Electronic Supplementary Material (ESI) for RSC Advances.

Supporting information

Enhanced microwave assisted pyrolysis of waste rice straw through lipid extraction with supercritical carbon dioxide.

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Table S1 Type and quantity of saturated and unsaturated fatty acids in rice straw waxes obtained from different conditions using $scCO_2$ extraction for 4 hours.

Free fatty acids	**Abundance in the extracts in µg/g of dry plant**				
	35°C, 75 bar	**35°C, 400 bar**	**50°C ,238 bar**	**65 °C, 75 bar**	**65°C, 400 bar**
Dodecanoic acid ($C_{12:0}$)	1.0 ± 0.0	3.8 ± 0.0	3.4 ± 0.5	0.3 ± 0.0	4.8 ± 0.1
Azelaic acid	0.7 ± 0.0	2.6 ± 0.0	1.4 ± 0.0	0.2 ± 0.0	3.5 ± 0.0
Tetradecanoic acid ($C_{14:0}$)	6.3 ± 0.0	17.6 ± 0.0	15.7 ± 0.0	4.8 ± 0.0	20.9 ± 0.0
Pentadecanoic acid ($C_{15:0}$)	1.4 ± 0.0	7.0 ± 0.1	6.1 ± 0.0	0.4 ± 0.0	7.7 ± 0.0
Hexadecanoic acid ($C_{16:0}$)	30.7 ± 0.0	252.0 ± 0.4	236.9 ± 0.1	7.2 ± 0.0	267.6 ± 0.6
Heptadecanoic acid ($C_{17:0}$)	0.9 ± 0.0	9.1 ± 0.3	8.1 ± 0.1	0.2 ± 0.0	10.3 ± 0.8
Linoleic acid ($C_{18:2}$)	0.3 ± 0.0	21.4 ± 0.6	31.2 ± 1.2	0.2 ± 0.0	2.1 ± 0.1
Oleic acid ($C_{18:1}$)	0.8 ± 0.0	79.0 ± 1.0	96.6 ± 0.9	0.2 ± 0.0	20.0 ± 0.1
Octadecanoic acid ($C_{18:0}$)	4.5 ± 0.0	78.0 ± 2.7	70.9 ± 0.0	2.7 ± 0.0	81.3 ± 0.3
Nonadecanoic acid ($C_{19:0}$)	4.3 ± 0.0	12.2 ± 0.3	11.6 ± 1.0	1.1 ± 0.0	14.2 ± 1.4
Eicosanoic acid ($C_{20:0}$)	1.0 ± 0.0	33.3 ± 0.1	29.8 ± 0.5	0.4 ± 0.0	36.7 ± 1.8
Heneicosanoic acid ($C_{21:0}$)	1.7 ± 0.0	6.2 ± 0.3	5.7 ± 0.1	0.2± 0.0	9.1 ± 0.3
Docosanoic acid ($C_{22:0}$)	0.4 ± 0.0	15.5 ± 0.3	13.6 ± 0.4	0.1 ± 0.0	18.0 ± 0.1
Tricosanoic acid ($C_{23:0}$)	0.5 ± 0.0	10.9 ± 0.1	10.8 ± 0.0	0.1 ± 0.0	11.7 ± 0.5
Tetracosanoic acid ($C_{24:0}$)	0.5 ± 0.0	27.1 ± 0.1	29.2 ± 0.5	0.4 ± 0.0	37.6 ± 0.7
Pentacosanoic acid ($C_{25:0}$)	0.2 ± 0.0	5.3 ± 0.0	6.2 ± 0.2	0.1 ± 0.0	8.4 ± 0.4
Hexacosanoic acid ($C_{26:0}$)	0.2 ± 0.0	6.9 ± 0.2	9.0 ± 0.3	0.1 ± 0.0	12.2 ± 0.2
Octacosanoic acid ($C_{28:0}$)	0.3 ± 0.0	35.0 ± 1.2	64.1 ± 0.5	0.2 ± 0.0	78.9 ± 0.5
Dotriacontanoic acid ($C_{32:0}$)	0.7 ± 0.0	29.2 ± 0.7	23.4 ± 8.6	0.1 ± 0.0	36.5 ± 2.4
Total saturated fatty acids	*55.3* ± 0.0	*551.7 ± 6.9*	*545.9 ± 12.8*	*18.6* ± 0.0	*659.4 ± 10.1*
Total unsaturated fatty acids	*1.1* ± 0.0	*100.4 ± 1.5*	*127.8 ± 2.1*	*0.4* ± 0.0	*22.1 ± 0.2*
Total Fatty acids identified	**56.4 ± 0.0**	**652.1 ± 8.4**	**673.7 ±14.9**	**19.0**	**681.5 ± 10.3**

Table S2 Types and quantity of main hydrocarbons in rice straw waxes obtained from different conditions using $scCO_2$ extraction for 4 hours.

***n*-Alkane**	**Abundance in the extracts in µg/g of dry plant**				
	35°C, 75 bar	**35°C, 400 bar**	**50°C, 238 bar**	**65 °C, 75 bar**	**65°C, 400 bar**
Heptacosane (C_{27})	0.7 ± 0.0	6.2 ± 0.4	6.4 ± 0.0	0.2 ± 0.0	7.7 ± 0.1
Nonacosane (C_{29})	0.8 ± 0.1	22.4 ± 0.2	27.9 ± 0.0	0.3 ± 0.0	34.1 ± 0.1
Hentriacontane (C_{31})	0.6 ± 0.0	23.9 ± 0.2	33.0 ± 0.1	0.2 ± 0.0	36.6 ± 1.5
Tritriacontane (C_{33})	0.4 ± 0.0	130.1 ± 0.2	126.0 ± 0.6	0.3 ± 0.0	119.3 ± 0.1
Total *n*-alkanes	**2.5 ± 0.1**	**182.6 ± 1.0**	**193.3 ± 0.7**	**1.0** ± 0.0	**197.8 ± 1.8**

Table S3 Types and quantities of long chain fatty alcohols in rice straw waxes obtained from different conditions using $scCO_2$ extraction for 4 hours.

Fatty alcohols	**Abundance in the extracts in µg/g of dry plant**				
	35°C, 75 bar	**35°C, 400 bar**	**50°C, 238 bar**	**65 °C, 75 bar**	**65°C, 400 bar**
1-Hexacosanol	0.1 ± 0.0	4.4 ± 0.0	5.4 ± 0.0	TR	6.3 ± 0.0
1-Octacosanol	0.1 ± 0.0	7.4 ± 0.3	13.1 ± 0.2	TR	15.6 ± 0.6
1-Triacontanol	0.6 ± 0.0	142.8 ± 0.1	127.3 ± 1.9	0.8 ± 0.0	107.4 ± 0.2
Total Fatty alcohol	**0.8 ± 0.0**	**154.6 ± 0.4**	**145.8 ± 2.1**	**0.8 ± 0.0**	**129.3 ± 0.8**

* TR = *trace* amount

Table S4 Types and quantities of long chain fatty aldehydes in rice straw waxes obtained from different conditions using $scCO_2$ extraction for 4 hours.

Aldehydes	Abundance in the extracts in µg/g of dry plant				
	35°C, 75 bar	**35°C, 400 bar**	**50°C, 238 bar**	**65 °C, 75 bar**	**65°C, 400 bar**
Triacontanal (C30)	0.1 ± 0.0	197.0 ± 2.0	177.9 ± 4.4	0.2 ± 0.0	149.8 ± 6.6
Dotriacontanal (C32)	0.9 ± 0.2	56.7 ± 0.7	79.6 ± 0.6	0.8 ± 0.0	107.6 ± 10.1
Total fatty aldehydes	**1.0 ± 0.2**	**253.7 ± 2.7**	**257.5 ± 5.0**	**1.0** ± 0.0	**257.4 ± 16.7**

Table S5 Types and quantities of long chain fatty aldehydes in rice straw waxes obtained from different conditions using $scCO_2$ extraction for 4 hours.

Sterols	Abundance in the extracts in µg/g of dry plant				
	35°C, 75 bar	**35°C, 400 bar**	**50°C, 238 bar**	**65 °C, 75 bar**	**65°C, 400 bar**
Campesterol	1.0	67.2 ± 0.9	148.0 ± 0.4	0.1	205.8 ± 0.7
β-sitosterol	0.4	30.2 ± 4.3	32.4 ± 19.4	0.3	60.9 ± 1.1
Total sterols	**1.4**	**97.4 ± 5.2**	**180.4 ± 19.8**	**0.4**	**266.7 ± 1.8**

Table S6 Types and quantities of steroid ketones in rice straw waxes obtained from different conditions using $scCO_2$ extraction for 4 hours.

Steroid ketones	Abundance in the extracts in µg/g of dry plant				
	35°C, 75 bar	**35°C, 400 bar**	**50°C, 238 bar**	**65 °C, 75 bar**	**65°C, 400 bar**
Stigmast-4-en-3-one	0.8	51.7 ± 0.2	84.6 ± 0.3	0.5	126.4 ± 2.4
5α-Stigmastane-3,6-dione	1.7 ± 1.5	39.5 ± 0.2	81.7 ± 1.5	1.1	98.0 ± 3.7
Total steroid ketones	**2.5 ± 1.5**	**91.2 ± 0.4**	**166.3 ± 1.8**	**1.6**	**224.4 ± 6.1**

Table S7 Types and quantities of wax esters in rice straw waxes obtained from different conditions using $scCO_2$ extraction for 4 hours.

Wax esters	**Abundance in the extracts in µg/g of dry plant**				
	35°C, 75 bar	**35°C, 400 bar**	**50°C ,238 bar**	**65 °C, 75 bar**	**65°C, 400 bar**
Wax C42	0.1	10.8	18.2 ± 1.0	TR	22.5
Wax C44	0.3	23.7	47.8 ± 0.1	0.1	56.2 ± 0.1
Wax C46	0.7	21.5 ± 0.1	49.6 ± 0.8	0.3	60.6 ± 0.2
Wax C48	0.6	12.0 ± 0.2	32.5	0.4	47.0 ± 0.2
Wax C50	0.4	7.4	20.6	0.3	37.2 ± 0.2
Wax C52	0.3	3.2	8.0 ± 0.1	0.2	21.5 ± 0.1
Wax C54	0.1	1.3	1.2 ± 0.1	4.5 ± 0.1	10.3
Total wax esters	**2.5**	**79.9 ± 0.3**	**177.9 ± 2.1**	**5.8 ± 0.1**	**255.3 ± 0.8**

Table S8 Extraction yields obtained at different pressures and temperatures for rice straw.

Experiments	Temperature (°C)	Pressure (bar)	Density of CO_2 ($g.cm^{-3}$)	Yield (dry biomass)
1	35	75	0.27	0.05
2	35	400	0.97	0.41
3	50	238	0.82	0.52
4	65	75	0.16	0.01
5	65	400	0.87	0.70

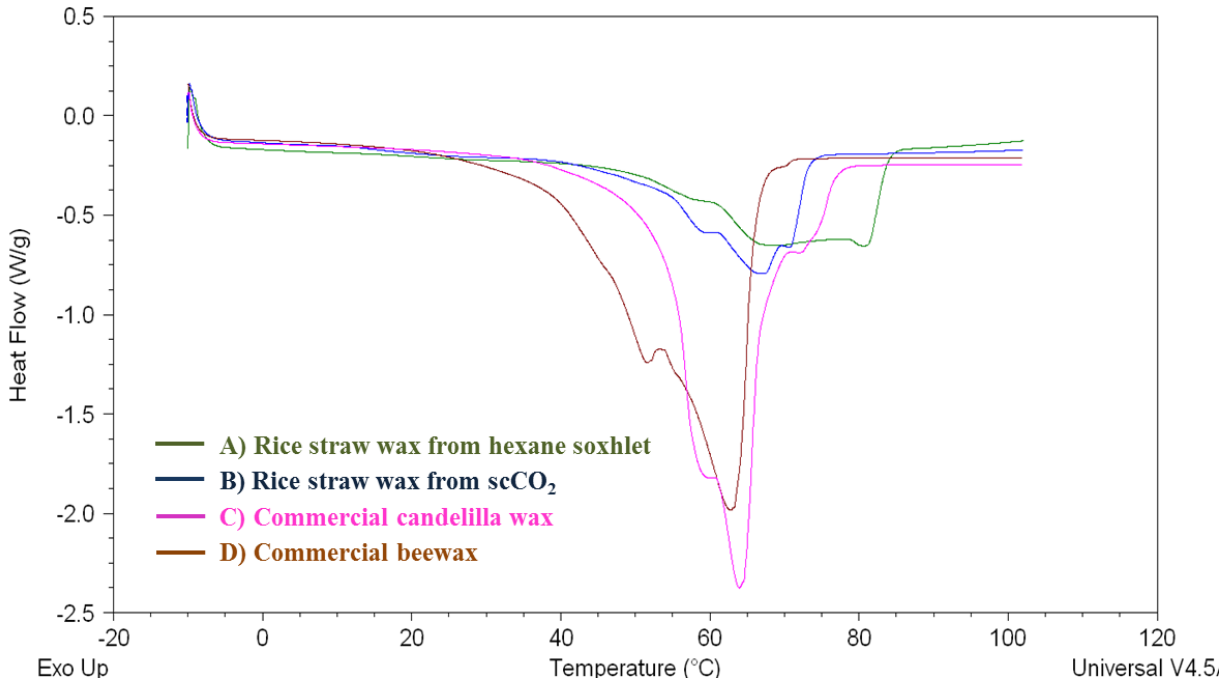
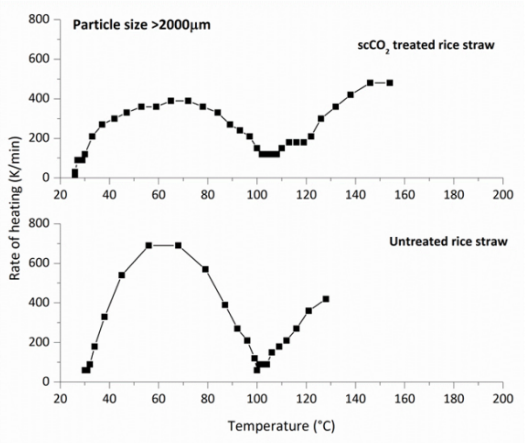
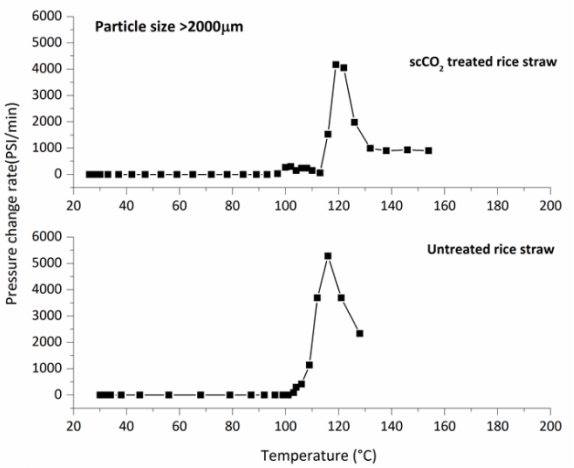


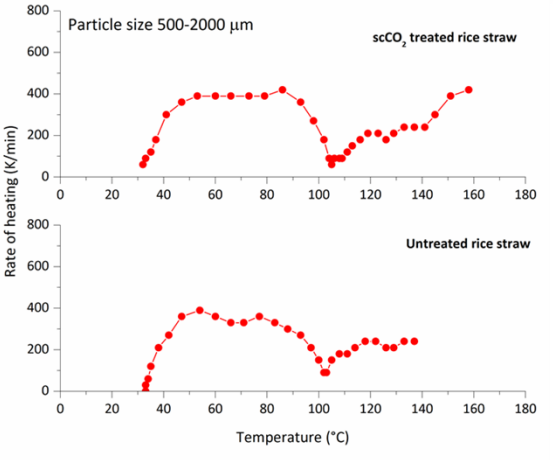
Figure S1 DSC plot showing the melting profiles for different waxes, (A) hexane Soxhlet, (B) $scCO_2$ at 65 °C and 400 bar for 4 hours, (C) Commercial candelilla wax, and (D) Commercial beeswax.

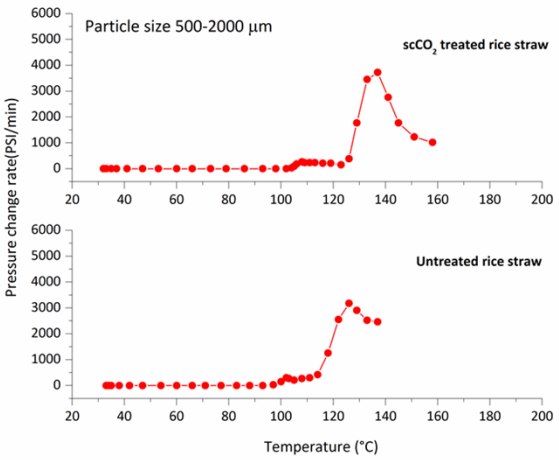
A


Particle size >2000µm
scCO2 treated rice straw
Untreated rice straw
Rate of heating (K/min)
Temperature (°C)

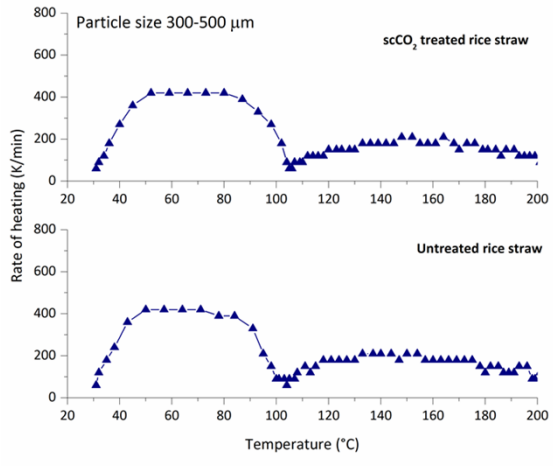

Particle size >2000µm
scCO2 treated rice straw
Untreated rice straw
Pressure change rate(PSI/min)
Temperature (°C)

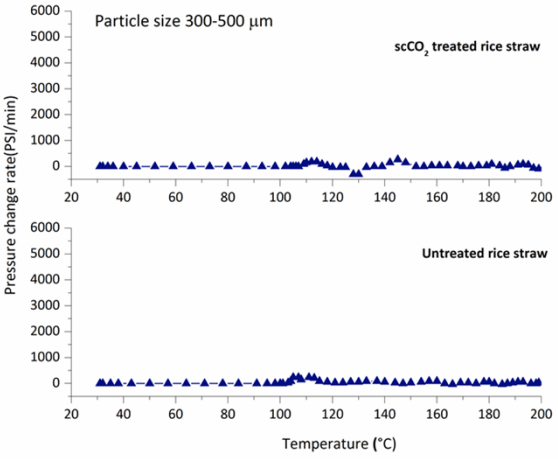
B


Particle size 500-2000 µm
scCO2 treated rice straw
Untreated rice straw
Rate of heating (K/min)
Temperature (°C)


Particle size 500-2000 µm
scCO2 treated rice straw
Untreated rice straw
Pressure change rate(PSI/min)
Temperature (°C)

C


Particle size 300-500 µm
scCO2 treated rice straw
Untreated rice straw
Rate of heating (K/min)
Temperature (°C)


Particle size 300-500 µm
scCO2 treated rice straw
Untreated rice straw
Pressure change rate(PSI/min)
Temperature (°C)

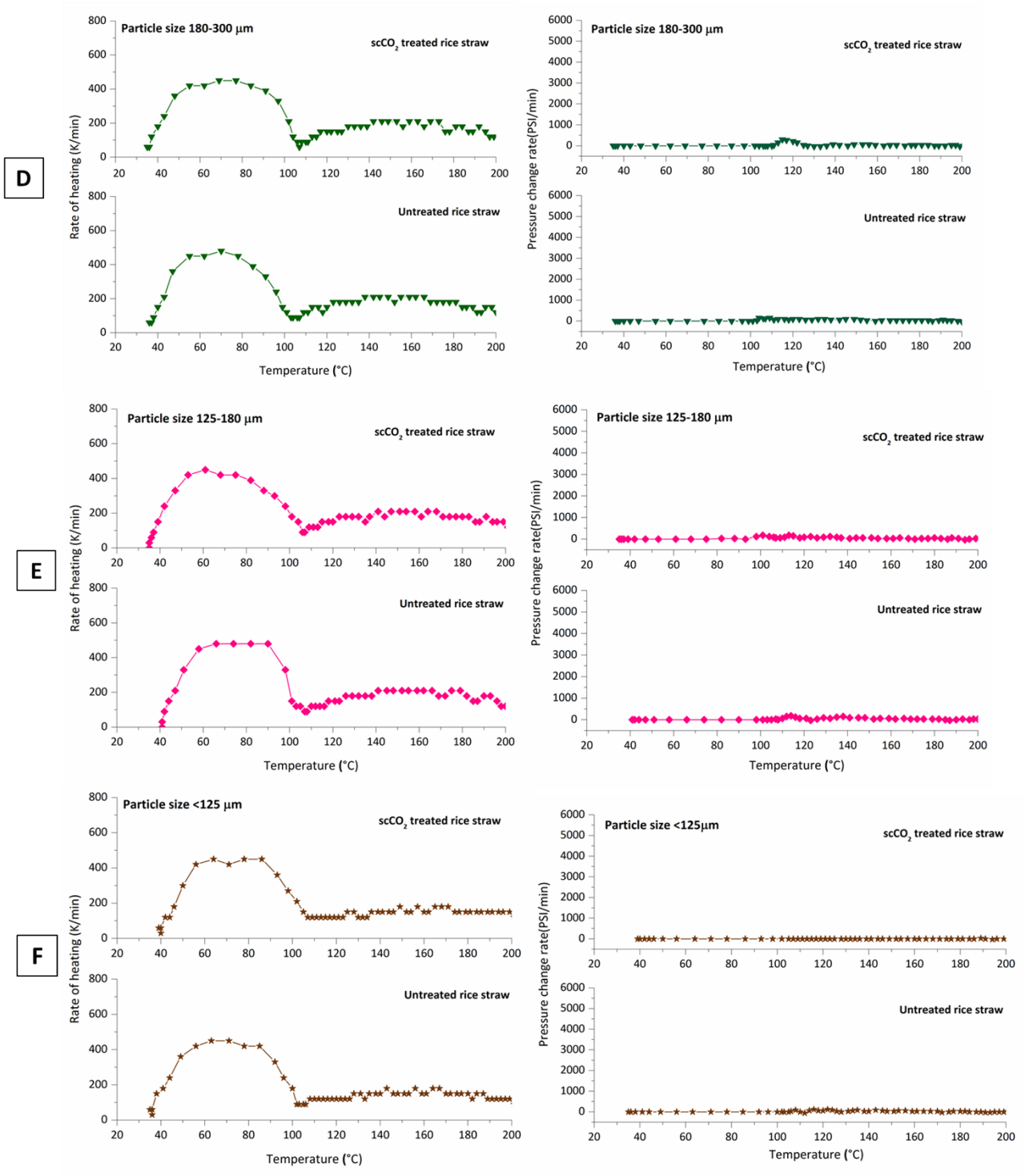


Figure S2 The comparison and the evolution of heating rates and pressure change rates of untreated and $scCO_2$ treated rice straw according to particle sizes A) >2000 µm, B) 500-2000 µm, C) 300-500 µm, D) 180-500 µm, E) 125-180 µm and F) <125 µm.

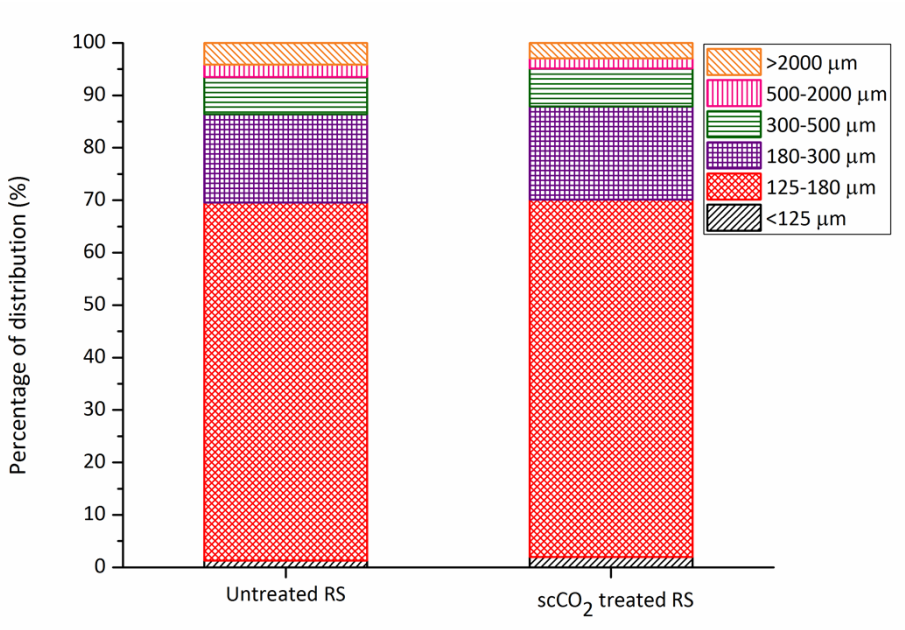


Figure S3 Particle size distribution of untreated and $scCO_2$ treated rice straw after milling.