

REFERENCES

- A.J.F. Carvalho, A.E. Job, N. Alves, A.A.S. Curvelo, A. Gandini, (2003) Thermo plastic starch/natural rubber blends, Carbohydrate Polymers, 53, 95–99.
- 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.
- Allenza, P., Schollmeyer, J., & Rohrbach, R. P. (1990). Degradable materials. Bocoton: CRC Press.
- 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, 6565-3537.
- C. Nakason, A. Kaesaman, K. Eardrod. (2005) Cure and mechanical properties of natural rubber-g-poly(methyl methacrylate)–cassava starch compounds. Materials Letters, 59, 4020 – 4025.
- Dufresne, A., Dupeyre, D., & 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 Proucts, 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.

- G.M. Glenn, W.J. Orts, G.A.R. Nobes, G.M. Gray. (2001) In situ laminating process for baked starch-based foams. Industrial Crops and Products, 14, 125–134.
- J.W. Lawton, R.L. Shogren, and K.F. Tiefenbacher (2004) Aspen fiber addition improves the mechanical properties of baked cornstarch foams. Industrial Crops and Products, 19, 41–48.
- Li, Y., Kloeppel, K. M., & Hsieh, F. (1998) Texture of glassy corn cakes as a function of moisture content. Journal of Food Science, 63, 869–872.
- 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.
- Preechawong D., Peesan M., Supaphol P., Rujiravanit R. (2005) Preparation and characterization of starch/poly(L-lactic acid) hybrid foams. Carbohydrate Polymers, 59, 329–337.
- Preechawong D., Peesan M., Supaphol P., Rujiravanit R. (2004) Characterization of starch/poly(ε-caprolactone) hybrid foams. Polymer Testing, 23, 651–657.
- Shey, J., Imam, S.H., Glenn, G.M., Orts, W.J. (2006) Properties of baked starch foam with natural rubber latex. Industrial Crops and Products, 24, 34-40.
- 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.

- Soykeabkaew N., Supaphol P., Rujiravanit R. (2004) Preparation and characterization of jute- and flax-reinforced starch-based composite foams. Carbohydrate Polymers, 58, 53–63.
- 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.
- Tiefencbacher, K. (1993) Starch-based foamed materials: use and degradation properties. Journal of Macromolecule Science: Pure Applied Chemistry, A30, 727-731.
- Van Soest, J. J. G., & Knooren, N. (1997) Influence of glycerol and water content on the structure and properties of extruded starch plastic sheets during aging. Journal of Applied Polymer Science, 64(7), 1411–1422.
- Zobel, H. F. (1998) Molecules to granules: A comprehensive starch review. Starch/Stärke, 40, 44–50.

APPENDICES

Appendix A Effect of natural rubber content on moisture content of foam products with various storage relative humidity

Table A1 Moisture content of native tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	7.08	4.47	4.03	3.68
Sample 2	7.28	6.41	3.85	3.81
Sample 3	7.61	4.18	3.83	3.70
Sample 4	7.31	4.61	4.01	3.65
Sample 5	7.21	4.33	4.03	3.12
Average (%)	7.3	4.8	3.95	3.59
SD	0.19	0.92	0.1	0.27

Table A2 Moisture content of native tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	7.87	6.84	5.74	4.49
Sample 2	7.66	7.11	5.66	4.75
Sample 3	7.61	6.67	5.73	4.69
Sample 4	7.77	6.27	5.72	4.60
Sample 5	7.35	6.22	5.52	4.623
Average (%)	7.65	6.62	5.67	4.63
SD	0.2	0.38	0.09	0.1

Table A3 Moisture content of native tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	7.95	6.93	5.65	4.84
Sample 2	8.03	6.85	5.69	4.76
Sample 3	8.01	6.94	5.84	4.74
Sample 4	7.88	6.94	5.80	4.45
Sample 5	7.95	6.46	5.82	4.56
Average (%)	7.96	6.83	5.76	4.67
SD	0.056	0.21	0.086	0.16

Table A4 Moisture content of native tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	9.60	8.28	6.66	5.24
Sample 2	9.69	8.36	6.63	5.38
Sample 3	9.70	8.15	6.77	5.32
Sample 4	9.65	8.10	7.04	5.33
Sample 5	9.65	7.92	6.87	5.48
Average (%)	9.66	8.16	6.79	5.35
SD	0.39	0.17	0.17	0.087

Table A5 Moisture content of native tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	13.44	12.46	10.77	8.543191
Sample 2	13.41	13.17	10.57	8.626162
Sample 3	13.40	12.41	10.39	9.133692
Sample 4	13.37	12.47	10.66	8.96053
Sample 5	13.28	12.24	10.16	8.26
Average (%)	13.38	12.55	10.51	8.7
SD	0.059	0.36	0.24	0.35

Table A6 Moisture content of octyl tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	6.02	5.57	3.49	3.12
Sample 2	5.86	5.34	3.21	3.11
Sample 3	6.03	5.26	3.43	3.01
Sample 4	5.87	5.47	2.99	3.00
Sample 5	5.61	5.48	2.54	2.74
Average (%)	5.88	5.42	3.13	3
SD	0.17	0.12	0.38	0.15

Table A7 Moisture content of octyl tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	7.44	6.09	4.32	3.82
Sample 2	7.41	5.99	4.14	3.63
Sample 3	7.17	5.52	4.09	3.67
Sample 4	6.98	5.87	3.87	3.71
Sample 5	6.89	5.80	3.94	3.83
Average (%)	7.17	5.86	4.07	3.73
SD	0.24	0.22	0.18	0.089

Table A8 Moisture content of octyl tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	6.99	6.17	4.78	4.04
Sample 2	7.39	6.23	4.94	3.88
Sample 3	7.03	6.17	4.93	4.00
Sample 4	6.85	5.89	4.81	3.78
Sample 5	7.02	5.66	4.78	3.60
Average (%)	7.06	6.03	4.85	3.86
SD	0.2	0.24	0.079	0.18

Table A9 Moisture content of octyl tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	8.79	7.07	5.55	4.34
Sample 2	8.73	6.87	5.26	4.48
Sample 3	8.92	7.04	5.35	4.30
Sample 4	8.61	7.08	5.77	4.35
Sample 5	8.09	7.48	5.12	4.39
Average (%)	8.63	7.11	5.41	4.37
SD	0.32	0.23	0.25	0.07

Table A10 Moisture content of octyl tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	12.70	11.40	9.43	9.18
Sample 2	12.89	11.22	9.88	9.06
Sample 3	12.91	11.27	10.07	9.00
Sample 4	12.77	11.56	10.10	8.97
Sample 5	12.45	10.80	9.83	8.57
Average (%)	12.75	11.25	9.86	8.95
SD	0.18	0.28	0.27	0.23

Appendix B Effect of natural rubber content on foam densities with various storage relative humidity

Table B1 Densities of native tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.17	0.25	0.42	0.53
Sample 2	0.17	0.24	0.42	0.52
Sample 3	0.16	0.26	0.48	0.54
Sample 4	0.19	0.25	0.45	0.52
Sample 5	0.16	0.22	0.48	0.53
Average (g/cm ³)	0.17	0.24	0.45	0.53
SD	0.013	0.014	0.027	0.0066

Table B2 Densities of native tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.16	0.24	0.48	0.55
Sample 2	0.17	0.23	0.50	0.53
Sample 3	0.17	0.25	0.48	0.55
Sample 4	0.17	0.26	0.51	0.55
Sample 5	0.17	0.26	0.45	0.54
Average (g/cm ³)	0.17	0.25	0.48	0.55
SD	0.0038	0.014	0.021	0.0082

Table B3 Densities of native tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.17	0.20	0.48	0.55
Sample 2	0.17	0.26	0.49	0.56
Sample 3	0.17	0.26	0.52	0.57
Sample 4	0.16	0.24	0.48	0.55
Sample 5	0.17	0.24	0.55	0.53
Average (g/cm ³)	0.17	0.24	0.51	0.55
SD	0.0071	0.024	0.032	0.018

Table B4 Densities of native tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.17	0.24	0.51	0.60
Sample 2	0.16	0.26	0.51	0.56
Sample 3	0.17	0.23	0.49	0.55
Sample 4	0.17	0.25	0.49	0.61
Sample 5	0.16	0.22	0.49	0.53
Average (g/cm ³)	0.17	0.24	0.50	0.57
SD	0.0071	0.016	0.012	0.035

Table B5 Densities of native tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.17	0.26	0.27	0.53
Sample 2	0.18	0.23	0.51	0.53
Sample 3	0.22	0.22	0.53	0.58
Sample 4	0.22	0.21	0.48	0.53
Sample 5	0.21	0.25	0.47	0.49
Average (g/cm ³)	0.20	0.23	0.45	0.53
SD	0.023	0.021	0.10	0.032

Table B6 Densities of octyl tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.19	0.23	0.27	0.51
Sample 2	0.17	0.23	0.28	0.49
Sample 3	0.19	0.26	0.24	0.51
Sample 4	0.17	0.22	0.29	0.47
Sample 5	0.22	0.22	0.30	0.42
Average (g/cm ³)	0.19	0.23	0.28	0.48
SD	0.019	0.018	0.022	0.036

Table B7 Densities of octyl tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.18	0.22	0.32	0.47
Sample 2	0.20	0.18	0.28	0.42
Sample 3	0.19	0.25	0.23	0.48
Sample 4	0.17	0.24	0.24	0.51
Sample 5	0.18	0.19	0.28	0.50
Average (g/cm ³)	0.18	0.22	0.27	0.48
SD	0.012	0.023	0.036	0.037

Table B8 Densities of octyl tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.24	0.23	0.31	0.46
Sample 2	0.19	0.22	0.32	0.43
Sample 3	0.18	0.22	0.27	0.44
Sample 4	0.28	0.24	0.25	0.47
Sample 5	0.28	0.25	0.26	0.45
Average (g/cm ³)	0.23	0.23	0.28	0.45
SD	0.069	0.012	0.029	0.013

Table B9 Densities of octyl tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.21	0.24	0.35	0.47
Sample 2	0.21	0.23	0.28	0.45
Sample 3	0.20	0.23	0.31	0.48
Sample 4	0.21	0.22	0.29	0.46
Sample 5	0.18	0.24	0.30	0.48
Average (g/cm ³)	0.2	0.23	0.31	0.47
SD	0.012	0.012	0.029	0.016

Table B10 Densities of octyl tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.23	0.25	0.26	0.51
Sample 2	0.21	0.21	0.30	0.46
Sample 3	0.20	0.22	0.29	0.45
Sample 4	0.16	0.21	0.29	0.48
Sample 5	0.19	0.23	0.37	0.49
Average (g/cm ³)	0.2	0.23	0.31	0.49
SD	0.025	0.019	0.048	0.025

Appendix C Effect of natural rubber content on specific flexural strength with various storage relative humidity

Table C1 Specific flexural strength of native tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	16.46	12.36	5.24	4.23
Sample 2	14.61	15.27	5.19	3.80
Sample 3	13.47	9.71	5.69	3.77
Sample 4	12.12	9.48	5.06	3.22
Sample 5	11.31	10.70	4.67	2.91
Average (kNm/kg)	13.59	11.50	5.17	3.59
SD	2.04	2.39	0.37	0.52

Table C2 Specific flexural strength of native tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	17.49	13.64	6.41	3.87
Sample 2	15.75	11.74	5.00	3.78
Sample 3	15.33	11.69	4.76	3.72
Sample 4	11.22	11.49	4.41	3.48
Sample 5	13.87	10.84	5.23	3.07
Average (kNm/kg)	14.73	11.88	5.16	3.59
SD	2.35	1.05	0.76	0.32

Table C3 Specific flexural strength of native tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	15.57	13.87	6.87	3.59
Sample 2	19.16	13.31	6.85	3.56
Sample 3	16.26	12.81	6.61	3.43
Sample 4	17.02	12.07	6.61	3.39
Sample 5	16.44	12.00	6.29	3.37
Average (kNm/kg)	16.89	12.81	6.65	3.47
SD	1.37	0.80	0.24	0.10

Table C4 Specific flexural strength of native tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	17.93	11.84	5.91	3.07
Sample 2	16.32	10.28	5.79	3.06
Sample 3	15.60	9.64	5.47	3.03
Sample 4	14.91	9.60	5.37	3.00
Sample 5	14.70	9.16	5.25	2.98
Average (kNm/kg)	15.89	10.10	5.56	3.03
SD	1.30	1.05	0.28	0.037

Table C5 Specific flexural strength of native tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	11.35	7.38	4.14	2.212892
Sample 2	10.85	6.83	3.48	2.190166
Sample 3	10.61	6.49	3.28	2.154038
Sample 4	8.47	6.47	3.23	2.1483
Sample 5	6.29	6.39	3.20	2.123258
Average (kNm/kg)	9.51	6.71	3.47	2.17
SD	2.11	0.41	0.39	0.036

Table C6 Specific flexural strength of octyl tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	16.47	9.57	7.16	3.65
Sample 2	12.31	5.14	4.77	3.42
Sample 3	11.17	4.82	3.25	3.36
Sample 4	8.05	4.39	2.90	3.31
Sample 5	6.19	3.67	2.86	2.93
Average (kNm/kg)	10.84	5.52	4.19	3.33
SD	3.98	2.33	1.84	0.26

Table C7 Specific flexural strength of octyl tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	19.76	10.75	8.44	3.68
Sample 2	17.00	10.51	5.43	3.63
Sample 3	14.12	10.26	3.05	3.62
Sample 4	13.40	9.52	2.29	3.57
Sample 5	13.15	6.63	4.55	3.39
Average (kNm/kg)	15.49	9.54	4.75	3.57
SD	2.84	1.69	2.40	0.11

Table C8 Specific flexural strength of octyl tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	14.55	10.10	4.44	2.92
Sample 2	18.03	7.17	4.25	2.91
Sample 3	11.45	4.19	4.03	2.70
Sample 4	8.41	3.03	3.82	2.57
Sample 5	15.59	2.95	3.42	2.52
Average (kNm/kg)	13.61	5.49	3.99	2.72
SD	3.74	3.09	0.40	0.18

Table C9 Specific flexural strength of octyl tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	15.25	5.44	4.11	2.77
Sample 2	12.96	5.22	2.97	2.71
Sample 3	12.31	4.84	2.36	2.59
Sample 4	11.01	2.92	2.05	2.58
Sample 5	9.72	2.72	1.91	2.50
Average (kNm/k)	12.25	4.23	2.68	2.63
SD	2.09	1.30	0.90	0.11

Table C10 Specific flexural strength of octyl tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	10.26	5.89	3.04	1.81
Sample 2	10.00	5.13	2.02	1.77
Sample 3	9.02	4.15	1.82	1.76
Sample 4	8.60	3.35	1.66	1.76
Sample 5	7.89	2.92	1.50	1.67
Average (kNm/kg)	9.15	4.29	2.01	1.75
SD	0.99	1.23	0.61	0.049

Appendix D Effect of natural rubber content on maximum flexural strain with various storage relative humidity

Table D1 Maximum flexural strain of native tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.024	0.015	0.026	0.034
Sample 2	0.023	0.015	0.027	0.033
Sample 3	0.022	0.013	0.025	0.028
Sample 4	0.022	0.013	0.024	0.028
Sample 5	0.021	0.012	0.022	0.027
Average	0.022	0.014	0.024	0.030
SD	0.0012	0.0013	0.0029	0.0032

Table D2 Maximum flexural strain of native tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.031	0.019	0.044	0.051
Sample 2	0.030	0.019	0.033	0.042
Sample 3	0.028	0.018	0.032	0.041
Sample 4	0.028	0.017	0.032	0.041
Sample 5	0.021	0.017	0.030	0.041
Average	0.028	0.018	0.034	0.043
SD	0.0037	0.00086	0.0054	0.0045

Table D3 Maximum flexural strain of native tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.025	0.016	0.027	0.044
Sample 2	0.023	0.015	0.027	0.041
Sample 3	0.022	0.015	0.027	0.039
Sample 4	0.020	0.015	0.025	0.037
Sample 5	0.020	0.015	0.024	0.036
Average	0.022	0.015	0.026	0.039
SD	0.0024	0.00036	0.0015	0.0032

Table D4 Maximum flexural strain of native tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.020	0.015	0.026	0.046
Sample 2	0.020	0.015	0.023	0.043
Sample 3	0.019	0.014	0.020	0.038
Sample 4	0.018	0.014	0.020	0.038
Sample 5	0.017	0.014	0.020	0.036
Average	0.019	0.014	0.022	0.040
SD	0.0015	0.00058	0.0029	0.0042

Table D5 Maximum flexural strain of native tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.016	0.013	0.020	0.040
Sample 2	0.015	0.012	0.019	0.041
Sample 3	0.015	0.012	0.019	0.042
Sample 4	0.013	0.012	0.018	0.042
Sample 5	0.013	0.012	0.018	0.042
Average	0.015	0.012	0.019	0.041
SD	0.0014	0.00040	0.0010	0.0010

Table D6 Maximum flexural strain of octyl tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.024	0.018	0.018	0.028
Sample 2	0.020	0.015	0.014	0.027
Sample 3	0.016	0.012	0.016	0.026
Sample 4	0.016	0.012	0.017	0.026
Sample 5	0.013	0.011	0.014	0.024
Average	0.018	0.014	0.016	0.026
SD	0.0043	0.0026	0.0017	0.0016

Table D7 Maximum flexural strain of octyl tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.029	0.016	0.023	0.040
Sample 2	0.028	0.016	0.022	0.035
Sample 3	0.027	0.016	0.022	0.034
Sample 4	0.026	0.015	0.021	0.030
Sample 5	0.026	0.014	0.020	0.030
Average	0.027	0.016	0.021	0.034
SD	0.0010	0.00073	0.0014	0.0040

Table D8 Maximum flexural strain of octyl tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.023	0.016	0.017	0.030
Sample 2	0.022	0.014	0.017	0.031
Sample 3	0.021	0.014	0.016	0.030
Sample 4	0.019	0.014	0.015	0.027
Sample 5	0.014	0.014	0.014	0.026
Average	0.020	0.014	0.016	0.029
SD	0.0035	0.00079	0.0012	0.0023

Table D9 Maximum flexural strain of octyl tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.021	0.016	0.016	0.032
Sample 2	0.021	0.015	0.016	0.031
Sample 3	0.018	0.014	0.015	0.031
Sample 4	0.018	0.014	0.014	0.030
Sample 5	0.017	0.012	0.013	0.023
Average	0.019	0.014	0.015	0.029
SD	0.0018	0.0018	0.0013	0.0039

Table D10 Maximum flexural strain of octyl tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	0.022	0.012	0.015	0.029
Sample 2	0.020	0.012	0.017	0.029
Sample 3	0.020	0.012	0.018	0.034
Sample 4	0.019	0.011	0.015	0.030
Sample 5	0.018	0.011	0.014	0.029
Average	0.020	0.011	0.016	0.030
SD	0.0019	0.00017	0.0017	0.0023

Appendix E Effect of natural rubber content on specific flexural modulus with various storage relative humidity

Table E1 Specific flexural modulus of native tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1307.53	975.58	565.96	270.85
Sample 2	1298.88	960.04	511.15	268.90
Sample 3	1277.62	943.69	485.45	263.97
Sample 4	1150.95	926.11	466.83	261.03
Sample 5	1108.78	917.46	466.00	258.37
Average (kNm/kg)	1228.75	944.58	499.08	264.63
SD	92.14	23.86	41.65	5.23

Table E2 Specific flexural modulus of native tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1525.65	986.72	389.98	207.93
Sample 2	1318.77	967.52	367.35	204.56
Sample 3	1268	947.64	360.50	196.85
Sample 4	921.18	918.64	358.44	193.95
Sample 5	916.29	836.16	366.17	193.78
Average (kNm/kg)	1189.98	931.34	368.49	199.41
SD	265.76	58.87	12.58	6.46

Table E3 Specific flexural modulus of native tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1367.53	949.83	427.66	211.16
Sample 2	1294.47	945.75	418.88	206.62
Sample 3	1204.82	915.83	353.56	201.04
Sample 4	1035.18	898.33	342.86	199.98
Sample 5	773.82	872.54	317.98	194.13
Average (kNm/kg)	1135.17	916.46	372.19	202.59
SD	237.06	32.52	48.48	6.53

Table E4 Specific flexural modulus of native tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1192.82	785.71	413.66	184.11
Sample 2	1163.88	779.92	404.88	182.42
Sample 3	1099.82	692.04	401.30	180.97
Sample 4	1052.94	688.70	365.84	178.54
Sample 5	994.65	647.92	335.14	174.47
Average (kNm/kg)	1100.82	718.86	384.164	180.1025
SD	80.63	60.95	32.9087	3.750351

Table E5 Specific flexural modulus of native tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	768.50	569.83	322.96	116.42
Sample 2	715.35	569.30	316.07	116.41
Sample 3	620.00	556.78	303.51	112.23
Sample 4	556.15	554.00	300.62	110.09
Sample 5	537.65	549.48	298.62	106.79
Average (kNm/kg)	639.53	559.88	308.36	112.39
SD	100.12	9.22	10.61	4.15

Table E5 Specific flexural modulus of octyl tapioca starch composite foams at 11.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1253.37	810.30	524.93	237.13
Sample 2	1164.26	761.13	324.50	200.38
Sample 3	1073.74	561.91	285.64	194.96
Sample 4	968.00	486.96	279.39	173.54
Sample 5	747.74	419.04	262.50	161.19
Average (kNm/kg)	1041.42	607.87	335.39	193.44
SD	195.38	170.92	108.36	29.13

Table E7 Specific flexural modulus of octyl tapioca starch composite foams at 32.8%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1221.33	713.18	479.26	231.38
Sample 2	1109.72	704.82	385.63	229.29
Sample 3	1063.22	688.23	290.74	227.85
Sample 4	1045.11	664.68	261.96	218.44
Sample 5	976.83	486.05	254.59	214.16
Average (kNm/kg)	1083.24	651.39	334.44	224.22
SD	90.76	94.27	96.35	7.50

Table E8 Specific flexural modulus of octyl tapioca starch composite foams at 43.2%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1535.35	562.52	432.57	238.84
Sample 2	1445.48	486.57	396.14	209.49
Sample 3	1324.78	433.39	338.82	206.98
Sample 4	1213.13	345.70	317.86	203.53
Sample 5	999.39	501.39	182.89	162.49
Average (kNm/kg)	1303.63	465.91	333.66	204.27
SD	209.17	81.44	95.78	27.28

Table E9 Specific flexural modulus of octyl tapioca starch composite foams at 53.9%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	1159.10	547.57	424.26	221.21
Sample 2	1144.15	528.61	311.16	220.53
Sample 3	1141.20	390.87	208.74	207.23
Sample 4	1075.20	385.91	201.16	206.26
Sample 5	886.30	274.70	197.65	199.60
Average (kNm/kg)	1081.19	425.53	268.59	210.97
SD	113.64	112.96	99.00	9.51

Table E10 Specific flexural modulus of octyl tapioca starch composite foams at 75.3%RH with various natural rubber content

Natural rubber content (% wt)	0% NR	10% NR	30% NR	50% NR
Sample 1	577.40	462.95	208.57	125.71
Sample 2	571.85	422.68	206.83	120.69
Sample 3	568.70	414.27	158.47	118.33
Sample 4	565.30	403.77	152.70	118.15
Sample 5	551.20	343.09	143.03	117.85
Average (kNm/kg)	566.89	409.3545	173.92	120.15
SD	9.836692	43.29201	31.33	3.31

Appendix F Effect of cellulose pulp content on foam density at 53.9%RH for fixed natural rubber content at 30%wt

Table F1 Densities of native tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	1% fiber	3% fiber	5% fiber
Sample 1	0.48	0.42	0.54	0.55
Sample 2	0.49	0.44	0.53	0.52
Sample 3	0.52	0.45	0.53	0.56
Sample 4	0.48	0.42	0.54	0.55
Sample 5	0.55	0.44	0.53	0.57
Average (g/cm ³)	0.51	0.43	0.53	0.55
SD	0.032	0.015	0.0043	0.019

Table F2 Densities of octyl tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	10% fiber	30% fiber	50% fiber
Sample 1	0.35	0.24	0.41	0.42
Sample 2	0.28	0.28	0.42	0.42
Sample 3	0.31	0.24	0.40	0.42
Sample 4	0.29	0.29	0.35	0.41
Sample 5	0.30	0.29	0.41	0.42
Average (g/cm^3)	0.31	0.27	0.40	0.42
SD	0.029	0.024	0.029	0.0028

Appendix G Effect of cellulose pulp content on flexural properties at 53.9%RH for fixed natural rubber content at 30%wt

Table G1 Specific flexural strength of native tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	1% fiber	3% fiber	5% fiber
Sample 1	5.91	6.15	7.60	9.70
Sample 2	5.79	5.86	7.60	9.59
Sample 3	5.47	5.53	6.69	9.31
Sample 4	5.37	5.14	6.46	9.20
Sample 5	5.25	5.01	6.06	8.65
Average (kNm/kg)	5.56	5.53	6.88	9.29
SD	0.28	0.48	0.69	0.41

Table G2 Specific flexural strength of octyl tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	10% fiber	30% fiber	50% fiber
Sample 1	4.11	5.90	7.16	8.37
Sample 2	2.97	5.67	6.46	8.16
Sample 3	2.36	5.23	6.23	8.09
Sample 4	2.05	5.20	6.16	7.77
Sample 5	1.91	5.03	6.13	7.58
Average (kNm/kg)	2.68	5.41	6.43	7.99
SD	0.90	0.37	0.43	0.31

Table G3 Maximum flexural strain of native tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	1% fiber	3% fiber	5% fiber
Sample 1	0.026	0.027	0.036	0.037
Sample 2	0.023	0.026	0.036	0.036
Sample 3	0.020	0.026	0.035	0.035
Sample 4	0.020	0.026	0.035	0.035
Sample 5	0.020	0.025	0.034	0.032
Average	0.022	0.026	0.035	0.035
SD	0.0029	0.00078	0.0010	0.0016

Table G4 Maximum flexural strain of octyl tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	10% fiber	30% fiber	50% fiber
Sample 1	0.016	0.023	0.026	0.030
Sample 2	0.016	0.022	0.025	0.029
Sample 3	0.015	0.0220	0.025	0.029
Sample 4	0.014	0.021	0.024	0.029
Sample 5	0.013	0.020	0.022	0.027
Average	0.015	0.022	0.024	0.029
SD	0.0013	0.0011	0.0015	0.0012

Table G5 Specific flexural modulus of native tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	1% fiber	3% fiber	5% fiber
Sample 1	413.66	395.68	459.23	579.48
Sample 2	404.88	392.61	376.51	546.88
Sample 3	401.3	388.39	361.83	531.40
Sample 4	365.84	385.29	348.30	530.28
Sample 5	335.14	376.48	416.34	501.85
Average (kNm/kg)	384.16	387.69	392.44	537.98
SD	32.91	7.42	45.20	28.33

Table G6 Specific flexural modulus of octyl tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	10% fiber	30% fiber	50% fiber
Sample 1	424.26	449.41	533.42	556.43
Sample 2	311.16	439.61	489.57	541.17
Sample 3	208.74	402.30	467.39	536.91
Sample 4	201.16	382.36	460.99	525.76
Sample 5	197.65	360.25	446.00	475.12
Average (kNm/kg)	268.59	406.79	479.47	527.08
SD	99.00	37.67	33.99	31.06

Appendix H Effect of cellulose pulp content on moisture content at 53.9%RH for fixed natural rubber content at 30%wt

Table H1 Moisture content of native tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	1% fiber	3% fiber	5% fiber
Sample 1	6.66	6.67	6.71	6.59
Sample 2	6.63	6.56	6.12	6.60
Sample 3	6.77	6.55	6.65	6.70
Sample 4	7.04	6.71	6.64	6.69
Sample 5	6.87	6.47	6.45	6.61
Average (%)	6.79	6.60	6.51	6.64
SD	0.17	0.096	0.24	0.051

Table H2 Moisture content of octyl tapioca starch composite foams at 53.9%RH with various cellulose pulp content

Cellulose pulp content (% wt)	0% fiber	10% fiber	30% fiber	50% fiber
Sample 1	5.55	5.47	5.93	5.92
Sample 2	5.26	5.39	6.02	5.80
Sample 3	5.35	5.59	5.98	5.82
Sample 4	5.77	5.74	5.93	5.90
Sample 5	5.12	5.67	5.90	5.97
Average (%)	5.41	5.57	5.95	5.88
SD	0.25	0.14	0.050	0.069

CURRICULUM VITAE

Name: Mr. Chaiyapruk Katepetch

Date of Birth: May 1, 1983

Nationality: Thai

University Education:

2001-2004 Bachelor Degree of Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhom-Pathom, Thailand.