Supplementary Information

Capacitive behavior of activated carbons obtained from coffee husk

Nathalia Ramirez,[a,b] Fabiana Sardella,[b] Cristina Deiana,[b] Anja Schlosser,[a] Dennis Müller,[a] Patrick A. Kissling,[a] Lars F. Klepzig,[a,c] and Nadja C. Bigall,[*a,c]

[a] Institute of Physical Chemistry and Electrochemistry, Leibniz Universität Hannover, Callinstraße 3A, 30167 Hannover, Germany. E-mail: nadja.bigall@pci.uni-hannover.de

[b] Institute of Chemical Engineering, Universidad Nacional de San Juan, Av. Lib. San Martín Oeste 1109, San Juan J5400ARL, Argentina.

[c] Cluster of Excellency PhoenixD (Photonics, Optics, and Engineering – Innovation Across Disciplines), Hannover, Germany.

Parameters obtained from XRD and Raman spectra

X-Ray diffraction patterns of the samples are obtained by means of Bruker AXS/D8 Advance diffractometer, between 2Θ= 10° and 85° using KαCu radiation (λ= 0.15418 nm, 40 kV, 30 mA) at a scan rate of 2Θ= 4°min^{-1}.The crystallite size (L_c and L_a) of the samples is calculated applying the Debye-Scherrer equation as follows,

$$L_a = \frac{1.84\lambda}{B_a\, cos(\theta_a)}, \qquad L_a = \frac{1.89\lambda}{B_c\, cos(\theta_c)},$$

where λ is the wavelength of the radiation, B_a and B_c are the full width at half maximum (FWHM) calculated from the radian of (100 & 101) and (002) reflection respectively, and Θ_a and Θ_c are the corresponding scattering angles or reflection positions in radians. OriginPro 8.5 software is used for deconvolution and baseline-correction of the diffractograms. In addition, Gaussian fitting is performed to find the reflection parameters (FWHM, reflection positions 2Θ).

Table S1. Crystallinity parameters extracted from XRD analysis of ACs from CH obtained by different activation routes

ACs	(002) Reflection				(100/101) Reflection			
	2θ (°)	d_{002} (Å)	FWHM (° 2θ)	Lc (Å)	2θ (°)	$d_{(100/101)}$ (Å)	FWHM (° 2θ)	La (Å)
CH-Steam	23.89	3.72	8.69	9.25	43.48	2.08	6.19	28.23
CH-KOH	22.22	3.99	10.74	7.45	43.32	2.08	6.27	27.88
CH-K_2CO_3	29.64	3.51	3.94	20.65	43.03	2.1	4.64	37.62

Raman spectroscopy is used to measure the degree of orientation of the graphitic structure in the ACs. The spectra are measured with a Bruker Senterra Raman microscope using a laser wavelength of 532 nm and a laser power of 5-10 mW. The ratio of intensities of the G and D bands ($R=I_D/I_G$), their positions and widths (FWHM) are reported. In this way, quantitative criteria that allow to compare the degree of structural order in the carbon samples are presented.

Table S2. Raman parameters of ACs from CH obtained by different activation routes

ACs	D- band			G- band			I_D/I_G
	Raman shift (cm^{-1})	FWHM (cm^{-1})	Height	Raman shift (cm^{-1})	FWHM (cm^{-1})	Height	
CH-Steam	1332	163	249	1588	66	238	1.04
CH-KOH	1349	386	171	1586	95	130	1.31
CH-K_2CO_3	1343	252	48	1581	93	50	0.96

Parameters from EIS data

Table S3. Parameters from EIS data of AC cells from CH obtained by different activation routes

Sample	R_s (Ohm)	R_{ct} (Ohm)	τ_0 (s)	f_k (Hz)
CH-Steam	2.91	20.0	63	16
CH-KOH	2.58	20.1	-	3
CH-K_2CO_3	2.59	18.2	79	20

AC cells reported in literature

Table S4. Specific capacitance of AC cells reported in literature

Biomass precursor	Activation method	S_{BET} ($m^2\ g^{-1}$)	Cs ($F\ g^{-1}$)	Current Apply ($A\ g^{-1}$)	Reference
Coffee husk	KOH	361	69	0.01	[13]
	CO_2	709	176	0.01	
Coconut Shell	Steam	1864	162	1	[44]
Fallen leaves	KOH	1003	219	0.5	[16]
	K_2CO_3	1078	222	0.5	
Argan seed shell	KOH	2062	355	0.25	[14]
Coffee husk	Steam	1447	138	0.5	This work
	KOH	2275	106	0.5	
	K_2CO_3	1156	129	0.5	

FTIR spectra of CH and ACs from CH

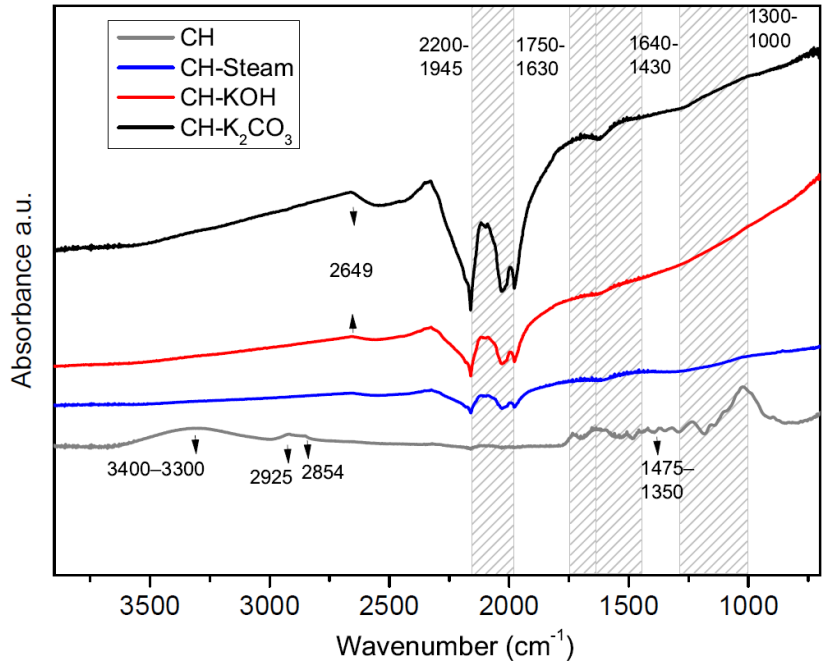

Figure S1. FTIR spectra of CH and ACs from CH (activation with steam, KOH, and K2CO3 are in blue, red, and black, respectively).

Specific capacitance (Cs) of AC cells

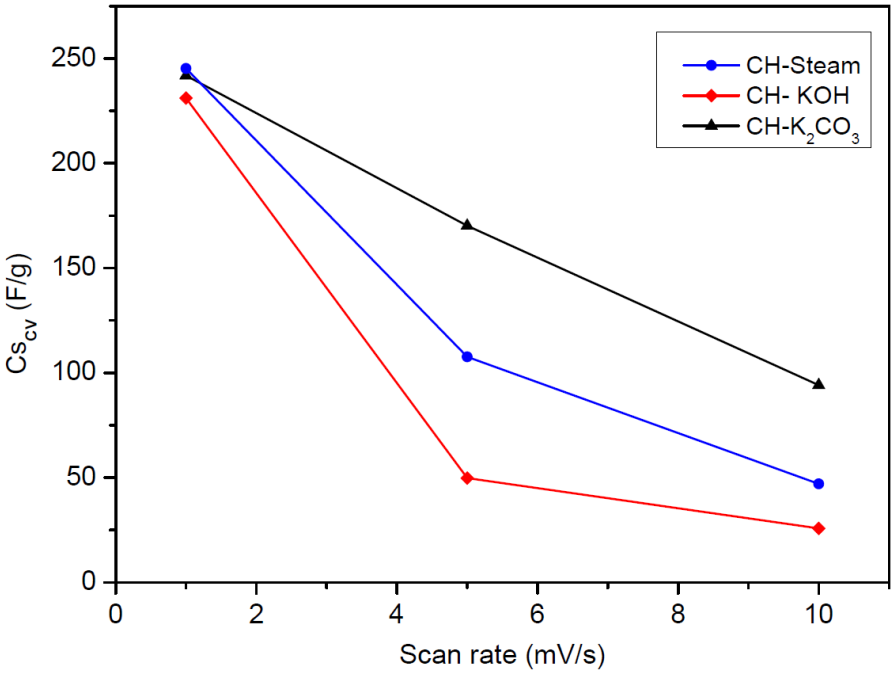

Figure S2. Specific capacitance from CV (Cs_{CV}) of ACs from CH (activation with steam, KOH, and K2CO3 are in blue, red, and black, respectively).