REFERENCES

Albano, C.; Reyes, J.; Ichazo, M.; Gonzalez, J.; and Chipara, M.I. Influence of gamma irradiation on the thermal stability of blends of PP with previously treated sisal fiber. Polym. Degrad. and Stab. 73 (2001): 225-236.

Albano, C.; Reyes, J.; Ichazo, M.; Gonzalez, J.; Brito M.; and Moronta, D. Analysis of the mechanical, thermal and morphological behaviour of polypropylene compounds with sisal fibre and wood flour, irradiated with gamma rays. Polym. Degrad. Stab. 76 (2002): 191-203.

Al-Maadeed, M.A. Change in structure of ultrahigh molecular weight polyethylene due to irradiation in air and in nitrogen. International Journal of Plymer Anal. Charact. 11 (2006): 71-84.

Bakraji, E.H.; Salman, N.; and Al-kassiri, H. Gamma-radiation-induced wood-plastic composites from Syrian tree species. Radiation Physics and Chemistry. 61 (2001): 137-141.

Bengtsson, M.; Gatenholm, P.; and Oksman, K. The effect of crosslinking on the properties of polyethylene/wood flour composites. Compos. Sci. and Tech. 65 (2005): 1468-1479.

Bengtsson, M.; and Oksman, K. Silane crosslinked wood plastic composites: processing and properties. Compos. Sci. and Tech. 66 (2006): 2177-2186.

Bigg, D.M. Mechanical Properties of Particulate Filled Polymers. Polym. Comp. 8 (1987): 115-122.

Birley, A.W.; Heath, R.J.; and Scott, M.J. Plastics Materials: Properties and Applications. New York: Chapman and Hall, 1988.

Bledzki, A.K.; Letman, M.; Viksne, A.; and Rence, L. A comparison of compounding processes and wood tye for wood fibre-PP composites. Composites: Part A. 36 (2005): 789-797.

Bodig, J.; and Jayne, B.A. Mechanicals of Wood and Wood Composites. New York : Van Nostrand Reinhold, 1982.

Doh, G.H.; Kang, I.A.; Lee, S.Y.; Kong, Y.T.; Jeong, C.S.; and Lim, B.S. Mecahnical properties and creep behavior of liquefied wood polymer composites (LWPC). Compos. Struct. 68 (2005): 225-233.

Fried, J.R. Polymer Science and Technology. New Jersey : Prentice-Hall International, Inc., 1995.

Gachter, R.; and Muller, H. Plastics Additives Handbook. New York: Hanser Gardner Publications, 1987.

Hillig, W.B. Composite Materials. Encyclopedia of Chemical Technology. 1981; 6.

Ichazo, M.N.; Albano, C.; Gonzalez, J.; Perera, R.; and Candal, M.V. Polypropylene/wood flour composites: treatments and properties. Compos. Struct. 54 (2001): 207-214.

Jenkins, A.D. Progress in Polymer Science. Oxford: Pergamon Press, 1975.

Jubsilp, C. Wood-Substituted Composites from Highly-Filled Polybenzoxazine System., Master's Thesis, Chemical Engineering, Chulalongkorn University, 2002.

Karian, H.G. Handbook of Polypropylene and Polypropylene Composite. New York : Marcel Dekker, 1999.

Klinkularb, M. Gamma ray-induced crosslinking of methyl methacrylate, acrylic acid and polyvinyl chloride with some sensitizers., Master's Thesis, Chemical Engineering, Chulalongkorn University, 1989.

Lee, S.Y.; Yang, H.S.; Kim, H.J.; Jeong, C.S.; Lim, B.S.; and Lee, J.N. Creep behavior and manufacturing parameters of wood flour filled polypropylene composites. Compos. Struct. 65 (2004): 459-469.

Li, B.; and Xu, M. Effect of a novel charring-foaming agent on flame retardancy and thermal degradation of intumescent flame retardantpolypropylene. Polym. Degrad. and Stab. 91(2006): 1380-1386.

Lu, Z. Chemical coupling wood polymer composite. Doctor in Philosphy, Louisiana State University, 2003.

Lumpoopinitpong, S. Mechanical Properties of Wood Flour-Filled Polypropylene Composites. Master's Thesis, Graduate School, Chulalongkorn University, 1994.

Nabi, S.D.; and Jog, J.P. Natural fiber polymer composites: A review. Advances in Polym. Tech. 18 (1999): 351-363.

Othman, N.; Ismail, H.; and Mariatti, M. Effect of compatibilizers on mechanical and thermal properties of bentonite filled polypropylene composites. Polym. Degrad. and Stab. 91(2006): 1761-1774.

Paul, D.R.; and Bucknall, C.B. Polymer Blends. New York : John Wiley, 2000.

Punyahlek, P. Quality improvement of bombax cambodiense robins by impregnation with methyl methacrylate and polymerized by gamma ray. Master's Thesis, Chemical Engineering, Chulalongkorn University, 1989.

Qiu, W. Effect of maleated polypropylene on the performance of polypropylene/cellulose composite. Polym. Compos. (2005): 448-453.

Raj, R.G.; kokta, B.V.; Grouleau, G.; and Daneault, C. The Influence of Coupling Agents on Mechanical Properties of composites Containing Cellulosic Fillers. Polym. Plas. Tech. Eng., 1990; 29.

Ranade, A.; Nayak, K.; Fairbrother, D.; and DSouza, N.A. Maleated and non-maleated polyethylene-montmorillonite layered silicate blown films: creep, dispersion and crystallinity. Polymer. 46 (2005): 7323-7333.

Reinhart, T.J.; and Clements, L.L. Engineered Material Handbook. Ohio: ASM International, 1989.

Reyes, J.; Albano, C.; Davidson, E.; Poleo, R.; Gonzalez, J.; Ichazo, M.; and Chipara, M. Effect of gamma irradiation on polypropylene, polypropylene + high density polyethylene and polypropylene + high density polyethylene + wood flour. Mat. Res. Innovat. 4 (2001): 294-300.

Rimdusit, S.; Tanthapanichakoon, Wiwat.; and Jubsilp, C. High performance woodcomposites from highly filled polybenzoxazine. J. Appl. Polym. Sci. 99 (2006): 1240-1253.

Simpson,; W.; and Tenwolde, A. Wood Handbook., Madison: U.S. Department of Agriculture, 1999.

Sombatsompop, N.; Yotinwattanakumtorn, C.; and Thongpin, C. Influence of type and concentration of maleic anhydride grafted polypropylene and impact modifiers on mechanical properties of PP/wood sawdust composites. J. Appl. Polym. Sci. 97 (2005): 475-484.

Stark, N.M.; and Berger, J.M. Effect of Species and Particle Size on Properties of Wood-Flour-Filled Polypropylene Composites., The Forest Product Laboratory, Chemical Engineering, University of Wisconsin, 1997.

Wu, J.; Yu, D.; Chan, C.M.; Kim, J.; and Mai, Y.W. Effect of fiber pretreatment condition on the interfacial strength and mechanical properties of wood fiber/PP composites. J. Appl. Polym. Sci. 76 (2000): 1000-1010.

Department of Argriculture. Area of rubber wood grown in Thailand. Available from: http://www.doa.go.th[2005 December 15]

APPENDICES

Appendix A

Theoretical Density Calculation

Theoretical density calculation of a filler-reinforced composite is based on the filler volume fraction in the material. Experimentally, it is easier to determine the filler weight fraction, W_f, from which the filler volume fraction, V_f, and composite density, ρ_c can be calculated: (Jubsilp, C., 2002)

$$V_f = \frac{W_f / \rho_f}{(W_f / \rho_f) + (1 - W_f) / \rho_m}$$

$$\rho_c = \frac{1}{(W_f / \rho_f) + (1 - W_f) / \rho_m}$$

where W_f = Filler weight fraction
$(1\text{-}W_f)$ = Matrix weight fraction
ρ_f = Filler density
ρ_m = Matrix density
ρ_c = Composite density

In term of filler volume fraction, V_f, the composite density, ρ_c, can be written as:

$$\rho_c = \rho_f V_f + \rho_m V_m$$

The proportion of polypropylene to woodflour for this research was fixed at 60:40 by weight. The densities of woodflour filler and polypropylene matrix are 1.49 g/cm^3 and 0.90 g/cm^3, respectively, which we can calculate theoretical density of polypropylene woodflour composite showing as follow.

$$\rho_c = \frac{1}{(0.40/1.49)+(1-0.40)/0.90}$$

$$\rho_c = 1.069 \quad \text{g/cm}^3$$

Appendix B

Mechanical Characterizations

Appendix B-1 Flexural properties of polypropylene at various doses.

Radiation doses (kGy)	Flexural modulus (GPa)		Flexural strength (MPa)	
	In air	In nitrogen	In air	In nitrogen
0	1.18±0.04	1.18±0.04	46.44±0.69	46.44±0.69
5	1.19±0.01	1.38±0.02	49.41±2.70	55.84±0.66
10	1.30±0.04	1.45±0.01	53.71±0.41	55.16±0.36
20	1.38±0.05	1.45±0.01	55.13±1.06	55.30±0.96
30	1.44±0.04	1.45±0.04	54.76±0.45	56.21±0.96

Appendix B-2 Tensile properties of polypropylene at various doses.

Radiation doses (kGy)	Tensile modulus (GPa)		Tensile strength (MPa)	
	In air	In nitrogen	In air	In nitrogen
0	1.12±0.02	1.12±0.02	34.01±0.32	34.01±0.32
5	1.18±0.03	1.24±0.02	34.85±0.24	34.59±0.24
10	1.21±0.05	1.25±0.02	34.85±0.23	34.54±0.18
20	1.23±0.02	1.23±0.02	34.12±1.49	34.13±42
30	1.23±0.02	1.23±0.02	34.21±0.13	33.67±1.20

Appendix B-3 Flexural properties of rubber wood at various doses.

Radiation doses (kGy)	Flexural modulus (GPa)	Flexural strength (MPa)
0	7.79±1.28	116.73±24.25
5	8.37±1.01	128.52±7.02
10	9.61±0.49	147.88±3.61
20	8.82±0.41	139.37±11.90
30	8.42±0.17	107.86±6.58

Appendix B-4 Flexural properties of PP/woodflour composite at various doses.

Radiation doses (kGy)	Flexural modulus (GPa)		Flexural strength (MPa)	
	In air	In nitrogen	In air	In nitrogen
0	2.87±0.11	2.87±0.11	48.59±0.32	48.59±0.32
5	2.31±0.08	3.34±0.05	48.30±0.54	50.07±0.18
10	3.36±0.05	3.51±0.01	48.57±0.55	50.87±0.55
20	3.29±0.05	3.44±0.04	48.48±0.58	49.02±0.57
30	3.07±0.06	3.21±0.56	46.31±0.63	47.76±0.63

Appendix B-5 Tensile properties of PP/woodflour composite at various doses.

Radiation doses (kGy)	Tensile modulus (GPa)		Tensile strength (MPa)	
	In air	In nitrogen	In air	In nitrogen
0	2.29±0.11	2.29±0.11	28.56±0.29	28.56±0.29
5	2.33±0.10	2.35±0.03	28.91±0.78	28.90±0.42
10	2.48±0.05	2.53±0.04	28.64±0.38	29.53±0.29
20	2.53±0.09	2.51±0.33	28.60±0.51	28.71±0.55
30	2.36±0.11	2.36±0.03	28.08±0.95	27.57±0.45

Appendix B-6 Flexural properties of PP/wood/PP-g-MA composite at various doses.

Radiation doses (kGy)	Flexural modulus (GPa)		Flexural strength (MPa)	
	In air	In nitrogen	In air	In nitrogen
0	2.96±0.07	2.96±0.07	57.06±0.85	57.06±0.85
5	2.84±0.10	2.89±0.06	49.86±0.92	48.65±0.26
10	3.04±0.14	3.20±0.07	46.70±0.68	48.43±0.53
20	2.85±0.14	2.89±0.06	48.86±0.76	47.87±0.42
30	2.80±0.52	2.78±0.06	47.19±0.53	46.89±0.31

Appendix B-7 Tensile properties of PP/wood/PP-g-MA composite at various doses.

Radiation doses (kGy)	Tensile modulus (GPa)		Tensile strength (MPa)	
	In air	In nitrogen	In air	In nitrogen
0	2.31±0.14	2.31±0.14	31.43±0.62	31.43±0.62
5	2.30±0.07	2.35±0.04	27.76±0.85	28.86±0.53
10	2.48±0.05	2.59±0.01	29.18±0.67	29.57±0.29
20	2.40±0.02	2.46±0.04	28.75±1.22	27.82±0.73
30	2.31±0.06	2.34±0.03	27.93±0.37	27.16±0.81

Appendix C

Extraction Percentages

Extraction percentages of the polymer matrix and its wood composites were evaluated using p-xylene extraction according to ASTM D2765 (Method C). Percent extraction was determined according to the following equation:

$$\text{Extraction (\%)} = \frac{(W_s - W_d)}{W_o} \times 100$$

Where:

W_s is weight of specimen being tested

W_d is weight of dried gel

W_o is original polymer weight

(the amount of polymer in the specimen being tested)

Appendix C-1 Extraction percentages of polypropylene at various doses.

Radiation dose (kGy)	Weight before extracted (g)	Weight after extracted (g)	Extraction (%)
0	0.4936	0.2990	65.71
5	0.5016	0.4202	27.05
10	0.5020	0.4840	5.98
20	0.5006	0.4819	6.23
30	0.5012	0.4772	7.98

Appendix C-2 Extraction percentages of polypropylene/ woodflour composites at various doses.

Radiation dose (kGy)	Weight before extracted (g)	Weight after extracted (g)	Extraction (%)
0	0.5008	0.2978	67.56
5	0.5020	0.4298	23.97
10	0.5017	0.4714	10.07
20	0.5003	0.4700	10.10
30	0.4938	0.4640	10.06

Appendix C-3 Extraction percentage of polypropylene/ woodflour composites with PP-g-MA at various doses.

Radiation dose (kGy)	Weight before extracted (g)	Weight after extracted (g)	Extraction (%)
0	0.5018	0.3081	64.34
5	0.5017	0.4605	13.67
10	0.5040	0.4867	5.72
20	0.4974	0.4758	7.24
30	0.5013	0.4790	7.41

VITA

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