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APPENDICES

APPENDIX A: X-RAY DIFFRACTION SPECTRA

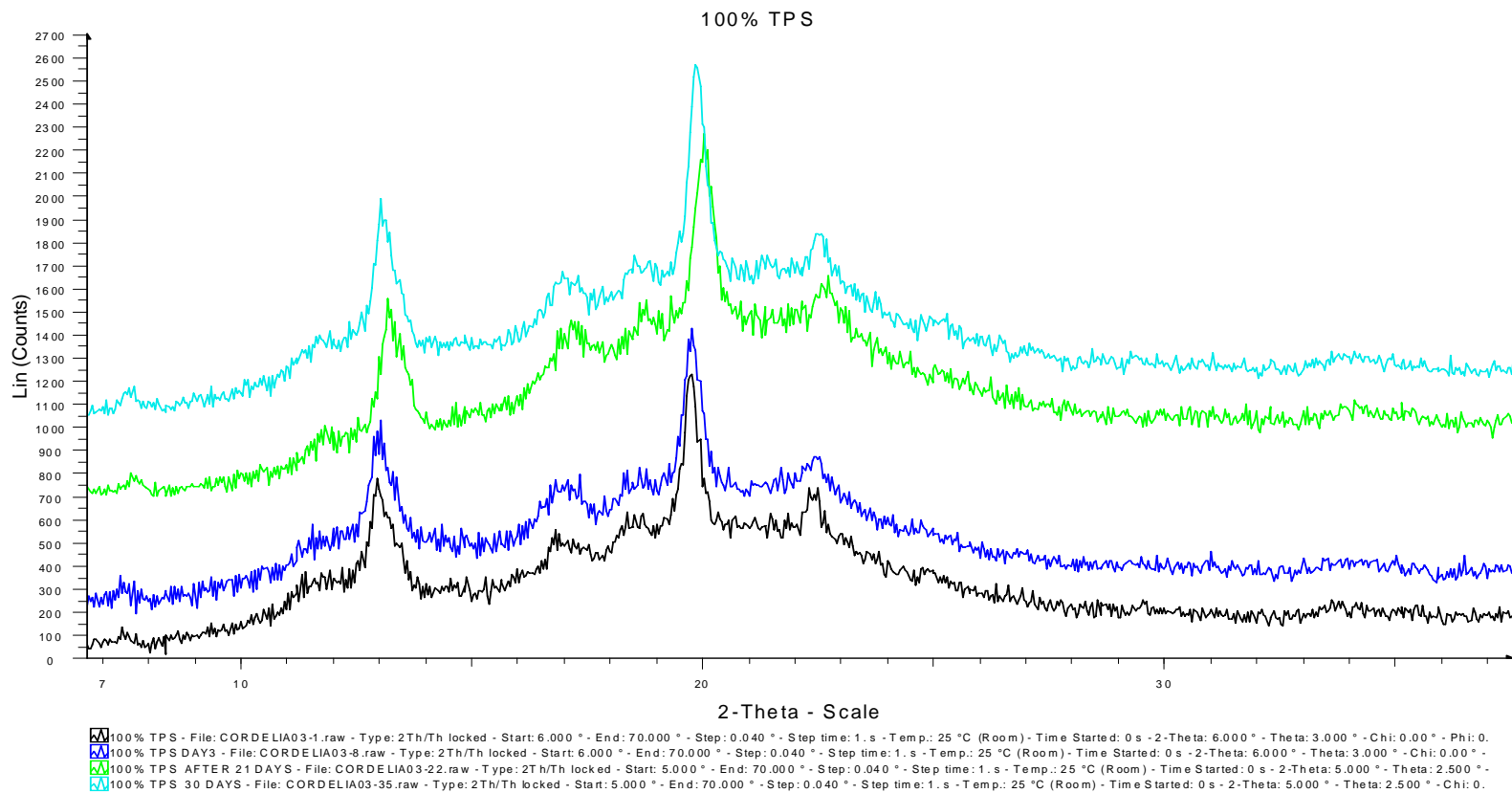


Figure A1: XRD spectra of the TPS-PVB blend containing 0% PVB blends at 30 °C and 60% RH

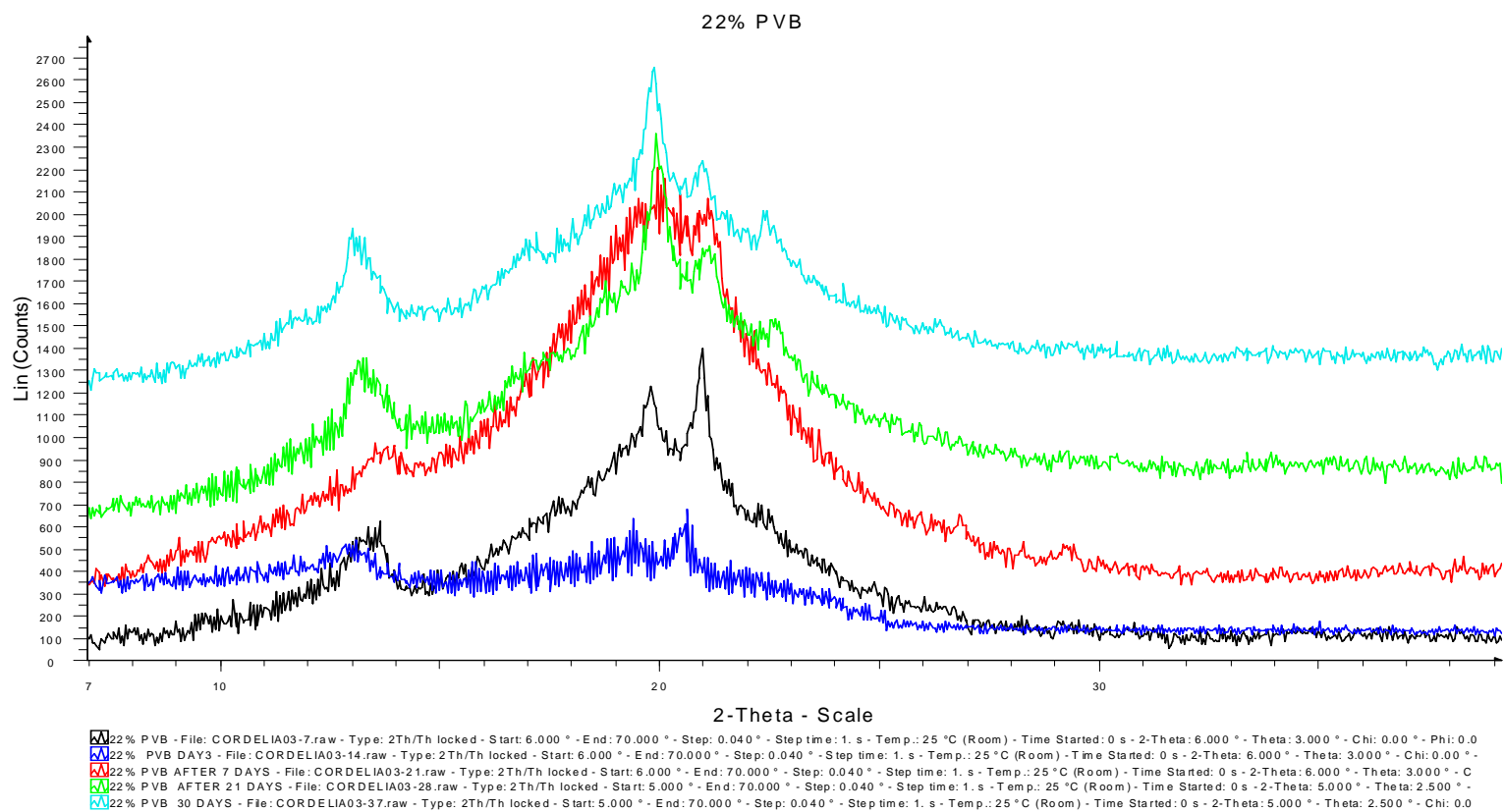


Figure A2: XRD spectra of the TPS-PVB blend containing 22% PVB blends at 30 °C and 60% RH

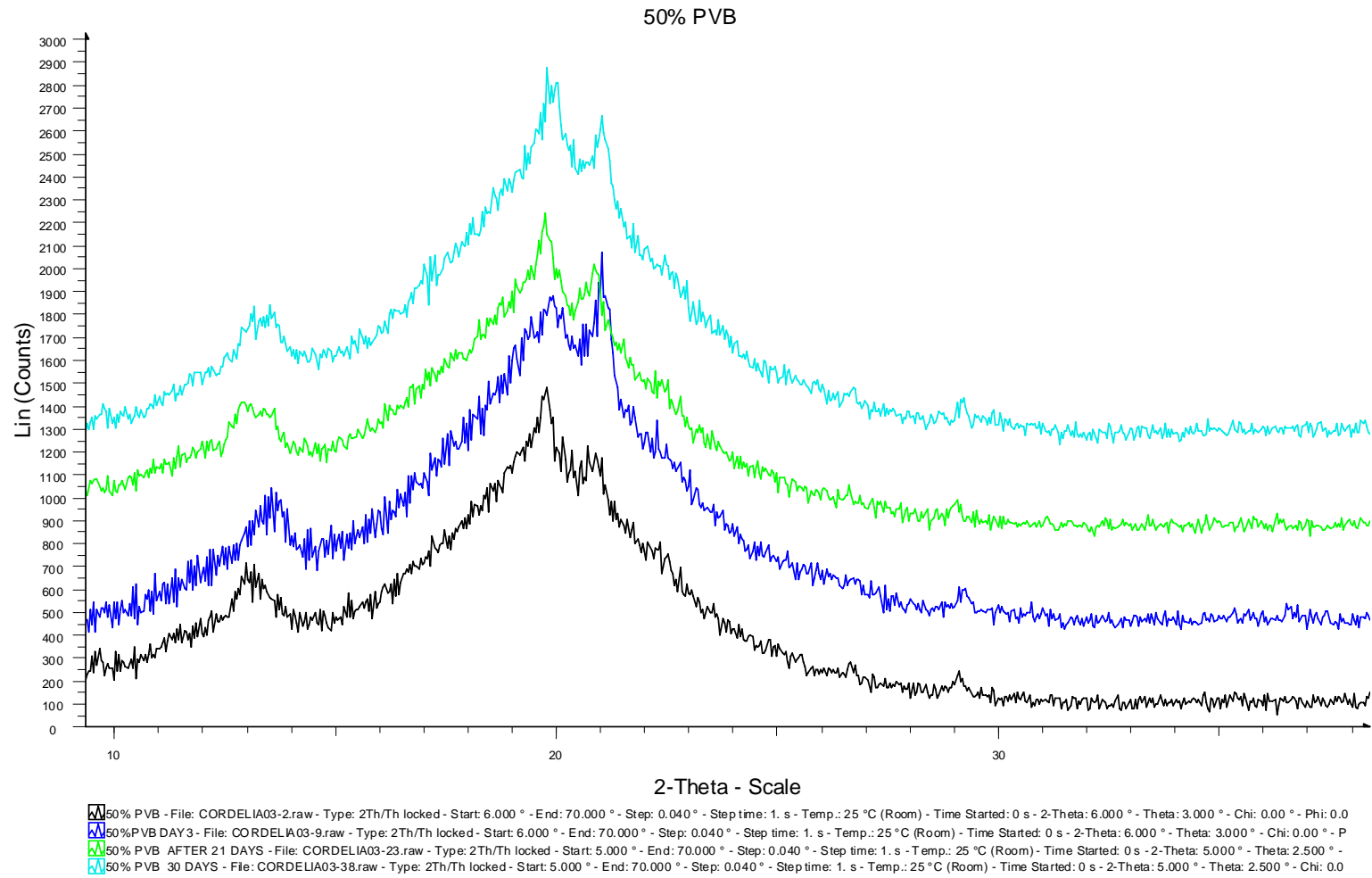


Figure A3: XRD spectra of the TPS-PVB blend containing 50% PVB blends at 30 °C and 60% RH

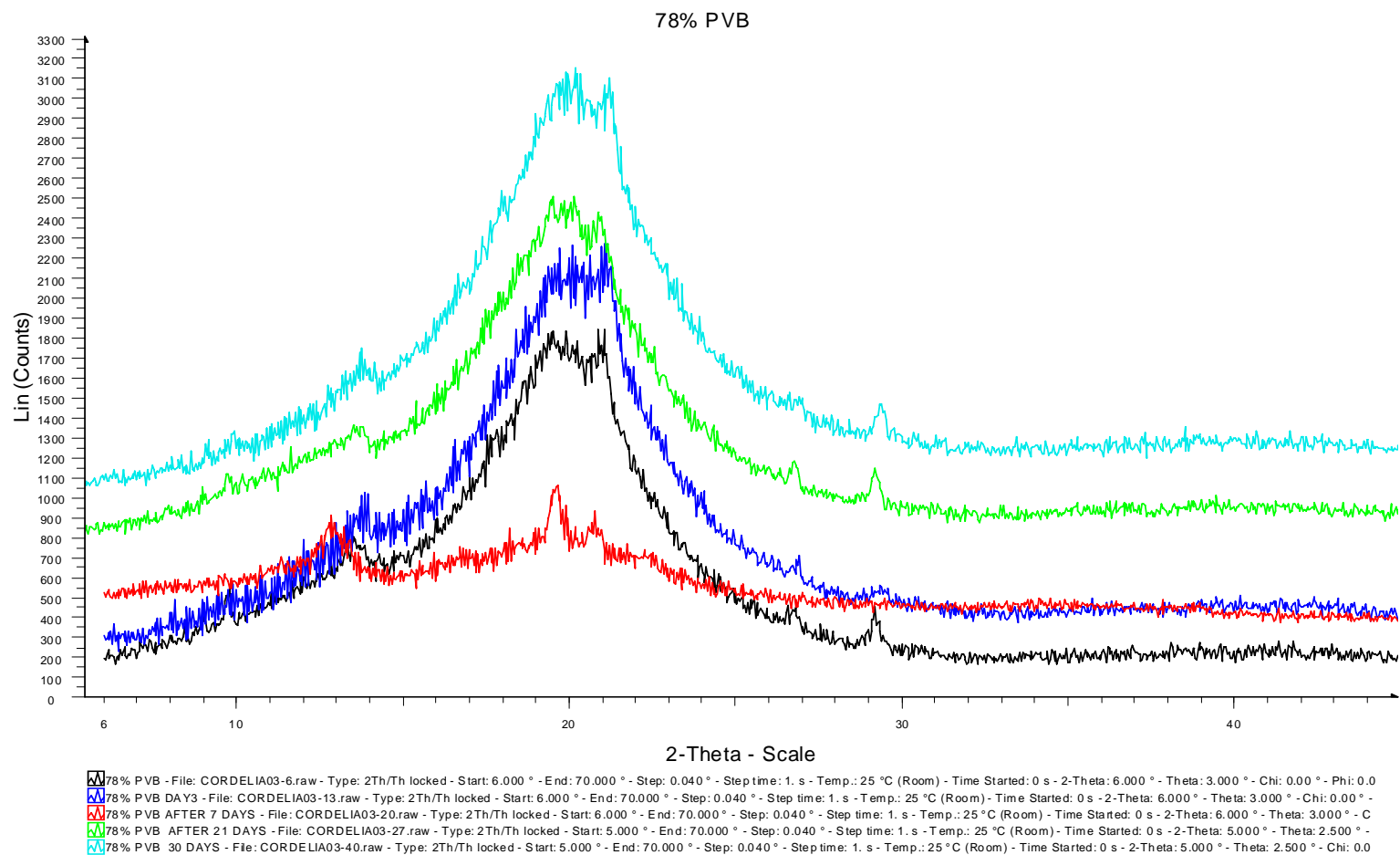


Figure A4: XRD spectra of the TPS-PVB blend containing 75% PVB blends at 30 °C and 60% RH

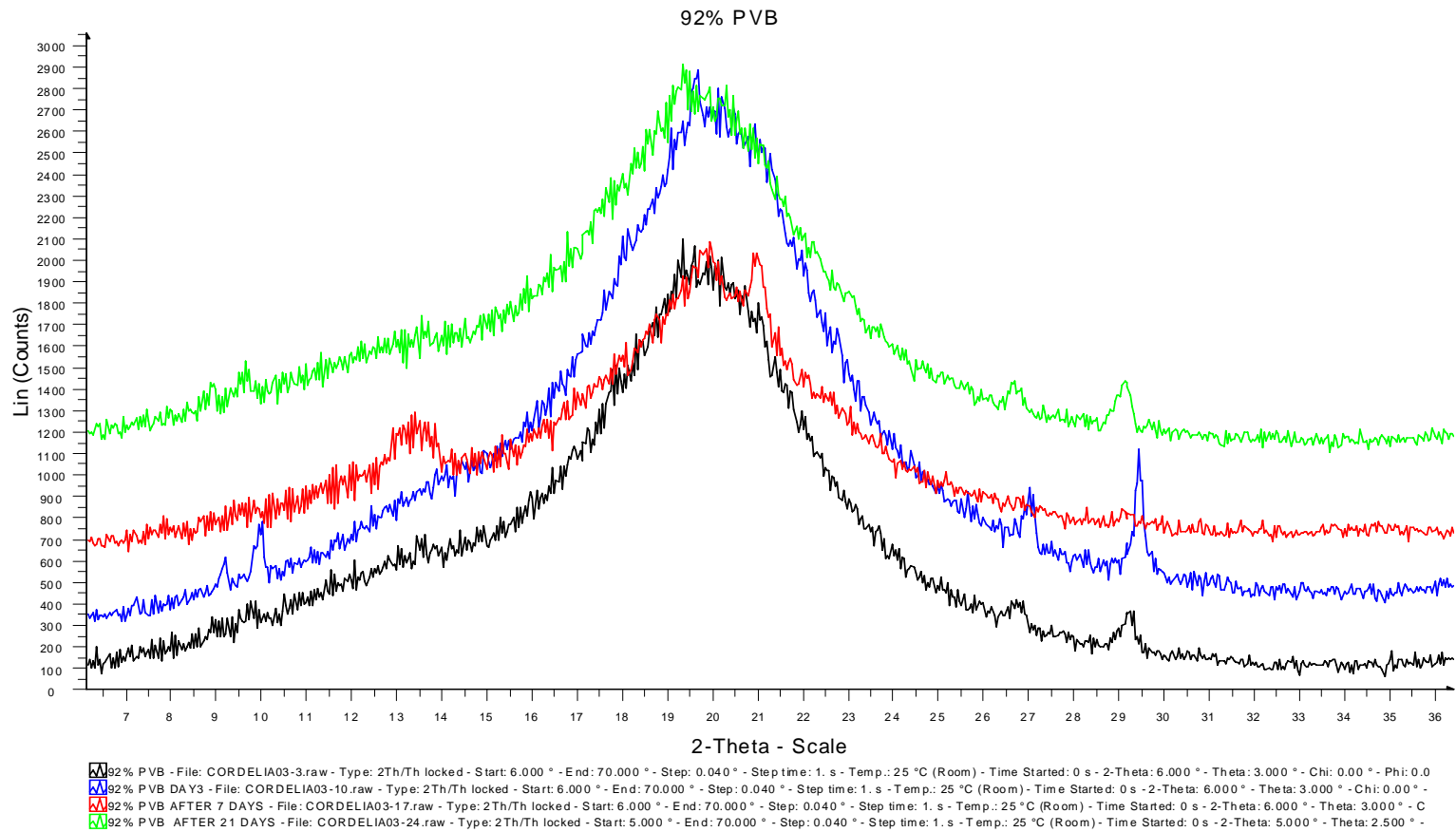


Figure A5: XRD spectra of the TPS-PVB blend containing 92% PVB blends at 30 °C and 60% RH

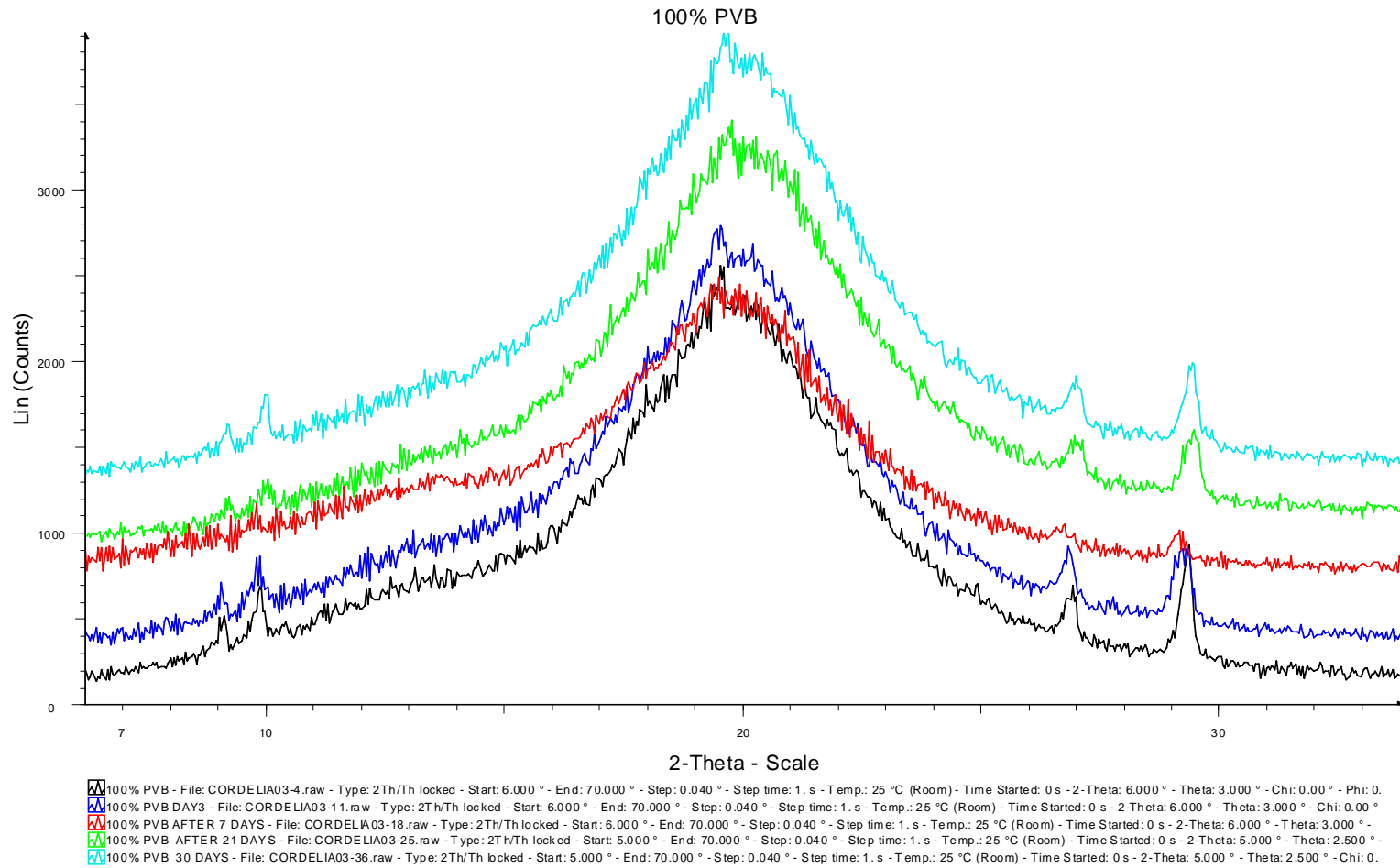


Figure A6: XRD spectra of the TPS-PVB blend containing 100% PVB blends at 30 °C and 60% RH

APPENDIX B: EXPERIMENTAL PROCEDURES

Blend Processing

Extrusion

For a single-screw extruder, assuming the extruder was initially purged with polyethylene:

1. Turn on the main power supply, open the cooling water tap and set the temperature. (The temperature profile will depend on the formulation of the blend.)
2. Purge the extruder using this 100% HDPE with a high MFI so as to push out the high-molecular-weight HDPE which is used for cleaning the extruder.
3. Stop the extruder and decrease the temperature settings to the intermediate values set for the respective blends to be extruded.
4. Fill the hopper with dry blend/TPS mixed with polyamide granules or with PVB shavings.
5. Turn the screw on and maintain the screw rate at 30 r/min.
6. Extrude all of the starch/polymer mix. (The extrudate is air-cooled and manually coiled after exiting extruder. This prevents the extrudate from forming lumps, resulting in long strands that can be pelletised.)
7. Monitor the current (torque) in the extruder and ensure that it does not exceed 10 amps. If it does, then proceed with emergency shut-down procedures.
8. Maintain a continuous supply of material in the feed hopper.
9. Pass 100% HDPE with a high MFI, while increasing the temperature profile. Once the temperatures are high, purge with a lower-MFI HDPE material to ensure that all the TPS/polymer blends have been cleaned out of the extruder.
10. Do not leave starch in the extruder for extended periods of time as material degrades in the extruder.
11. Turn off the main power supply.
12. Leave the system to cool and after 40 minutes, turn off the cooling water supply.



Injection Moulding Machine

Start-up

1. Turn on the main power switch at the wall and at the back right of the machine.
2. Turn on the cooling water pump and adjust to the required flow.
3. Check D button for any alarms.
4. Press the temperature button to set the temperatures. Enter the password when prompted, then set the desired temperature value.
5. Start the heating.
6. Wait for the oil to heat to the setpoint temperature of 45 °C and for all temperature zones to reach the setpoint. Allow 20 minutes for the machine to equilibrate.
7. Ensure that the nozzle is in place on the barrel end and set the temperature.
8. Empty the hopper of previous material and remove dust particles.
9. Fill the hopper with the material to be injection moulded.
10. Load the correct mould and set the mould open.
11. Initially set all speeds low (for safety reasons).
12. Set the clamping force at the desired value of 500 kN – based on the mould.
13. Press the ‘speed profiles’ key and set all the values.

Operation and Optimisation

1. The soft keys from both the injection unit page and the mould set-up page can access the injection profile, the holding profile and the dosing profile pages. These pages and the process optimisation page can be used to optimise the automatic process during operation. Initially, set one value for dosing speed, injection speed and holding pressure.
2. Set the machine on either manual or automatic mode and press the start button for the procedure of injection moulding.

Shut-down

1. Clear all alarms.
2. Turn off the main power switch at the wall and at the back right of machine.
3. Leave the water pump on for an hour to allow the machine to reach room temperature.



Tensile Tests

1. Turn on the main power supply to the Lloyds machine.
2. Ensure that the 5 kN load cell is connected to the machine.
3. Set the test conditions for extension to 5 mm/min.
4. Input the sample shape and dimensions and specify the number of replicates.
5. Balance the load.
6. Shut the grips until they are touching and reset the extension distance to zero.
7. Open the grips to the desired gap.
8. Reset the distance to zero.
9. Balance the load.
10. Place the sample between the grips and ensure that it is vertical.
11. Start the test.
12. Remove the sample after it has snapped and the test is complete.
13. Reset the gap between the plates.
14. Balance the load.
15. Place the next sample between the grips and start the next test.
16. When testing of all the samples is complete, save the data and exit Merlin.
17. Turn off the main power supply.



APPENDIX C: RAW DATA ON TENSILE TESTS

Table C1: TPS-PVB blends – day 1 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
PVB	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	127.41	5.85	6.47	2.02	31.50	7.06
0.08	0.92	139.12	2.12	6.90	0.67	32.55	1.58
0.22	0.78	91.87	5.84	4.61	3.49	31.34	7.37
0.50	0.5	30.82	6.28	3.06	5.69	228.72	11.11
0.78	0.22	8.69	7.46	13.90	5.85	364.39	4.08
0.92	0.08	5.52	11.48	9.12	13.07	345.68	3.24
1	0	2.98	0.15	7.54	0.55	346.03	14.69

Table C2: TPS-PVB blends – day 3 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
PVB	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	193.37	3.37	8.46	3.25	24.93	1.49
0.08	0.92	189.71	2.54	8.61	1.39	27.30	2.60
0.22	0.78	124.22	4.20	5.44	5.03	26.91	5.78
0.50	0.5	39.19	17.17	4.01	7.57	195.12	31.10
0.78	0.22	7.46	17.37	13.61	18.06	369.20	2.93
0.92	0.08	5.30	12.62	9.47	10.32	353.57	3.37
1	0	4.77	8.58	8.81	7.69	389.78	3.91



Table C3: TPS-PVB blends – day 7 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
PVB	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	283.16	3.30	10.69	3.09	20.05	4.06
0.08	0.92	243.79	2.25	9.74	1.62	23.05	5.34
0.22	0.78	161.27	4.54	6.30	3.13	22.63	8.04
0.50	0.5	41.70	4.87	4.39	3.45	267.51	5.02
0.78	0.22	8.83	2.61	14.36	3.30	345.26	1.24
0.92	0.08	4.89	9.82	8.39	11.56	318.23	5.46
1	0	4.06	8.12	6.91	5.60	328.38	2.03

Table C4: TPS-PVB blends – day 14 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
PVB	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	269.68	8.00	10.03	7.35	15.54	27.77
0.08	0.92	227.18	9.04	9.79	3.73	19.18	9.59
0.22	0.78	143.43	1.78	6.56	3.39	24.14	10.18
0.50	0.5	40.51	11.42	4.62	3.19	216.90	14.07
0.78	0.22	6.82	2.25	12.86	2.59	380.18	2.81
0.92	0.08	4.05	8.88	7.34	7.51	359.67	4.02
1	0	3.99	10.07	7.26	10.07	374.93	4.83



Table C5: TPS-PVB blends – day 21 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
PVB	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	267.27	3.63	10.49	1.40	16.79	0.76
0.08	0.92	145.53	0	8.89	0	22.47	0
0.22	0.78	145.01	12.35	5.89	4.37	23.46	8.02
0.50	0.5	45.34	5.23	3.49	2.57	241.05	16.07
0.78	0.22	5.86	5.39	10.38	7.63	409.13	2.67
0.92	0.08	2.46	15.91	5.49	12.83	396.46	4.43
1	0	1.61	4.46	2.97	12.37	332.93	7.27

Table C6: TPS-PVB blends – day 30 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
PVB	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	314.99	0	10.35	0	13.31	0
0.22	0.78	149.09	6.77	6.22	3.73	19.71	5.38
0.50	0.5	44.38	3.46	3.47	4.04	255.95	7.35
0.78	0.22	5.42	7.66	9.95	7.12	409.30	2.37
0.92	0.08	1.84	15.72	3.65	14.85	353.29	3.67
1	0	1.56	12.49	1.37	10.36	205.94	19.84



PVB-Euremelt blends

Table C7: PVB-E2138 blends – day 1 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
E2138	PVB	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0.0	1	3.2	15.41	6.10	11.15	335	4
0.25	0.75	2.7	12.20	3.86	15.90	364	7
0.5	0.5	6.8	9.24	5.30	2.72	417	1
0.75	0.25	21.1	3.30	2.97	2.94	260	7
1.0	0	30.9	4.9	4.0	2.3	459.7	6.1

Table C8: PVB-E2138 blends – day 17 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
E2138	PVB	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0.0	1	4.05	8.88	7.34	7.51	359.67	4.02
0.3	0.75	3.80	8.10	3.11	5.14	320.82	2.55
0.5	0.5	7.80	12.97	3.98	2.50	370.47	2.83
0.8	0.25	25.31	6.41	2.96	3.69	238.48	2.51
1.0	0	32.59	12.08	3.76	2.39	356.82	18.90



Table C9: PVB-E2138 blends – day 51 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
E2138	PVB	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0.25	0.75	3.0	1	3	0	344	6
0.50	0.5	7.1	0	4	0	367	22
0.75	0.25	24.9	0	3	1	235	16
1	0	31.2	1	4	0	292	26

Table C10: PVB-E2140 blends – day 1 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
E2140	PVB	Average	Std.Dev, %	Average	Std.Dev, %	Average	Std.Dev, %
0	1	3.23	15.41	6.10	11.15	335.23	4.18
0.25	0.75	2.05	12.37	2.17	6.88	405.04	9.44
0.5	0.5	3.41	5.67	2.55	3.14	382.36	7.39
0.75	0.25	8.43	8.72	2.78	1.40	314.18	4.61
1	0	15.35	0.06	5.25	10.30	509.72	3.07

Table C11: PVB-E2140 blends – day 14 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
E2140	PVB	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	4	8.88	7.3	7.5	359.7	4.0
0.25	0.75	4	10.10	2	8	323	9
0.5	0.5	2	3.87	2	10	388	6
0.75	0.25	9	4.45	2	4	272	12
1	0	17	0.00	4	0	499	0



Table C12: PVB-E2140 blends – day 30 data

Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
E2140	PVB	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	2	12.5	1.4	10.4	205.9	19.8
0.25	0.75	4	7.1	3	3.1	385	5
0.5	0.5	5	8.0	3	3.5	345	4
0.75	0.25	11	10.0	3	1.6	295	3
1	0	17	3.0	5	0.1	486	2

Table C13: TPS-E2140 blends – day 1 data

Mass Fraction		Young's Modulus (MPa)		Tensile Strength (MPa)		Elongation-to-break, %	
E2140	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	127.4	6	6	2	31	7
0.08	0.92	95.3	9	6	7	45	14
0.22	0.78	39.0	11	3	4	112	4
0.50	0.5	25.2	4	2	7	169	14
0.78	0.22	21.5	14	2	8	371	20
0.92	0.08	18.4	7	2	3	479	13
1	0	3.2	15	6	11	335	4



Table C14: TPS-E2140 blends – day 14 data

Mass Fraction		Young's Modulus (MPa)		Tensile Strength (MPa)		Elongation-to-break, %	
E2140	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	269.7	8	10	7	16	27.8
0.08	0.92	181.4	10	9	6	31	27.7
0.22	0.78	75.1	7	5	3	82	17.0
0.50	0.5	35.9	8	2	15	107	9.4
0.78	0.22	24.9	10	2	7	389	20.4
0.92	0.08	20.4	6	2	7	319	7.1
1	0	4.0	10	7	10	375	4.8

Table C15: TPS-E2140 blends – day 30 data

Mass Fraction		Young's Modulus (MPa)		Tensile Strength (MPa)		Elongation-to-break, %	
E2140	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	315.0	0	10	0	13	0
0.08	0.92	133.1	6	7	6	31	8
0.22	0.78	64.3	12	5	5	76	12
0.50	0.5	20.9	10	2	9	322	27
0.78	0.22	17.0	8	2	15	271	30
0.92	0.08	3.2	15	6	11	335	4
1	0	315.0	0	10	0	13	0



Table C16: TPS - E2138 blends – day 1 data

Mass Fraction		Young's Modulus (MPa)		Tensile Strength (MPa)		Elongation-to-break, %	
E 2138	TPS	Average	Std. Dev,%	Average	Std. Dev,%	Average	Std. Dev,%
0	1	127.4	5.85	6.47	2.02	31	7
0.8	0.92	84.6	8.27	4.45	0.08	23	2
0.22	0.78	62.2	7.57	4.48	0.52	46	5
0.5	0.5	48.5	4.70	2.60	0.42	61	11
0.78	0.22	26.0	2.13	1.80	0.14	109	17
1	0	18.9	0.00	2.97	0.00	205	0

Table C17: TPS - E2138 blends – day 7 data

Mass Fraction		Young's Modulus (MPa)		Tensile Strength (MPa)		Elongation-to-break, %	
E 2138	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	1	283.16	3.30	10.69	3.09	20.05	4.06
0.8	0.92	171.18	2.13	7.90	17.27	17.39	4.55
0.22	0.78	117.88	7.02	5.51	5.00	29.97	17.42
0.5	0.5	48.90	12.65	2.32	15.16	59.05	15.74
0.78	0.22	32.80	11.16	2.47	11.05	99.90	10.94
1	0	3.23	15.41	6.10	11.15	335.23	4.18



Table C18: TPS - E2138 blends – day 35 data

Mass Fraction		Young's Modulus (MPa)		Tensile Strength (MPa)		Elongation-to-break, %	
E2138	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0.8	0.92	179.3	14	6.78	0	11	1
0.22	0.78	123.3	13	6.54	3	23	10
0.5	0.5	49.3	2	3.23	0	40	5
0.78	0.22	35.0	1	2.29	0	77	0
1	0	3.2	15	6.10	0	335	4

Table C19: TPS-PVB-E2140 blends – day 1 data

Mass Fraction			Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
TPS	PVB	Eu2140	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
1	0	0	127	5.9	6.5	2.0	31.5	7.1
0.67	0.17	0.17	26	1.9	2.1	0.1	207.5	6.1
0.33	0.33	0.33	5	0.2	1.4	0.0	353.9	30.5
0.16	0.17	0.67	12	0.8	1.2	0.0	242.3	29.4
0.17	0.67	0.17	2	0.2	1.5	0.2	450.7	24.5



Table C20: TPS-PVB-E2140 blends – day 14 data

Mass Fraction			Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
TPS	PVB	E2140	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
1	0	0	269.68	8.00	10.03	7.35	15.54	27.77
0.66	0.17	0.17	47	4.4	4.2	0.2	176.7	8.9
0.33	0.33	0.33	7	0.4	2.3	0.1	349.4	12.0
0.17	0.17	0.67	12	2.4	2.2	0.1	388.8	79.5
0.17	0.67	0.17	2	0.2	3.1	0.3	404.3	23.3

Table C21: TPS-PVB-E2140 blends – day 30 data

Mass, %			Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
TPS	PVB	E2140	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
100	0	0	315	0	10.4	0	13.3	0
66.8	16.6	16.6	49	2.6	4.2	0.1	150.4	3.4
33.3	33.3	33.3	9	0.9	2.3	0.1	356.9	14.4
16.6	16.6	66.8	14	0.8	1.5	0.2	212.7	22.1
16.5	66.8	16.6	3	0.2	3.1	0.2	431.1	18.2



Table C22: TPS-PVB-anhydride blends – day 1 data

Mass, %			Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
TPS	PVB	Anhydride	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%		
0	0	0	127	5.9	6.5	2.0	31.5	7.1		
0.92	0	0.08	135	3.0	7.9	1.5	29.3	6.8		
0.78	0.11	0.11	79	18.8	3.9	7.4	17.2	14.3		
0.5	0.25	0.25	57	16.6	3.4	2.6	33.2	5.0		
0.39	0.38	0.25	36	19.5	3.8	1.9	111.4	1.4		
0.25	0.5	0.25	8	16.3	6.5	5.7	219.1	1.5		
0.11	0.64	0.25	6	3.5	10.0	2.2	265.1	1.8		

Table C23: TPS-PVB-anhydride blends – day 3 data

Mass, %			Mass Fraction		Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
TPS	PVB	Anhydride	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%		
100	0	0	193.4	3.0	8.0	3.0	25.0	1.0		
92	0	8	205	4.8	9.9	2.0	25.9	4.8		
78	11	11	129	19.2	4.5	2.7	12.9	12.1		
50	25	25	70	7.5	3.7	3.0	34.2	6.7		
39	38	25	35	18.1	3.4	2.6	108.0	9.5		
25	50	25	7	11.5	6.5	3.1	233.9	1.1		
11	64	25	5	5.1	8.9	2.2	283.9	2.1		



Table C24: TPS-PVB-anhydride blends – day 7 data

Mass, %		Mass Fraction	Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
PVB	Anhydride	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	0	1	283.2	3.3	10.7	3.1	20.0	4.1
0	8	0.92	286	12.0	12.0	0.0	20.2	2.0
11	11	0.78	157	2.8	5.8	0.2	14.1	2.0
25	25	0.5	85	4.0	4.4	0.1	32.3	1.4
38	25	0.39	44	285.8	4.3	0.1	106.3	20.2
50	25	0.25	7	0.6	7.5	0.5	222.2	5.3
64	25	0.11	7	0.1	11.0	0.2	263.3	5.2

Table C25: TPS-PVB-anhydride blends – day 14 data

Mass, %		Mass Fraction	Modulus, MPa		Tensile Strength, MPa		Elongation-to-break, %	
% PVB	% gypsum	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	0	1	269.68	8.00	10.03	7.35	15.54	27.77
0	8	0.92	268.42	7.25	12.47	0.15	22.23	0.55
11	11	0.78	248.34	78.18	5.12	0.31	12.77	1.94
25	25	0.5	99.29	13.58	4.41	0.01	29.57	2.32
38	25	0.39	42.29	7.87	4.01	0.13	123.07	13.10
50	25	0.25	10.70	4.48	7.03	1.11	293.84	55.70
64	25	0.11	6.27	0.38	10.61	0.38	285.27	3.64



Table C26: TPS-E2140-Anhydride blends – day 30 data

Mass, %		Mass Fraction	Modulus, MPa		Tensile Strength, Ma		Elongation-to-break, %	
PVB	Anhydride	TPS	Average	Std.Dev,%	Average	Std.Dev,%	Average	Std.Dev,%
0	0	1	314.99	0	10.35	0	13.31	0
0	8	0.92	255.95	23.41	10.90	0.18	21.74	0.47
11	11	0.78	154.25	20.10	5.15	0.75	14.39	5.76
25	25	0.5	135.69	17.26	4.13	0.12	21.25	1.54
38	25	0.39	34.48	8.26	3.44	0.23	88.81	21.24
50	25	0.25	5.64	0.41	4.99	0.41	259.99	13.24
64	25	0.11	4.59	0.26	8.50	0.58	287.83	22.68