

The comparison of cost estimation for activated carbon that produced from bamboo solid residue with $K_2C_2O_4$, K_2CO_3 and KOH in experiment scale were calculated as followed:

For comparison purpose, assuming that the equipment cost and labor cost for three kinds of activated carbon were equally due to the production process between them is extremely similar and will not calculated in this part. The energy cost and materials cost were provided as of 2023 at experiment scale in Fukuoka prefecture (Table S3).

Table S3: Energy and materials cost (as of October 2023, Fukuoka, Japan)

Items	Amount	Unit	Price (yen)	Yen per unit	USD per unit (1USD=155yen)	Remark
Bamboo powder	200	g	880	4.4	0.028	
$K_2C_2O_4$	500	g	3,700	7.4	0.048	Wako
K_2CO_3	500	g	3,750	7.5	0.048	Wako
KOH	500	g	2,100	4.2	0.027	Wako
Electricity	1	kWh	32	31.76	0.205	
N_2	7,619	L	3,150	0.41	0.003	
Distilled water	20	L	3,000	150	0.968	

1. Cost estimation for activated carbon from bamboo solid residue with $K_2C_2O_4$

The schematic for production line is described as Figure S7

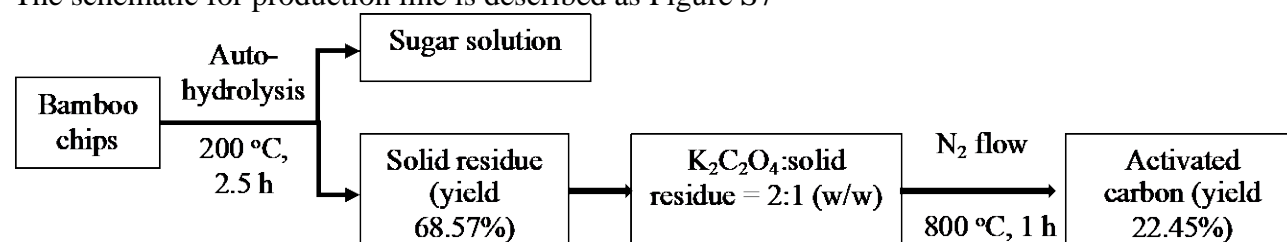


Figure S7: Process flow diagram for the production of activated carbon by $K_2C_2O_4$

The ratio of $K_2C_2O_4$: solid residue was selected as 2:1 as it had the highest CO_2 capture capacity. The yields of steam treatment and activation process were selected from this study. Based on the yield at Figure S7, the cost for 1 g activated carbon from steam treated solid residue with $K_2C_2O_4$ was estimated (Table S4).

Table S4: Cost estimation for 1 g activated carbon from solid residue with $K_2C_2O_4$

Items	Amount	Unit	Price/unit	Cost (\$)
Bamboo powder	6.5	g	0.028	0.18
$K_2C_2O_4$	8.9	g	0.048	0.43
Electricity	7.9	kWh	0.205	1.62
N_2	150	L	0.003	0.40
Distilled water	2.0	L	0.968	1.94
Activated carbon	1.0	g		4.56

2. Cost estimation for activated carbon from bamboo solid residue with K_2CO_3

The diagram for production line for activated carbon from K_2CO_3 is explained as Figure S8

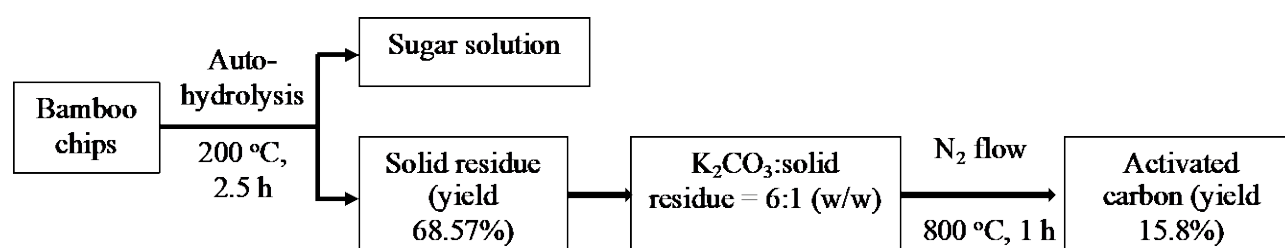


Figure S8: Process flow diagram for the production of activated carbon by K_2CO_3

The ratio of K_2CO_3 : solid residue was selected as 6:1 as it had the highest CO_2 capture capacity. Additionally, the yields of steam treatment and activation process were selected from previous research [1]. Based on the parameters at Figure S8, the price for 1 g activated carbon from steam treated solid residue with K_2CO_3 was calculated (Table S5).

Table S5: Cost estimation for 1 g activated carbon from solid residue with K_2CO_3

Items	Amount	Unit	Price/unit	Cost (\$)
Bamboo powder	9.2	g	0.028	0.26
K_2CO_3	38.0	g	0.048	1.84
Electricity	7.9	kWh	0.205	1.62
N_2	150	L	0.003	0.40
Distilled water	2.0	L	0.968	1.94
Activated carbon	1.0	g		6.05

3. Cost estimation for activated carbon from bamboo solid residue with KOH

Figure S9 showed the schematic for production line of activated carbon produced from KOH and solid residue.

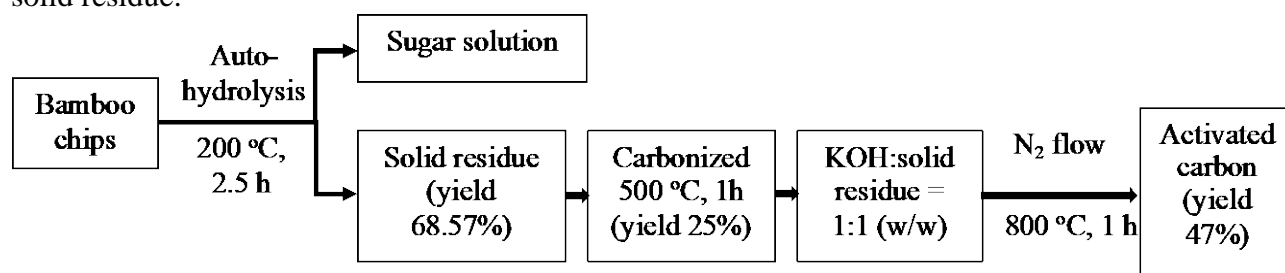


Figure S9: Process flow diagram for the production of activated carbon by KOH

The ratio of KOH : solid residue was selected as 1:1 to compare with other activated carbon above. The yields of steam treatment and activation procedure were collected from previous research [2,3]. Based on the data at Figure S9, the price for 1 g activated carbon that treated with KOH was calculated and presented at Table S6.

Table S6: Cost estimation for 1 g activated carbon from solid residue with KOH

Items	Amount	Unit	Price/unit	Cost (\$)
Bamboo powder	12.4	g	0.028	0.35
KOH	8.5	g	0.027	0.23
Electricity	10.9	kWh	0.205	2.23
N ₂	285	L	0.003	0.76
Distilled water	2.0	L	0.968	1.94
Activated carbon	1.0	g		5.51

The activated carbon from this study was compared with other activated carbon that prepared from different activating agents (Table S7).

Table S7: Comparison of CO₂ adsorption on activated carbons prepared from different activation agents

Precursors	Activating agents	Agents:precursor (w/w)	CO ₂ uptake (mmol g ⁻¹)	Cost (\$)
Bamboo residue	K ₂ C ₂ O ₄	2	4.1	4.56
Bamboo residue	K ₂ CO ₃	6	4.1 ^[1]	6.05
Bamboo	KOH	1	4 ^[2]	5.51

Table S8: Comparison of CO₂ uptake capacity at 25 °C and 1 bar of carbons derived from different materials

Raw materials	Activation agents and conditions	S _{BET} (m ² g ⁻¹)	V _{total} (cm ³ g ⁻¹)	CO ₂ uptake (mmol g ⁻¹)	Ref.
Algae	Pyrolyzed at 500 °C and activated with KOH at 800 °C	1019	0.46	2.76	[4]
Cellulose	Pyrolyzed at 200 °C then activated with CO ₂ at 800 °C	1364	1.42	3.42	[5]
Cellulose	Hydrothermal with melamine at 270 °C and activated with KOH	1703	1.06	1.56	[6]
Coconut shell	Pyrolyzed at 500 °C then activated with urea and K ₂ CO ₃ at 600 °C	1082	0.39	3.71	[7]
Crab shell	Activated with KOH at 650 °C	1196	0.5	4.37	[8]
D-glucose	Hydrothermal with urea at 180 °C and KOH at 650 °C	1734	0.78	4.26	[9]
Licorice residue	Hydrothermal at 270 °C and activated with KOH at 600 °C	1305	0.73	3.89	[10]
Lotus leaf	Carbonized at 500 °C and activated with KOH, melamine at 500 °C	1487	0.69	3.87	[11]
Palm sheath	Activated with KOH at 650 °C	840	0.46	3.48	[12]

Pine cone	Pyrolyzed at 500 °C and activated with KOH at 600 °C	1787	0.58	4.15	[13]
Rice husk	Activated with CO ₂ at 900 °C and using K ₂ CO ₃	1097	-	3.1	[14]
Seaweed	Carbonized at 800 °C then doping with urea at 350 °C and activated with KOH at 600 °C	579.2	0.44	4.06	[15]
Sugarcane bagasse	Pyrolyzed with zinc acetate at 900 °C then activated with melamine at 900 °C	1111	0.67	3.34	[16]
Walnut shell	Hydrothermal at 250 °C and activated with KOH at 700 °C	1489	0.78	2.1	[17]
Water chestnut shell	Carbonized at 500 °C and activated with NaNH ₂ at 500 °C	1416	0.58	4.5	[18]
Bamboo	Autohydrolysis at 200 °C and activated with K ₂ C ₂ O ₄ at 800 °C	1431	0.88	4.1	This study

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