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APPENDICES

Appendix A Determination of Degree of Swelling and Weight Loss of Gelatin Films

The degree of swelling and weight loss of gelatin were measured in water at 37 °C for 5 days according to the following equations (Bigi *et* al., 2001):

$$\text{Degree of swelling (\%)} = \frac{M - M_d}{M_d} \times 100 \qquad (1)$$

and

$$\text{Weight loss (\%)} = \frac{M_i - M_d}{M_i} \times 100 \qquad (2)$$

where M = the weight of each sample after submersion in the buffer solution.

M_d = the weight of sample after submersion in the buffer solution in its dry state.

M_i = the initial weight of the sample in its dry state.

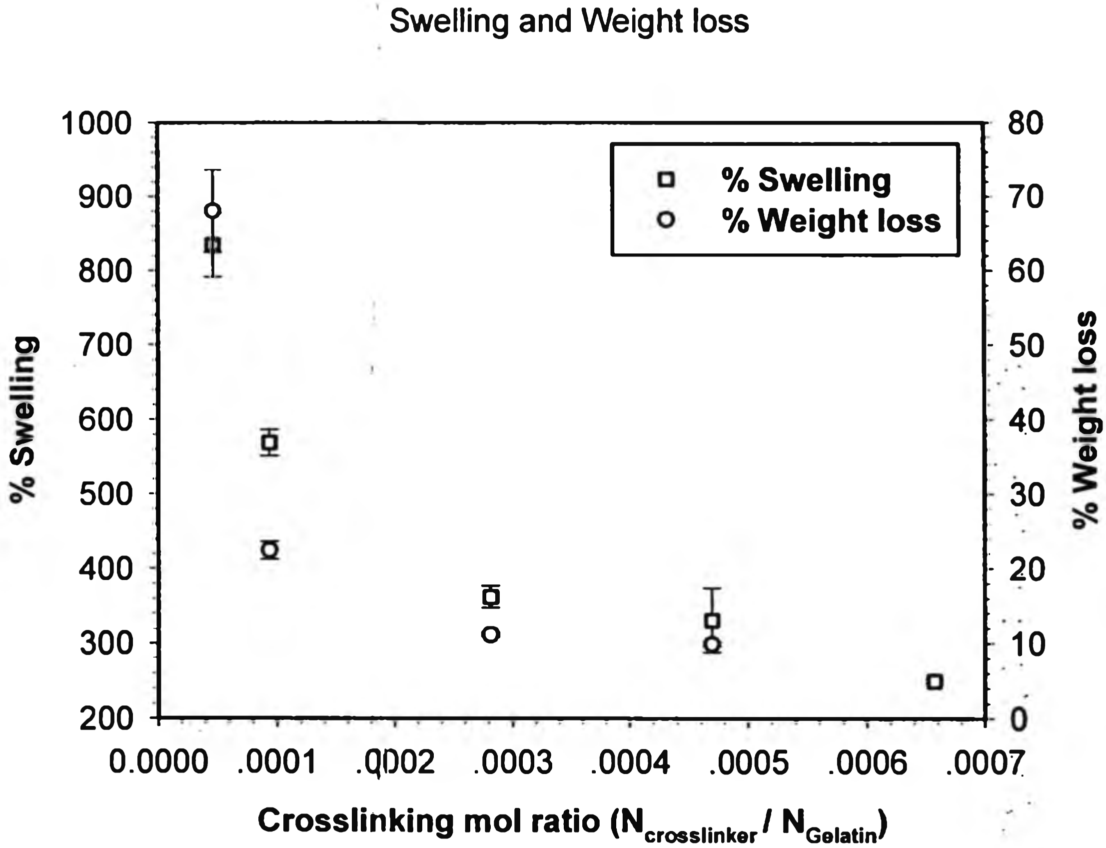

Figure A1 % swelling and % weight loss of crosslinked gelatin (High gel strength) at various crosslinking ratios, 27 oC (#samples = 3).

Table A1. Molecular weight between crosslinker of gelatin (High gel strength) at various crosslinking ratio, 27°C. (#samples = 3)

Sample	Crosslink ratio	Molecular weight between crosslinker (g/mol)	Crosslink density (mol/cm^3 x 10^4)
GT_0.5	4.69×10^{-5}	13757 ± 687	0.73 ± 0.04
GT_1	9.39×10^{-5}	12875 ± 344	0.85 ± 0.073
GT_3	2.81×10^{-4}	1928 ± 296	6.09 ± 0.085
GT_5	4.69×10^{-4}	696 ± 75	16.68 ± 0.33
GT_7	6.57×10^{-4}	327 ± 16	30.58 ± 1.53

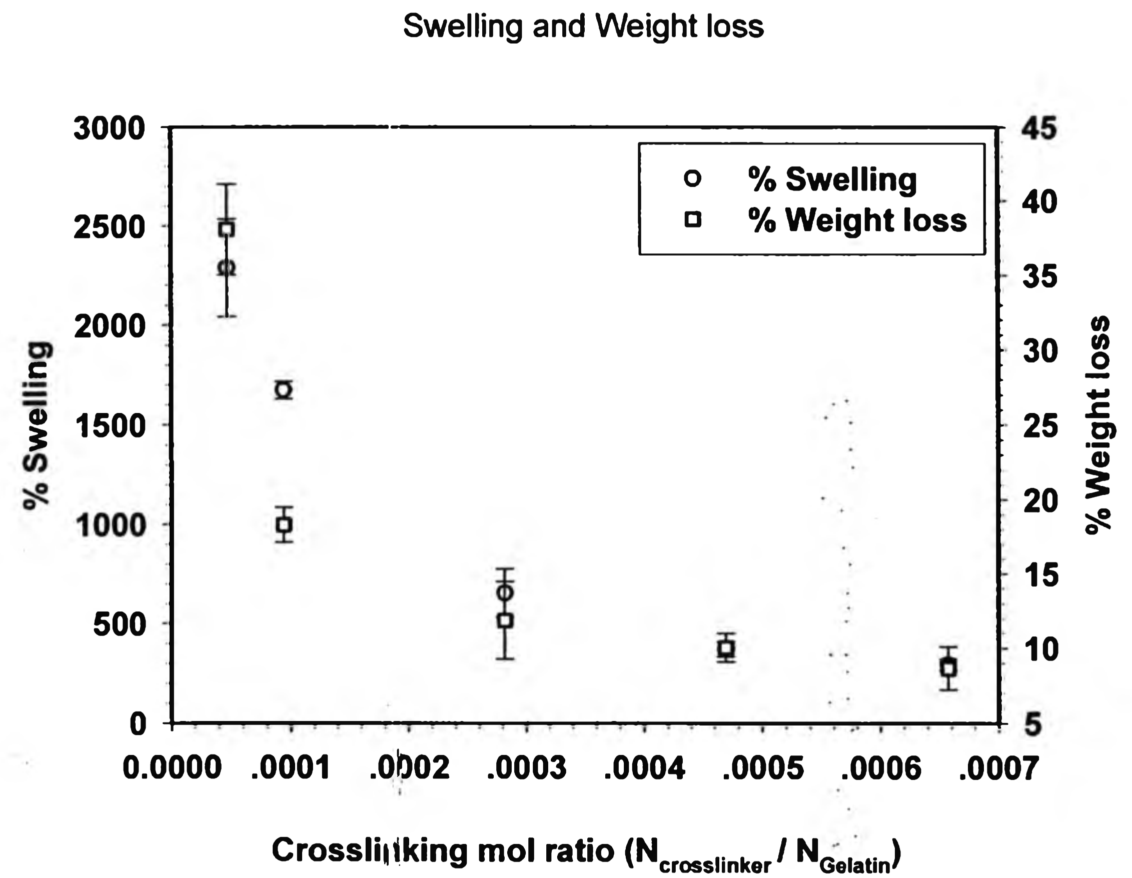

Figure A2 % swelling and % weight loss of crosslinked gelatin (Mid gel strength) at various crosslinking ratios, 27 °C (#samples = 3).

Table A2. Molecular weight between crosslinker of gelatin (Mid gel strength) at various crosslinking ratios, 27°C (#samples = 3)

Sample	Crosslink ratio (Ncrosslinker / Ngelatin)	Molecular weight between crosslinker (g/mol)	Crosslink density (mol/cm^3 x 10^4)
GT_0.5	4.69×10^{-5}	12939 ± 647	0.77 ± 0.04
GT_1	9.39×10^{-5}	12475 ± 624	0.80 ± 0.04
GT_3	2.81×10^{-4}	1525 ± 76	6.56 ± 0.33
GT_5	4.69×10^{-4}	573 ± 29	17.45 ± 0.87
GT_7	6.57×10^{-4}	203 ± 10	49.26 ± 2.46

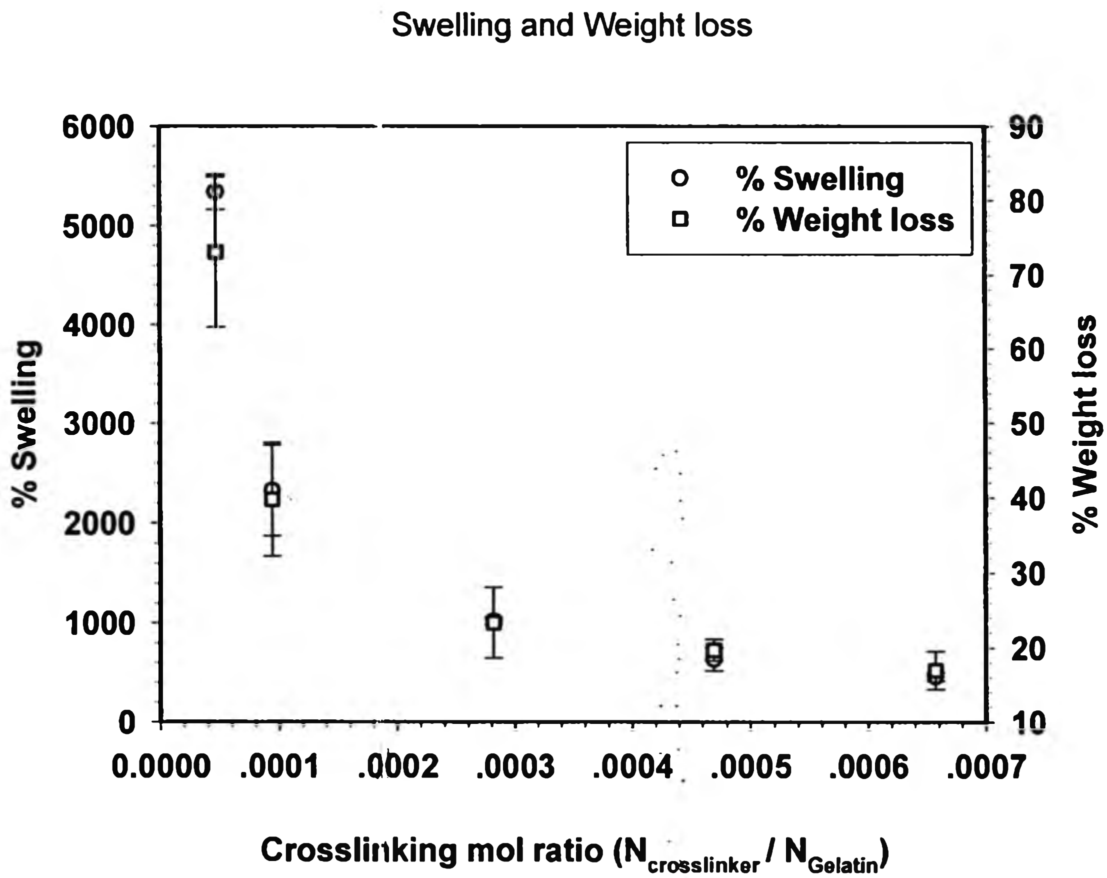

Figure A3 % swelling and % weight loss of crosslinked gelatin (Low gel strength) at various crosslinking ratios. 27 °C (#samples = 3).

Table A3. Molecular weight between crosslinker of gelatin (Low gel strength) at various crosslinking ratios, 27 °C (#samples = 3)

Sample	Crosslink ratio (Ncrosslinker / Ngelatin)	Molecular weight between crosslinker (g/mol)	Crosslink density (mol/cm^3 x 10^4)
GT_0.5	4.69×10^{-5}	13939 ± 766	0.80 ± 0.04
GT_1	9.39×10^{-5}	11475 ± 542	0.75 ± 0.054
GT_3	2.81×10^{-4}	1445 ± 66	5.06 ± 0.20
GT_5	4.69×10^{-4}	673 ± 40	16.55 ± 0.27
GT_7	6.57×10^{-4}	303 ± 15	49.26 ± 1.64

Appendix B The Thermogravimetric Thermogram of Crosslinked Gelatin

The thermogravimetric analyzer (DuPont, model TGA 2950) was used to determine the thermal behavior of polymers. The experiment was carried out by weighting a powder sample of 7-13 mg and placed it in a platinum pan, and then heated it under nitrogen flow with the heating rate 5°C/min from room temperature to 600 °C.

There are two transitions for the gelatin and the crosslinked gelatin (0.5, 1, 3, 5, 7%) respectively. The first transition (45-100°C) refers to the loss of water. The second transition (260-340°C) refers to the gelatin degradation. The TGA results of the gelatin and the crosslinked gelatin showe that temperature decomposition does not change significantly. % maximum weight residue of gelatin is 7%.

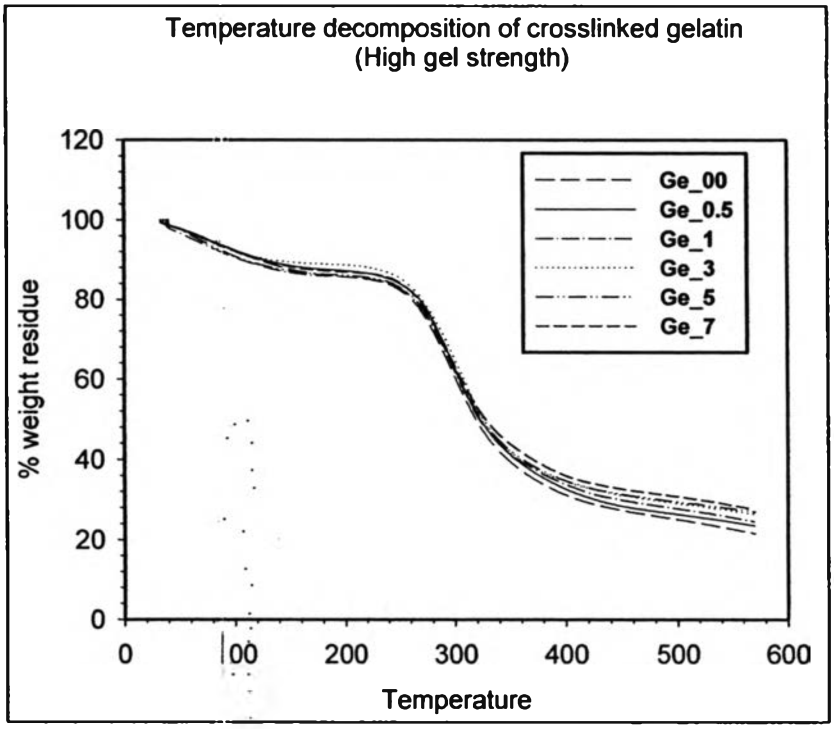

Figure B1 Temperature decomposition of Crosslinked Gelatin (High gel strength)

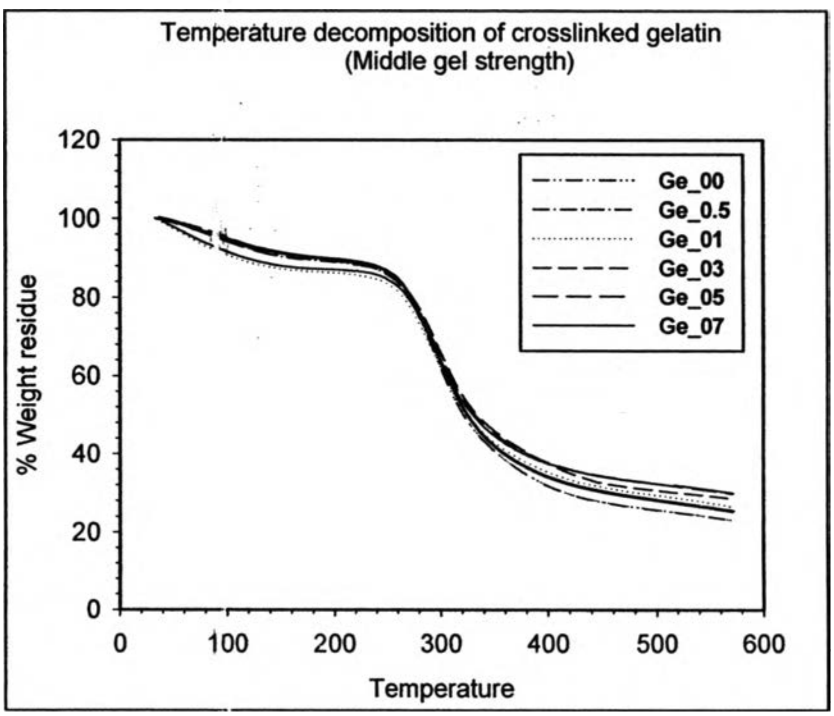

Figure B2 Temperature decomposition of Crosslinked Gelatin (Mid gel strength)

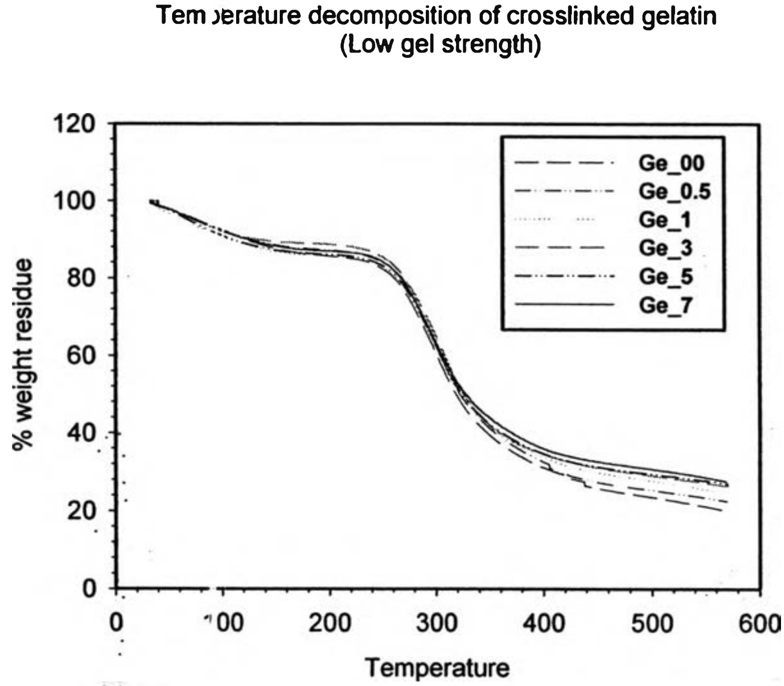

Figure B3 Temperature decomposition of Crosslinked Gelatin (Low gel strength)

Table B1. The summary of the degradation temperature in the TGA thermogram of Gelatin and Crosslinked Gelatin

Sample	T_d (°C)
High gelatin strength	320
Middle gelatin strength	310
Low gelatin strength	298

Appendix C Electrorheological properties Measurement of Gelatin
(Temporal response of gelatin film by using stretch fixture)

The temporal response of pure gelatin films with different morphology; High gel strength; Middle gel strength; and Low gel strength were investigated by melt rheometer meter (Rheometric Scientific, ARES). It was fitted with a custom-built stretch fixture, gap = 30 mm. A DC voltage was applied with a DC power supply (Gold Sun 3000, GPS 3003D) work with high voltage power supply (Gamma High Voltage, UC5-30P), which can deliver electric field strength to 1 kV/mm. A digital multimeter was used to monitor the voltage input. In the temporal response testing, the dynamic strain was applied and the dynamic moduli (G' and G") were measured as functions of time and electric field strength. Dynamic strain sweep test were first carried out to determine suitable strains to measured G' and G" in linear viscoelastic regime, as following figures (Figure F1, F2, and F3).

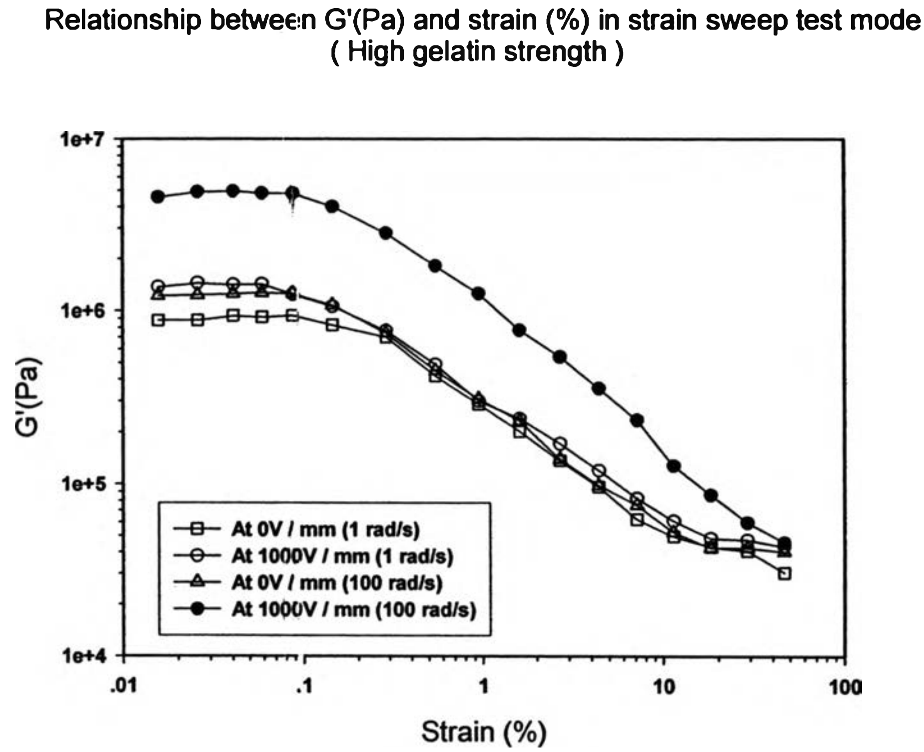

Figure C1 High molecular weight gelatin film in strain sweep test (stretch fixture, gap = 30 mm, film thickness = 0.890 mm, film width = 7.0 mm, 25°C)

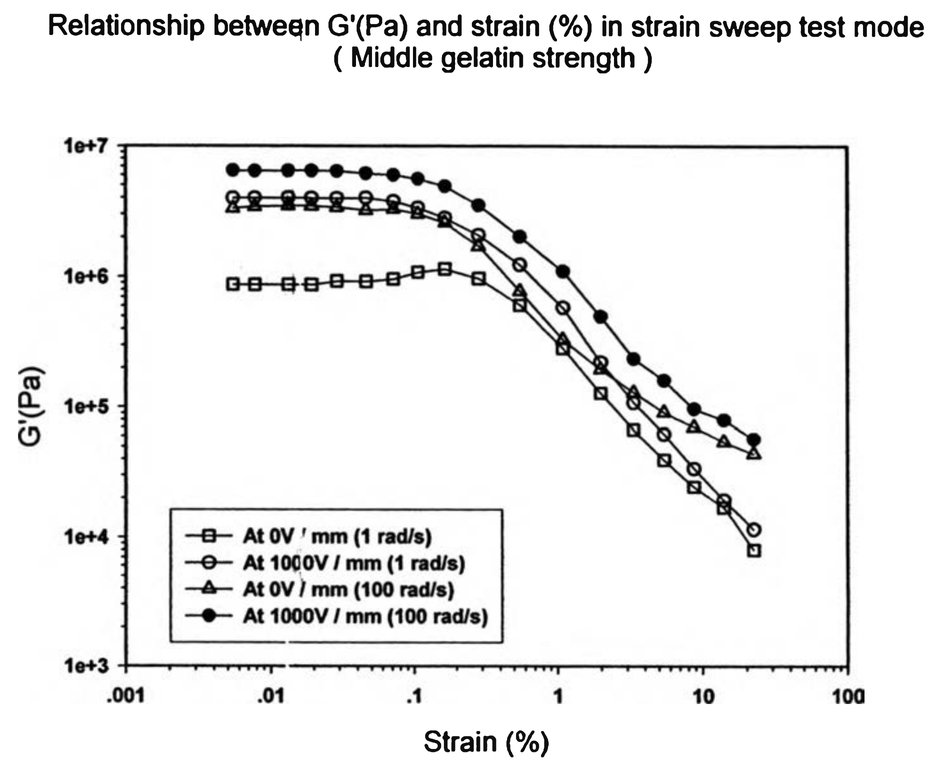

Figure C2 Middle molecular weight gelatin film in strain sweep test (stretch fixture, gap = 30 mm, film thickness = 0.826 mm, film width = 7.0 mm, 25°C)

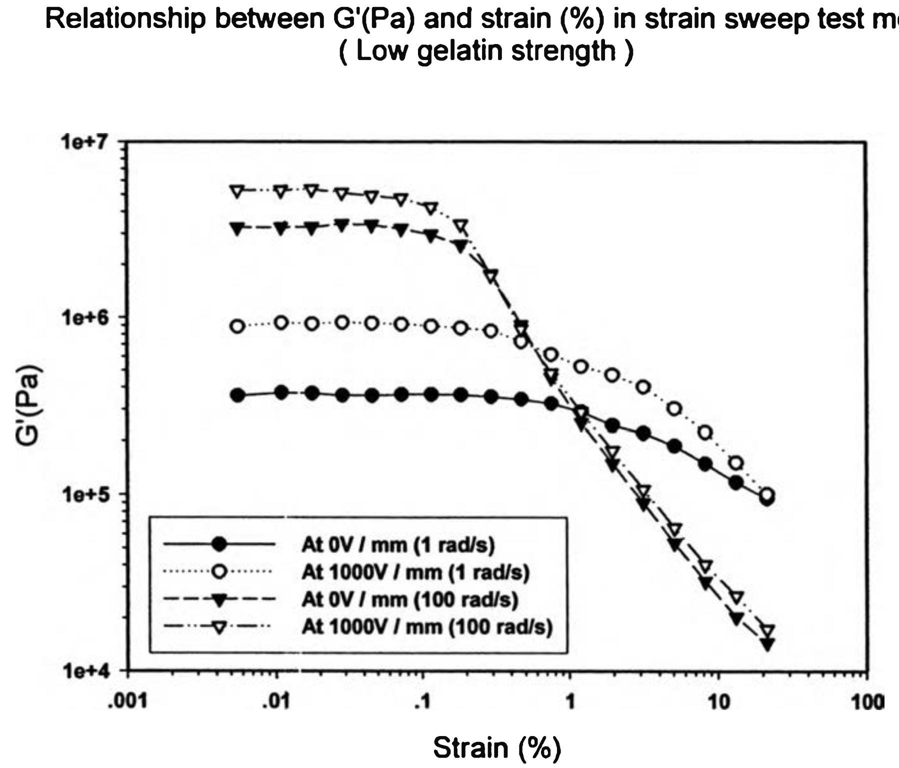

Figure C3 Low molecular weight gelatin film in strain sweep test (stretch fixture, gap = 30 mm, film thickness = 1.405 mm, film width = 7.0 mm, 25°C).

The time sweep test was carried out with electric field applied on and off, alternatively. The G'of each film was investigated to measure time that each film response reach to steady state and there response under electric field stimulation. Figure F4, shows G' of High gelatin strength was steady state after 310 s of measurement. Moreover, the film gelatin does not reversible by electric field (1 kV/mm). In the case of, Figure F5 and F6, Middle gelatin strength and Low gelatin strength were steady state after 550 s and 500 s, respectively. There also shows the similar response under electric field as the High gelatin strength film.

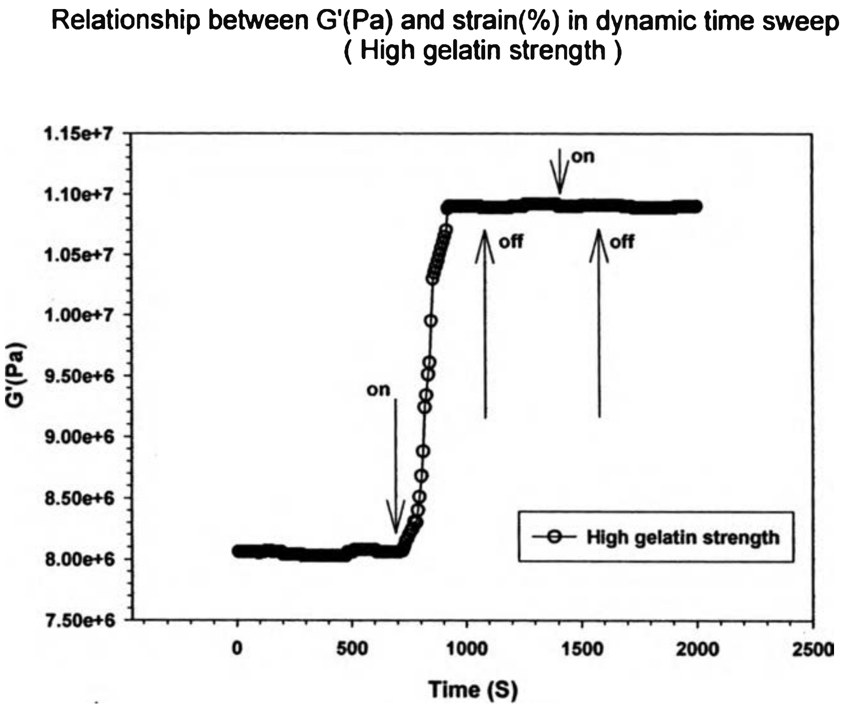

Figure C4 Temporal response testing of storage modulus (G') of High gelatin strength (gap 30 mm, film thickness 0.890 mm, film width 7.0 mm, freguency 100 rad/s, electric field (E) 1 kV/mm, 25°C)

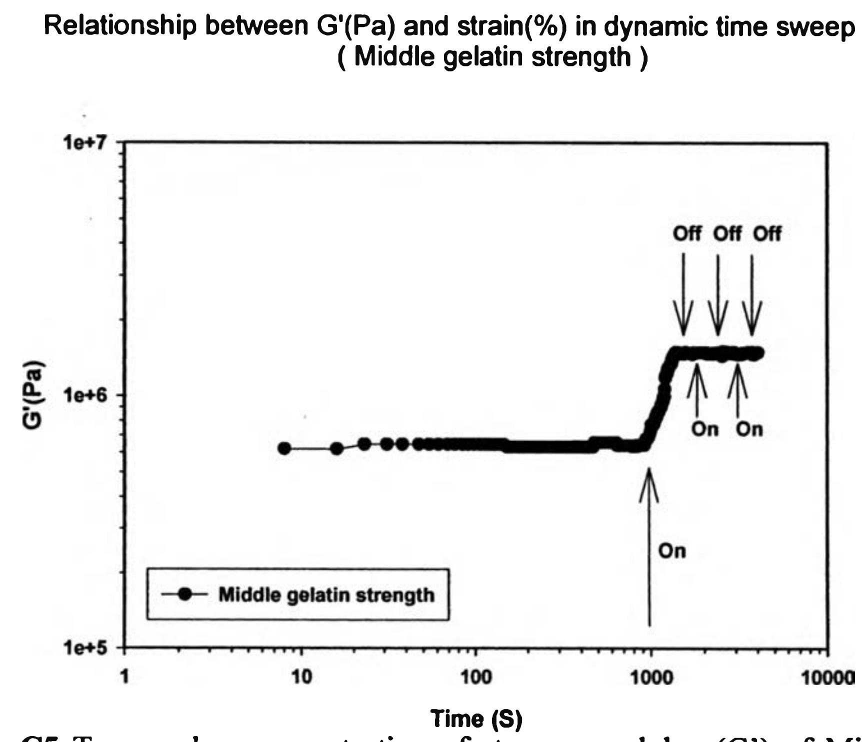

Figure C5 Temporal response testing of storage modulus (G') of Middle gelatin strength (gap 30 mm, film thickness 0.826 mm, film width 7.0 mm, freguency 100 rad/s, electric field (E) 1 kV/mm, 25°C)

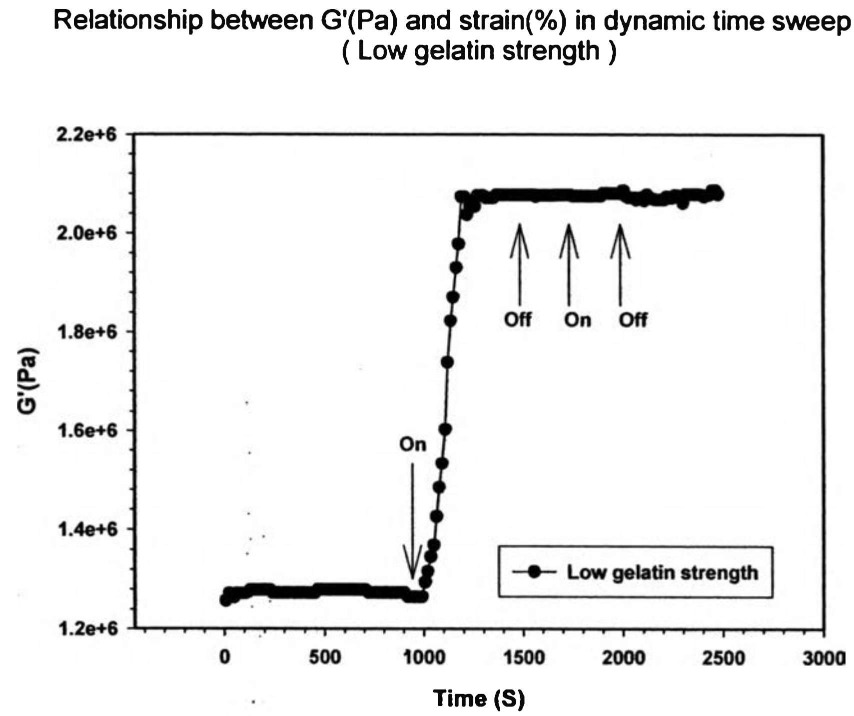

Figure C6 Temporal response testing of storage modulus (G') of Middle gelatin strength (gap 30 mm, film thickness 1.405 mm, film width 7.0 mm, freguency 100 rad/s, electric field (E) 1 kV/mm, 25°C).

Appendix D Frequency Sweep test; various Electric fields of Gelatin Films

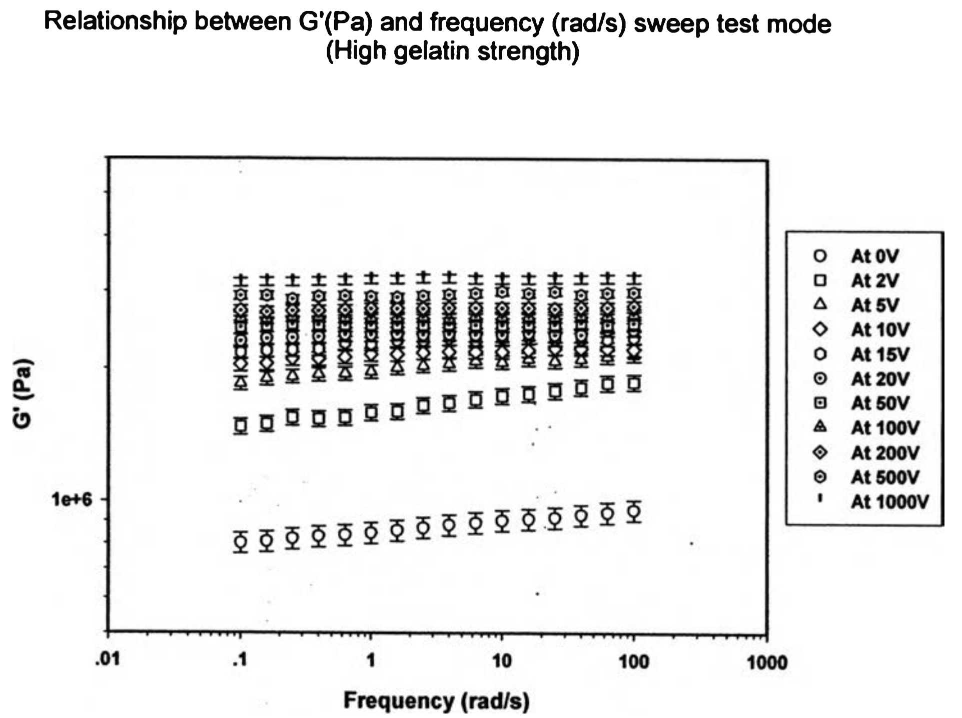

Figure D1 High molecular weight gelatin film in frequency sweep test (gap = 30 mm, film thickness = 0.890 mm, film width = 7.0 mm, 25°C)

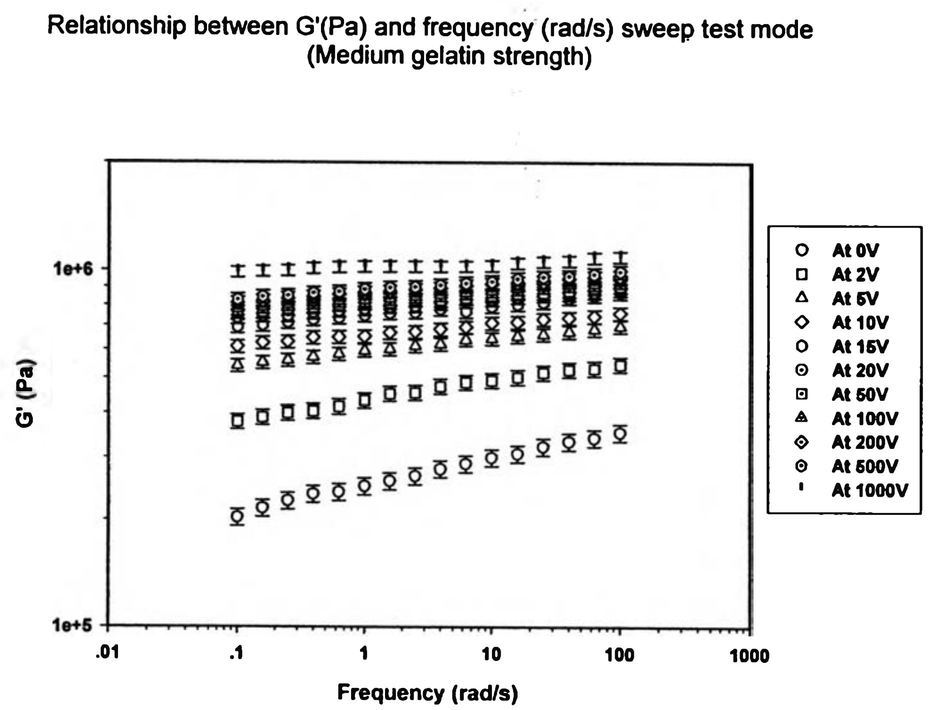

Figure D2 Middle molecular weight gelatin film in frequency sweep test (gap = 30 mm, film thickness = 0.826 mm, film width = 7.0 mm, 25°C)

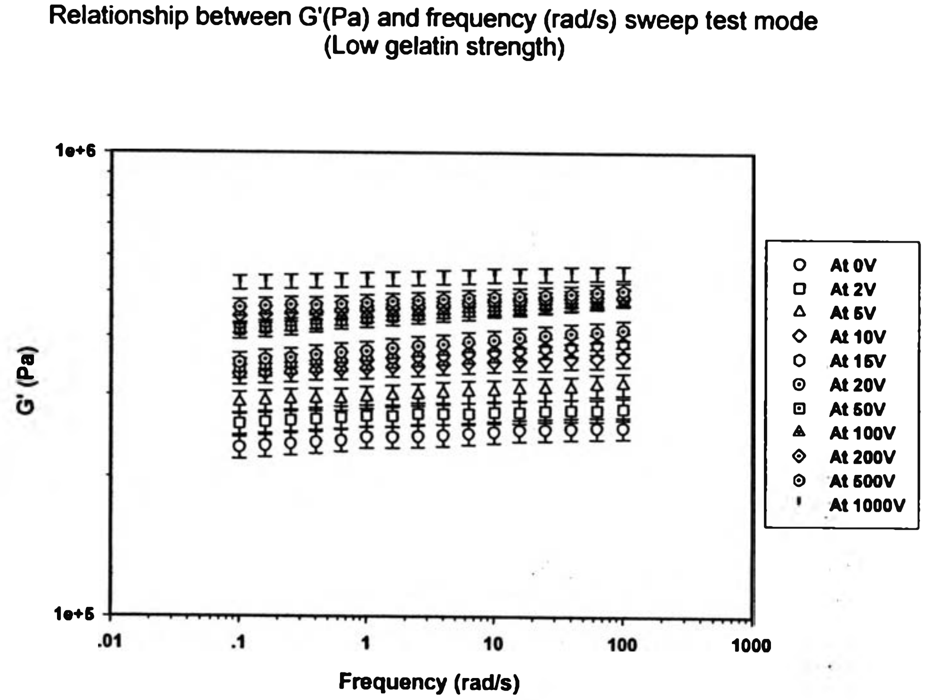

Figure D3 Low molecular weight gelatin film in frequency sweep test (gap = 30 mm, film thickness = 1.420 mm, film width = 7.0 mm, 25°C)

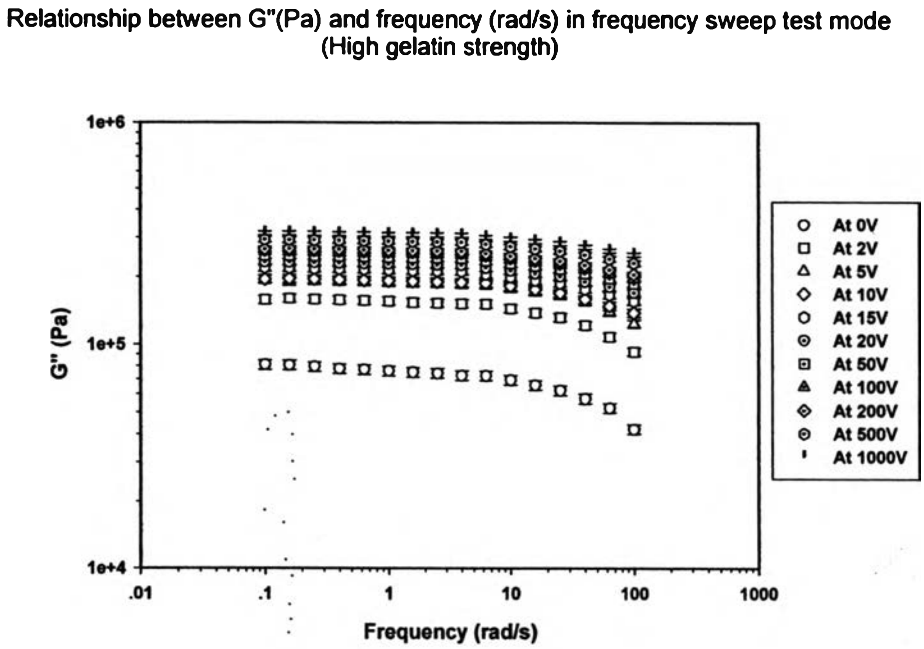

Figure D4 High molecular weight gelatin film in frequency sweep test (gap = 30 mm, film thickness = 0.890 mm, film width = 7.0 mm, 25°C)

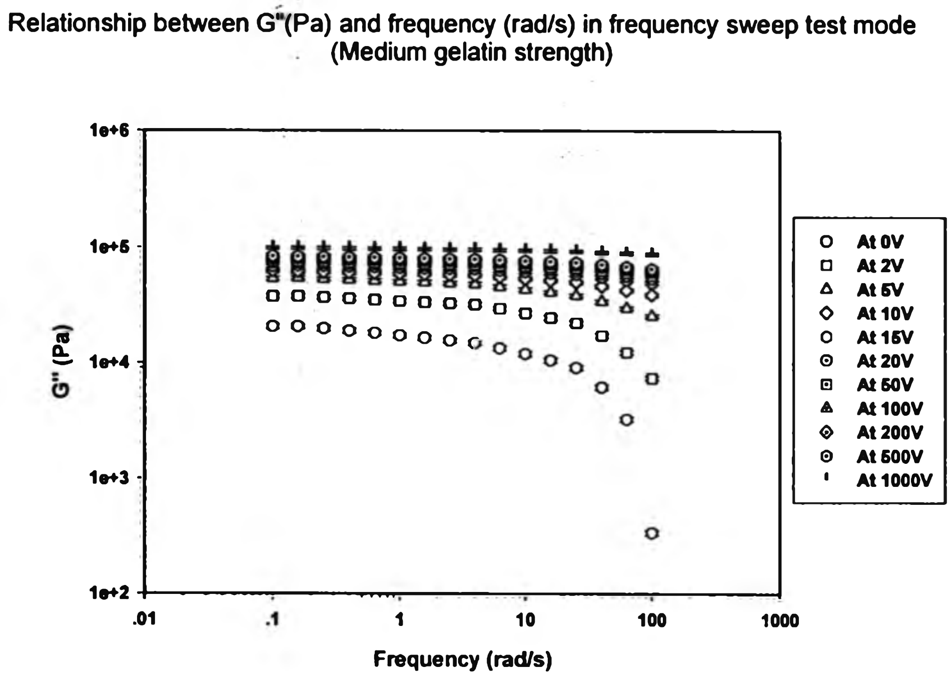

Figure D5 Middle molecular weight gelatin film in frequency sweep test (gap = 30 mm, film thickness = 0.826 mm, film width = 7.0 mm, 25°C)

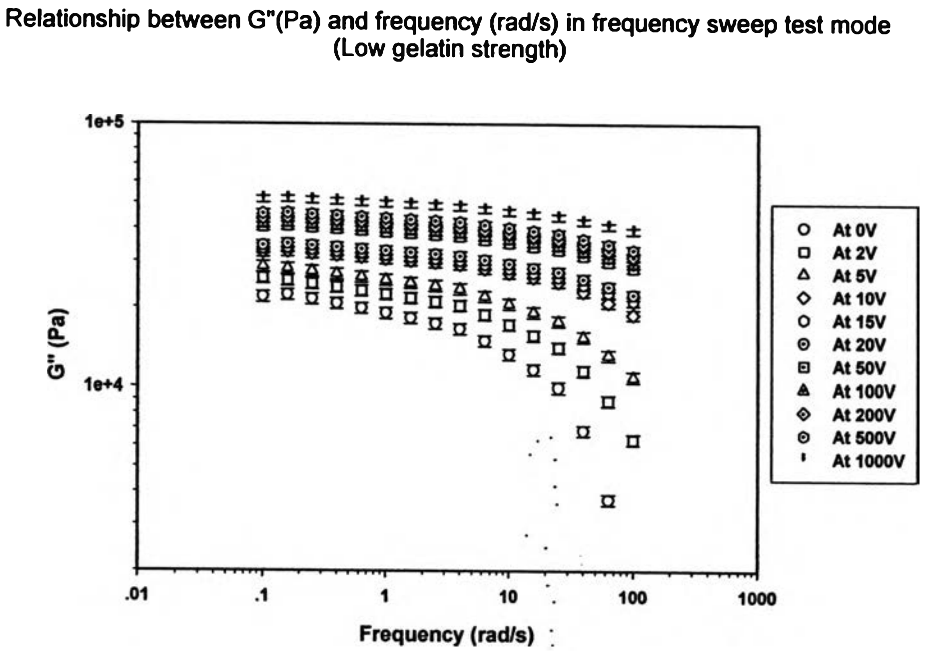

Figure D6 Low molecular weight gelatin film in frequency sweep test (gap = 30 mm, film thickness = 1.420 mm, film width = 7.0 mm, 25°C)

Appendix E Effect of Electric field and Frequency on Storage modulus Sensitivity of Gelatin Films

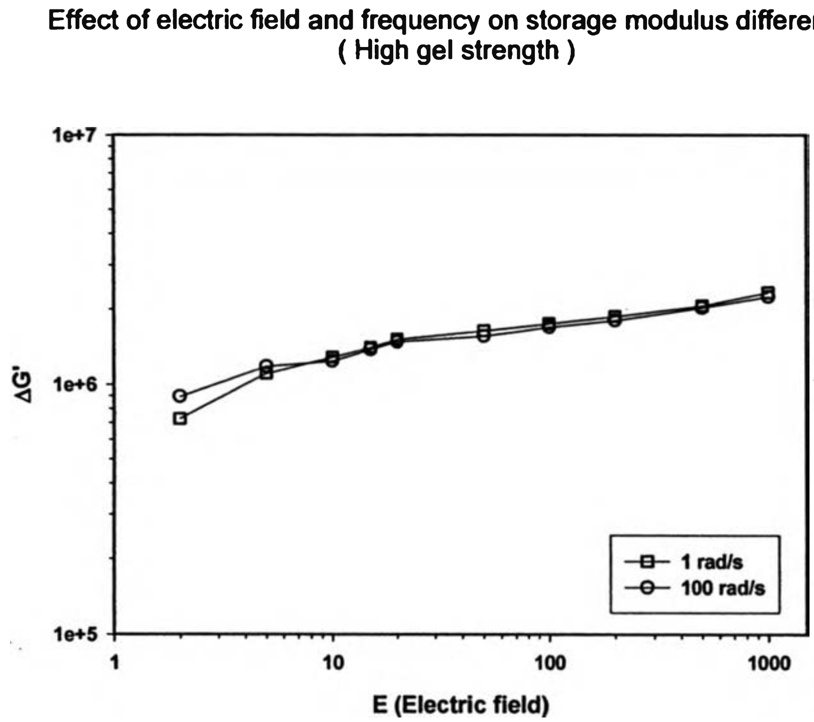

Figure E1 High molecular weight gelatin film in effect of electric field and frequency on storage modulus sensitivity (gap = 30 mm, film thickness = 0.890 mm, film width = 7.0 mm, 25°C)

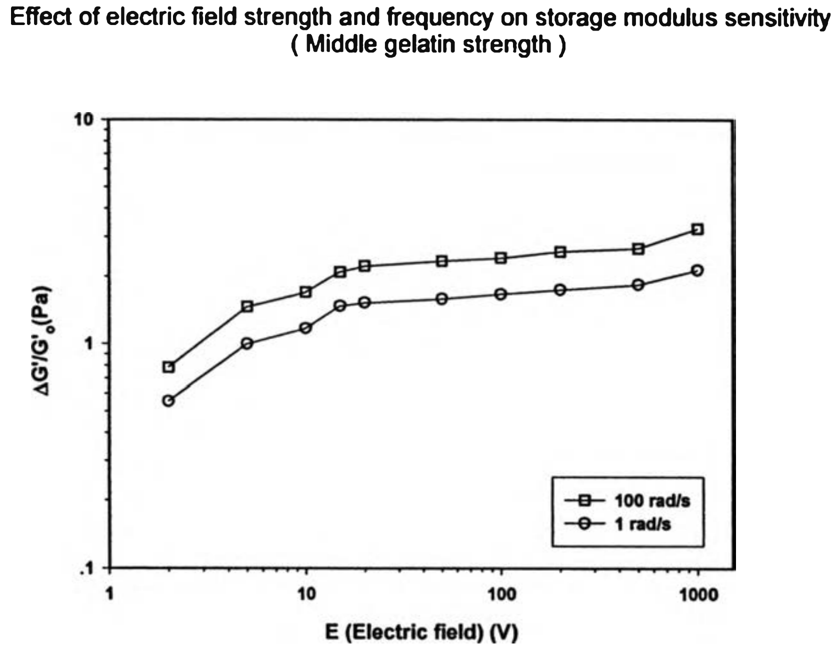

Figure E2 Middle molecular weight gelatin film in effect of electric field and frequency on storage modulus sensitivity (gap = 30 mm, film thickness = 0.826 mm, film width = 7.0 mm, 25°C)

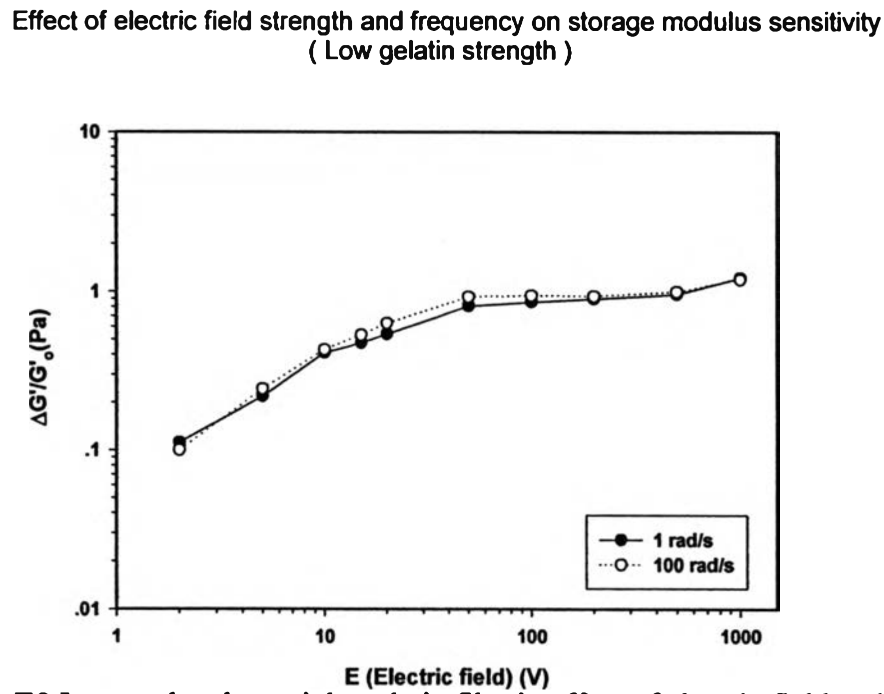

Figure E3 Low molecular weight gelatin film in effect of electric field and frequency on storage modulus sensitivity (gap = 30 mm, film thickness = 1.420 mm, film width = 7.0 mm, 25°C)

Effect of electric field strength and frequency on storage modulus sensitivity of gelatin

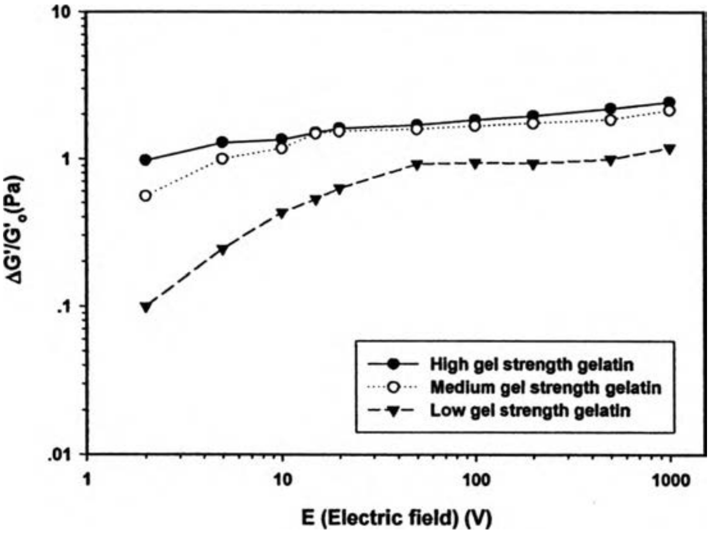

Figure E4 Compare effect of electric field strength and frequency on storage modulus sensitivity of gelatin; High gel strength(●), Medium gel strength(○), and Low gel strength(▼)

Apendix F Frequency Sweep test at various Electric field and Temperatures

Frequency sweep test of Gelatin films

Relationship between G'(Pa) and frequency (rad/s) at various temperatures in frequency sweep test mode (High molecular weight gelatin)

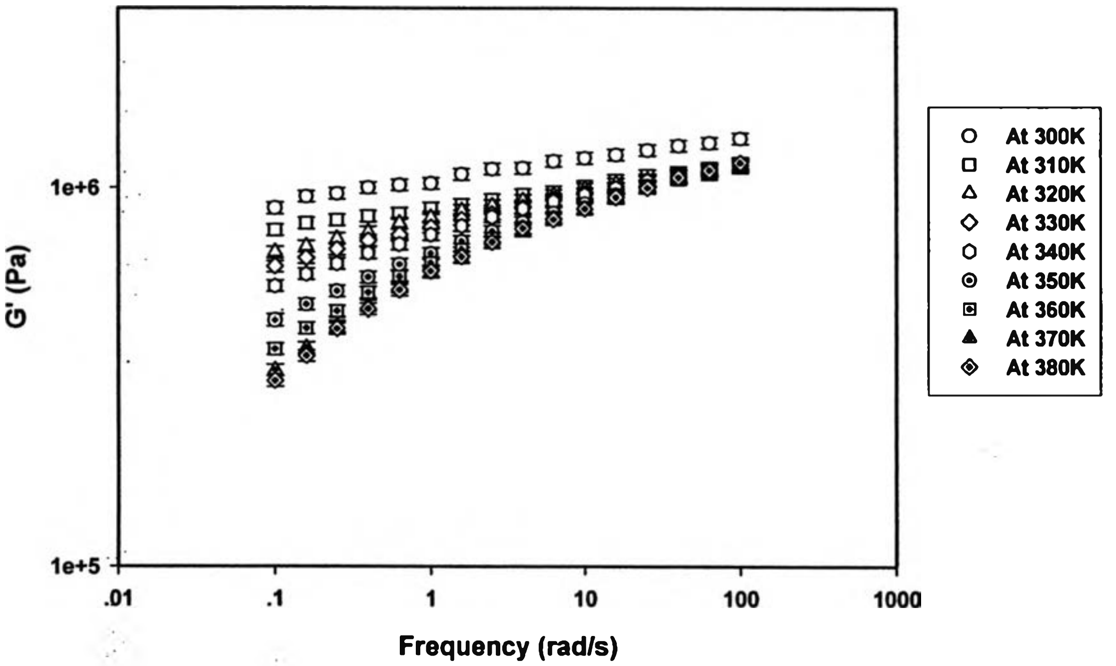

Figure F1 High molecular weight gelatin film in effect of electric field and temperature on storage modulus sensitivity (gap = 30 mm, film thickness = 0.897 mm, film width = 7.0 mm, E = 0 v/mm)

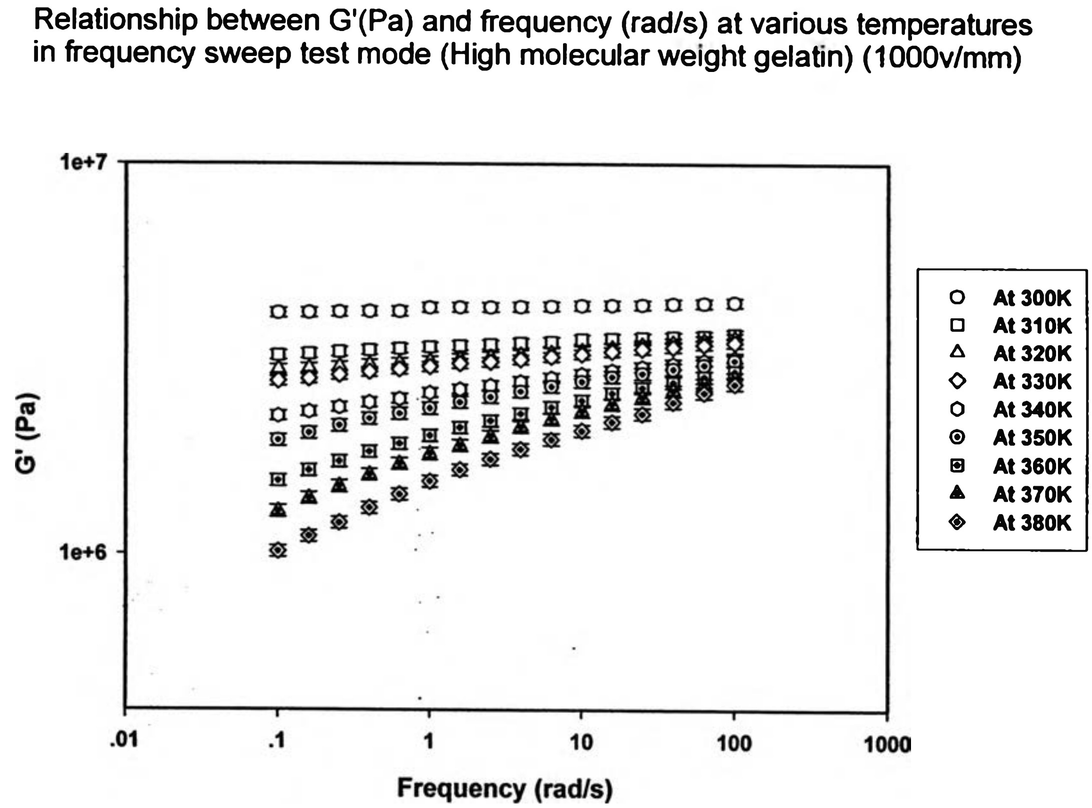

Figure F2 High molecular weight gelatin film in effect of electric field and temperature on storage modulus sensitivity (gap = 30 mm, film thickness = 0.897 mm, film width = 7.0 mm, E = 1000 v/mm)

Relationship between G'(Pa) and frequency (rad/s) at various temperatures in frequency sweep test mode (Medium molecular weight gelatin)

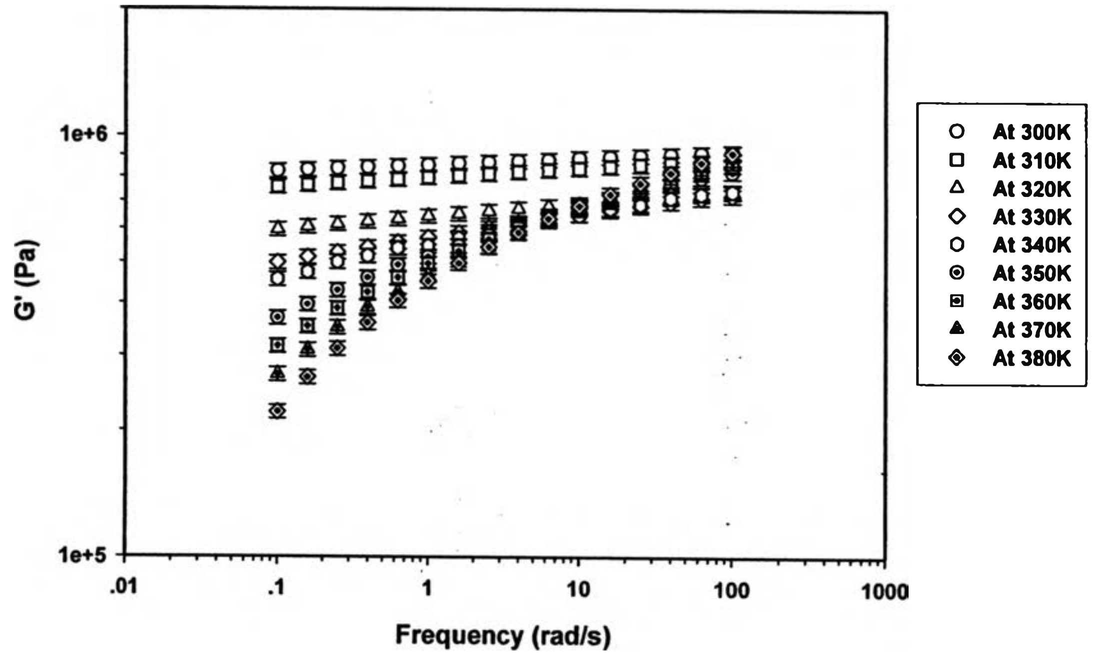

Figure F3 Medium molecular weight gelatin film in effect of electric field and temperature on storage modulus sensitivity (gap = 30 mm, film thickness = 0.878 mm, film width = 7.0 mm, E = 0 v/mm)

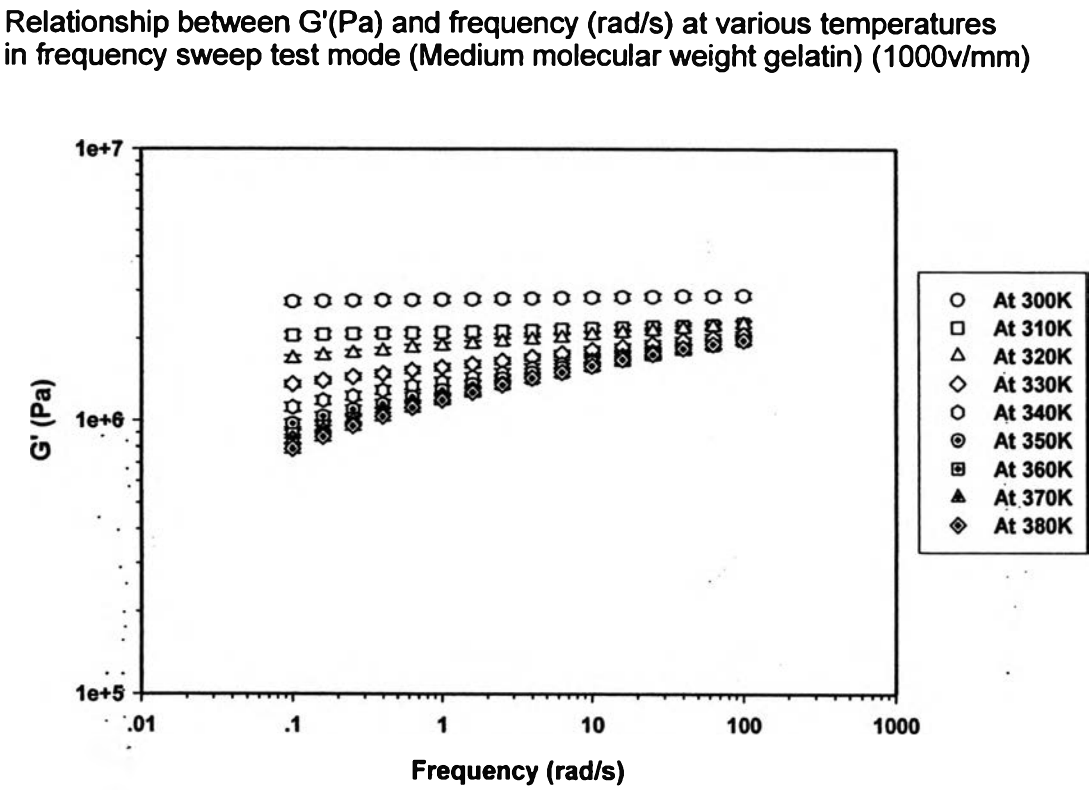

Figure F4 Medium molecular weight gelatin film in effect of electric field and temperature on storage modulus sensitivity (gap = 30 mm, film thickness = 0.878 mm, film width = 7.0 mm, E = 1000 v/mm)

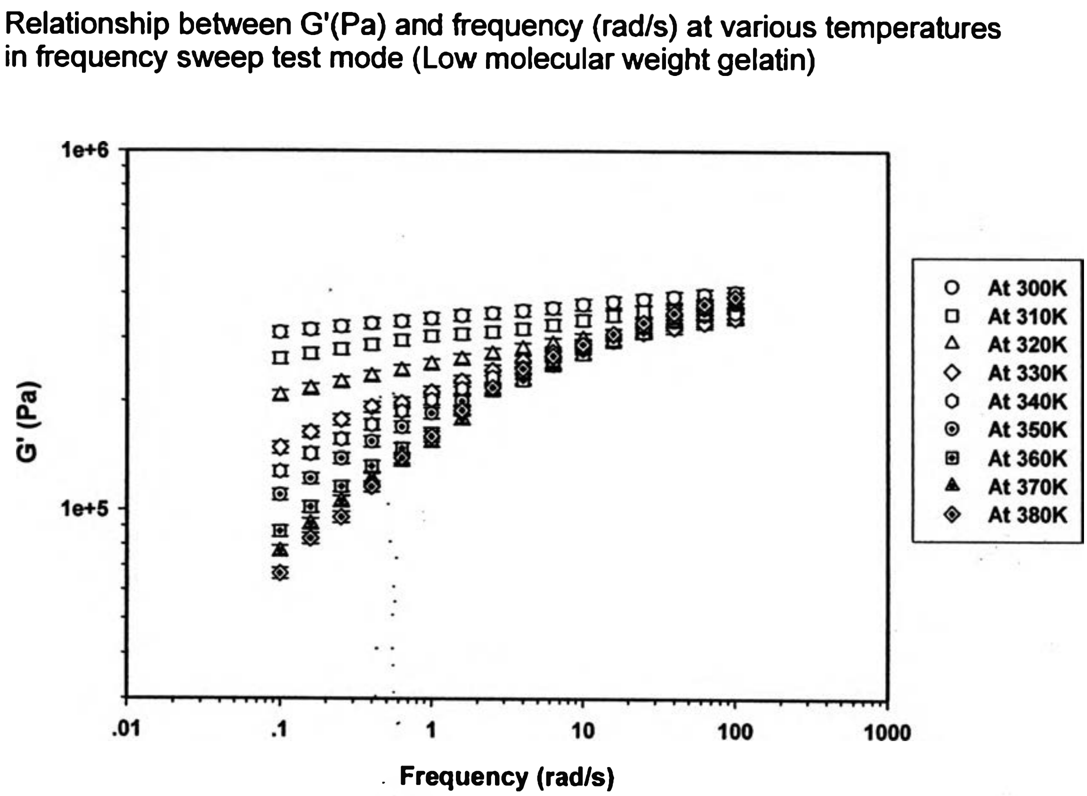

Figure F5 Low molecular weight gelatin film in effect of electric field and temperature on storage modulus sensitivity (gap = 30 mm, film thickness = 0.878 mm, film width = 7.0 mm, E = 0 v/mm)

Relationship between G'(Pa) and frequency (rad/s) at various temperatures in frequency sweep test mode (Low molecular weight gelatin) (1000v/mm)

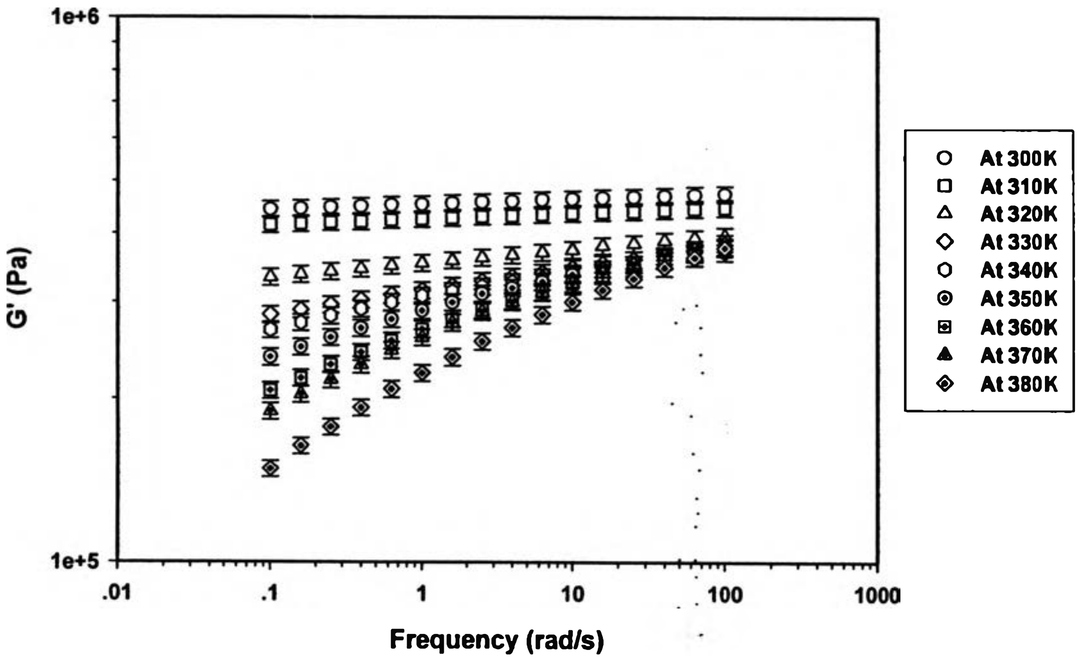

Figure F6 Low molecular weight gelatin film in effect of electric field and temperature on storage modulus sensitivity (gap = 30 mm, film thickness = 0.878 mm, film width = 7.0 mm, E = 1000 v/mm)

Apendix G The Sensitivity of The Storage modulus of Gelatin Films at various Temperature

Effect of electric field strength and temperatures on storage modulus differences of gelatin films (100 rad/s)

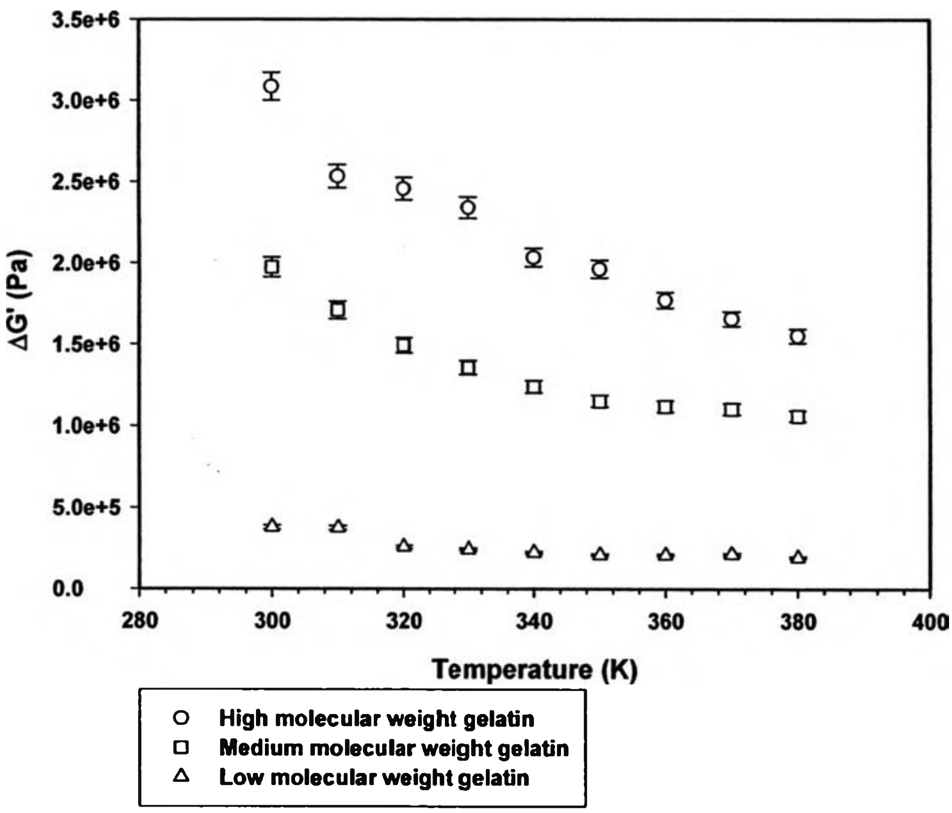

Figure G1 Compare effect of electric field strength and temperature on differentials storage modulus of gelatin; High gel strength(●), Medium gel strength(○), and Low gel strength(▼)

Effect of electric field strength and temperatures on storage modulus sensitivity of gelatin films (100 rad/s)

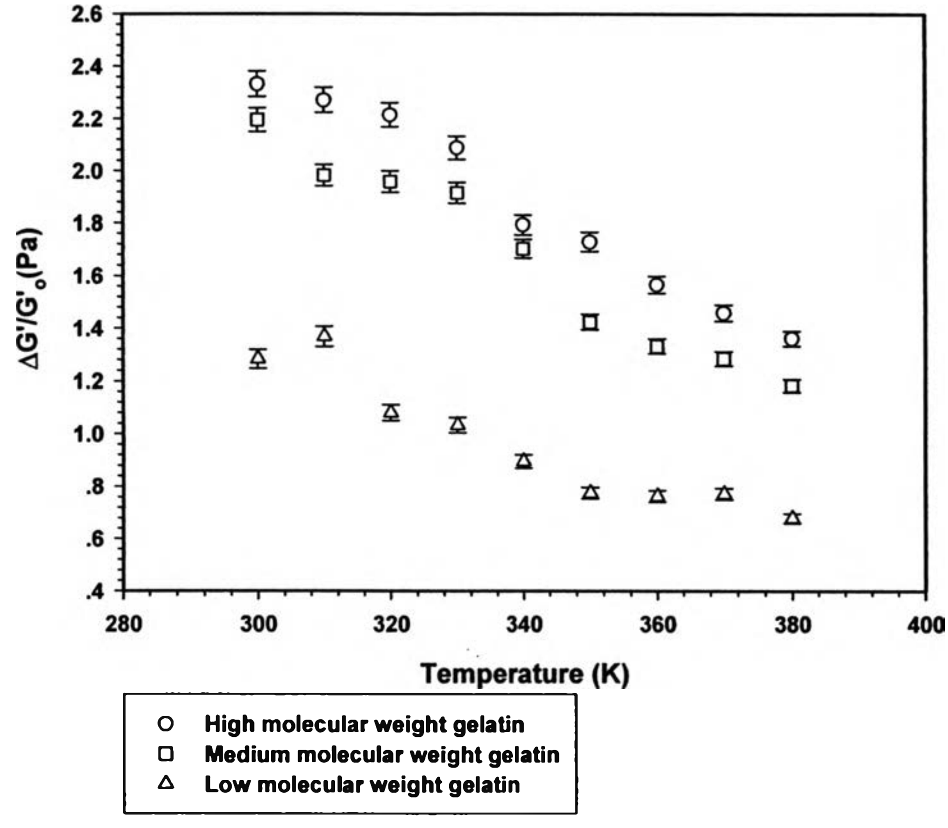

Figure G2 Compare effect of electric field strength and temperature on storage modulus sensitivity of gelatin; High gel strength(●), Medium gel strength(○), and Low gel strength(▼)

Compare effect of electric field and temperatures on storage modulus of gelatin films (100 rad/s)

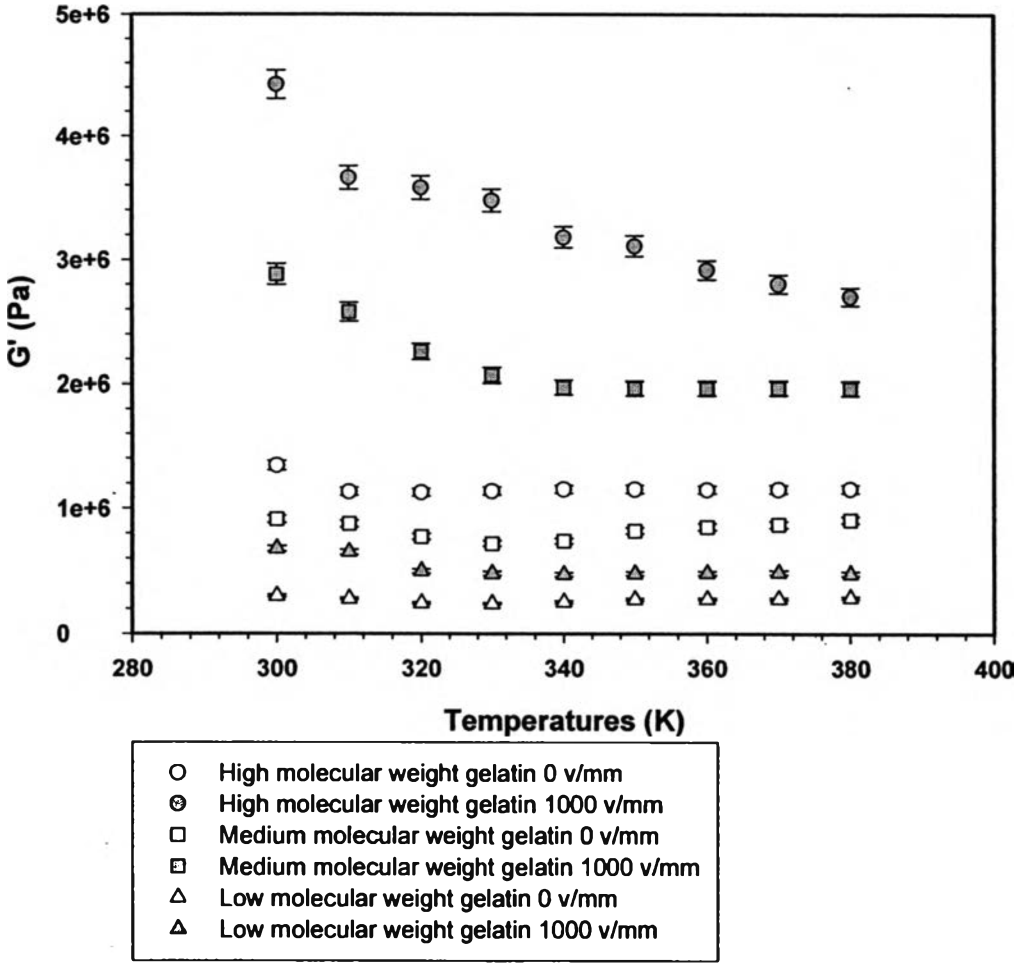

Figure G3 Compare effect of electric field strength and temperature on storage modulus gelatin films

Table G1 Compare Sensitivity of Storage modulus of Gelatin Films

Material	Electric field (kv/mm)	Frequecy (rad/s)	Temperature (C°)	Storage modulus (G') Pa	Initial storage modulus (G°) Pa	Sensitivity of storage modulus (ΔG'/G°) Pa
High molecular weight gelatin	1000	100	27	4340900	1316500	2.3
Medium molecular weight gelatin	1000	100		2823500	892800	2.16
Low molecular weight gelatin	1000	100		292800	661300	1.26

Apendix H Review Sensity of Storage modulus of Materials on Electroactive Response

Materials	Electric field (kv/mm)	Frequecy (rad/s)	Temperature (C°)	Storage modulus sensitivity $(\Delta G'/G_{o})$ Pa	Reference
Acrylic elastomer 70	2000	100	27	0.439	Kunanuruksapong [15]
Acrylic elastomer 71				0.586	
Acrylic elastomer 72				0.148	
Styrene-acrylic copolymers				1.195	
Styrene-isoprene-styrene triblock D1112P				0.746	
Acrylic elastomer 71 + PPP 10%(v/v)		1		0.306	
Acrylic elastomer 71 + PPP 30%(v/v)				0.971	
Styrene-isoprene-styrene triblock D1114P				0.122	Thongsek [16]
Styrene-isoprene-styrene triblock D1164P				0.102	
Styrene-isoprene-styrene triblock D1162P				0.050	
D114P + PDPA 5%(v/v)				0.040	
D114P + PDPA 10%(v/v)				0.256	
D114P + PDPA 30%(v/v)	1000	1		0.095	
AR71/lead zirconate titanate Pb(Zr0.5Ti0.5)O3 (0.000019%v/v)	2000	1		0.149	Tangboriboon [17]
AR71/lead zirconate titanate Pb(Zr0.5Ti0.5)O3 (0.038%v/v)				0.587	
poly (dimethyl siloxane) (PDMS)	2000	100		0.104	Piyanoot [18]
poly (dimethyl siloxane) (PDMS) + PANi 20% (v/v)				0.25	
poly (dimethyl siloxane) (PDMS) + PANi 2% (v/v)				0.111	
PDMS_5%PEDOT/PSS/EG	2000	100		0.077	Wijittra [19]
PDMS_15%PEDOT/PSS/EG				0.333	

Materials	Electric field (v/mm)	Frequecy (rad/s)	Temperature (C°)	Storage modulus sensitivity ($\Delta G'/G_{\circ}$) Pa	Reference
Crosslinked Polyisoprene 3% + Polythiopene 5% (v/v)	2000	100	27	0.523	Toempong (4)
Crosslinked Polyisoprene 3% + Polythiopene 10% (v/v)				0.33	
Crosslinked Polyisoprene 3% + Polythiopene 30% (v/v)				0.435	
Silicone gel	5000	60		not response	Tohru Shiga [21,22]
Silicone gel + PMACO 46%	1000			0.25	
Silicone gel + PMACO 46%	2000			0.75	
Silicone gel + PMACO 46%	3000			2	
Silicone gel + poly(p-phenylenes) 10%	1000	300		0.333	
Silicone gel + poly(p-phenylenes) 10%	3000	300		1.133	
Silicone gel + poly(p-phenylenes) 10%	5000	300		1.666	
poly(3-hexylthiophene) doped iodine (amorphous)	8.7	–		0.28	

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