Supplementary Information (SI) for Journal of Materials Chemistry A.


**SUPPLEMENTARY MATERIALS for:**

# Drive-Throughs to Driveways: High-Strength Composites from Multi-Material Post-Consumer Waste Collected from Fast Food Restaurants

*Katelyn M. Derr, Perla Y. Sauceda-Oloño,* Ashlyn D. Smith,* Andrew G. Tennyson,* and Rhett C. Smith**

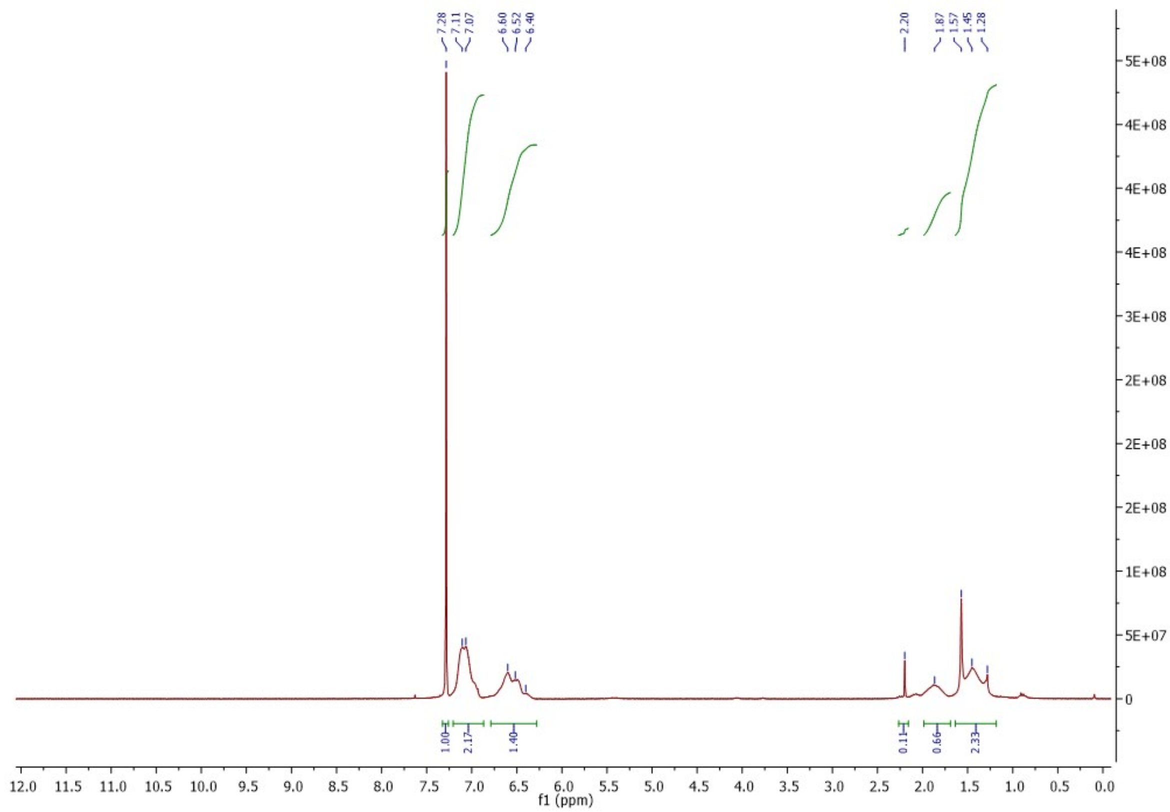



**Figure S1.** Proton NMR spectrum (300 MHz, $CDCl_3$) of the straw.

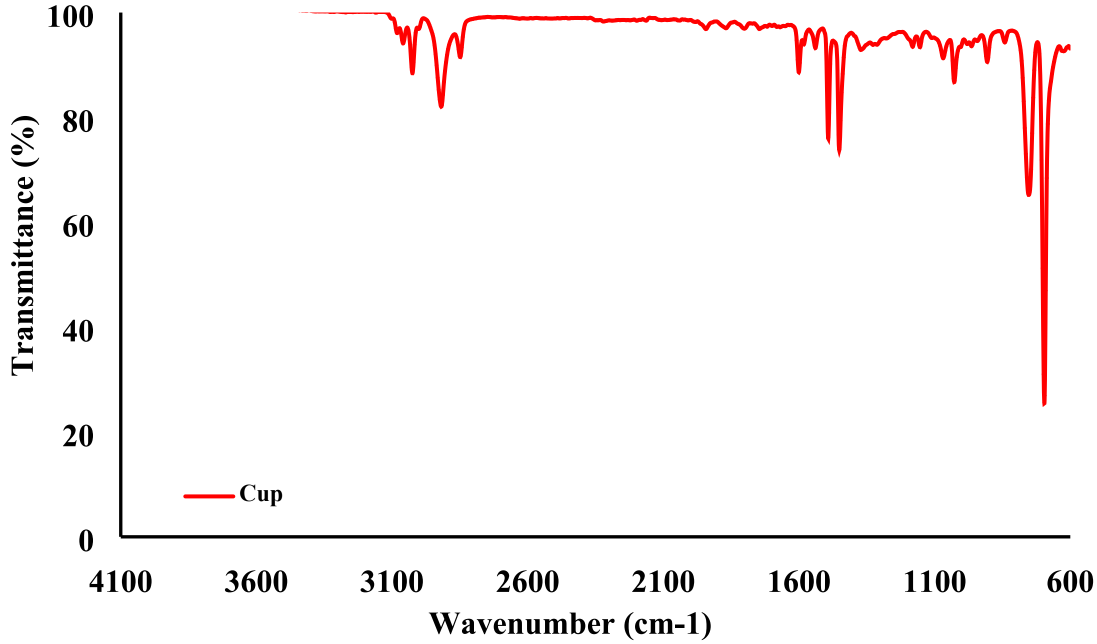



**Figure S2.** Full IR spectrum of the cup over a range of 4000 to 600 $cm^{-1}$.

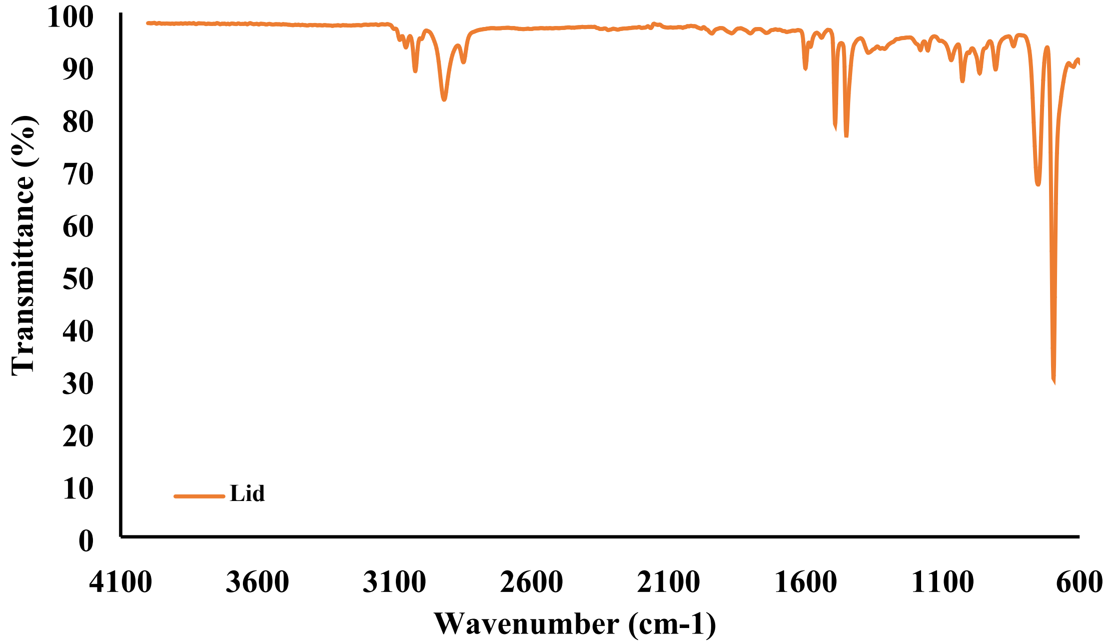



**Figure S3.** Full IR spectrum of the lid for the cup over a range of 4000 to 600 $cm^{-1}$.

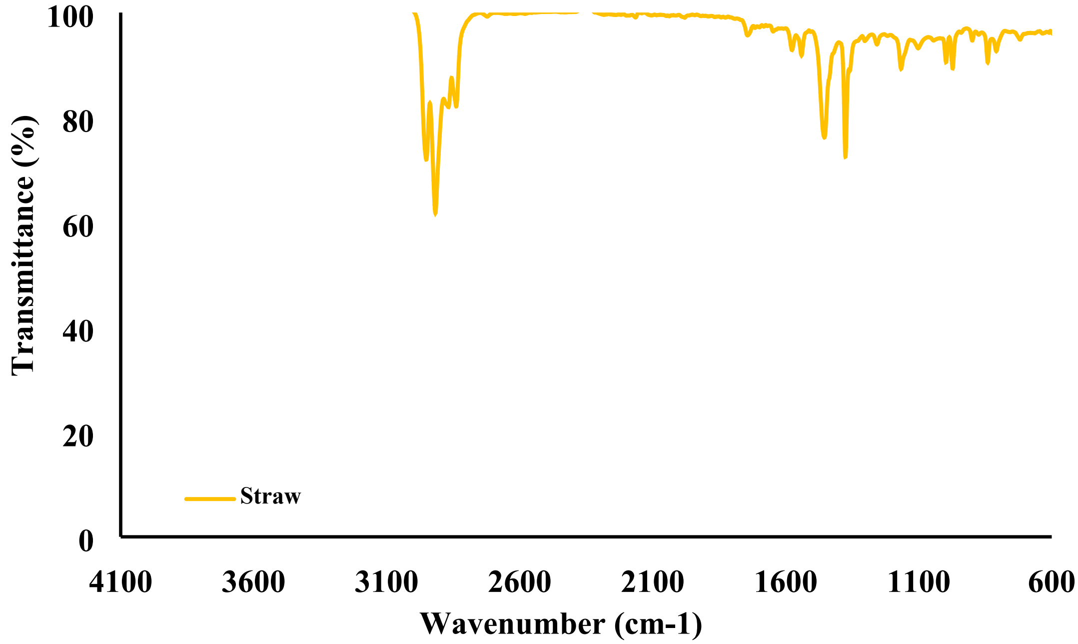



**Figure S4.** Full IR spectrum of the straw over a range of 4000 to 600 cm$^{-1}$.

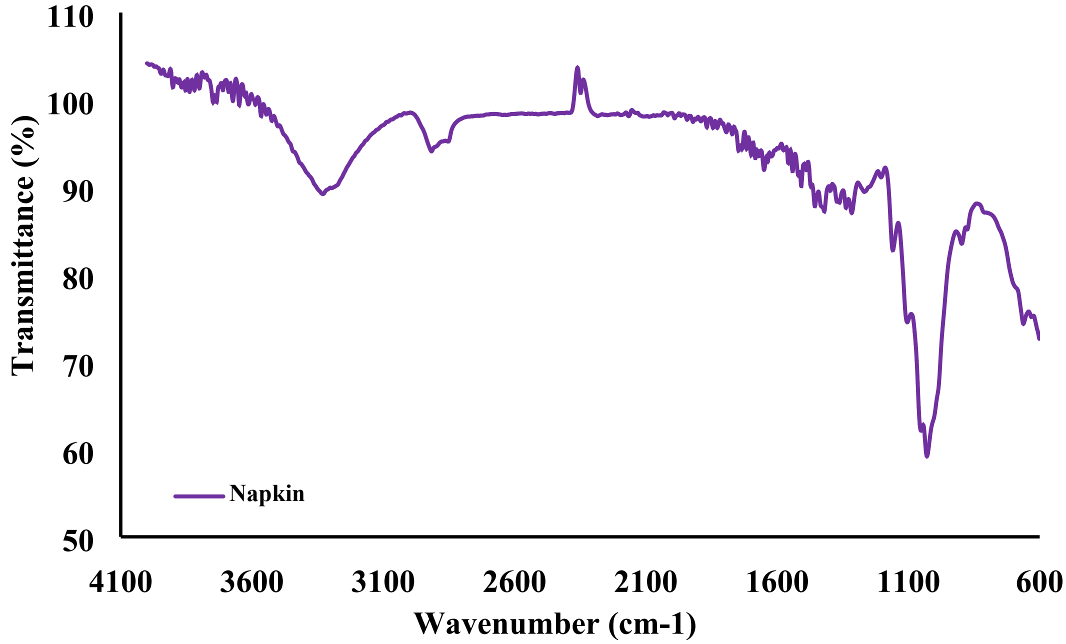



**Figure S5.** Full IR spectrum of the napkin over a range of 4000 to 600 $cm^{-1}$. The feature observed between 1900 and 2400 $cm^{-1}$ is an artifact of the ATR attachment.

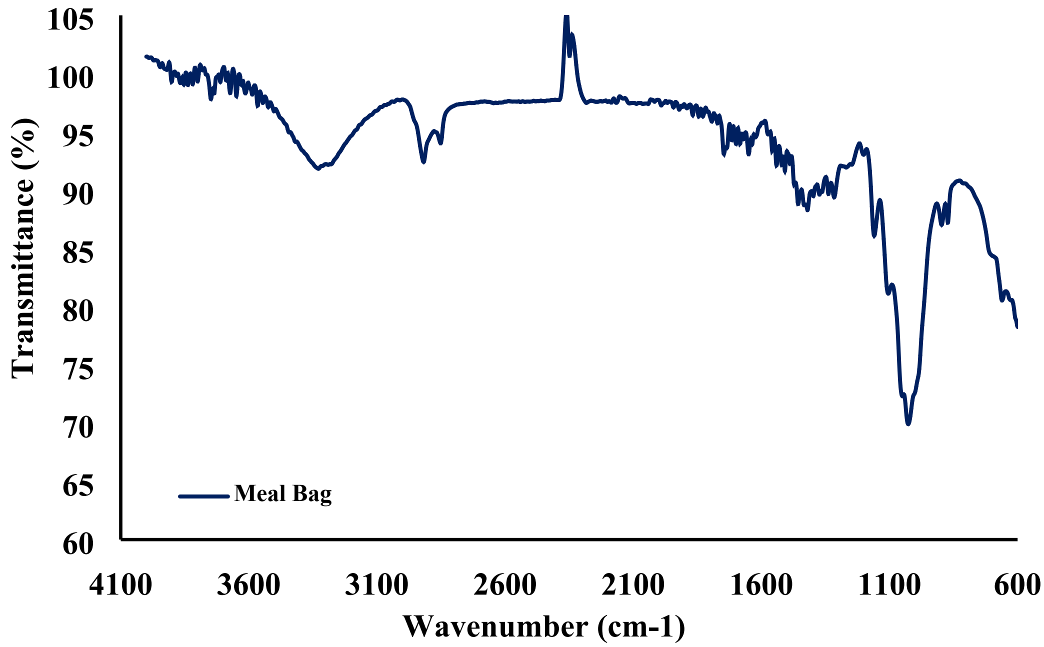



**Figure S6.** Full IR spectrum of the meal bag over a range of 4000 to 600 cm$^{-1}$. The feature observed between 1900 and 2400 cm$^{-1}$ is an artifact of the ATR attachment.

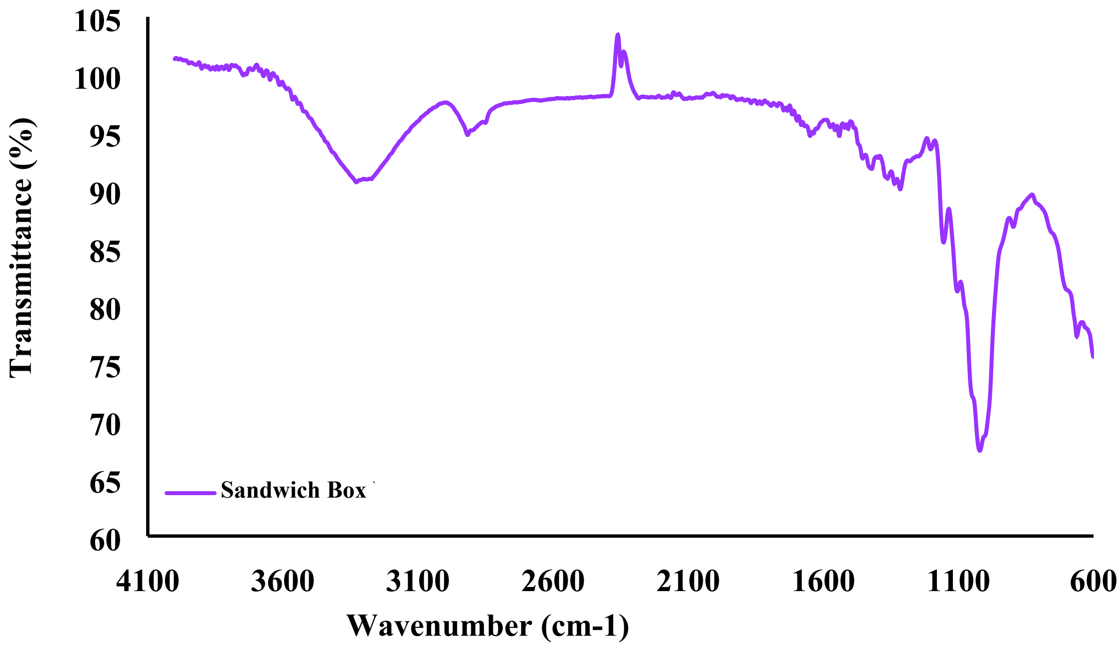



**Figure S7.** Full IR spectrum of the sandwich box over a range of 4000 to 600 $cm^{-1}$. The feature observed between 1900 and 2400 $cm^{-1}$ is an artifact of the ATR attachment.

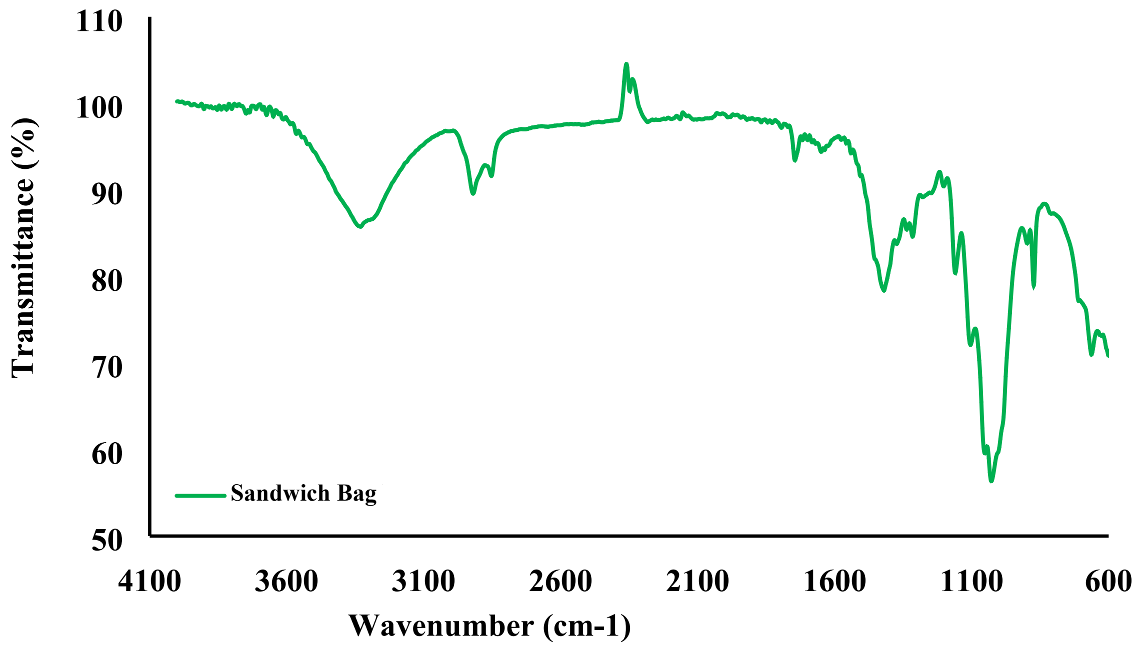



**Figure S8.** Full IR spectrum of the sandwich bag over a range of 4000 to 600 cm$^{-1}$. The feature observed between 1900 and 2400 cm$^{-1}$ is an artifact of the ATR attachment.

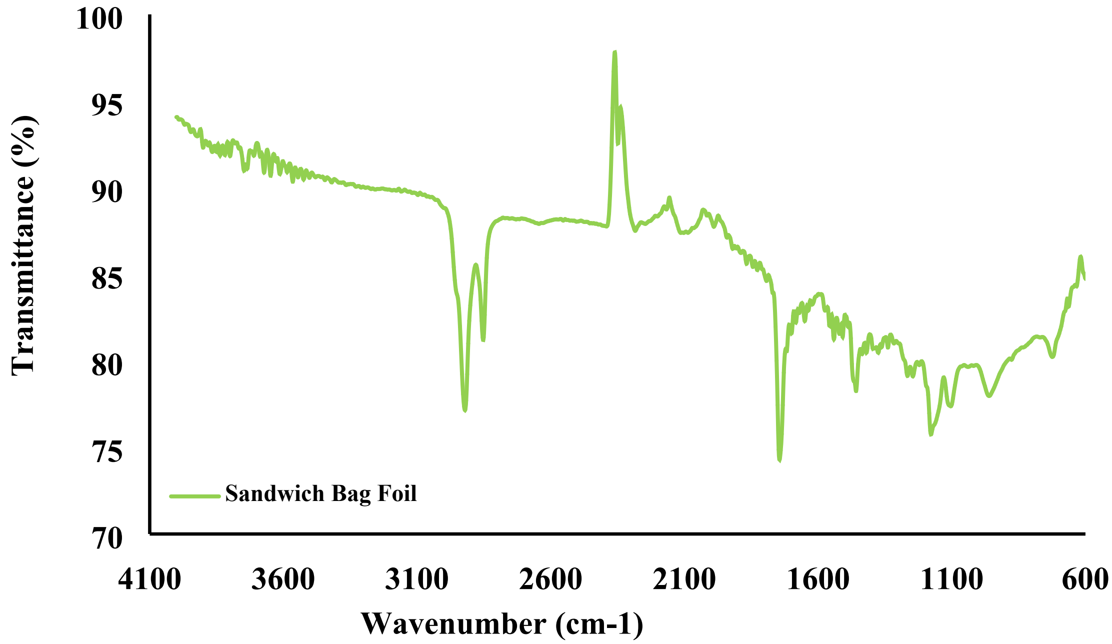



**Figure S9.** Full IR spectrum of the foil side of the sandwich bag over a range of 4000 to 600 $cm^{-1}$. The feature observed between 1900 and 2400 $cm^{-1}$ is an artifact of the ATR attachment.

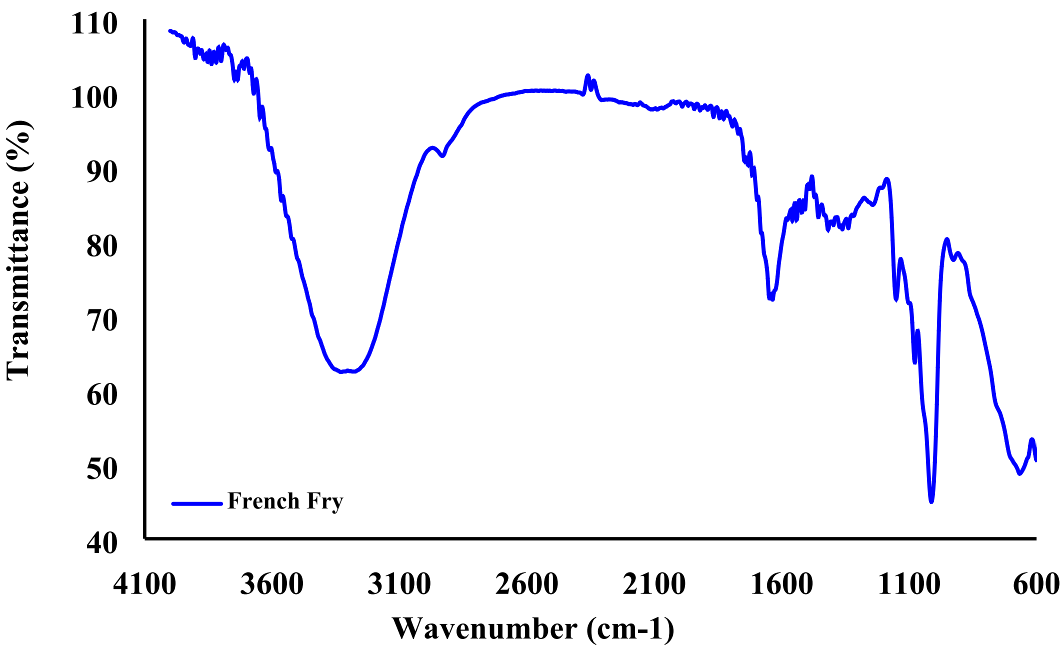



**Figure S10.** Full IR spectrum of a French fry over a range of 4000 to 600 cm$^{-1}$. The feature observed between 1900 and 2400 cm$^{-1}$ is an artifact of the ATR attachment.

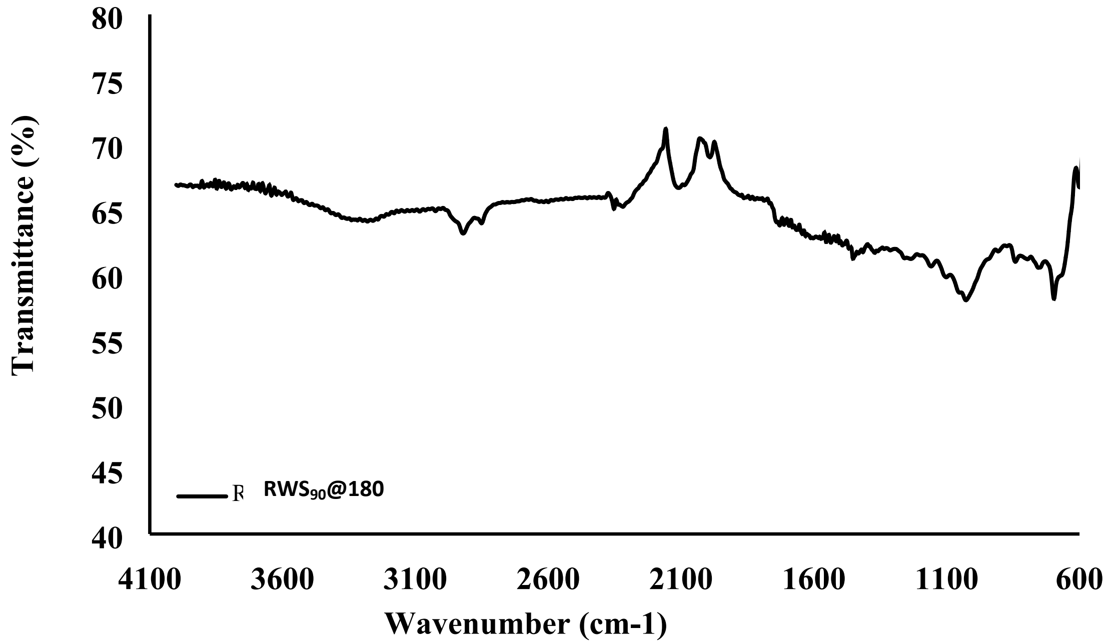



**Figure S11.** Full IR spectrum of **$RWS_{90}$@180** over a range of 4000 to 600 $cm^{-1}$. The feature observed between 1900 and 2400 $cm^{-1}$ is an artifact of the ATR attachment.

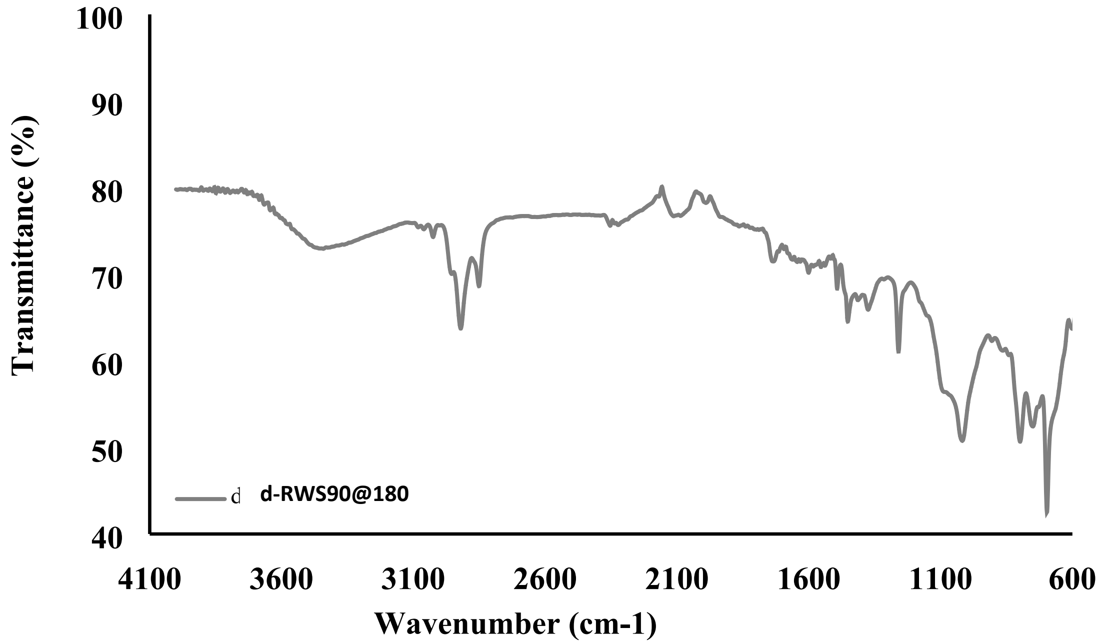



**Figure S12.** Full IR spectrum of **d-RWS$_{90}$@180** over a range of 4000 to 600 cm$^{-1}$. The feature observed between 1900 and 2400 cm$^{-1}$ is an artifact of the ATR attachment.

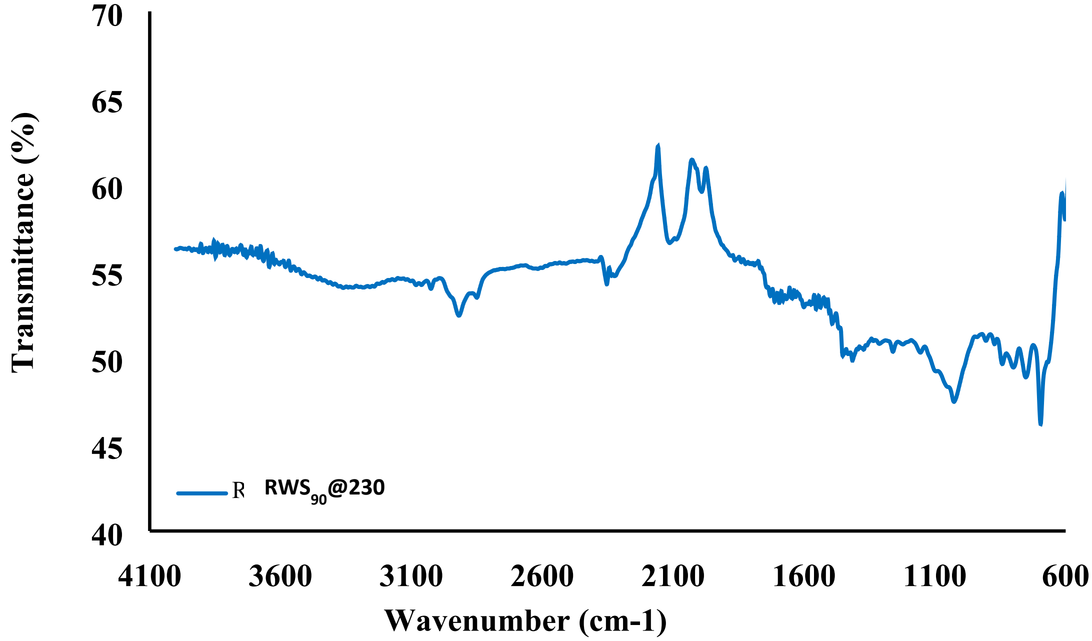



**Figure S13.** Full IR spectrum of **RWS$_{90}$@230** over a range of 4000 to 600 cm$^{-1}$. The feature observed between 1900 and 2400 cm$^{-1}$ is an artifact of the ATR attachment.

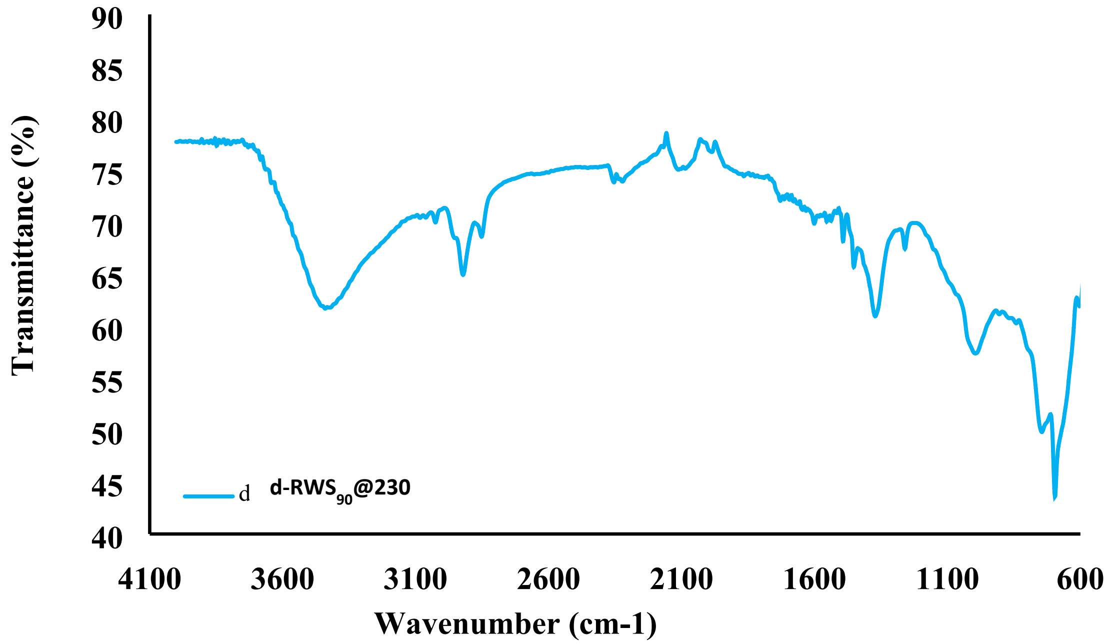



**Figure S14.** Full IR spectrum of **d-RWS$_{90}$@230** over a range of 4000 to 600 cm$^{-1}$. The feature observed between 1900 and 2400 cm$^{-1}$ is an artifact of the ATR attachment.

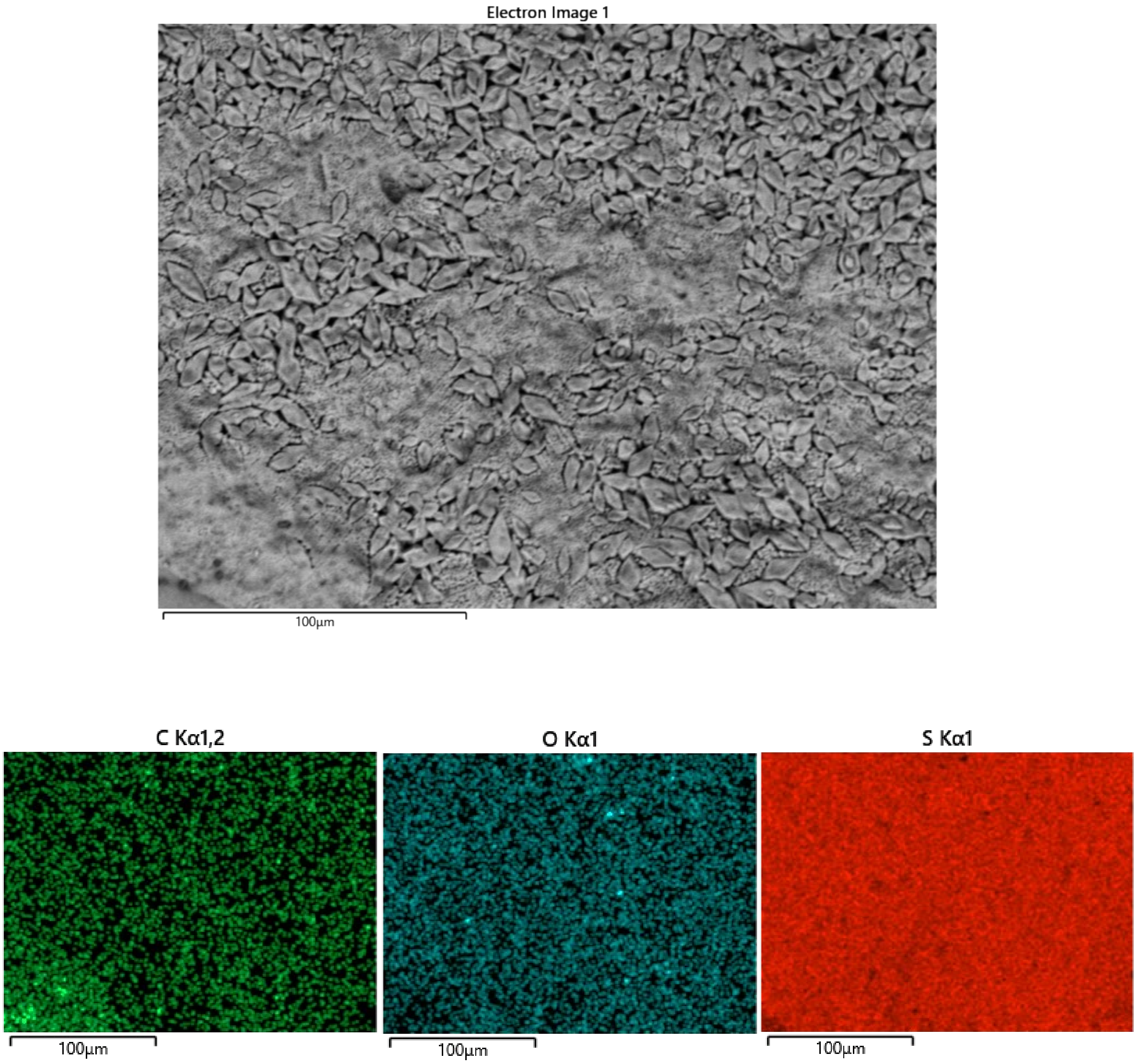



**Figure S15.** Scanning electron microscopy (SEM, gray) with elemental mapping by energy dispersive X-ray (EDX) of carbon (green), oxygen (blue), and sulfur (red) of **RWS$_{90}$@180**.

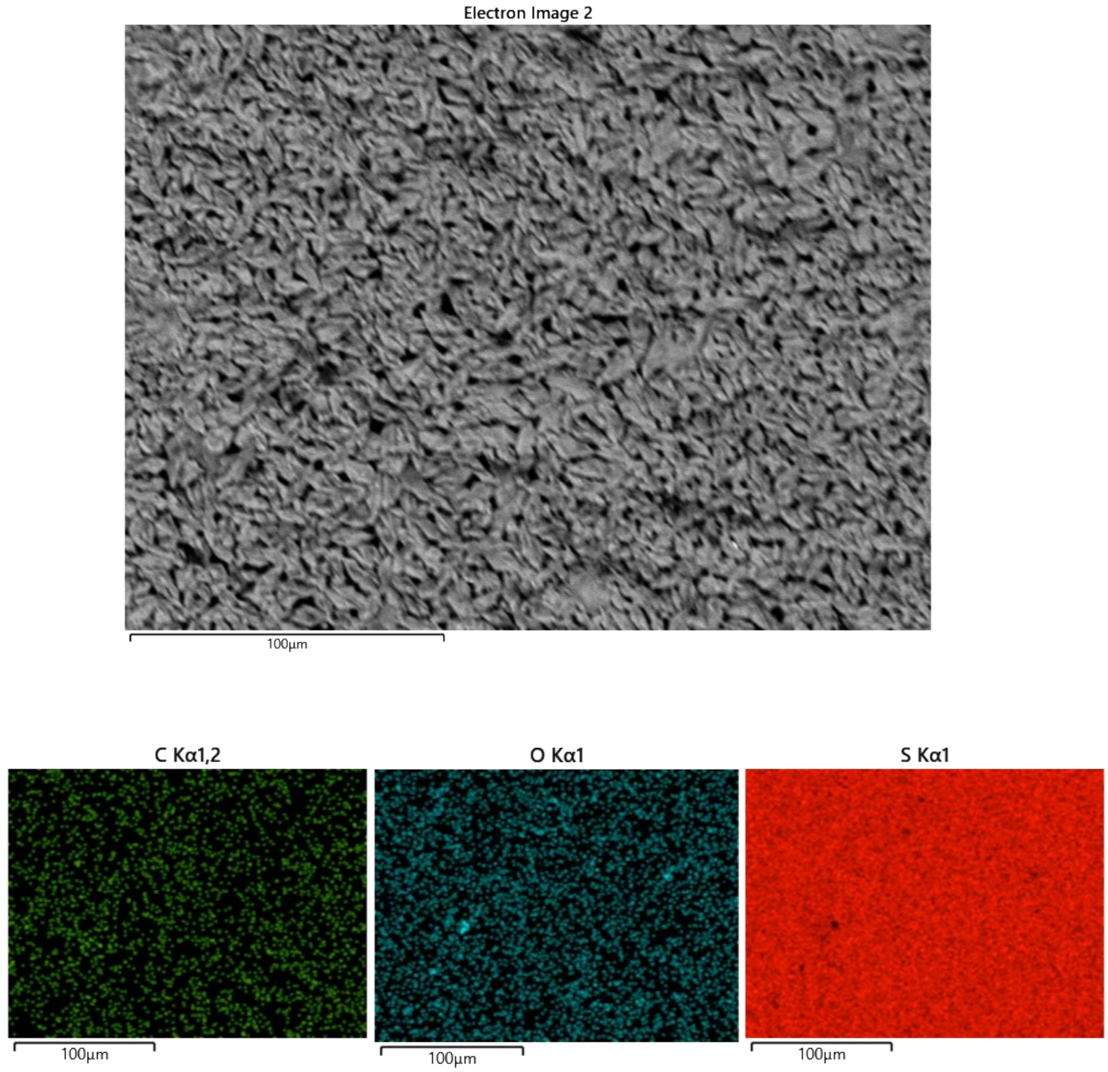



**Figure S16.** Scanning electron microscopy (SEM, gray) with elemental mapping by energy dispersive X-ray (EDX) of carbon (green), oxygen (blue), and sulfur (red) of **RWS$_{90}$@230**.

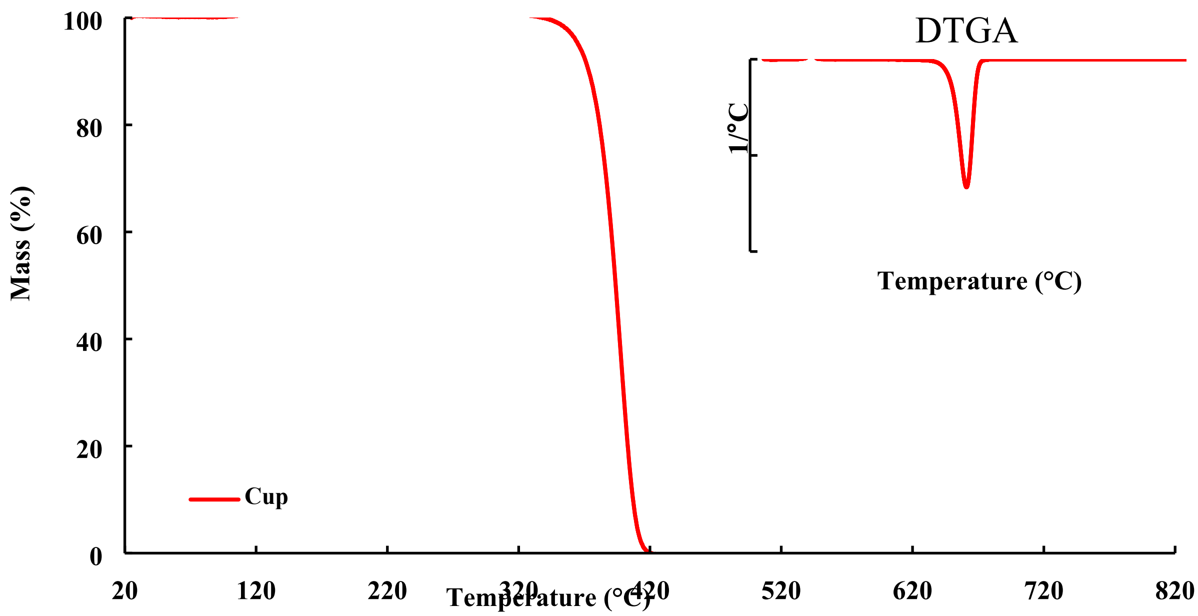



**Figure S17.** Mass loss curve and DTGA from thermogravimetric analysis for the cup over the range 25–800 °C.

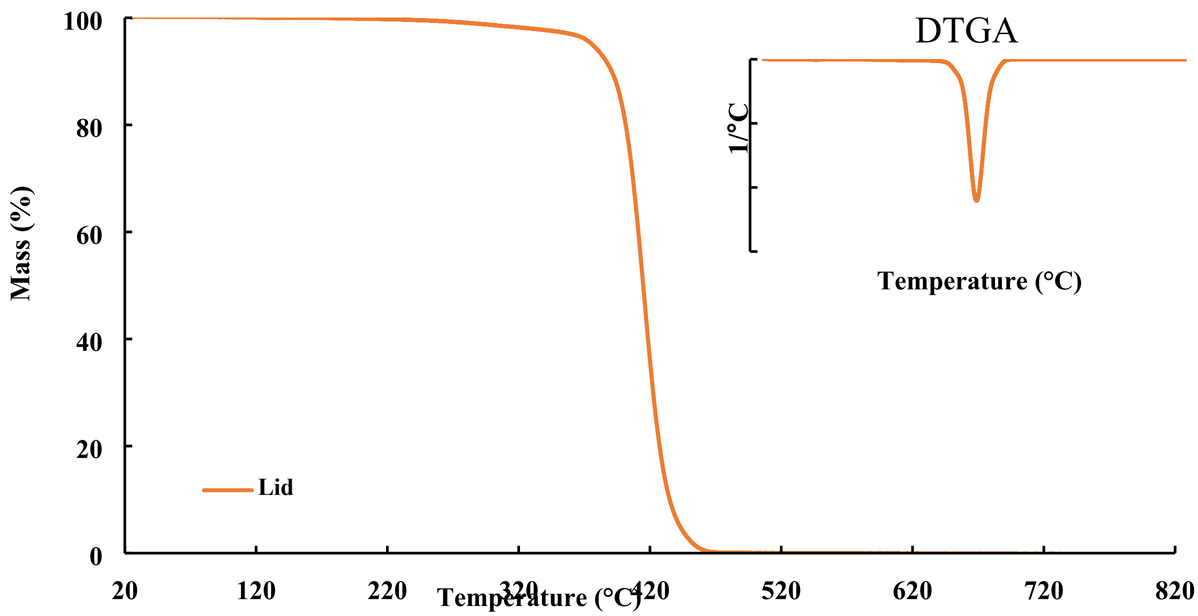



**Figure S18.** Mass loss curve and DTGA from thermogravimetric analysis for the lid over the range 25–800 °C.

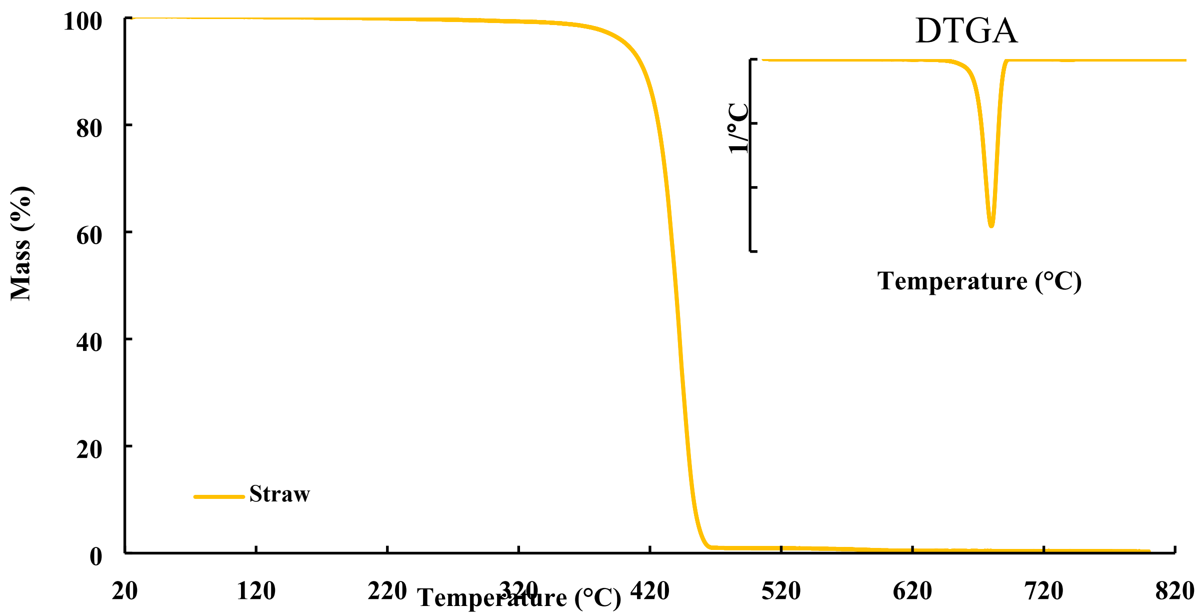



**Figure S19.** Mass loss curve and DTGA from thermogravimetric analysis for the straw over the range 25–800 °C.

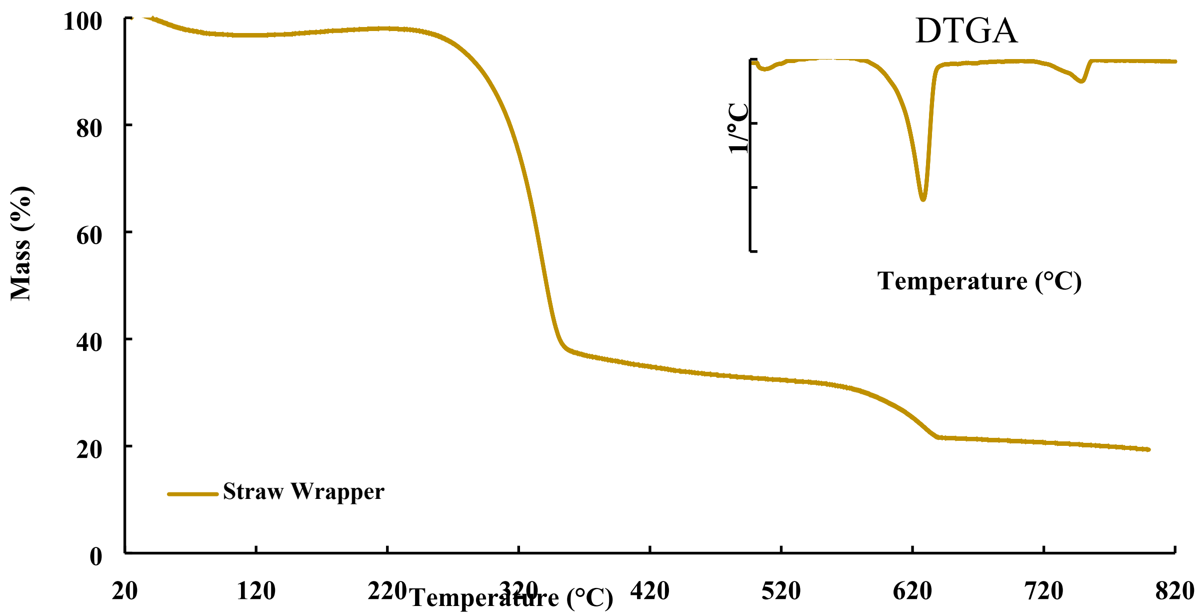



**Figure S20.** Mass loss curve and DTGA from thermogravimetric analysis for the straw wrapper over the range 25–800 °C.

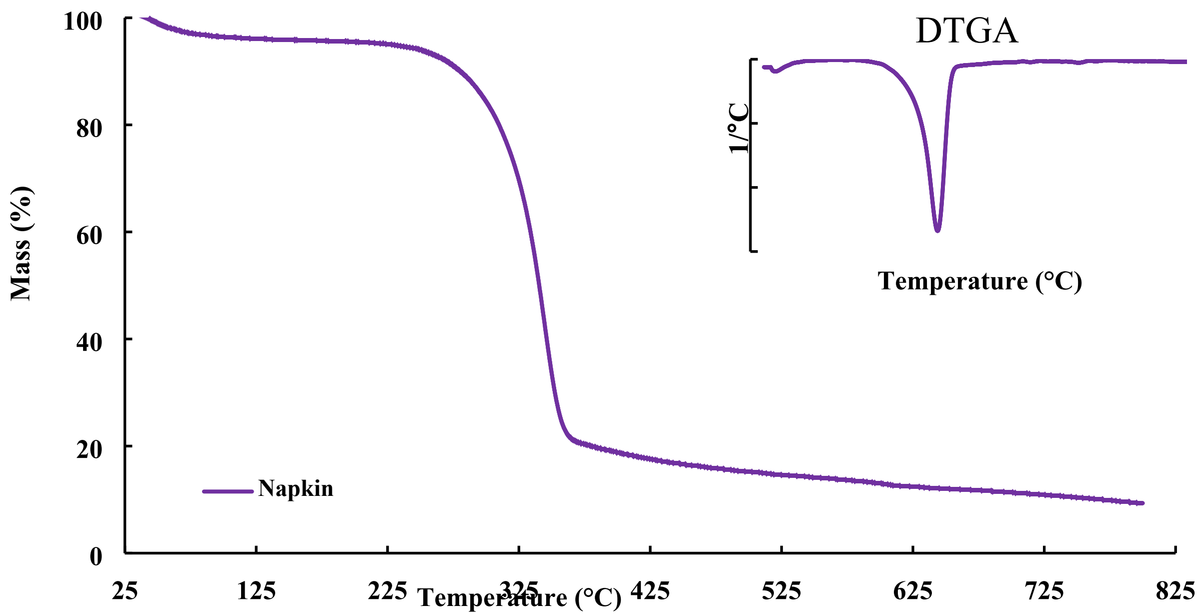



**Figure S21.** Mass loss curve and DTGA from thermogravimetric analysis for the napkin over the range 25–800 °C.

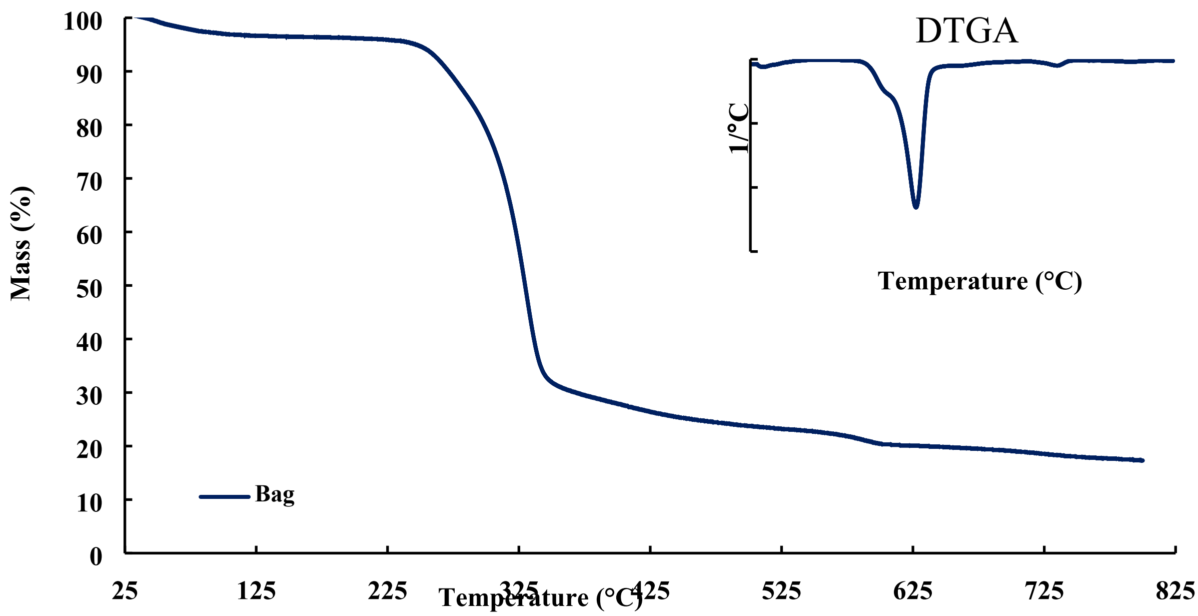



**Figure S22.** Mass loss curve and DTGA from thermogravimetric analysis for the meal bag over the range 25–800 °C.

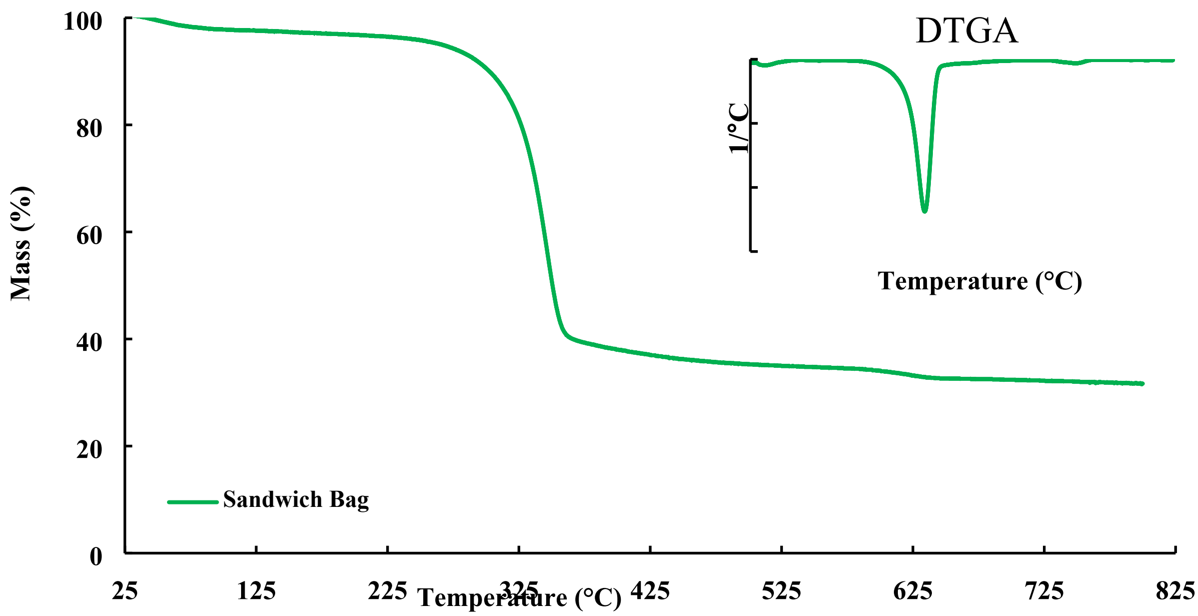



**Figure S23.** Mass loss curve and DTGA from thermogravimetric analysis for the sandwich bag over the range 25–800 °C.

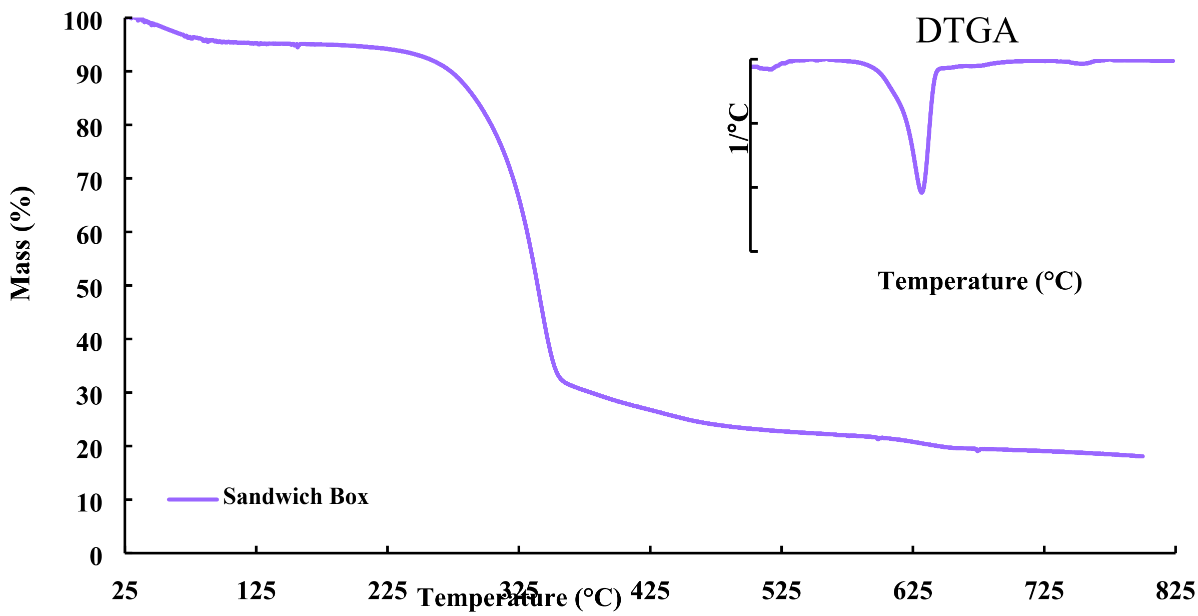



**Figure S24.** Mass loss curve and DTGA from thermogravimetric analysis for the sandwich box over the range 25–800 °C.

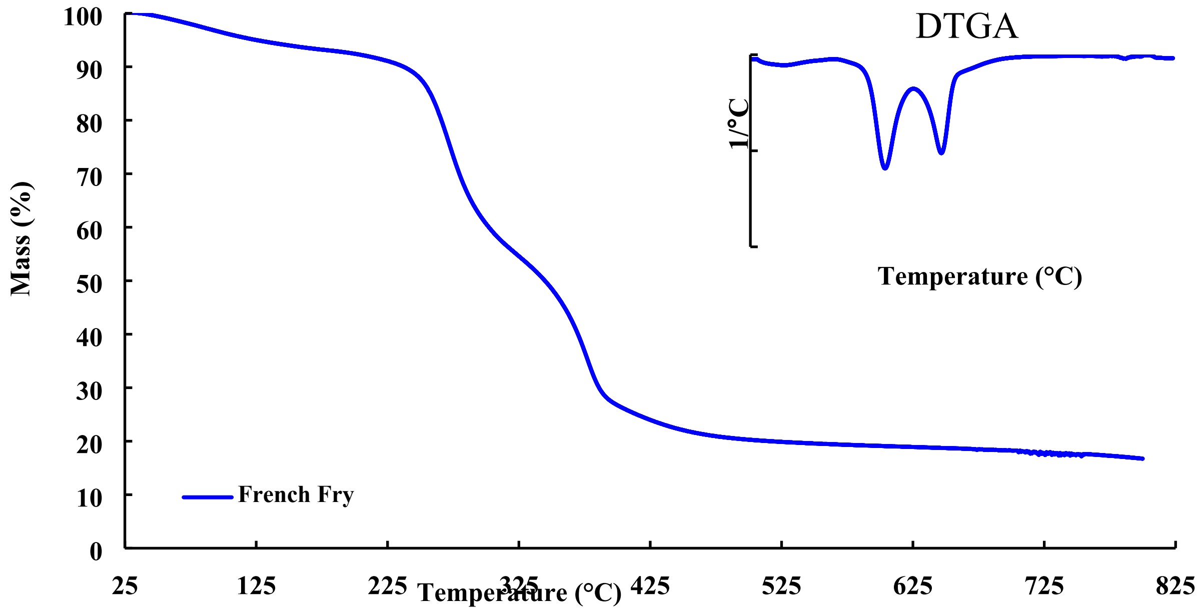



**Figure S25.** Mass loss curve and DTGA from thermogravimetric analysis for the French fry over the range 25–800 °C.

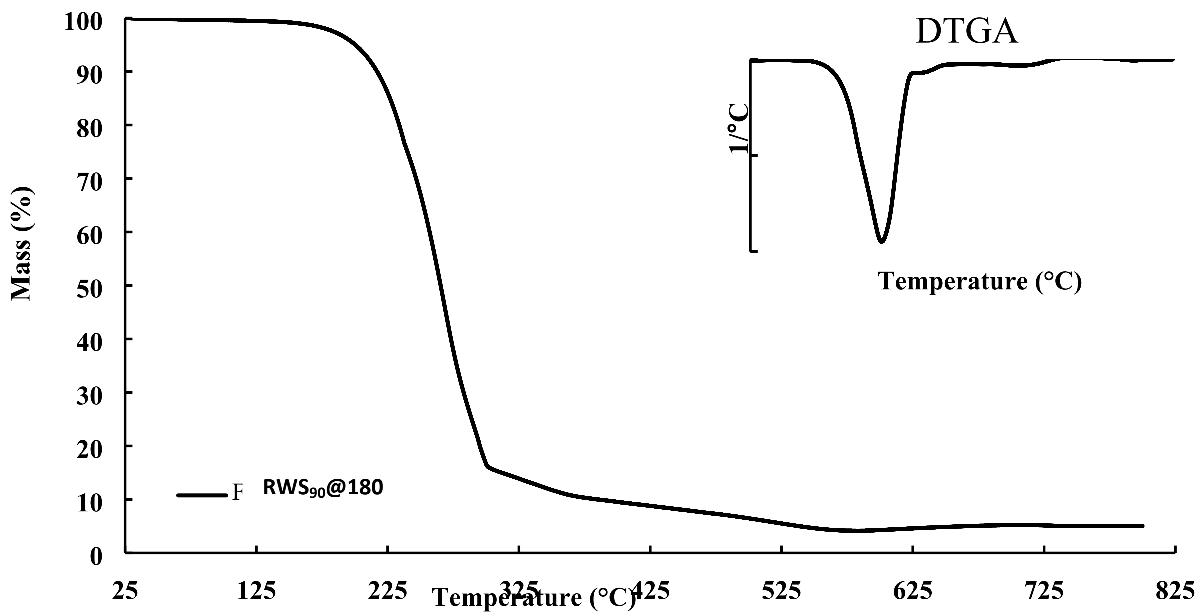



**Figure S26.** Mass loss curve and DTGA from thermogravimetric analysis for **RWS$_{90}$@180** over the range 25–800 °C.

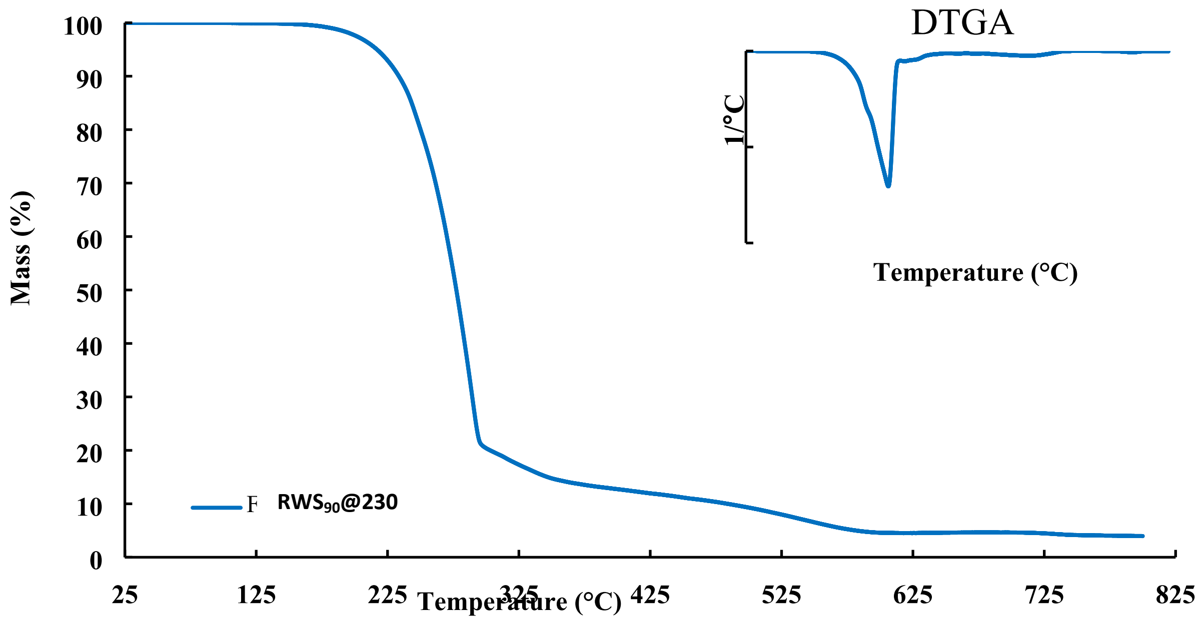



**Figure S27.** Mass loss curve and DTGA from thermogravimetric analysis for **RWS$_{90}$@230** over the range 25–800 °C.

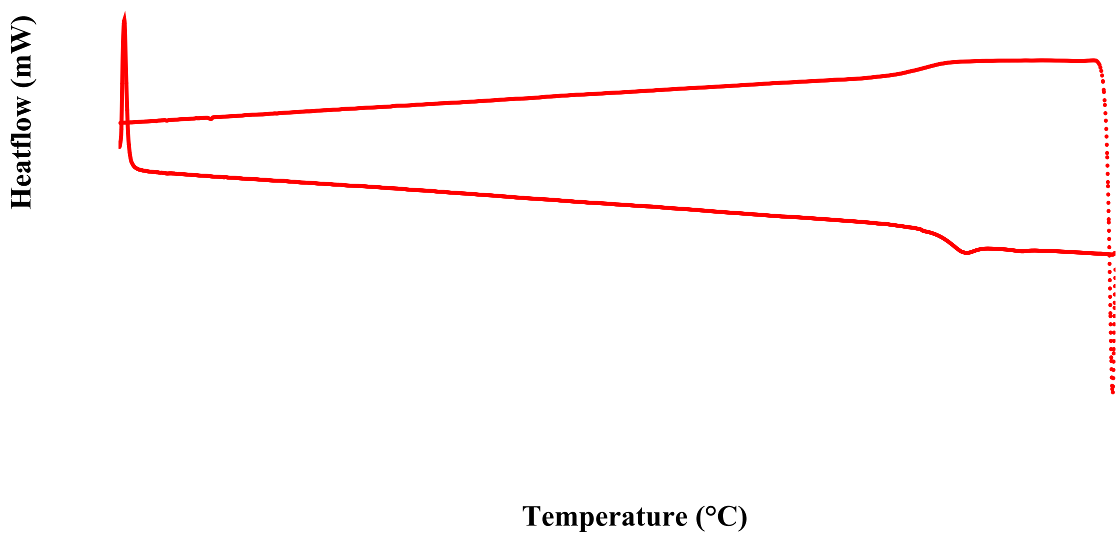



**Figure S28.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the cup over the range –60–140 °C.

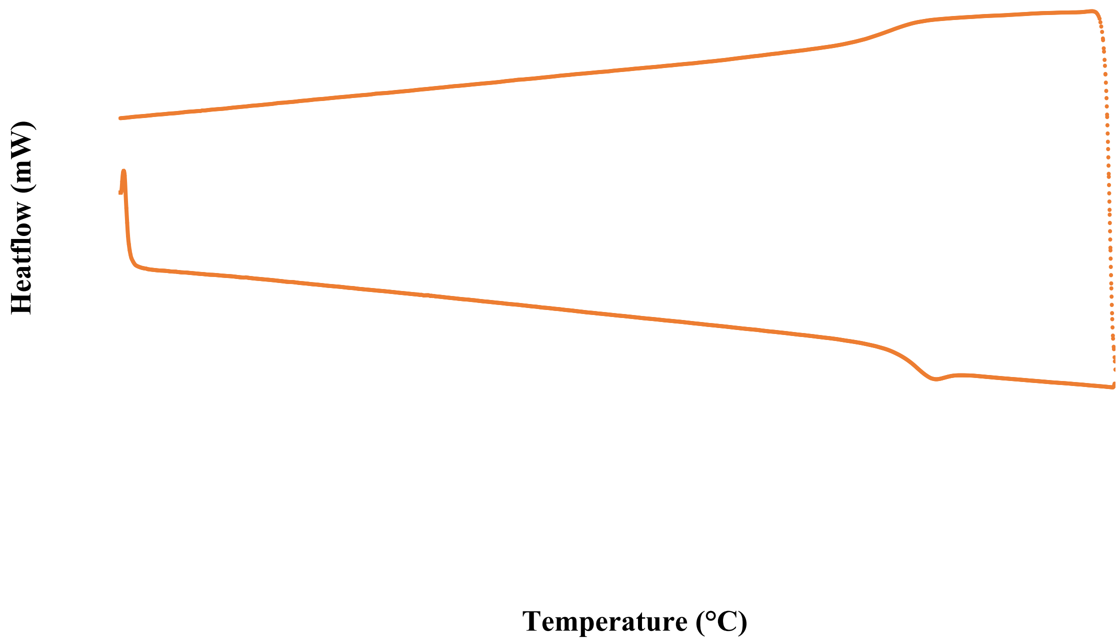



**Figure S29.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the lid over the range –60–140 °C.

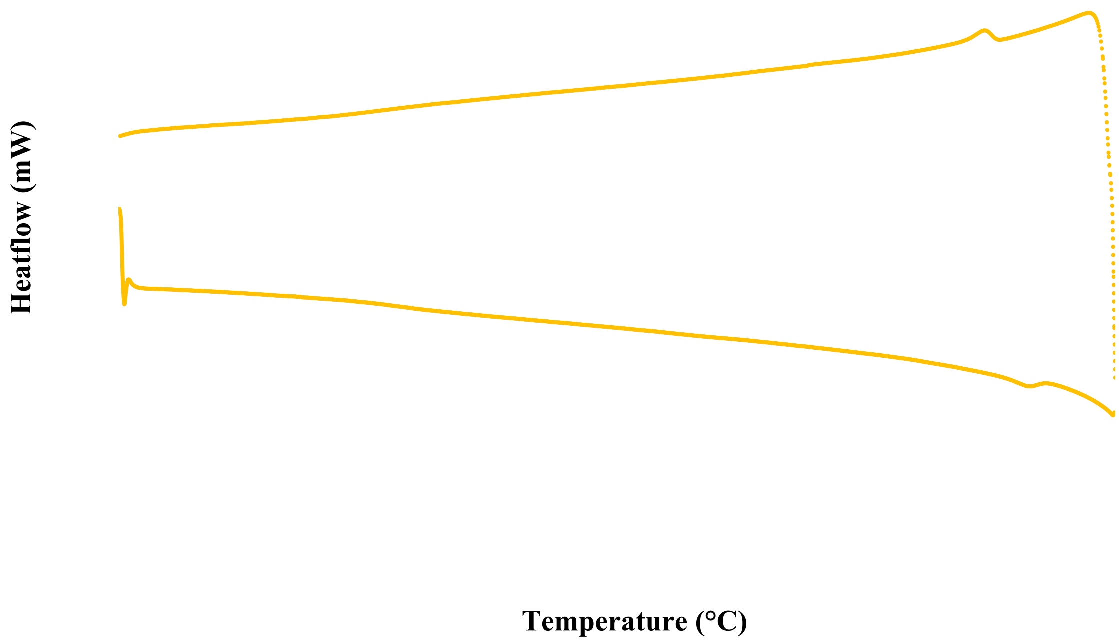



**Figure S30.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the straw over the range –60–140 °C.

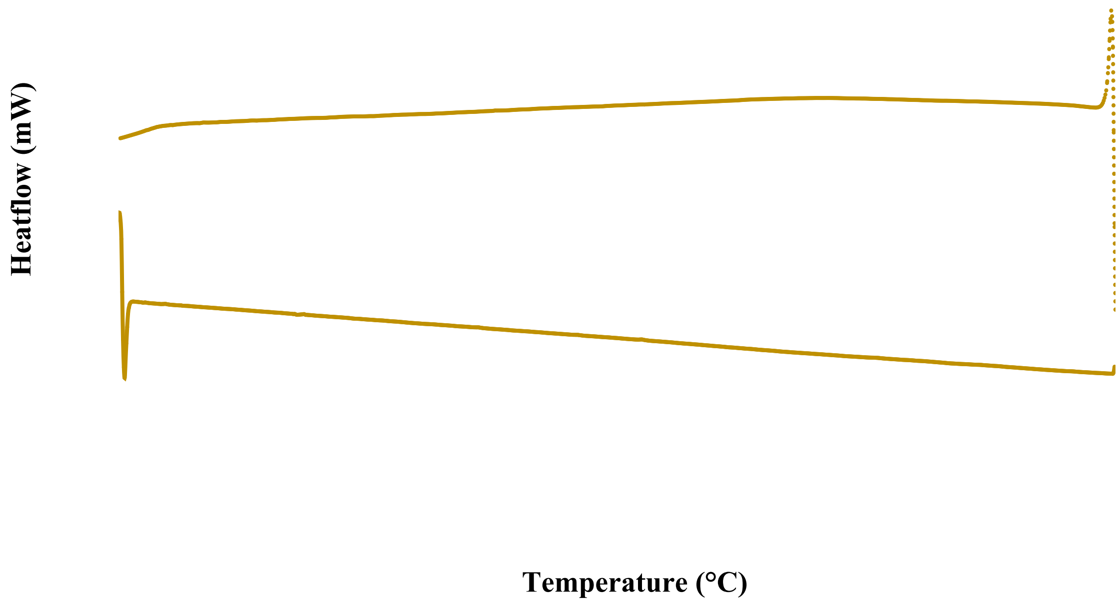



**Figure S31.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the straw wrapper over the range –60–140 °C.

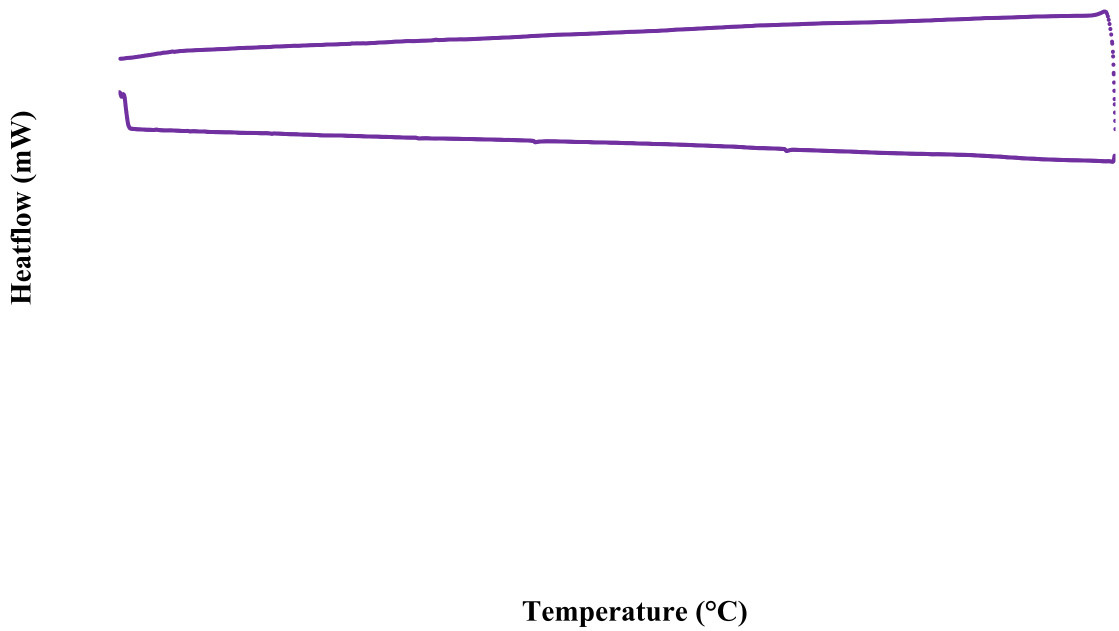



**Figure S32.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the napkin over the range –60–140 °C.

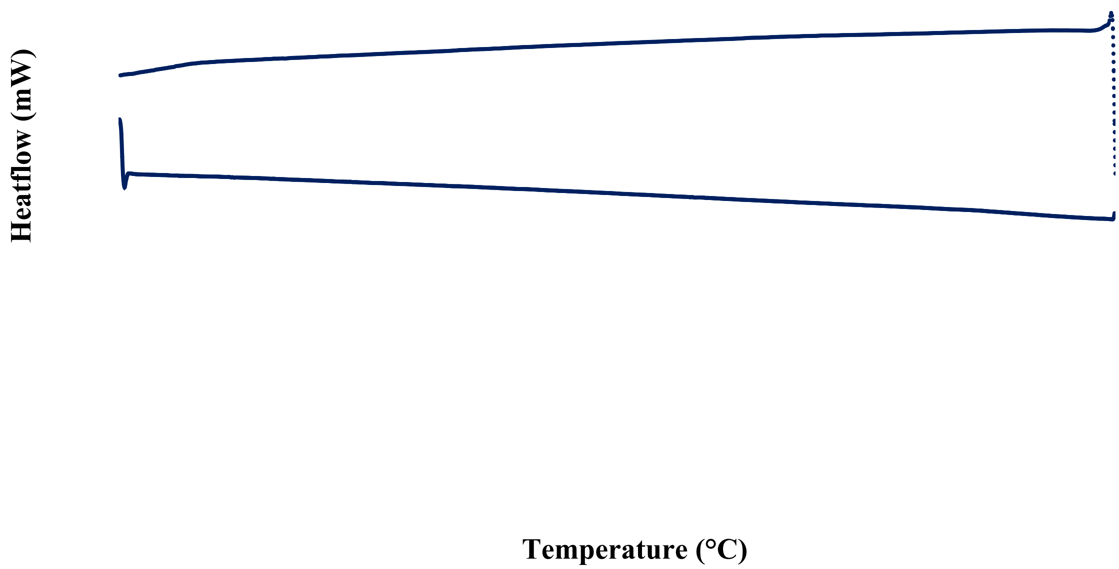



**Figure S33.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the meal bag over the range –60–140 °C.

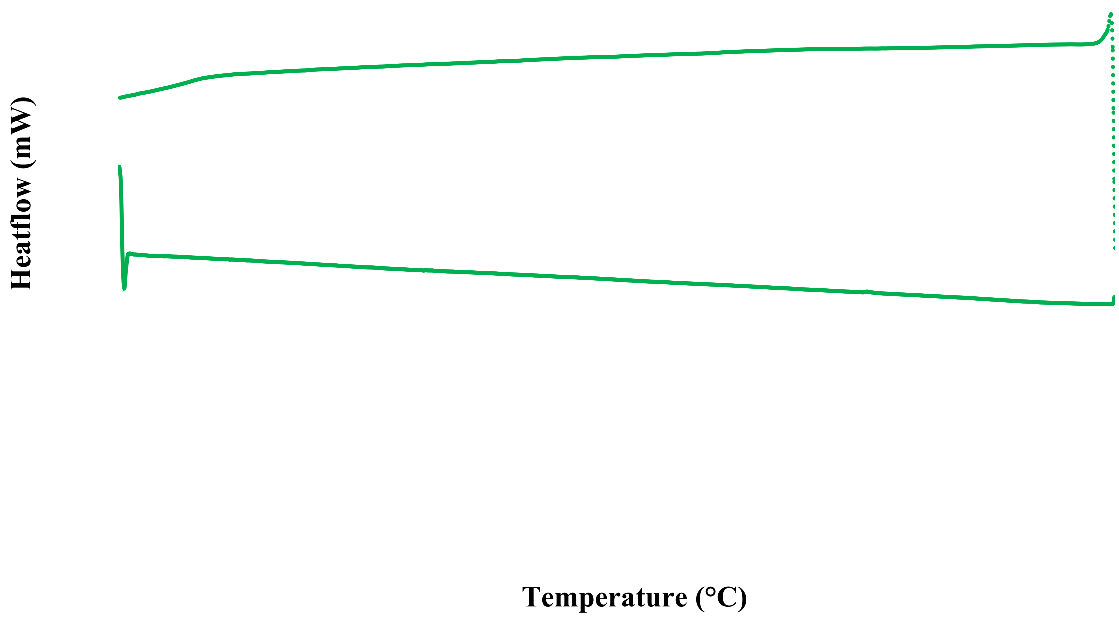



**Figure S34.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the sandwich bag over the range –60–140 °C.

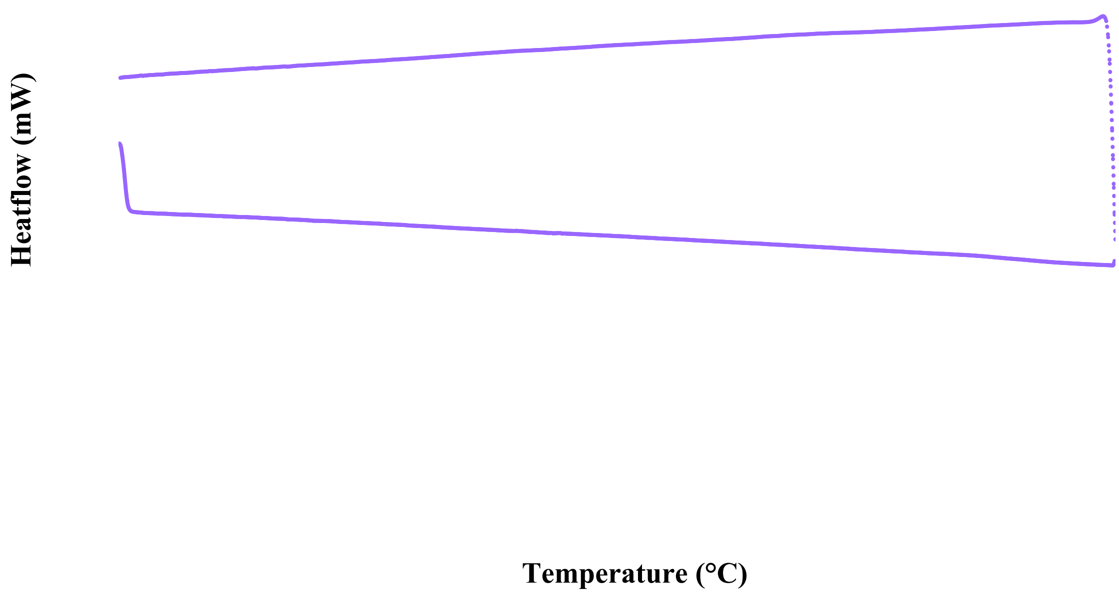



**Figure S35.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the sandwich box over the range –60–140 °C.

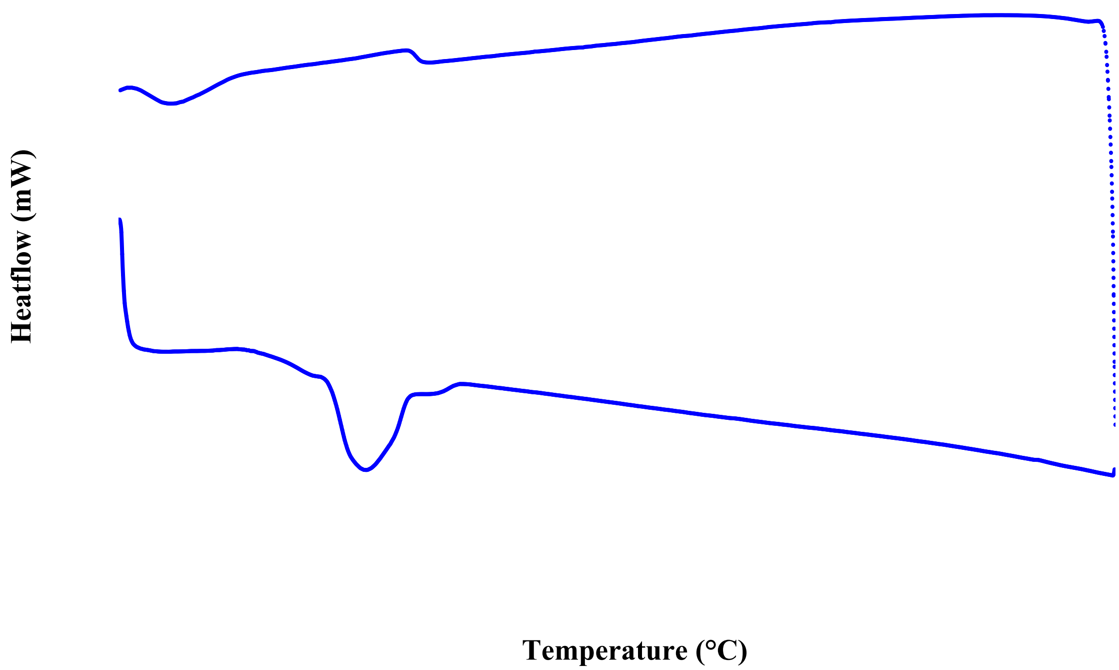



**Figure S36.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for the French fry over the range –60–140 °C.

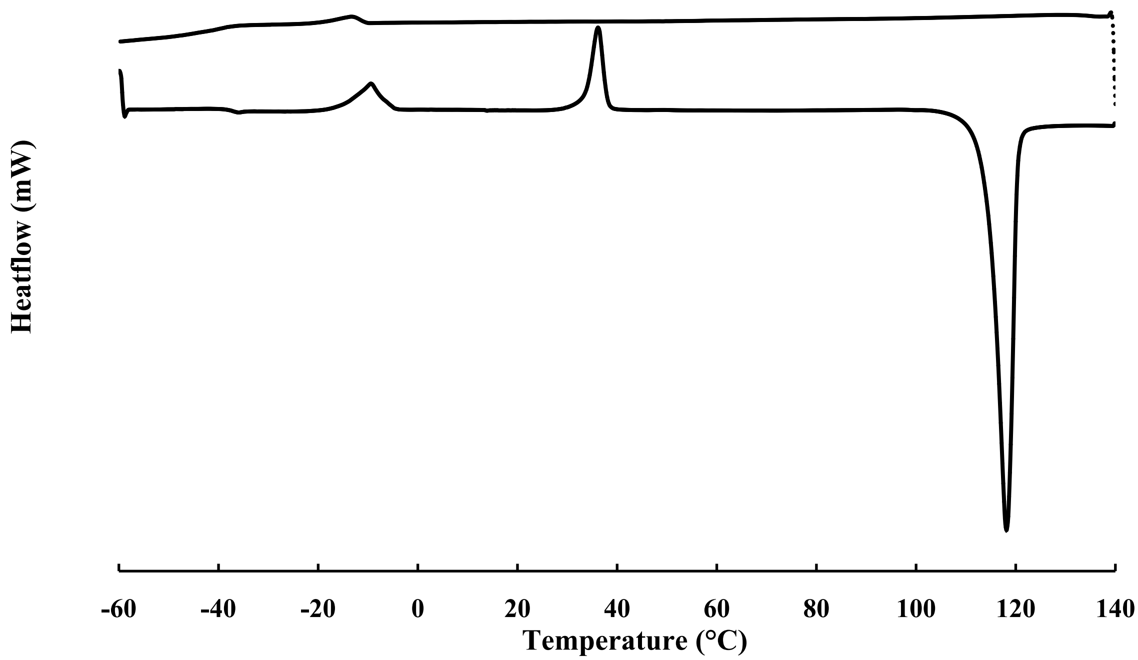



**Figure S37.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for **RWS$_{90}$@180** over the range –60–140 °C.

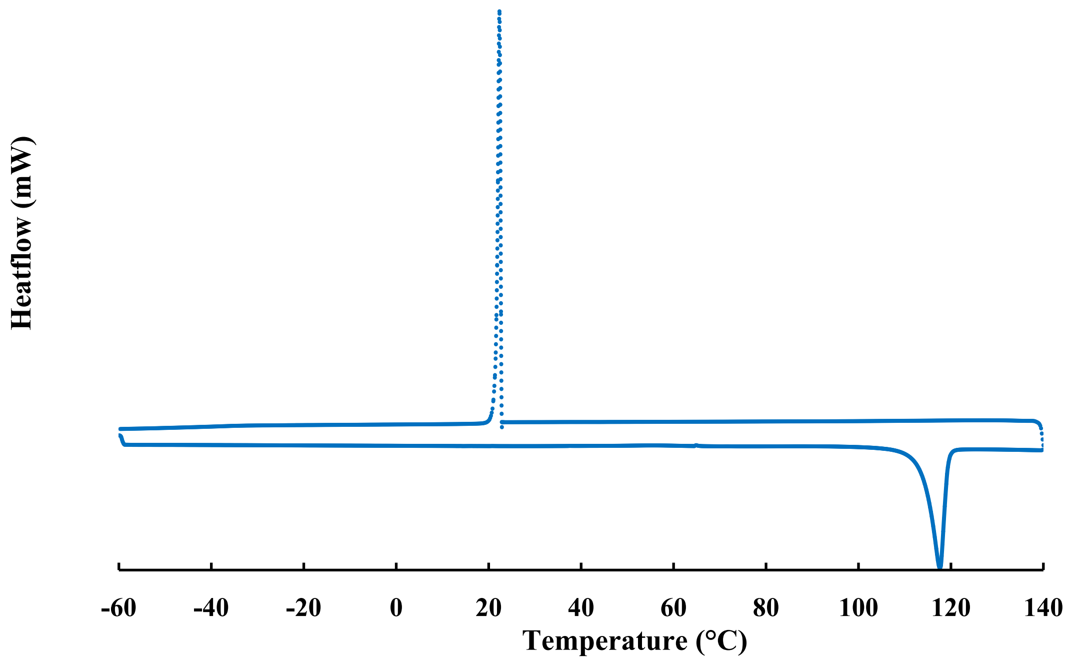
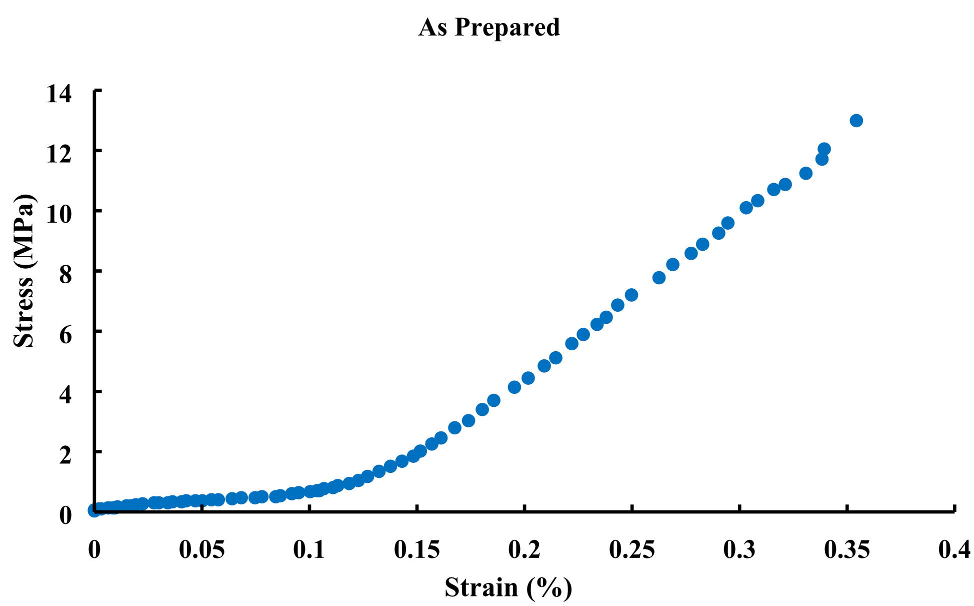



**Figure S38.** Thermogram from differential scanning calorimetry (endothermic down) for the third heating (solid trace) and cooling (dotted trace) cycles for **RWS$_{90}$@230** over the range –60–140 °C.


As Prepared
Stress (MPa)
14
12
10
8
6
4
2
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Strain (%)

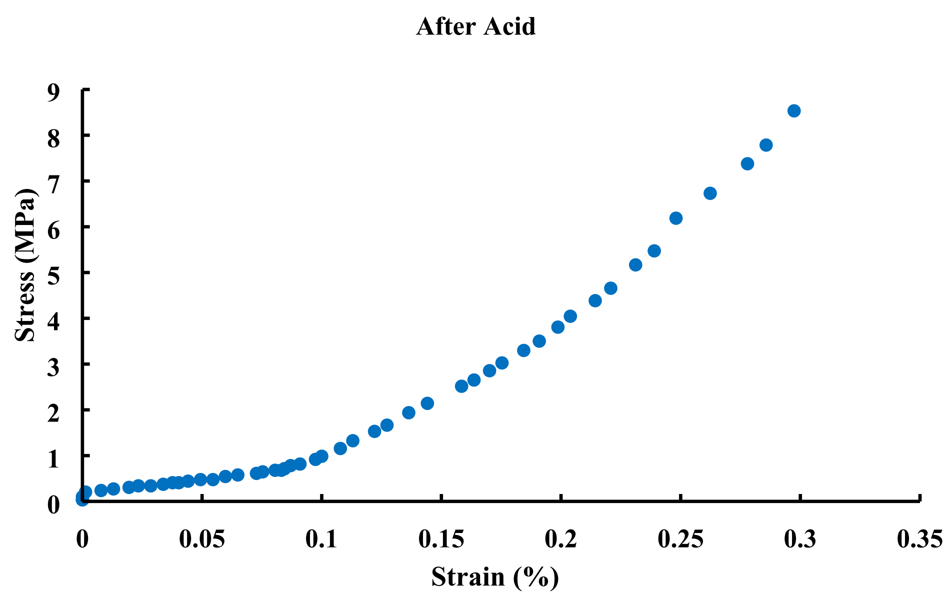
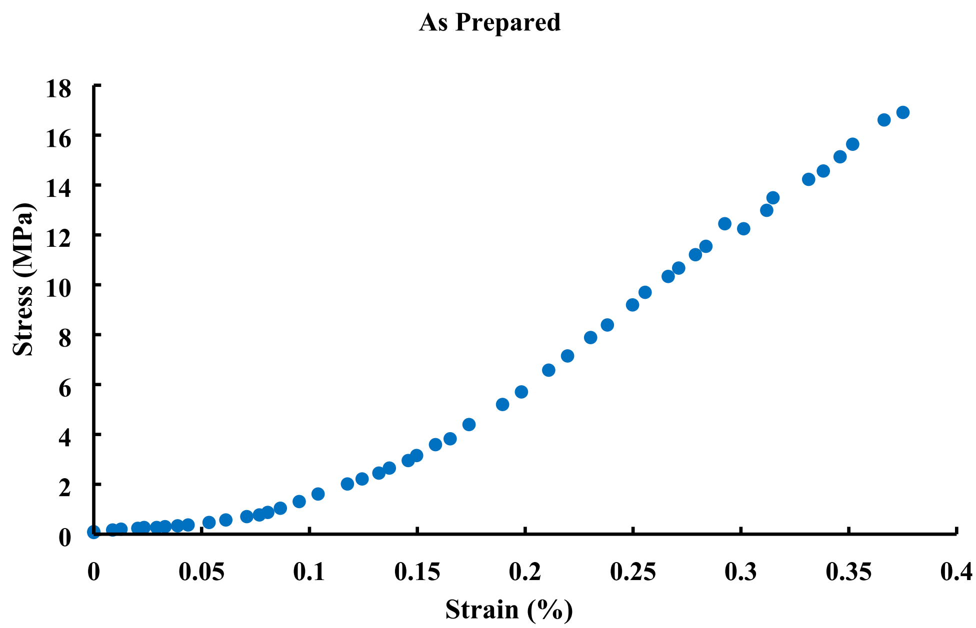

After Acid
Stress (MPa)
9
8
7
6
5
4
3
2
1
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Strain (%)

**Figure S39.** Stress-strain plots for measurements of the compressive strength of **RWS$_{90}$@180** as prepared (top, 12.2 ± 0.8 MPa) and after acid challenge (bottom, 8.2 ± 1.0 MPa).



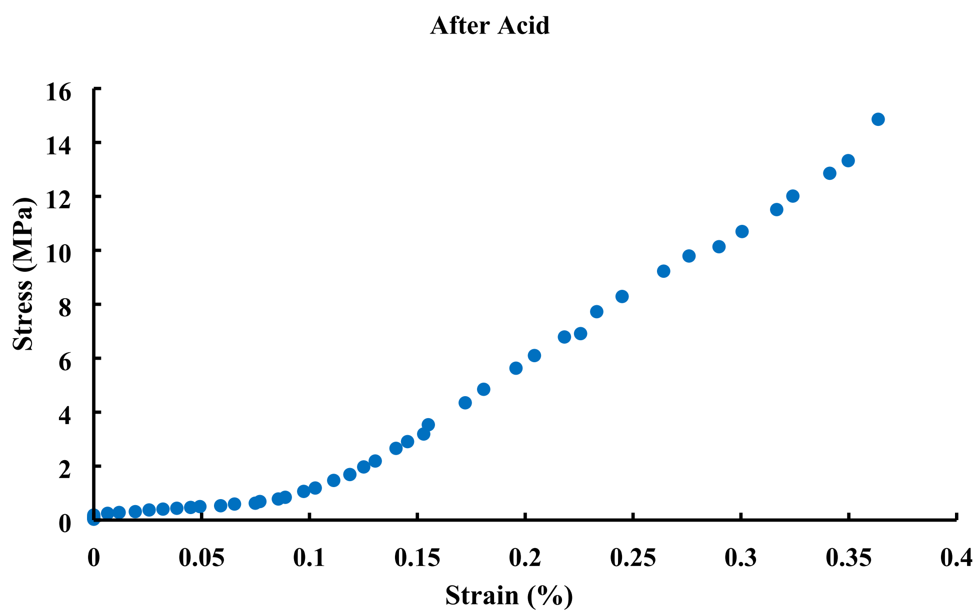




**Figure S40.** Stress-strain plots for measurements of the compressive strength of **RWS$_{90}$@230** as prepared (top, 16.3 ± 0.6 MPa) and after acid challenge (bottom, 14.9 ± 0.6 MPa).

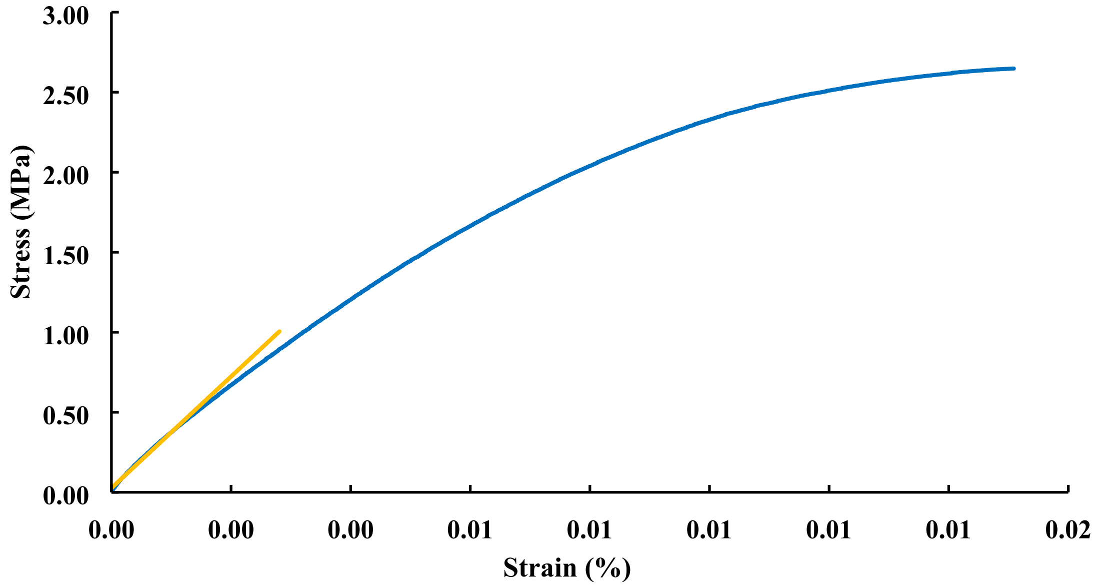



**Figure S41.** Stress-strain curve of **$RWS_{90}$@180** determined during flexural strength testing.

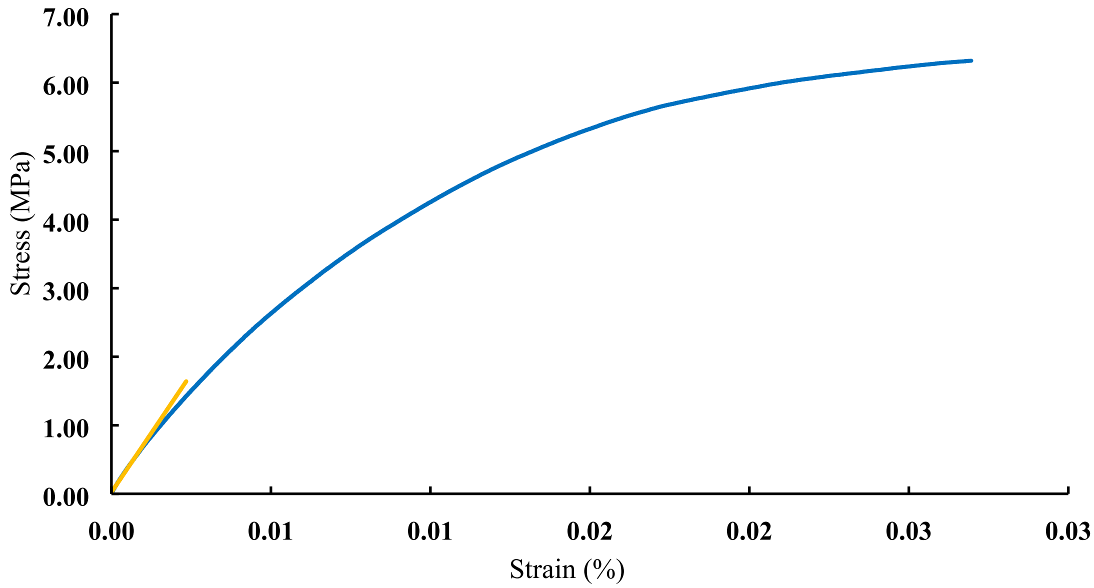



**Figure S42.** Stress-strain curve of **RWS$_{90}$@230** determined during flexural strength testing.

**Global Warming Potential Assumptions**

When calculating the global warming potential of a material, it is crucial to lay out the scope and assumptions used to provide the end value with meaning. In the calculations below, it was assumed that had the sulfur not been used in this process, it would remain landfilled, and therefore, does not count against the syntheses of **$RWS_{90}$@180** and **$RWS_{90}$@230**. The individual components considered in this calculation include the cellulose-based materials (paper), French fries, polystyrene, and polypropylene. These calculations assume that the paper, polystyrene, and polypropylene components would have been sorted out for recycling and thus incinerated had they not been used in the preparation of these composites; it was likewise assumed that the waste French fries would remain landfilled. The values for the incineration of paper, polystyrene, and polypropylene are 1.62 kg $CO_2$e/kg, 3.40 kg $CO_2$e/kg, and 3.14 kg $CO_2$e/kg, respectively. The reported global warming potentials used in these calculations for paper are 0.942 kg $CO_2$e/kg,[72] for French fries 3.62 kg $CO_2$e/kg,[73] for polystyrene 3.00 kg $CO_2$e/kg,[74] and for polypropylene 2.14 kg $CO_2$e/kg.[74] The energy required to grind 1.00 kg of material requires an average of 0.500 kg $CO_2$e/kWh for the electricity.[75-80] The heating of each material takes into account the energy needed to raise the temperature of the reaction from 20 °C to 180 °C or 230 °C, respectively, and holding that temperature for 24 h. These values for the reaction temperatures of 180 °C and 230 °C were determined to be 0.0160 kg $CO_2$e/kg[81-86] and 0.0250 kg $CO_2$e/kg,[87] respectively.

| Process for **$RWS_{90}$@180** | Cost (+) or Credit (–) | Value (kg $CO_2$e) |
|---|---|---|
| Make Paper (0.00875 kg × 0.942 kg $CO_2$e/kg) | + | 0.000820 |
| Make Fries (0.0194 kg × 3.62 kg $CO_2$e/kg) | – | 0.0700 |
| Make Polystyrene (0.00561 kg × 3.00 kg $CO_2$e/kg) | + | 0.0170 |
| Make Polypropylene (0.000366 kg × 2.14 kg $CO_2$e/kg) | + | 0.000780 |
| Grinding (0.100 kg × 0.500 kg $CO_2$e/kg) | + | 0.0500 |
| Heating and Evaporating 0.0410 kg water) | + | 0.0150 |
| Prevent Incineration of Paper (0.00875 kg × 1.62 kg $CO_2$e/kg) | – | 0.0140 |
| Prevent Incineration of Polystyrene (0.00561 kg × 3.40 kg $CO_2$e/kg) | – | 0.0190 |
| Prevent Incineration of Polypropylene (0.000366 kg × 3.14 kg $CO_2$e/kg) | – | 0.00110 |
| Heating (1.00 kg × 0.0160 kg $CO_2$e/kg) | + | 0.0160 |
| | **TOTAL** | **–0.00450** |

| Process for **$RWS_{90}$@230** | Cost (+) or Credit (–) | Value (kg $CO_2$e) |
|---|---|---|
| Make Paper (0.00875 kg × 0.942 kg $CO_2$e/kg) | + | 0.000820 |
| Make Fries (0.0194 kg × 3.62 kg $CO_2$e/kg) | – | 0.0700 |
| Make Polystyrene (0.00561 kg × 3.00 kg $CO_2$e/kg) | + | 0.0170 |
| Make Polypropylene (0.000366 kg × 2.14 kg $CO_2$e/kg) | + | 0.000780 |
| Grinding (0.100 kg × 0.500 kg $CO_2$e/kg) | + | 0.0500 |
| Heating and Evaporating 0.0410 kg water) | + | 0.0150 |
| Prevent Incineration of Paper (0.00875 kg × 1.62 kg $CO_2$e/kg) | – | 0.0140 |
| Prevent Incineration of Polystyrene (0.00561 kg × 3.40 kg $CO_2$e/kg) | – | 0.0190 |
| Prevent Incineration of Polypropylene (0.000366 kg × 3.14 kg $CO_2$e/kg) | – | 0.00110 |
| Heating (1.00 kg × 0.0250 kg $CO_2$e/kg) | + | 0.0250 |
| | **TOTAL** | **+0.00450** |