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APPENDICES

APPENDIX A

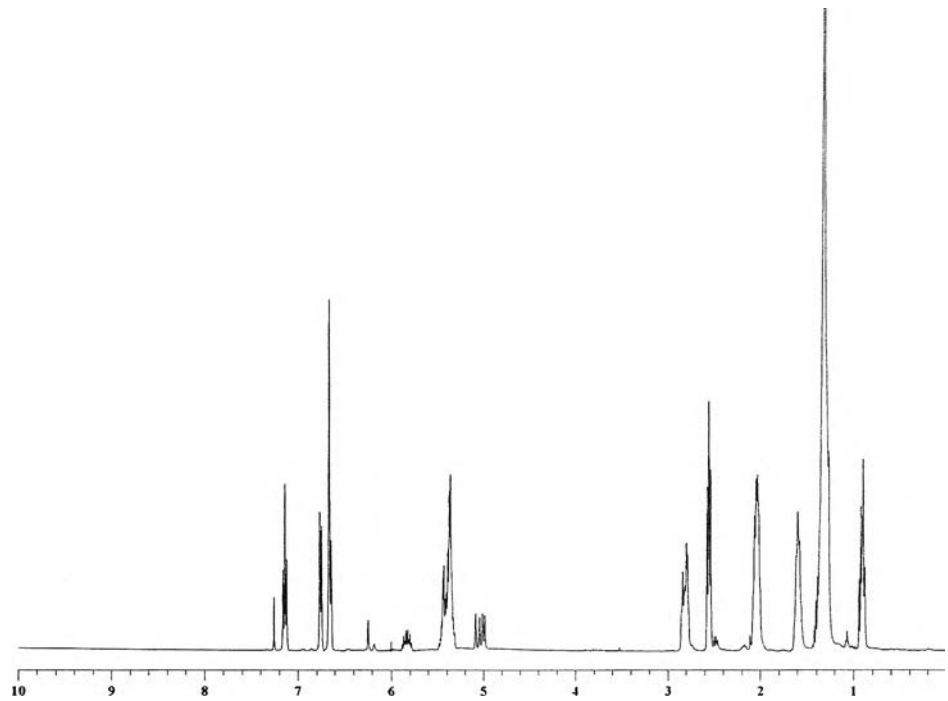


Figure A1 ^{1}H-NMR spectra of cardanol (in $CDCl_3$)

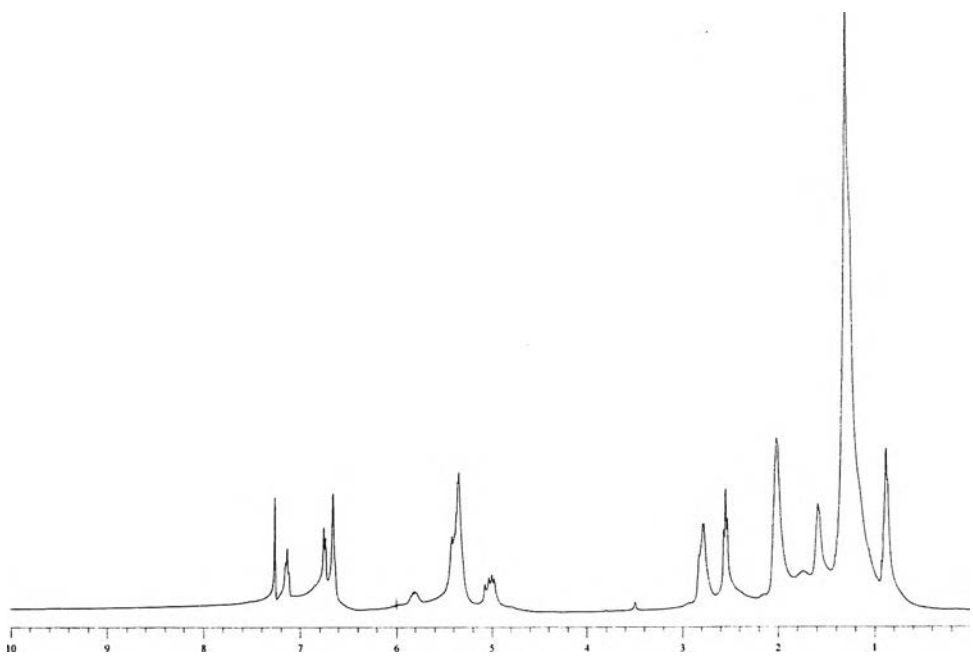


Figure A2 ^{1}H-NMR spectra of polycardanol synthesized using Fe-salen (in $CDCl_3$)

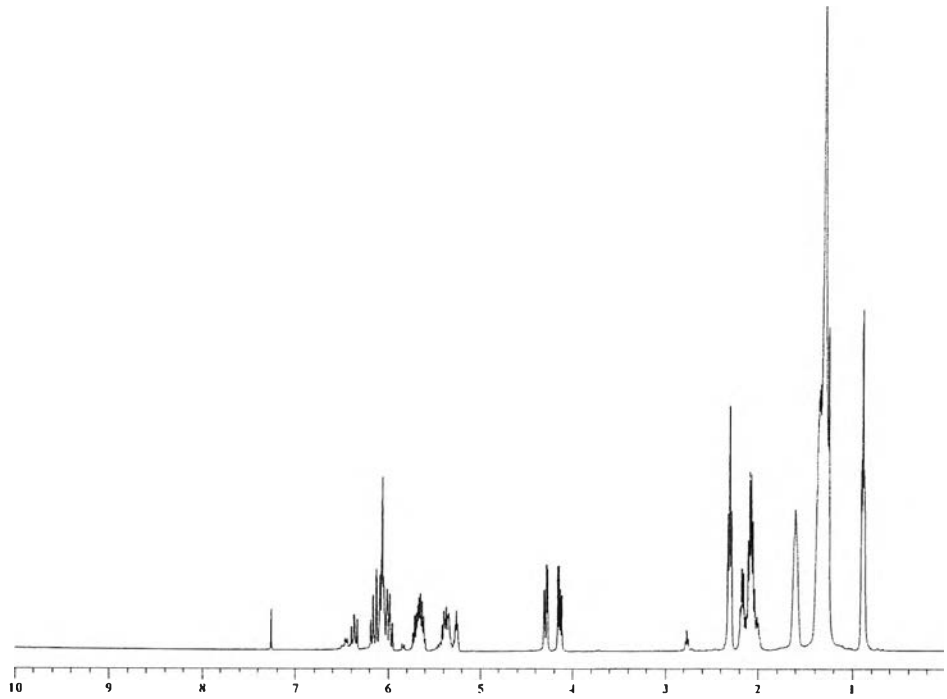


Figure A3 ^{1}H-NMR spectra of tung oil (in $CDCl_3$)

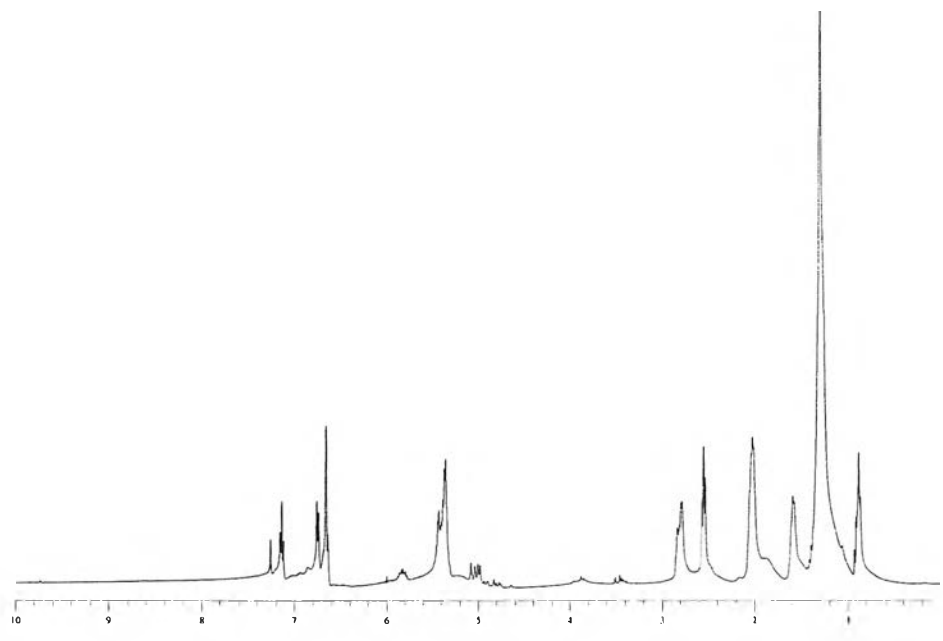


Figure A4 ^{1}H-NMR spectra of cardanol-formaldehyde resin (in $CDCl_3$)

APPENDIX B

ต้นฉบับ หน้าขาดหาย

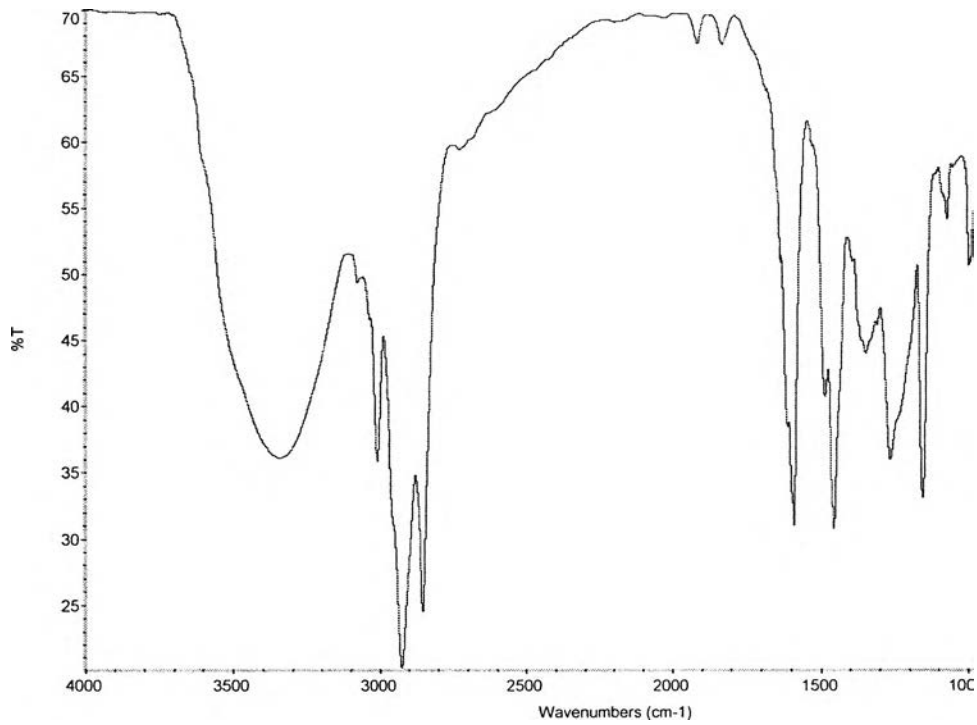
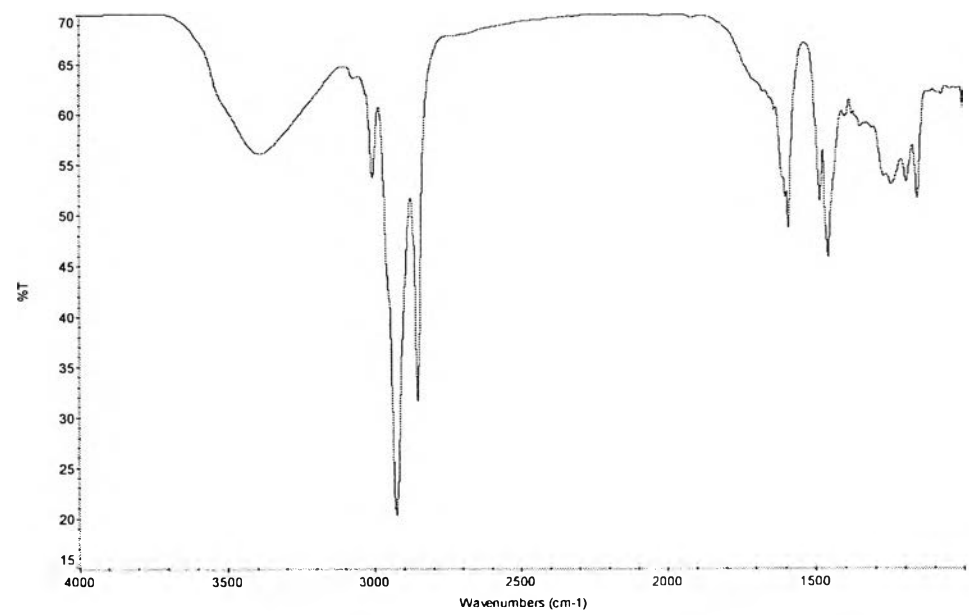


Figure B1 FT-IR spectra of cardanol



FigureB2 FT-IR spectra of polycardanol synthesized using Fe-salen.

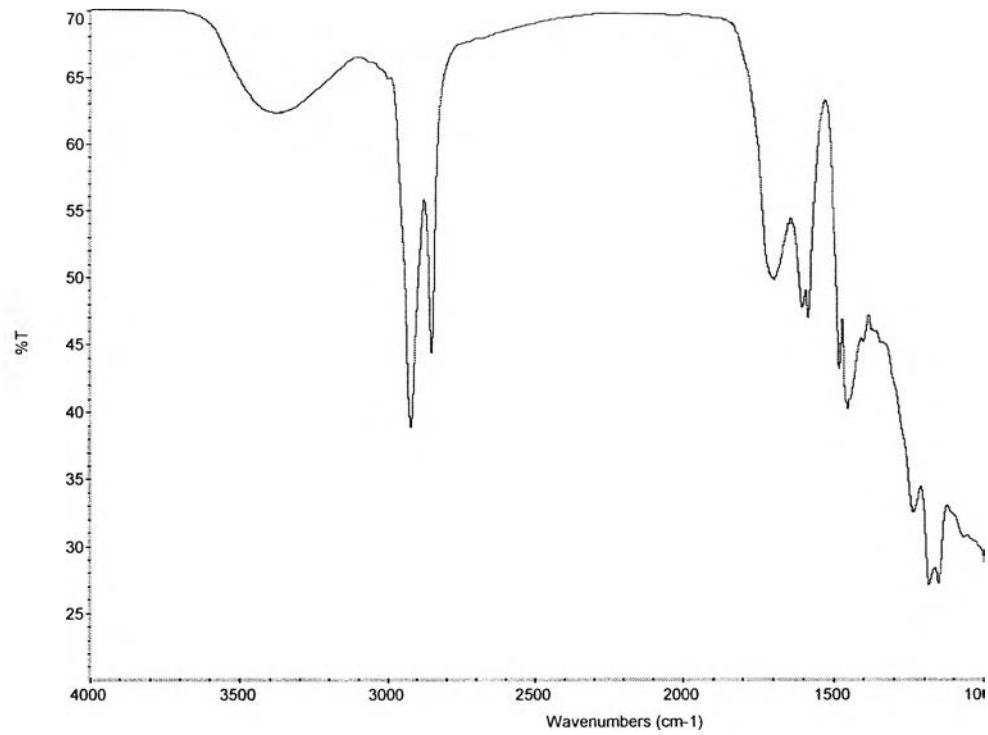


Figure B3 FT-IR spectra of polycardanol film

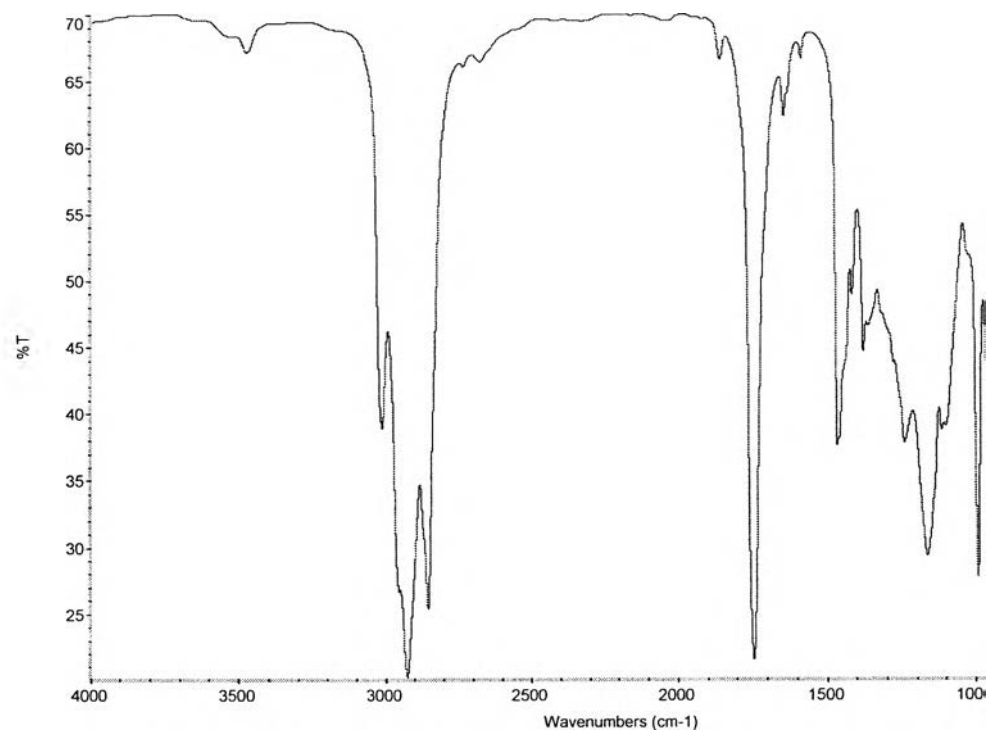


Figure B4 FT-IR spectra of tung oil

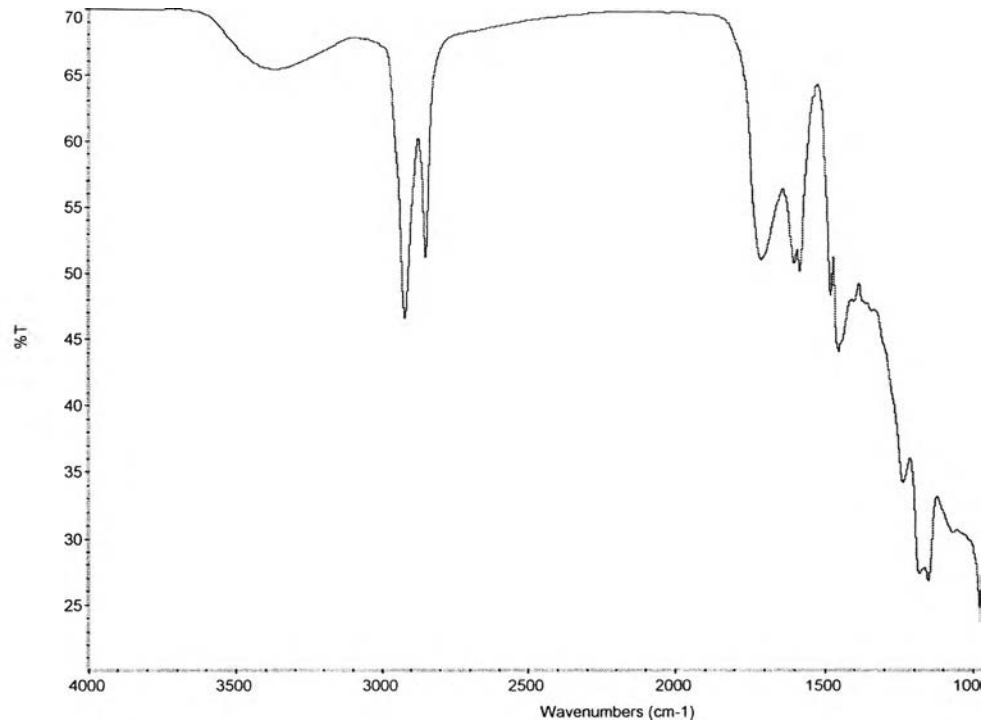


Figure B5 FT-IR spectra of cardanol-tung oil film

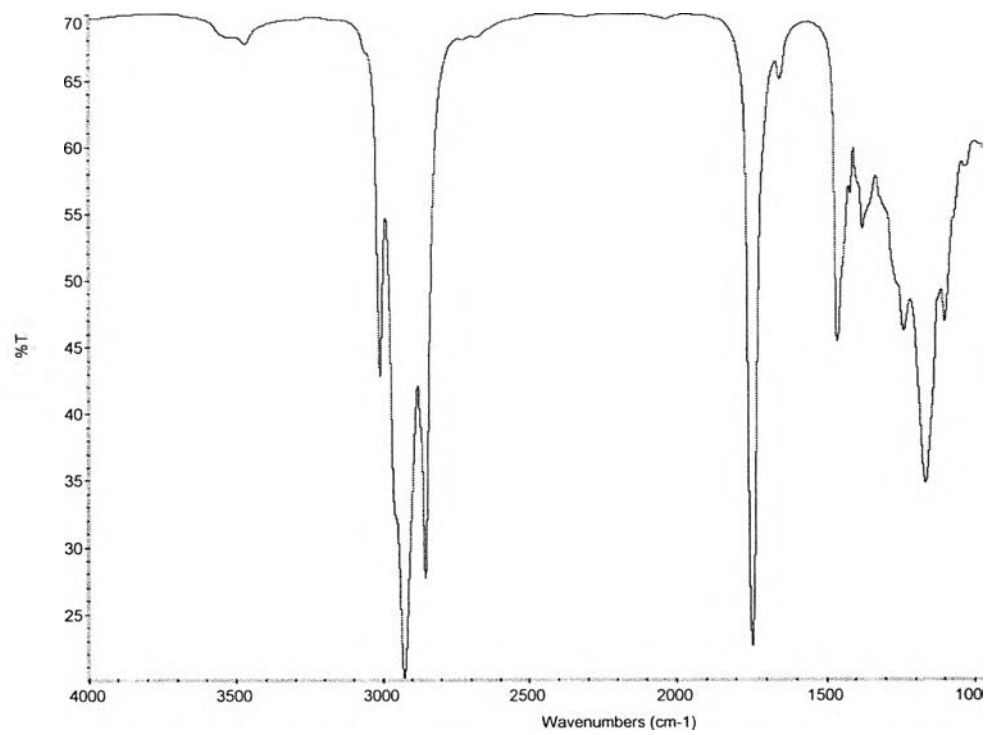


Figure B6 FT-IR spectra of linseed oil

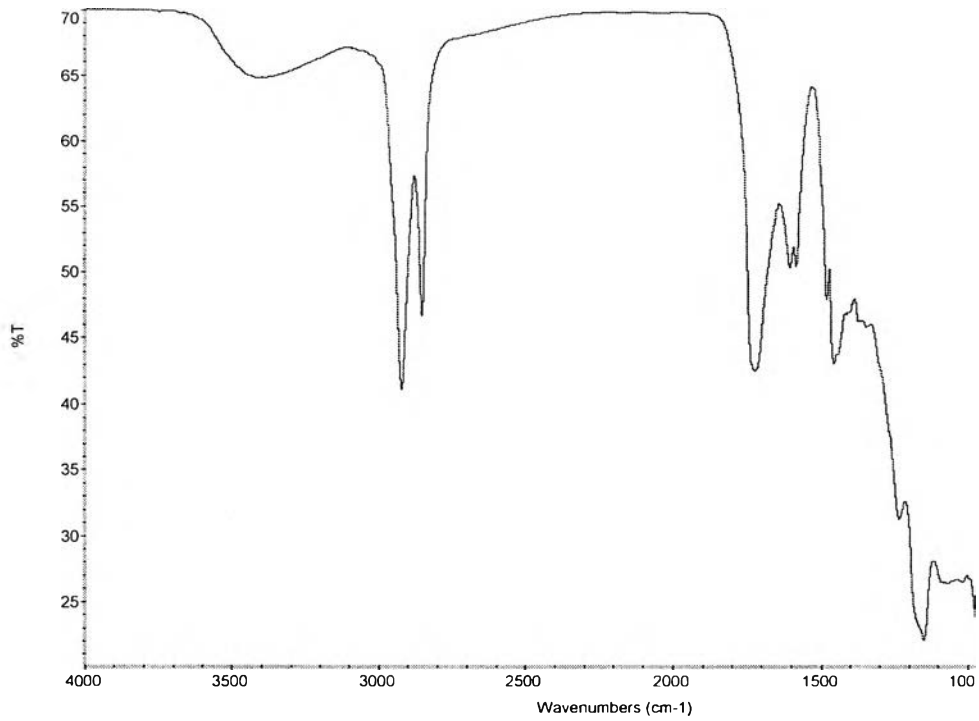


Figure B7 FT-IR spectra of cardanol-linseed oil film

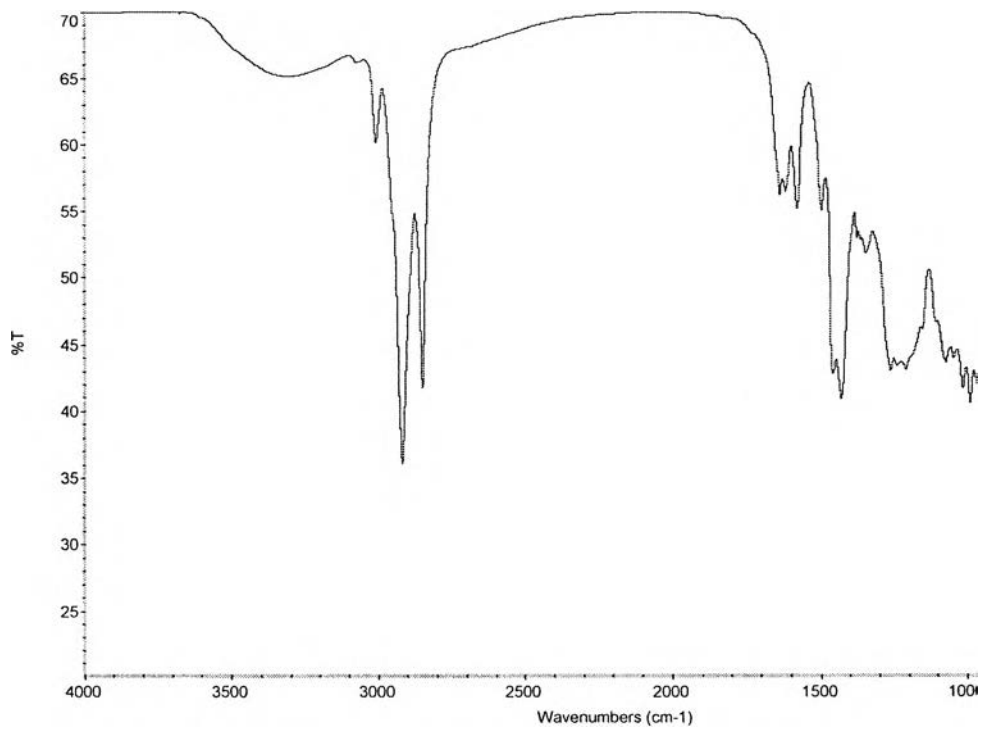


Figure B8 FT-IR spectra of cardanol- formaldehyde film

APPENDIX C

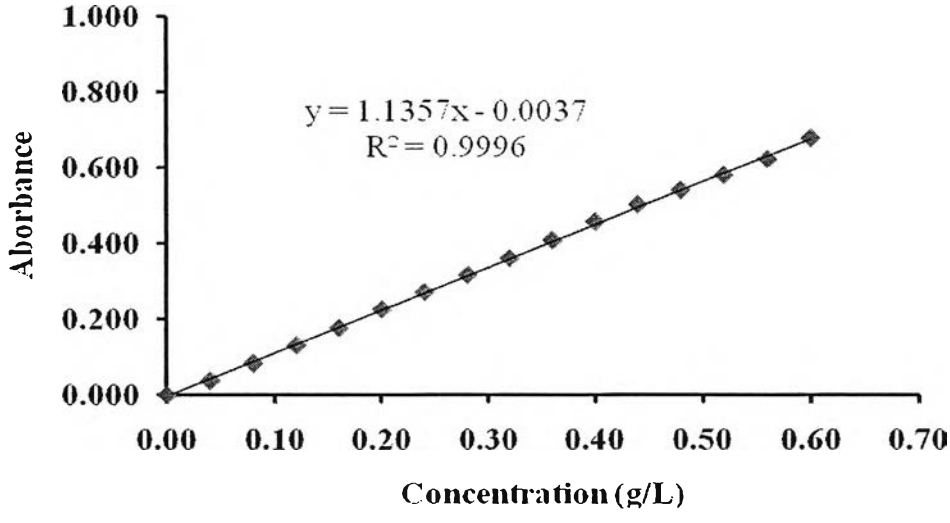
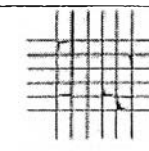
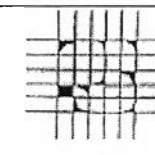
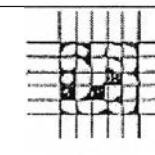
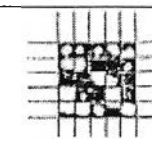


Figure C1 Calibration curve of standard urea solution

APPENDIX D

Table D1 Qualification of adhesion test results (ASTM D3359)

Grade	Description	Surface
5B	The edges of the cuts are completely smooth: none of the squares of the lattice is detached	
4B	Small flakes of the coating are detached at intersections: less than 5% of the area is affected.	
3B	Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5-15% of the lattice.	
2B	The coating has flaked along the edges and on parts of the squares. The area affected is 15-35% of the lattice	
1B	The coating has flaked along the edges of cuts in large ribbons and whole square have detached. The area affected is 35-65% of the lattice.	
0B	Flaking and detachment worse than Grade 1.	Greater than 65%

Procedure

1. Brush the area before test

2. Make the grid in a different location

3. Place the center of the tape over the grid and in the area of the grid smooth into place by a finger. To ensure good contact with the film rub the tape with eraser on the end of a pencil.

4. Within 90 + 30 seconds of application, remove the tape rapidly pulling it off at as close to and angle of 180° as possible.

5. Inspect the grid area for removal of coating from the substrate. Rate the adhesion in accordance with the following scale illustrated in Table C1.

Table D2 The average coated percentage of cardanol-tung oil of urea fertilizer coating

Number of layer	Thickness of coatings (micron)			Average (micron)	S.D.
	1	2	3		
1	50.00	52.63	55.26	52.63	2.63
3	73.68	68.42	71.05	71.05	2.63
5	123.68	121.05	128.95	124.56	4.02
7	173.68	173.68	178.95	175.44	3.04
9	223.68	236.84	231.58	230.70	6.62

Table D3 The average thickness of cardanol-tung oil of urea fertilizer coating

Number of layer	% Coating		Average (%)	S.D.
	1	2		
1	9.66	9.63	9.65	0.02
3	26.89	26.45	26.67	0.31
5	37.52	38.64	38.08	0.79
7	48.94	48.43	48.69	0.36
9	56.34	56.76	56.55	0.30

Table D4 Calibration curve of standard urea solution for urea content determination (UV-Vis Spectrophotometry)

Amount of 0.5 g/L urea stock solution (ml)	**Concentration (g/L)**	**Absorbance**
0	0.00	0.000
1	0.04	0.037
2	0.08	0.083
3	0.12	0.130
4	0.16	0.176
5	0.20	0.225
6	0.24	0.271
7	0.28	0.316
8	0.32	0.361
9	0.36	0.408
10	0.40	0.458
11	0.44	0.503
12	0.48	0.541
13	0.52	0.581
14	0.56	0.623
15	0.60	0.679

Table D5 The solubility of uncoated urea fertilizer

Time (min.)	Absorbance	Concentration (g/L)	Urea fertilizer (%)	Released urea (%)
1*	0.207	0.56	10.58	46.01
2*	0.332	0.89	17.23	74.90
3*	0.393	1.05	20.07	87.25
4*	0.383	1.02	20.12	87.48
5*	0.397	1.06	20.34	88.42
6*	0.397	1.06	20.40	88.70
7*	0.412	1.10	20.53	93.61
8*	0.419	1.12	21.60	93.92
9*	0.427	1.14	22.54	97.99
10*	0.429	1.14	22.60	98.25

*3 times dilution

Table D6 Effect of thickness on releasing rate of cardanol-tung oil of urea fertilizer coating

Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)	Released urea (%)
52.63 micron				
1*	0.291	0.7785	0.5071	73.87
2*	0.299	0.7996	0.5100	75.45
3*	0.300	0.8022	0.5103	76.65
4*	0.340	0.9079	0.5221	83.68
5*	0.334	0.8907	0.5082	84.34
6*	0.341	0.9105	0.5111	85.73
7*	0.345	0.9211	0.5129	86.42
14*	0.341	0.9105	0.5152	85.05
21*	0.334	0.8920	0.5073	84.62
28*	0.347	0.9264	0.5046	88.35
35*	0.331	0.8841	0.5031	84.57
42*	0.329	0.8775	0.5108	82.67
49*	0.352	0.9396	0.5198	86.98
56*	0.361	0.9620	0.5031	92.02
63*	0.361	0.9634	0.5011	92.51
70*	0.375	1.0004	0.5156	93.36
77*	0.371	0.9898	0.5061	94.11
84*	0.389	1.0360	0.5249	94.98
71.05 micron				
1**	0.274	0.4882	0.5068	57.11
2**	0.322	0.5727	0.5106	66.50
3*	0.216	0.5803	0.5276	65.21
4*	0.213	0.5711	0.5138	65.90
5*	0.198	0.5328	0.5114	61.77
6*	0.216	0.5803	0.5161	66.67
7*	0.221	0.5922	0.5180	67.78
14*	0.227	0.6081	0.5232	68.91
21*	0.222	0.5962	0.5224	67.66
28*	0.201	0.5407	0.5018	63.89
35*	0.233	0.6253	0.5240	70.74
42*	0.235	0.6305	0.5077	73.63
49*	0.223	0.5988	0.5281	67.23
56*	0.236	0.6332	0.5062	74.16
63*	0.254	0.6807	0.5155	78.29
70*	0.261	0.6979	0.5095	81.68
77*	0.272	0.7283	0.5160	83.68
84*	0.275	0.7349	0.5073	85.88

Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)	Released urea (%)
124.56 micron				
1	0.018	0.0182	0.5102	2.51
2	0.024	0.0244	0.5049	3.39
3	0.035	0.0350	0.5098	4.81
4	0.030	0.0301	0.5644	3.75
5	0.059	0.0587	0.5059	8.15
6	0.112	0.1124	0.5101	15.48
7	0.260	0.1459	0.5123	31.82
14	0.268	0.2322	0.5283	31.84
21	0.327	0.2395	0.5242	38.95
28***	0.320	0.2907	0.5188	43.29
35***	0.295	0.3199	0.5204	39.78
42**	0.157	0.2948	0.5071	39.19
49***	0.255	0.3410	0.5035	47.56
56**	0.368	0.3684	0.5295	48.85
63*	0.415	0.4151	0.5108	57.06
70*	0.453	0.4529	0.5278	60.26
77*	0.501	0.5014	0.5224	67.39
84**	0.352	0.6255	0.5182	84.76
175.44 micron				
1	0.006	0.0085	0.5165	1.40
2	0.006	0.0085	0.5074	1.43
3	0.008	0.0099	0.5198	1.61
4	0.007	0.0090	0.5096	1.49
5	0.007	0.0090	0.5132	1.48
6	0.008	0.0099	0.5053	1.65
7	0.008	0.0103	0.5257	1.66
14	0.009	0.0107	0.5152	1.77
21	0.009	0.0107	0.5086	1.79
28	0.009	0.0107	0.5111	1.78
35	0.037	0.0358	0.5226	5.81
42	0.212	0.1899	0.5216	30.86
49	0.282	0.2511	0.5259	40.46
56	0.271	0.2414	0.5177	39.52
63	0.253	0.3390	0.5149	55.80
70***	0.275	0.3674	0.5221	59.64
77	0.519	0.4598	0.5243	73.31
84	0.567	0.5025	0.5101	83.48

Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)	Released urea (%)
230.70 micron				
1	0.003	0.0059	0.5141	1.15
2	0.005	0.0077	0.5226	1.47
3	0.006	0.0081	0.5162	1.57
4	0.006	0.0081	0.5121	1.58
5	0.006	0.0085	0.5267	1.62
6	0.006	0.0081	0.5047	1.61
7	0.007	0.0085	0.5183	1.65
14	0.007	0.0090	0.5261	1.71
21	0.008	0.0090	0.5255	1.71
28	0.012	0.0010	0.5293	1.86
35	0.027	0.0138	0.5231	2.64
42	0.114	0.0266	0.5265	5.05
49	0.169	0.1032	0.5160	20.01
56	0.182	0.1635	0.5217	31.36
63	0.225	0.2014	0.5144	39.17
70	0.337	0.2997	0.5291	56.68
77	0.370	0.3286	0.5253	62.60
84	0.446	0.3963	0.5171	76.68

* 3 times dilution, ** 2 times dilution, *** 1.5 times dilution

Table D7 Effect of temperature on releasing rate of cardanol-tung oil of urea fertilizer coating

Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)	Released urea (%)
25°C				
2	0.003	0.0059	0.5041	0.82
4	0.007	0.0094	0.5240	1.26
6	0.043	0.0411	0.5138	5.62
8	0.060	0.0561	0.5147	7.65
30°C				
2	0.007	0.0094	0.5263	1.26
4	0.009	0.0112	0.5253	1.49
6	0.055	0.0518	0.5224	6.97
8	0.126	0.1142	0.5261	15.24
35°C				
2	0.011	0.0125	0.5263	1.67
4	0.013	0.0147	0.5226	1.98
6	0.067	0.0623	0.5081	8.60
8	0.182	0.1635	0.5170	22.21
40°C				
2	0.024	0.0244	0.5080	3.37
4	0.027	0.0266	0.5091	3.67
6	0.098	0.0895	0.5181	12.14
8	0.191	0.1714	0.5190	23.19

Table D8 Effect of pH on releasing rate of cardanol-tung oil of urea fertilizer coating

Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)	Released urea (%)
pH 5				
2	0.002	0.0050	0.5184	0.68
4	0.036	0.0347	0.5264	4.62
6	0.147	0.1323	0.5017	18.51
8	0.195	0.1745	0.5090	24.07
pH 6				
2	0.505	0.0046	0.5049	0.64
4	0.015	0.0165	0.5138	2.25
6	0.126	0.1142	0.5190	15.45
8	0.143	0.1292	0.5160	17.58
pH 7				
2	0.521	0.0046	0.5208	0.62
4	0.518	0.0085	0.5177	1.16
6	0.510	0.0182	0.5097	2.51
8	0.523	0.0561	0.5277	7.53
pH 8				
2	0.001	0.0037	0.5030	0.52
4	0.512	0.0059	0.5124	0.81
6	0.503	0.0151	0.5030	2.11
8	0.525	0.0442	0.5247	5.92

Table D9 Comparison of urea fertilizers coated with cardanol-tung oil and commercial controlled-release fertilizers (osmocoteTM)

Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)
52.63 micron			
1*	0.291	0.7785	0.5071
2*	0.299	0.7996	0.5100
3*	0.300	0.8022	0.5103
4*	0.340	0.9079	0.5221
5*	0.334	0.8907	0.5082
6*	0.341	0.9105	0.5111
7*	0.345	0.9211	0.5129
14*	0.341	0.9105	0.5152
21*	0.334	0.8920	0.5073
28*	0.347	0.9264	0.5046
35*	0.331	0.8841	0.5031
42*	0.329	0.8775	0.5108
49*	0.352	0.9396	0.5198
56*	0.361	0.9620	0.5031
63*	0.361	0.9634	0.5011
70*	0.375	1.0004	0.5156
77*	0.371	0.9898	0.5061
84*	0.389	1.0360	0.5249
71.05 micron			
1**	0.274	0.4882	0.5068
2**	0.322	0.5727	0.5106
3*	0.216	0.5803	0.5276
4*	0.213	0.5711	0.5138
5*	0.198	0.5328	0.5114
6*	0.216	0.5803	0.5161
7*	0.221	0.5922	0.5180
14*	0.227	0.6081	0.5232
21*	0.222	0.5962	0.5224
28*	0.201	0.5407	0.5018
35*	0.233	0.6253	0.5240
42*	0.235	0.6305	0.5077
49*	0.223	0.5988	0.5281
56*	0.236	0.6332	0.5062
63*	0.254	0.6807	0.5155
70*	0.261	0.6979	0.5095
77*	0.272	0.7283	0.5160
84*	0.275	0.7349	0.5073

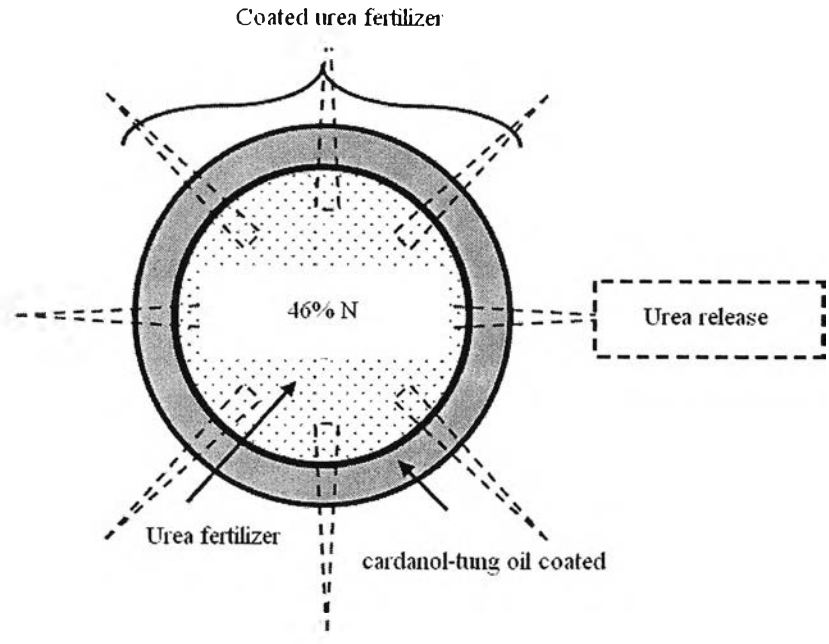
Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)
124.56 micron			
1	0.018	0.0182	0.5102
2	0.024	0.0244	0.5049
3	0.035	0.0350	0.5098
4	0.030	0.0301	0.5644
5	0.059	0.0587	0.5059
6	0.112	0.1124	0.5101
7	0.260	0.1459	0.5123
14	0.268	0.2322	0.5283
21	0.327	0.2395	0.5242
28***	0.320	0.2907	0.5188
35***	0.295	0.3199	0.5204
42**	0.157	0.2948	0.5071
49***	0.255	0.3410	0.5035
56**	0.368	0.3684	0.5295
63*	0.415	0.4151	0.5108
70*	0.453	0.4529	0.5278
77*	0.501	0.5014	0.5224
84**	0.352	0.6255	0.5182
175.44 micron			
1	0.006	0.0085	0.5165
2	0.006	0.0085	0.5074
3	0.008	0.0099	0.5198
4	0.007	0.0090	0.5096
5	0.007	0.0090	0.5132
6	0.008	0.0099	0.5053
7	0.008	0.0103	0.5257
14	0.009	0.0107	0.5152
21	0.009	0.0107	0.5086
28	0.009	0.0107	0.5111
35	0.037	0.0358	0.5226
42	0.212	0.1899	0.5216
49	0.282	0.2511	0.5259
56	0.271	0.2414	0.5177
63	0.253	0.3390	0.5149
70***	0.275	0.3674	0.5221
77	0.519	0.4598	0.5243
84	0.567	0.5025	0.5101

Time	Absorbance	Concentration (g/L)	$W_{fertilizer}$ (g)
230.70 micron			
1	0.003	0.0059	0.5141
2	0.005	0.0077	0.5226
3	0.006	0.0081	0.5162
4	0.006	0.0081	0.5121
5	0.006	0.0085	0.5267
6	0.006	0.0081	0.5047
7	0.007	0.0085	0.5183
14	0.007	0.0090	0.5261
21	0.008	0.0090	0.5255
28	0.012	0.0010	0.5293
35	0.027	0.0138	0.5231
42	0.114	0.0266	0.5265
49	0.169	0.1032	0.5160
56	0.182	0.1635	0.5217
63	0.225	0.2014	0.5144
70	0.337	0.2997	0.5291
77	0.370	0.3286	0.5253
84	0.446	0.3963	0.5171
OsmocoteTM			
1	0.010	0.0118	0.5260
2	0.008	0.0100	0.5133
3	0.022	0.0229	0.5134
4	0.021	0.0220	0.5114
5	0.021	0.0217	0.5164
6	0.010	0.0118	0.5143
7	0.005	0.0080	0.5084
14	0.010	0.0121	0.5186
21	0.009	0.0112	0.5184
28	0.009	0.0112	0.5231
35	0.009	0.0085	0.5256
42	0.009	0.0115	0.5108
49	0.011	0.0125	0.5072
56	0.011	0.0132	0.5134
63	0.011	0.0125	0.5147
70	0.011	0.0132	0.5143
77	0.011	0.0125	0.5088
84	0.011	0.0113	0.5116

* 3 times dilution, ** 2 times dilution, *** 1.5 times dilution

APPENDIX E

Calculation of released urea



$$\text{released urea (\%)} = \frac{C/10 \times 100}{X_O} \quad (1)$$

C; urea content (g/L) calculated from calibration curve

Because urea fertilizer contained 46% of N, the value of U should be nearly 23%. The actually of urea in uncoated fertilizer can be calculated from the following equation.

$$X_O \text{; urea in uncoated fertilizer (g)} = \frac{W_F \times U}{100} \quad (2)$$

$$W_F \text{; weight of urea fertilizer} = \frac{W_C\,(100 - \%\text{coating})}{100} \quad (3)$$

W_C; weight of coated fertilizer

Determination of coating percentage [5]

10 g. of coated urea fertilizer was crushed and blended with deionized water to accelerate the dissolution and separate urea from the coating. The solution was filtered and washed with deionized water to ensure that no urea remained. The insoluble solid was dried in the oven at 100°C for 4 hours or until its weight become constant. The coating percentage was calculated by equation 4.

$$\% \text{ coating} = \frac{\text{weight of solid (g.)} \times 100}{10} \quad (4)$$

VITA

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Conference

10-11 September 2009	"Preparation and properties of cardanol-tung oil film" The 14th National Graduate Research Conference King Mongkut's University of Technology North Bangkok