REFERENCES

Albano, C., Ichazo, M., Gonzalez, J., Delgado, M., and Poleo, R. (2001). Effects of filler treatments on the mechanical and morphological behavior of PP+wood flour and PP+sisal fiber. Materials Research Innovations, 4, 284-293.

Andersen, P. and Hodson, S. (1998). Systems for molding articles which include a hinged starch-bound cellular matrix. US Patent No. 5,705,203.

Andersen, P.J., Kumar, A., and Hodson, S.K. (1999). Inorganically filled starch based fiber reinforced composite foam materials for food packaging. Materials Research Innovations, 3, 2-8.

Averous, L., Fringant, C., and Moro, L. (2001). Plasticized starch-cellulose interactions in polysaccharide composites. Polymer, 42, 6565-6572.

Clemons, C.M., Caulfield, D.F., and Giacomin, A.J. (1999). Dynamic fracture toughness of cellulose fiber-reinforced polypropylene: preliminary investigation of microstructural effects. Journal of Elastomers and Plastics, 31, 367-378.

Dufresne, A., Dupeyre, D., and Vignon, M.R., (1999). Cellulose microfibrils from potato tuber cells: processing and characterization of starch-cellulose microfibril composites. Journal of Applied Polymer Science, 76, 2080-2092.

Glenn, G.M. and Hsu, J. (1997). Compression-formed starch-based plastic. Industrial Crops and Products, 7, 37-44.

Glenn, G.M., and Orts, W.J. (2001a). Properties of starch-based foam formed by compression/explosion processing. Industrial Crops and Products, 13, 135-143.

Glenn, G.M., Orts, W.J., and Nobes G.A.R. (2001b). Starch, fiber and CaCO3 effects on the physical properties of foams made by a baking process. Industrial Crops and Products, 14, 201-212.

Karnani, R., Krishnan, M., and Narayan, R. (1997). Biofiber-reinforced polypropylene composites. Polymer Engineering and Science, 37(2), 476-483.

Lee, B.J., McDonald, A.G., and James, B. (2001). Influence of fiber length on the mechanical properties of wood-fiber/polypropylene prepreg sheets. Materials Research Innovations, 4, 97-103.

Lodha, P. and Netravali, A.N. (2002). Characterization of interfacial and mechanical properties of "green" composites with soy protein isolate and ramie fibers. Journal of Material Science, 37, 3657-3665.

Lourdin, D., Coignard, L., Bizot, H., and Colonna, P. (1997). Influence of equilibrium relative humidity and plasticizer concentration on the water content and glass transition of starch materials. Polymer, 38, 5401-5406.

Oksman, K., Wallstrom, L., Berglund, L.A., and Filho, R.D.T. (2002). Morphology and mechanical properties of unidirectional sisal-epoxy composites. Journal of Applied Polymer Science, 84, 2358-2365.

Shogren, R.L. and Lawton, J.W. (1998a). Enhanced water resistance of starch-based materials. US Patent No. 5,756,194.

Shogren, R.L., Lawton, J.W., Tiefenbacher, K.F., and Chen, L. (1998b). Starch-Poly (vinyl alcohol) foamed articles prepared by a baking process. Journal of Applied Polymer Science, 68, 2129-2140.

Shogren, R.L., Lawton, J.W., Doane, W.M., and Tiefenbacher, K.F. (1998c). Structure and morphology of baked starch foams. Polymer, 39(25), 6649-6655.

Shogren, R.L., Lawton, J.W., and Tiefenbacher, K.F. (2002). Baked starch foams: starch modifications and additives improve process parameters, structure and properties. Industrial Crops and Products, 16, 69-79.

Stenhouse, P.J., Ratto, J.A., and Schneider, N.S. (1997). Structure and properties of starch/poly(ethylene-*co*-vinyl alcohol) blown films. Journal of Applied Polymer Science, 64, 2613-2622.

Tiefenbacher, K. (1993). Starch-based foamed materials: use and degradation properties. Journal of Macromolecule Science: Pure Applied Chemistry. A30, 727-731.

APPENDICES

APPENDIX A

Effects of storage relative humidity and storage time on moisture content for pure starch foams

Table A1 Effects of storage relative humidity at 11.3 % and storage time on moisture content for pure starch foams

Storage RH (%)	Storage time (day)	Moisture content (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
11.3	1	2.8745	2.7200	2.8166	3.0620	2.6119	2.8170	0.1694
	2	3.3837	3.2138	3.5163	3.3150	3.1420	3.3142	0.1461
	3	3.5562	3.4971	3.7047	3.8995	3.5571	3.6429	0.1626
	4	3.5480	3.3676	3.4804	3.6989	3.5124	3.5214	0.1200
	5	3.7040	3.5781	3.5971	3.7861	3.6081	3.6547	0.0881
	6	3.5233	3.6186	3.4715	3.7599	3.4932	3.5733	0.1185
	7	3.7369	3.4000	3.7047	3.7338	3.5762	3.6303	0.1445

Table A2 Effects of storage relative humidity at 32.8 % and storage time on moisture content for pure starch foams

Storage RH (%)	Storage time (day)	Moisture content (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
32.8	1	7.7863	7.5875	7.7671	7.3930	7.5688	7.6205	0.1617
	2	7.6971	7.7798	7.8131	7.5362	7.6336	7.6920	0.1119
	3	7.9558	8.0042	7.9445	7.6476	7.7716	7.8647	0.1499
	4	7.9022	7.9160	8.0957	7.6158	7.8527	7.8765	0.1723
	5	7.9201	7.8279	7.9445	7.7511	7.8040	7.8495	0.0810
	6	7.8666	8.0202	8.0168	7.7113	7.7878	7.8805	0.1374
	7	8.0628	7.9962	7.9380	7.6715	7.9257	7.9188	0.1486

Table A3 Effects of storage relative humidity at 43.2 % and storage time on moisture content for pure starch foams

Storage RH (%)	Storage time (day)	Moisture content (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
43.2	1	9.2904	9.2676	9.0797	9.2722	9.2931	9.2406	0.0906
	2	9.1807	9.3852	8.9999	9.2651	9.2240	9.2110	0.1405
	3	9.3589	9.5841	9.3480	9.4431	9.5537	9.4576	0.1086
	4	9.3521	9.5841	9.2392	9.4787	9.4771	9.4262	0.1330
	5	9.3658	9.6203	9.2392	9.4004	9.5307	9.4313	0.1481
	6	9.3041	9.5570	9.2828	9.4787	9.4617	9.4169	0.1185
	7	9.4001	9.6293	9.2102	9.4289	9.4617	9.4260	0.1499

Table A4 Effects of storage relative humidity at 52.9 % and storage time on moisture content for pure starch foams

Storage RH (%)	Storage time (day)	Moisture content (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
52.9	1	11.0369	11.1181	10.7449	11.1070	11.0371	11.0088	0.1523
	2	10.9214	10.9393	10.5578	10.9240	10.8944	10.8474	0.1627
	3	11.2018	11.3236	10.8168	11.3194	11.0942	11.1512	0.2095
	4	11.0699	11.1985	10.8816	11.1803	11.1227	11.0906	0.1273
	5	11.1689	11.2611	10.7953	11.2169	11.1037	11.1091	0.1849
	6	11.0781	11.2432	10.8024	11.1363	11.0086	11.0537	0.1647
	7	11.0286	11.2164	10.8024	11.2095	11.0181	11.0550	0.1701

Table A5 Effects of storage relative humidity at 75.3 % and storage time on moisture content for pure starch foams

Storage RH (%)	Storage time (day)	Moisture content (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
75.3	1	16.2692	16.2881	16.4630	16.3900	16.0859	16.2992	0.1428
	2	16.1492	16.1061	16.2005	16.2141	15.9800	16.1300	0.0942
	3	16.6213	16.6089	16.8075	16.7909	16.5999	16.6857	0.1041
	4	16.5973	16.6782	16.7419	16.6714	16.4336	16.6245	0.1184
	5	16.5013	16.5915	16.7090	16.6292	16.4109	16.5684	0.1154
	6	16.5253	16.5569	16.6680	16.5799	16.4109	16.5482	0.0933
	7	16.5093	16.6696	16.6926	16.6151	16.4412	16.5855	0.1073

APPENDIX B

Effect of moisture content on the mechanical properties of pure starch foams

Table B1 Effect of moisture content on flexural strength of pure starch foams

Fiber content (%)	Storage RH (%)	Flexural strength (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
0	11.3	3.8824	4.8913	5.0436	3.2697	3.2751	4.0724	0.8559
	32.8	5.1431	5.6254	6.0637	4.9076	5.3627	5.4205	0.4470
	43.2	5.0444	5.3190	5.1754	5.2479	4.0430	4.9659	0.5259
	52.9	3.7668	3.8280	2.7954	3.3580	3.8653	3.5227	0.4545
	75.3	1.6610	2.7016	2.7173	2.7461	2.3645	2.4381	0.4614

Table B2 Effect of moisture content on flexural strain at maximum force of pure starch foams

Fiber content (%)	Storage RH (%)	Flexural strain at maximum force (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
0	11.3	1.0786	1.2731	1.2595	1.0136	0.9207	1.1091	0.1541
	32.8	1.9881	2.2701	1.8202	1.8415	1.7211	1.9282	0.2136
	43.2	2.2341	2.2544	2.7140	1.8688	1.9454	2.2034	0.3327
	52.9	2.1527	1.9967	1.3553	1.4993	2.0534	1.8115	0.3588
	75.3	0.8805	1.5000	1.4646	1.6558	1.3378	1.3678	0.2950

Table B3 Effect of moisture content on flexural modulus of elasticity of pure starch foams

Fiber content (%)	Storage RH (%)	Flexural modulus of elasticity (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
0	11.3	407.05	443.60	451.40	405.06	429.75	427.37	20.96
	32.8	328.54	303.29	430.45	354.68	405.18	364.43	52.77
	43.2	347.81	336.98	287.99	373.81	285.72	326.46	38.56
	52.9	272.42	264.17	259.09	284.24	246.70	265.33	14.10
	75.3	257.87	216.57	218.88	207.10	206.86	221.45	21.07

APPENDIX C

Effect of moisture content on the mechanical properties of 1, 5, and 10 wt% jute-reinforced starch-based composite foams

Table C1 Effect of moisture content on flexural strength of 1 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strength (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
1	11.3	3.1352	3.3698	4.2606	4.0431	3.8319	3.7281	0.4673
	32.8	5.2574	5.3623	5.1857	4.6484	4.5632	5.0034	0.3696
	43.2	4.4934	4.8104	5.2004	5.1270	3.7267	4.6716	0.5981
	52.9	3.1521	3.7760	3.3164	3.4018	3.0560	3.3405	0.2786
	75.3	2.2255	2.2198	2.8266	2.9073	2.1910	2.4740	0.3600

Table C2 Effect of moisture content on flexural strength of 5 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strength (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
5	11.3	4.8658	4.9793	4.6630	4.5360	4.2678	4.6624	0.2800
	32.8	5.9312	7.0904	6.6489	6.1661	5.5465	6.2766	0.6053
	43.2	7.1037	5.7894	5.3276	6.4199	6.3984	6.2078	0.6771
	52.9	5.4558	4.8825	5.8835	4.9010	5.1376	5.2521	0.4222
	75.3	3.3047	3.5804	3.6966	3.5551	3.4105	3.5095	0.1532

Table C3 Effect of moisture content on flexural strength of 10 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strength (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
10	11.3	5.7322	5.0461	5.3119	5.3658	5.2843	5.3480	0.2472
	32.8	7.2010	7.0488	7.0106	7.4575	7.4532	7.2342	0.2141
	43.2	7.0264	6.9849	7.5989	7.7274	7.6977	7.4070	0.3698
	52.9	6.7566	6.5379	6.1485	6.7938	6.9384	6.6350	0.3075
	75.3	5.1355	4.9957	5.4940	4.8418	4.7811	5.0496	0.2842

Table C4 Effect of moisture content on flexural strain at maximum force of 1 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strain at maximum force (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
1	11.3	0.8206	0.9021	1.1158	1.0848	1.0449	0.9936	0.1267
	32.8	1.5853	1.6713	1.7025	1.4616	1.4116	1.5665	0.1273
	43.2	1.4454	2.0985	2.3181	1.8700	1.5122	1.8488	0.3738
	52.9	1.9823	1.4840	1.1777	1.8521	1.2501	1.5493	0.3574
	75.3	1.2276	1.0893	1.1720	1.2909	1.2321	1.2024	0.0759

Table C5 Effect of moisture content on flexural strain at maximum force of 5 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strain at maximum force (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
5	11.3	0.8590	1.0337	0.8390	1.0534	1.0052	0.9581	0.1013
	32.8	1.3658	1.5231	1.5194	1.2479	1.4043	1.4121	0.1151
	43.2	1.9518	1.6787	1.4270	1.6991	1.7464	1.7006	0.1874
	52.9	1.5716	1.5173	1.2999	1.5790	1.7211	1.5378	0.1529
	75.3	1.2811	1.2902	1.3847	1.1917	1.2592	1.2814	0.0694

Table C6 Effect of moisture content on flexural strain at maximum force of 10 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strain at maximum force (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
10	11.3	0.9667	0.9384	1.0285	1.0153	0.8364	0.9571	0.0766
	32.8	1.3474	1.3644	1.3212	1.3382	1.2724	1.3287	0.0351
	43.2	1.4721	1.3314	1.5777	1.5250	1.5428	1.4898	0.0964
	52.9	1.5324	1.4727	1.4711	1.5118	1.3699	1.4716	0.0626
	75.3	1.2418	1.2636	1.3506	1.2737	1.1133	1.2486	0.0860

Table C7 Effect of moisture content on flexural modulus of elasticity of 1 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural modulus of elasticity (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
1	11.3	526.69	404.64	453.77	510.21	403.71	459.80	57.53
	32.8	400.21	372.77	363.28	379.31	367.68	376.65	14.46
	43.2	383.63	363.46	320.98	346.20	304.59	343.77	31.77
	52.9	204.80	324.00	343.54	240.41	325.07	287.56	61.12
	75.3	232.30	242.38	280.68	276.42	217.70	249.90	27.63

Table C8 Effect of moisture content on flexural modulus of elasticity of 5 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural modulus of elasticity (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
5	11.3	618.91	579.83	625.36	485.09	480.16	557.87	70.88
	32.8	485.65	532.33	517.80	539.13	496.13	514.21	22.94
	43.2	463.05	444.25	434.17	461.89	446.53	449.98	12.32
	52.9	446.59	390.10	492.58	384.95	400.33	422.91	45.94
	75.3	309.59	327.15	326.15	322.04	330.13	323.01	8.04

Table C9 Effect of moisture content on flexural modulus of elasticity of 10 wt% jute-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural modulus of elasticity (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
10	11.3	710.65	586.83	600.10	611.90	708.85	643.67	60.98
	32.8	590.77	579.46	655.69	648.20	679.43	630.71	43.38
	43.2	585.78	654.94	596.90	599.10	597.14	606.77	27.43
	52.9	532.82	565.55	556.26	539.28	667.81	572.34	54.94
	75.3	525.63	506.49	499.56	473.22	560.65	513.11	32.54

APPENDIX D

Effect of moisture content on the mechanical properties of 1, 5, and 10 wt% flax-reinforced starch-based composite foams

Table D1 Effect of moisture content on flexural strength of 1 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strength (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
1	11.3	3.3893	4.7499	3.1109	4.5414	3.1065	3.7796	0.8022
	32.8	5.9760	5.9545	4.3519	6.0765	5.9871	5.6692	0.7379
	43.2	6.2379	5.7387	4.5012	6.4873	4.8218	5.5574	0.8685
	52.9	4.8597	5.2283	4.5270	3.7921	5.6178	4.8050	0.6975
	75.3	3.1010	3.3593	2.9454	3.6073	3.0195	3.2065	0.2731

Table D2 Effect of moisture content on flexural strength of 5 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strength (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
5	11.3	4.2879	3.5913	4.8476	3.2405	4.0590	4.0052	0.6222
	32.8	6.3026	4.9554	6.9641	5.6117	4.6475	5.6963	0.9527
	43.2	5.4540	5.4174	6.2462	5.0914	6.2144	5.6847	0.5178
	52.9	4.5698	4.7351	5.8662	5.7025	5.1936	5.2134	0.5720
	75.3	3.0315	3.2932	3.4676	3.9028	3.0823	3.3555	0.3520

Table D3 Effect of moisture content on flexural strength of 10 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strength (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
10	11.3	4.2672	4.0950	3.4019	4.4496	4.2912	4.1010	0.4105
	32.8	5.0390	6.8813	5.7835	5.4605	6.1745	5.8678	0.7038
	43.2	4.6646	6.8786	5.9117	6.2364	6.5334	6.0449	0.8505
	52.9	5.4461	6.0971	5.3441	5.7798	5.7647	5.6864	0.2994
	75.3	3.6248	3.6636	3.3527	3.4174	3.5533	3.5223	0.1334

Table D4 Effect of moisture content on flexural strain at maximum force of 1 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strain at maximum force (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
1	11.3	1.0887	0.9146	0.8063	1.4065	0.7303	0.9893	0.2693
	32.8	1.5328	1.5394	2.0411	1.6691	1.9028	1.7370	0.2266
	43.2	1.9035	1.9520	1.7191	2.1152	1.5056	1.8391	0.2338
	52.9	1.9610	1.4041	1.6508	1.5650	2.1767	1.7515	0.3124
	75.3	1.2048	1.2950	1.4277	1.6841	1.1963	1.3616	0.2029

Table D5 Effect of moisture content on flexural strain at maximum force of 5 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strain at maximum force (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
5	11.3	1.1227	0.8477	1.0182	0.7857	0.9514	0.9451	0.1340
	32.8	1.3675	1.6991	1.3798	1.6006	1.1340	1.4362	0.2210
	43.2	1.4021	1.1023	2.0127	1.7600	2.0899	1.6734	0.4171
	52.9	1.4281	1.3925	1.5877	1.7106	1.6474	1.5532	0.1381
	75.3	1.2350	1.1929	1.1767	1.2055	1.4471	1.2514	0.1114

Table D6 Effect of moisture content on flexural strain at maximum force of 10 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural strain at maximum force (%)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
10	11.3	1.1704	1.1631	0.9317	1.1364	1.1868	1.1177	0.1055
	32.8	1.3863	1.7563	1.7005	1.2110	1.7036	1.5515	0.2400
	43.2	1.3057	1.8544	1.3993	1.8727	1.6499	1.6164	0.2584
	52.9	1.4004	1.4052	1.5141	1.6731	1.6337	1.5253	0.1263
	75.3	1.5665	1.3107	1.1902	1.3740	1.2692	1.3421	0.1421

Table D7 Effect of moisture content on flexural modulus of elasticity of 1 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural modulus of elasticity (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
1	11.3	396.06	588.17	562.14	372.20	461.20	475.95	96.68
	32.8	451.95	465.39	331.44	468.49	397.15	422.88	58.64
	43.2	420.79	412.25	379.34	414.03	367.74	398.83	23.66
	52.9	345.45	481.93	362.99	297.71	367.88	371.19	67.83
	75.3	317.99	328.31	337.63	263.19	299.39	309.30	29.43

Table D8 Effect of moisture content on flexural modulus of elasticity of 5 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural modulus of elasticity (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
5	11.3	448.33	513.80	530.89	433.53	521.59	489.63	45.17
	32.8	605.45	393.81	601.35	439.94	473.15	502.74	96.12
	43.2	524.78	552.15	413.73	429.82	490.00	482.09	59.58
	52.9	482.88	494.57	499.31	487.31	415.79	475.97	34.24
	75.3	340.01	364.01	374.91	391.51	260.29	346.15	51.51

Table D9 Effect of moisture content on flexural modulus of elasticity of 10 wt% flax-reinforced starch-based composite foams

Fiber content (%)	Storage RH (%)	Flexural modulus of elasticity (MPa)						
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
10	11.3	479.69	450.09	477.14	453.27	432.09	458.46	19.95
	32.8	460.78	526.55	475.91	520.08	593.14	515.29	51.80
	43.2	501.84	565.03	571.83	589.59	575.08	560.67	34.09
	52.9	558.02	564.49	537.95	577.89	486.93	545.06	35.54
	75.3	394.36	387.41	354.89	345.52	376.93	371.82	20.95

APPENDIX E

Effect of fiber content on densities of jute- and flax-reinforced starch-based composite foams

Table E1 Effect of fiber content on densities of jute- and flax-reinforced starch-based composite foams

Number of Samples	Density (g/cm^3)						
	SF[1]	Jute-reinforced SCF[2] with different fiber content			Flax-reinforced SCF[2] with different fiber content		
		1 wt%	5 wt%	10 wt%	1 wt%	5 wt%	10 wt%
1	0.2117	0.2252	0.3049	0.3419	0.2777	0.2854	0.3371
2	0.2228	0.2041	0.2790	0.3164	0.2502	0.3013	0.3139
3	0.2111	0.2284	0.2698	0.3283	0.2429	0.2990	0.3375
4	0.2343	0.2522	0.2650	0.3247	0.2260	0.2632	0.3698
5	0.2175	0.2150	0.2871	0.3235	0.2353	0.2840	0.3514
6	0.2047	0.2056	0.2818	0.3540	0.2706	0.2945	0.3064
7	0.2229	0.1967	0.2824	0.3405	0.2446	0.3053	0.3638
8	0.1998	0.2140	0.2622	0.3040	0.2390	0.3235	0.3346
9	0.2317	0.2282	0.2672	0.3190	0.2545	0.2677	0.3357
10	0.2284	0.2575	0.3024	0.3216	0.2231	0.2856	0.3277
11	0.2319	0.2211	0.2952	0.3226	0.2501	0.2883	0.3128
12	0.2173	0.2091	0.2555	0.3071	0.2336	0.3015	0.3018
13	0.1841	0.1958	0.2608	0.3218	0.2306	0.3079	0.3741
14	0.2151	0.2462	0.2535	0.2970	0.2606	0.2516	0.3502
15	0.2388	0.2184	0.2750	0.3591	0.2216	0.2937	0.3558
16	0.1953	0.2429	0.2983	0.3294	0.2837	0.3298	0.3582
17	0.2137	0.2190	0.2516	0.3080	0.2701	0.2920	0.3561
18	0.1919	0.2605	0.3189	0.3071	0.2566	0.3135	0.3013
19	0.2152	0.1971	0.2561	0.3246	0.2611	0.2973	0.2996
20	0.2354	0.2542	0.2591	0.3474	0.2340	0.2781	0.3219
21	0.2159	0.2116	0.3030	0.3376	0.2775	0.3088	0.3525
22	0.2001	0.1959	0.2547	0.3014	0.2421	0.3086	0.3525
23	0.1943	0.2318	0.2775	0.3121	0.2263	0.3426	0.3068
24	0.2250	0.2193	0.2705	0.3123	0.2269	0.2803	0.3299
25	0.1926	0.2351	0.2677	0.3103	0.2576	0.2808	0.3363
Average	0.2141	0.2234	0.2760	0.3229	0.2478	0.2954	0.3355
Standard deviation	0.0154	0.0201	0.0189	0.0165	0.0186	0.0205	0.0227

[1] denotes starch-based foam

[2] denotes starch-based composite foam

APPENDIX F

Effect of fiber aspect ratio on the mechanical properties of 10 wt% jute-reinforced starch-based composite foams

Table F1 Effect of fiber aspect ratio on flexural strength of 10 wt% jute-reinforced starch-based composite foams

Fiber aspect ratio (%)	Flexural strength (MPa)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
28.75	7.0264	6.9849	7.5989	7.7274	7.6977	7.4070	0.3698
143.76	8.0302	8.4650	8.2820	8.8946	7.9258	8.3195	0.3847
287.52	12.029	10.819	10.224	9.244	9.347	10.333	1.1493

Table F2 Effect of fiber aspect ratio on flexural strain at maximum force of 10 wt% jute-reinforced starch-based composite foams

Fiber aspect ratio (%)	Flexural Strain at maximum force (%)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
28.75	1.4721	1.3314	1.5777	1.5250	1.5428	1.4898	0.0964
143.76	1.3720	1.5653	1.6788	1.4475	1.6969	1.5521	0.1419
287.52	1.8355	1.8687	1.7757	1.6264	1.6402	1.7493	0.1111

Table F3 Effect of fiber aspect ratio on flexural modulus of elasticity of 10 wt% jute-reinforced starch-based composite foams

Fiber aspect ratio (%)	Flexural modulus of elasticity (MPa)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
28.75	585.78	654.94	596.90	599.10	597.14	606.77	27.43
143.76	756.21	664.37	688.33	822.87	698.70	726.09	63.76
287.52	887.54	742.05	777.52	765.68	797.20	794.00	55.97

APPENDIX G

Effect of fiber aspect ratio on the mechanical properties of 10 wt% flax-reinforced starch-based composite foams

Table G1 Effect of fiber aspect ratio on flexural strength of 10 wt% flax-reinforced starch-based composite foams

Fiber aspect ratio (%)	Flexural strength (MPa)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
28.53	4.6646	6.8786	5.9117	6.2364	6.5334	6.0449	0.8505
142.67	6.3466	5.3894	6.3262	7.5328	8.3712	6.7932	1.1646
285.33	10.6028	7.9129	8.0128	7.7821	7.9096	8.4441	1.2096

Table G2 Effect of fiber aspect ratio on flexural strain at maximum force of 10 wt% flax-reinforced starch-based composite foams

Fiber aspect ratio (%)	Flexural Strain at maximum force (%)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
28.53	1.3057	1.8544	1.3993	1.8727	1.6499	1.6164	0.2584
142.67	2.2802	1.7734	2.4412	2.2032	2.2175	2.1831	0.2477
285.33	2.6902	2.4717	2.6100	3.0749	2.0568	2.5807	0.3686

Table G3 Effect of fiber aspect ratio on flexural modulus of elasticity of 10 wt% flax-reinforced starch-based composite foams

Fiber aspect ratio (%)	Flexural modulus of elasticity (MPa)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
28.53	501.84	565.03	571.83	589.59	575.08	560.67	34.09
142.67	515.54	554.33	501.57	627.50	629.50	565.69	60.51
285.33	604.17	544.76	532.67	498.29	549.21	545.82	38.24

APPENDIX H

Effect of fiber aspect ratio on densities of jute- and flax-reinforced starch-based composite foams

Table H1 Effect of fiber aspect ratio on densities of jute- and flax-reinforced starch-based composite foams

Sample number	Density (g/cm^3)					
	Jute-reinforced SCF[2] with different fiber aspect ratio			Flax-reinforced SCF[2] with different fiber aspect ratio		
	28.75	143.76	287.52	28.53	142.67	285.33
1	0.3226	0.3301	0.3320	0.3128	0.3410	0.3341
2	0.3071	0.3600	0.3989	0.3018	0.3407	0.3631
3	0.3218	0.3328	0.3733	0.3741	0.3533	0.3451
4	0.2970	0.3389	0.3603	0.3502	0.3366	0.3367
5	0.3591	0.3436	0.3341	0.3558	0.3483	0.3536
Average	0.3215	0.3411	0.3597	0.3389	0.3440	0.3465
Standard deviation	0.0236	0.0118	0.0280	0.0305	0.0067	0.0120

[2] denotes starch-based composite foam

APPENDIX I

Effect of fiber orientation on the mechanical properties of starch-based composite foams reinforced with 10 wt% flax fibers of different fiber orientations

Table I1 Effect of fiber orientation on flexural strength of starch-based composite foams reinforced with 10 wt% flax fibers of different fiber orientations

Fiber aspect ratio (%)	Flexural strength (MPa)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
Transverse	4.5568	6.1037	4.8043	5.2536	5.6652	5.2767	0.6278
Random	12.585	9.294	10.652	9.977	9.740	10.450	1.2907
Longitudinal	14.752	14.214	16.991	14.033	17.055	15.409	1.4972

Table I2 Effect of fiber orientation on flexural strain at maximum force of starch-based composite foams reinforced with 10 wt% flax fibers of different fiber orientations

Fiber aspect ratio (%)	Flexural strain at maximum force (%)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
Transverse	1.5822	1.5247	1.6411	1.5981	1.6032	1.5899	0.0424
Random	2.0376	2.1929	2.0847	1.8907	1.8828	2.0177	0.1322
Longitudinal	2.4963	2.5040	2.1499	2.2748	2.6990	2.4248	0.2148

Table I3 Effect of fiber orientation on flexural modulus of elasticity of starch-based composite foams reinforced with 10 wt% flax fibers of different fiber orientations

Fiber aspect ratio (%)	Flexural modulus of elasticity (MPa)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
Transverse	382.33	510.08	378.12	423.59	467.20	432.26	56.51
Random	792.76	739.74	589.80	714.58	697.63	706.90	74.68
Longitudinal	907.60	910.86	955.40	907.34	1006.75	937.59	43.67

APPENDIX J

Effect of fiber orientation on densities of jute- and flax-reinforced starch-based composite foams

Table J1 Effect of fiber orientation on densities of jute- and flax-reinforced starch-based composite foams

Sample number	Density (g/cm^3)		
	Flax-reinforced SCF[2] with different fiber orientation		
	Transverse	Random	Longitudinal
1	0.3128	0.3410	0.3341
2	0.3018	0.3407	0.3631
3	0.3741	0.3533	0.3451
4	0.3502	0.3366	0.3367
5	0.3558	0.3483	0.3536
Average	0.3389	0.3440	0.3465
Standard deviation	0.0305	0.0067	0.0120

[2] denotes starch-based composite foam

APPENDIX K

Diameter of natural fibers

Table K1 Diameter of jute fibers

Sample number	Diameter (μm)	Sample number	Diameter (μm)	Sample number	Diameter (μm)	Sample number	Diameter (μm)
1	65.87	26	72.94	51	125.40	76	62.58
2	99.43	27	56.42	52	69.70	77	58.10
3	68.41	28	67.42	53	52.47	78	56.14
4	69.26	29	79.76	54	63.50	79	71.68
5	74.66	30	83.06	55	94.04	80	41.48
6	66.60	31	61.91	56	74.78	81	76.05
7	61.21	32	72.56	57	48.23	82	52.76
8	74.62	33	30.91	58	97.95	83	69.26
9	68.93	34	61.47	59	69.93	84	85.65
10	56.14	35	74.68	60	93.21	85	79.79
11	40.68	36	53.54	61	103.88	86	62.99
12	72.37	37	38.73	62	83.31	87	91.35
13	111.33	38	107.65	63	54.59	88	58.95
14	52.76	39	68.06	64	52.76	89	39.13
15	71.60	40	65.03	65	30.68	90	100.60
16	41.48	41	70.39	66	94.24	91	56.65
17	61.66	42	59.39	67	77.49	92	61.91
18	52.24	43	46.37	68	83.70	93	46.41
19	80.54	44	44.67	69	63.45	94	46.52
20	80.09	45	44.60	70	54.93	95	77.91
21	114.72	46	88.18	71	55.34	96	114.29
22	100.92	47	108.04	72	51.31	97	103.70
23	52.76	48	53.79	73	33.60	98	46.71
24	92.27	49	80.54	74	109.33	99	55.93
25	89.98	50	68.86	75	73.20	100	48.80

Average of jute fiber's diameter = 69.56 μm (with the standard deviation of 20.32).

Table K2 Diameter of flax fibers

Sample number	Diameter (μm)	Sample number	Diameter (μm)	Sample number	Diameter (μm)	Sample number	Diameter (μm)
1	364.48	26	92.70	51	103.32	76	211.49
2	303.22	27	126.91	52	166.41	77	267.92
3	174.82	28	138.20	53	75.77	78	382.17
4	294.03	29	217.97	54	196.40	79	231.36
5	108.76	30	227.97	55	197.26	80	300.40
6	131.74	31	138.13	56	96.71	81	126.91
7	154.88	32	156.20	57	279.00	82	283.14
8	295.59	33	266.53	58	89.66	83	223.60
9	257.27	34	331.48	59	252.66	84	107.59
10	174.58	35	214.59	60	209.08	85	237.82
11	232.95	36	289.53	61	301.15	86	239.07
12	122.55	37	208.63	62	304.76	87	288.49
13	137.83	38	304.20	63	196.04	88	113.32
14	140.92	39	327.96	64	332.49	89	278.51
15	266.11	40	223.60	65	86.25	90	143.98
16	110.30	41	153.90	66	92.14	91	221.88
17	138.91	42	111.02	67	93.95	92	150.36
18	114.35	43	105.61	68	303.23	93	75.65
19	277.03	44	257.89	69	198.40	94	92.14
20	148.57	45	123.31	70	330.91	95	326.82
21	217.09	46	234.40	71	327.73	96	275.48
22	143.56	47	177.67	72	316.42	97	279.32
23	267.32	48	306.28	73	209.71	98	199.46
24	121.16	49	300.54	74	190.11	99	309.40
25	156.17	50	281.79	75	322.77	100	217.80

Average of flax fiber's diameter = 210.28 μm (with the standard deviation of 80.68).

APPENDIX L

Density of natural fibers

Table L1 Density of natural fibers

Fiber Type	Density (g/cm^3)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Standard deviation
Jute	0.2633	0.2413	0.2633	0.2194	0.3510	0.2677	0.0500
Flax	0.2809	0.3049	0.2857	0.3505	0.2473	0.2939	0.0379

APPENDIX M

The tensile properties of natural fibers

Table M1 The tensile properties of jute fibers

Sample number	Tensile strength (MPa)	Elongation (%)	Modulus of Elasticity (MPa)
1	288.72	2.091	14654
2	637.93	2.989	24129
3	452.12	1.385	26464
4	314.47	1.863	13913
5	325.03	1.225	29029
6	354.67	1.671	24389
7	337.44	1.262	28742
8	456.28	2.263	19100
9	335.03	1.740	22166
10	333.18	1.561	22407
11	747.50	2.032	27936
12	664.42	1.941	30428
13	462.67	2.415	17942
14	488.05	2.627	16469
15	421.73	2.114	20165
16	272.33	1.642	18461
17	499.36	1.867	27038
18	390.70	1.816	21536
19	441.65	1.685	27529
20	339.76	2.175	16942
21	559.47	1.684	29919
22	323.73	1.522	22018
23	356.62	1.851	19415
24	450.91	2.285	20406
25	379.31	1.567	26695
Average	425.32	1.891	22716
Standard deviation	121.97	0.417	4938

Table M2 The tensile properties of flax fibers

Sample number	Tensile strength (MPa)	Elongation (%)	Modulus of Elasticity (MPa)
1	619.0	4.655	18210
2	675.8	5.977	11330
3	821.7	5.518	18230
4	450.2	4.937	10050
5	655.7	5.139	12230
6	517.8	4.538	16060
7	386.3	4.588	11040
8	558.2	4.749	17520
9	665.5	4.829	18220
10	648.6	5.115	16120
11	746.6	4.356	25700
12	555.4	4.780	13930
13	828.7	4.741	24790
14	510.5	5.321	10330
15	480.5	4.647	12670
16	711.9	5.086	15360
17	594.3	5.462	10320
18	778.7	4.664	17360
19	977.0	5.210	19520
20	677.1	4.178	20330
21	620.6	5.199	15920
22	595.1	5.180	12340
23	944.2	4.803	21140
24	752.4	5.658	10390
25	803.0	4.814	19560
Average	663.0	4.966	15946
Standard Deviation	146.7	0.419	4479

APPENDIX N

Thermograms of tapioca starch, jute, and flax fibers

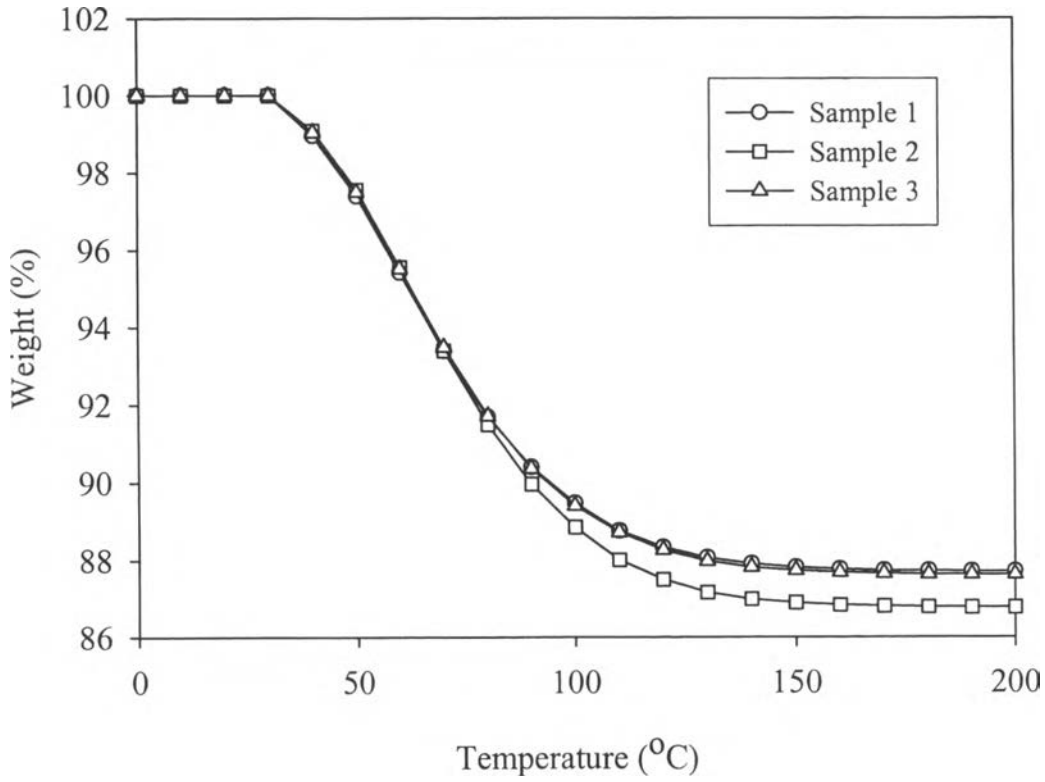

Figure N1 Thermograms of tapioca starch.

Average value of moisture content in tapioca starch equals to 12.66 %.

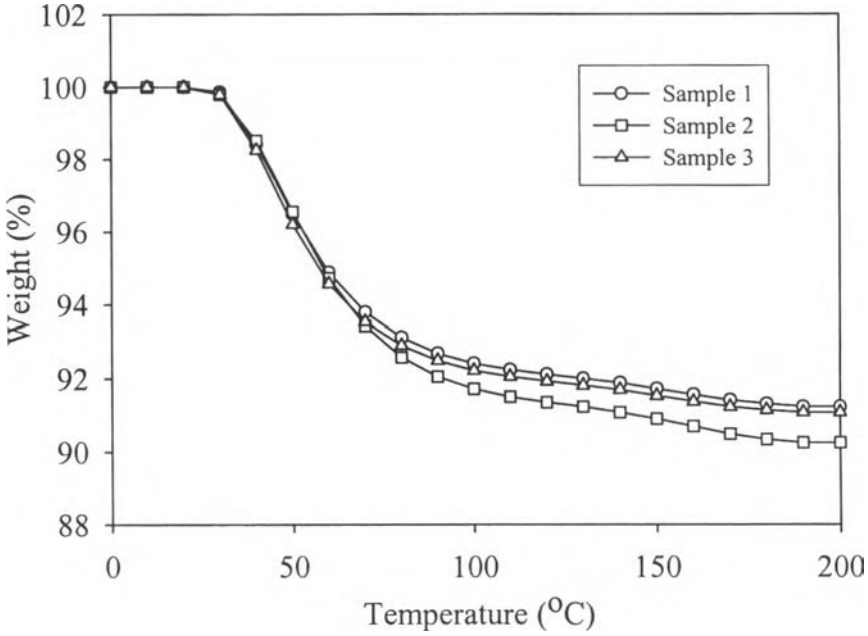

Figure N2 Thermograms of jute fibers.

Average value of moisture content in jute fibers equals to 8.25 %.

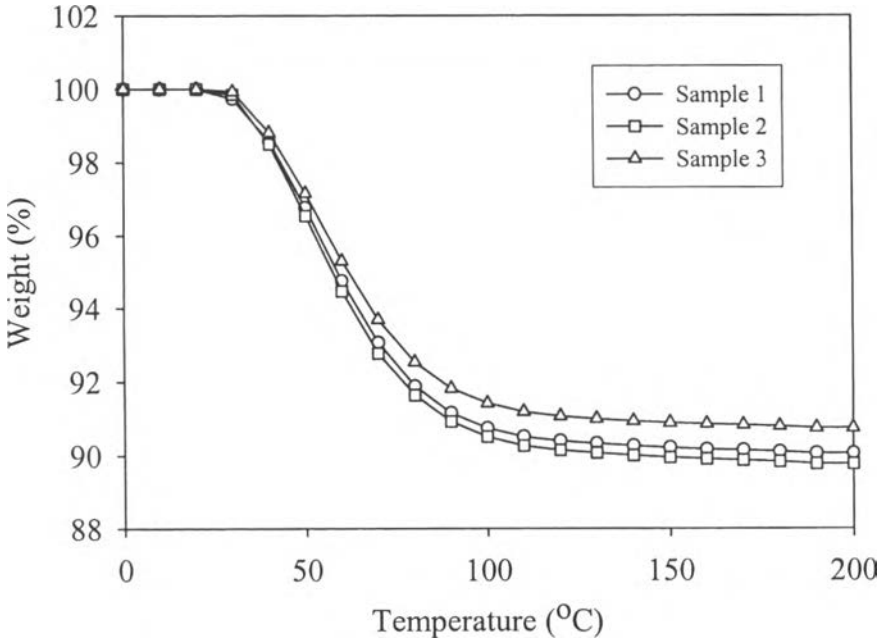

Figure N3 Thermograms of flax fibers.

Average value of moisture content in flax fibers equals to 9.77 %.

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