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The suitable condition for fresh latex deproteinization by papain

1. Effect of temperature on deproteinization

Time	30°C		35°C		40°C		45°C		50°C		55°C	
(min)	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction
0	0.570	0.00	0.560	0.00	0.576	0.00	0.566	0.00	0.580	0.00	0.566	0.00
5	0.293	48.60	0.236	57.93	0.210	63.49	0.200	64.60	0.221	61.82	0.267	53.97
10	0.258	54.75	0.225	59.80	0.201	65.14	0.208	63.22	0.204	64.85	0.204	64.83
15	0.211	62.90	0.200	64.30	0.203	64.68	0.195	65.61	0.187	67.83	–	–
20	0.201	64.75	0.200	64.30	0.194	66.25	0.183	67.61	0.186	68.00	–	–
25	0.202	64.62	0.186	66.77	0.175	69.60	0.175	69.09	0.165	71.60	–	–
30	0.187	67.18	0.190	66.07	0.176	69.42	0.170	69.97	0.158	72.71	–	–
40	0.181	68.22	0.185	66.91	0.169	70.71	0.158	72.03	0.142	75.46	–	–
50	0.181	68.22	0.181	67.67	0.163	71.65	0.161	71.48	0.126	78.26	–	–
60	0.168	70.44	0.161	71.17	0.144	74.93	0.133	76.50	0.111	80.79	–	–

Note : –, % N was not determined, because the latex coagulated

2. Effect of agitation speed on deproteinization

2.1 Effect of agitation speed on deproteinization using a reactor of 11 cm in diameter

Time	57 r.p.m.	
(hour)	% N	% reduction
0	0.543	0.00
1	0.161	70.28
2	0.156	71.27
3	0.156	71.27
4	0.156	71.27

2.2 Effect of agitation speed on deproteinization using a reactor of 41 cm in diameter

Time	37 rpm		50 rpm		60 rpm		80 rpm		100 rpm	
(min)	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction
0	0.576	0.00	0.591	0.00	0.581	0.00	0.557	0.00	0.552	0.00
5	0.172	70.19	0.169	71.37	0.166	71.50	0.154	72.36	0.167	69.82
10	0.178	69.13	0.147	75.09	0.146	74.87	0.173	68.90	0.143	74.13
15	0.143	75.18	0.138	76.69	0.132	77.26	0.144	74.23	0.133	75.81
20	0.145	74.82	0.126	78.62	0.124	78.72	0.134	75.91	0.131	76.20
25	0.136	76.46	0.112	80.98	0.110	81.06	0.110	80.28	0.118	78.69
30	0.144	75.05	0.110	81.44	0.107	81.54	0.109	80.35	0.106	80.73
40	0.146	74.68	0.108	81.69	0.101	82.62	0.110	80.28	0.102	81.58
50	0.117	79.63	0.101	82.92	0.096	83.42	0.108	80.69	0.114	79.30
60	0.117	79.63	0.100	83.00	0.098	83.04	0.108	80.69	0.124	77.54
80	0.118	79.51	0.100	83.00	0.102	82.46	0.116	79.11		
100	0.119	79.30								
120	0.116	79.77								

2.3 Repeated experiment on the effect of agitation speed at 50 and 60 r.p.m. in a 41 cm reactor

Time (min)	50 rpm				60 rpm			
	9/1/93		11/1/93		9/1/93		25/1/93	
	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction
0	0.591	0.00	0.615	0	0.581	0.00	0.590	0.00
5	0.169	71.37	0.196	68.00	0.166	71.50	0.172	70.92
10	0.147	75.09	0.182	70.45	0.146	74.87	0.156	73.63
15	0.138	76.69	0.158	74.30	0.132	77.26	0.146	75.20
20	0.126	78.62	0.143	76.70	0.124	78.72	0.131	77.84
25	0.112	80.98	0.133	78.41	0.110	81.06	0.117	80.22
30	0.110	81.44	0.130	78.92	0.107	81.54	0.109	81.49
40	0.108	81.69	0.121	80.23	0.101	82.62	0.105	82.20
50	0.101	82.92	0.118	80.75	0.096	83.42	0.104	82.40
60	0.100	83.00	0.118	80.75	0.098	83.04	0.103	82.48
80	0.100	83.00			0.102	82.46	0.102	82.65

3. Effect of papain concentration on deproteinization

3.1 Effect of papain concentration

Time	0.0 p.h.r.		0.2 p.h.r.		0.25 p.h.r.		0.30 p.h.r.	
(min)	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction
0	0.595	0.00	0.555	0.00	0.589	0.00	0.590	0.00
5			0.214	61.43	0.192	67.41	0.149	74.68
10	0.586	1.50	0.183	66.94	0.155	73.68	0.126	78.57
15			0.175	68.44	0.139	76.33	0.115	80.49
20	0.582	2.22	0.174	68.65	0.131	77.79	0.108	81.75
25			0.159	71.38	0.125	78.73	0.107	81.90
30	0.586	1.50	0.154	72.33	0.122	79.31	0.109	81.49
40	0.584	1.82	0.138	75.09	0.114	80.57	0.105	82.20
50	0.585	1.71	0.145	73.95	0.115	80.49	0.104	82.40
60	0.582	2.22	0.128	76.86	0.114	80.57	0.102	82.67
80	0.584	1.82	0.146	73.77	0.114	80.57	0.102	82.67

3.2 Repeated experiment at papain concentration 0.25 and 0.3 p.h.r.

| Time	0.25 p.h.r.				0.3 p.h.r.			
(min)	25/1/93		30/1/93		9/1/93		25/1/93	
	% N	% reduction	% N	% reduction	% N	% reduction	% N	% reduction
0	0.589	0.00	0.587	0.00	0.581	0.00	0.590	0.00
5	0.192	67.41	0.21	64.22	0.165	71.59	0.149	74.68
10	0.155	73.68	0.173	70.53	0.142	75.54	0.126	78.57
15	0.139	76.33	0.157	73.25	0.132	77.26	0.115	80.49
20	0.131	77.79	0.146	75.13	0.119	79.59	0.108	81.75
25	0.125	78.73	0.136	76.83	0.109	81.25	0.107	81.90
30	0.122	79.31	0.129	78.02	0.098	83.07	0.109	81.49
40	0.114	80.57	0.124	78.88	0.104	82.04	0.105	82.20
50	0.115	80.49	0.12	79.56	0.106	81.69	0.104	82.40
60	0.114	80.57	0.124	78.88	0.105	82.00	0.102	82.67
80	0.114	80.57	0.119	79.73	0.102	82.36	0.102	82.67
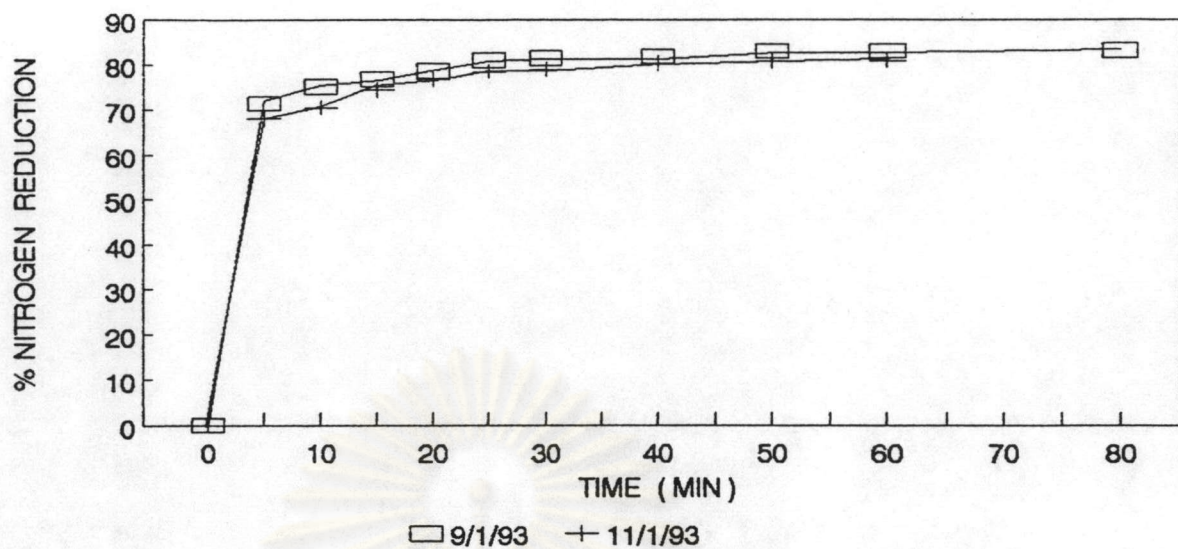
Figure A. 1.1 Repeated experiment on the effect of agitation speed at 50 r.p.m
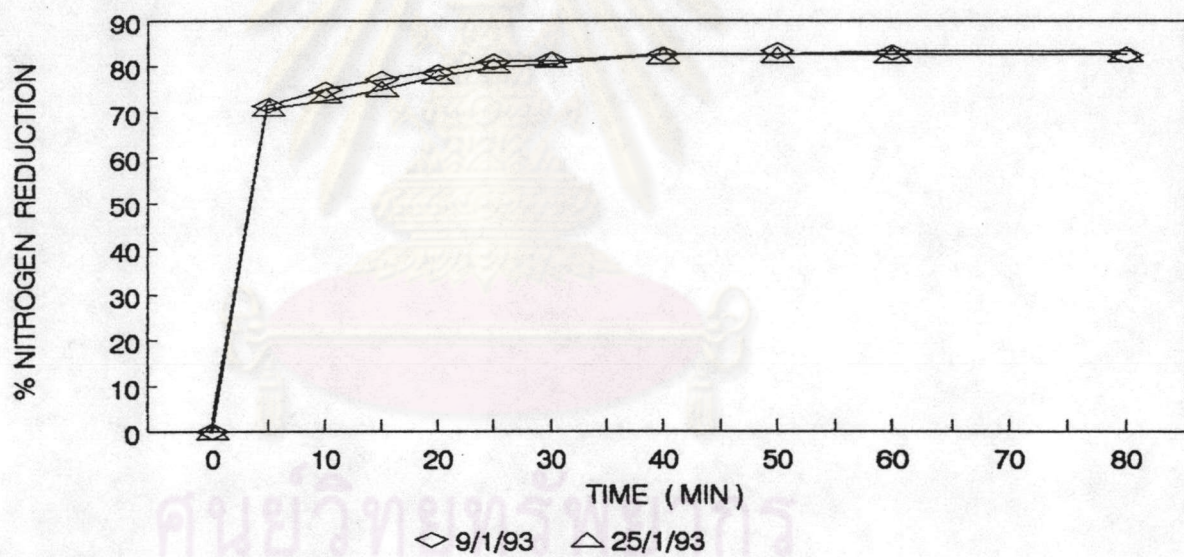

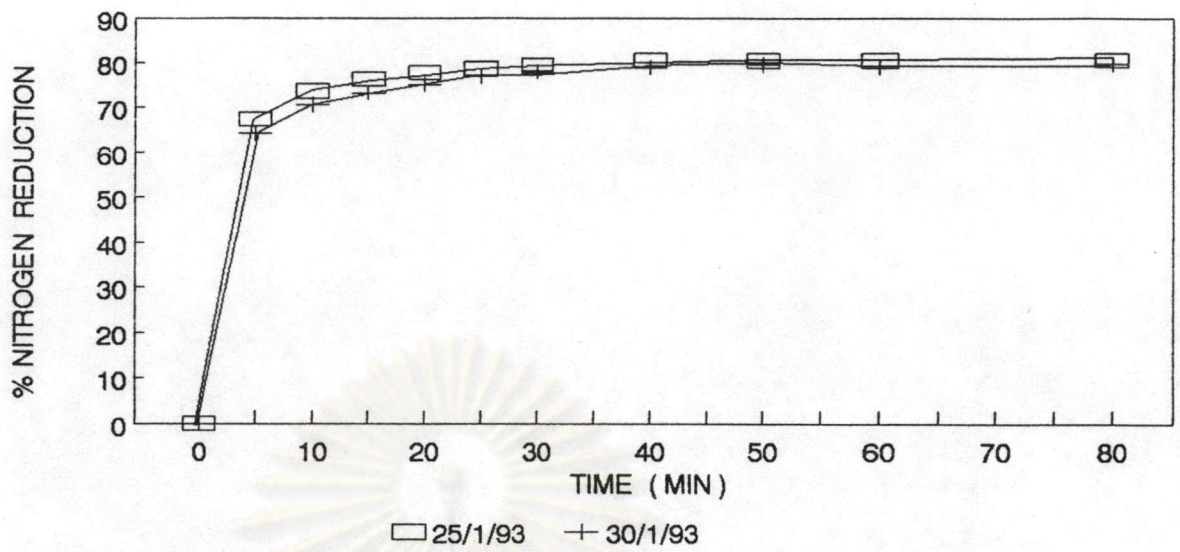Figure A. 1.2 Repeated experiment on the effect of agitation speed at 60 r.p.m

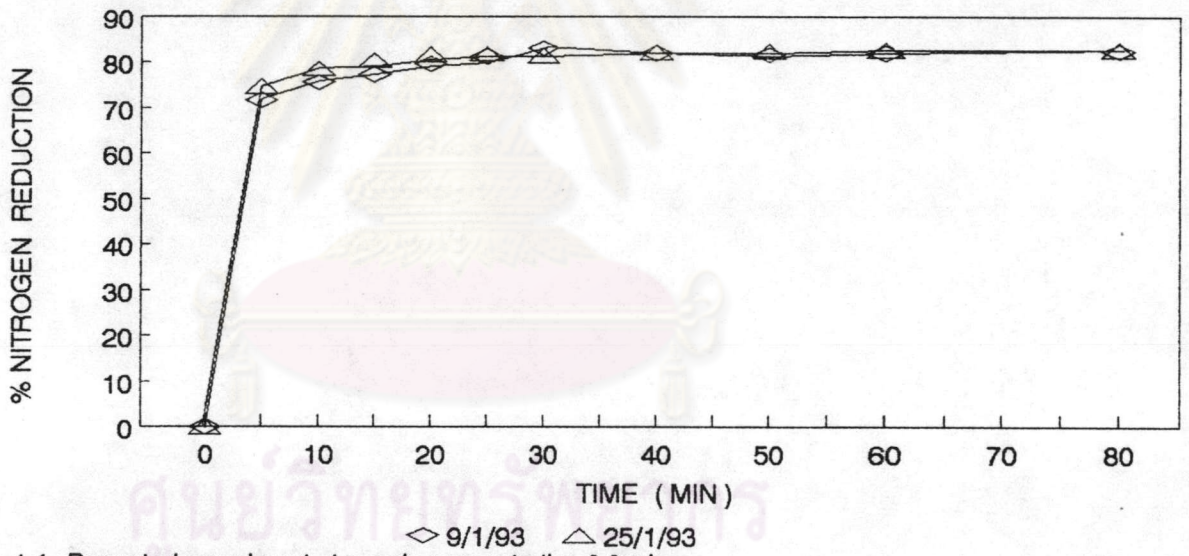Figure A. 1.3   Repeated experiment at papain concentration 0.25 p.h.r.

Figure A. 1.4   Repeated experiment at papain concentration 0.3 p.h.r.

APPENDIX 2

1. Testing of the properties of DPNR

1.1 Raw rubber testing (RRIM, 1970)

1.1.1 Preparation of test piece by homogenization

Each rubber sample was passed six times through a two-roll mill with gap setting of 1.65 mm between the rolls at room temperature. After each pass the rubber was rolled into a cylinder shape and then introduced endwise for the next pass. The homogenized sample was cut for further tests.

1.1.2 Determination of dirt content

About 30 g of homogenized rubber was taken and passed twice through the cold mill with 0.330 mm nip setting. A test portion of approximately 10 g of this rubber is accurately weighed, cut into small strips and placed in a 500 ml conical flask containing 250 ml of mineral turpentine and 1 ml of RPA No.3 (xylyl mercaptan (36%)). The flask is placed on the infra-red unit and heated to about 140 ^{O}C with occasional agitation until dissolution was complete (2 hours). The hot solution was filtered through a previously weighed, cleaned and dried sieve. The dirt in the flask was washed twice with 30-50 ml of hot mineral turpentine each time. The washings were then decanted into the sieve and washed with cold mineral turpentine. The washing was completed with a rinse of hot mineral turpentine around the inside wall of the sieve. The sieve with dirt was dried in an oven at 90-100 ^{O}C for 1 hour, cooled in a desiccator and reweighed (to the nearest 0.1 mg). The percentage of dirt content was expressed as follows :

$$\% \text{ dirt} = \frac{\text{weight of dirt}}{\text{weight of test portion}} \times 100$$

1.1.3 Determination of ash content

The ash from natural rubber contains oxides in varying proportions, carbonates and phosphates of potassium, magnesium, calcium, sodium and other trace elements. Additionally it can contain silica and silicates arising either from the rubber or from extraneous foreign matter to an extent depending on the history of the material. The ash represents as minimal figure for the amount of mineral matter present in the rubber. Weigh accurately 5-10 g each test portion of the homogenized rubber. Wrap in ashless filter paper and place in a crucible which had been previously ignited and weighed. Introduce the crucible into a muffle furnace controlled at $550 \pm 20\ ^{\circ}\text{C}$ until free from carbon (2-4 hour). When ashing was completed, allow the crucible to cool in a desiccator and weighed (to the nearest 0.1 mg). The ash content is calculated as follow:

$$\text{Ash wt (\%)} = \frac{A - B}{W} \times 100$$

where   A = weight of crucible plus ash

B = weight of empty crucible

W = weight of rubber taken

1.1.4 Determination of nitrogen content

Nitrogen occurred in raw rubber chiefly as protein and it can be used to provide an indication of the protein content, by protein = 6.25 x % nitrogen content.

Weigh accurately about 0.2-0.3 g of rubber sample into the Semimicro Kjeldahl flask and add about 0.65 g of the catalyst mixture (K_2SO_4 : $CuSO_4.5H_2O$: SeO = 30 : 4 :1) and 7-8 ml of concentrated sulphuric acid. The mixture was boiled until the digest became clear green in color (or colorless) with no yellow tint and cooled. The cool digestion was transfered to the distillation flask and washed three times with distilled water. Add 10 ml of boric acid solution (20 g/l) to the receiving flask and add 2-3 drops of methyl red-bromcresol green indicator, placed receiver and dipped the end of the condenser below the surface of the H_3BO_3 solution. Add 40 % of NaOH solution to the distillation flask and pass steam until the total volume of solution in the receiver was about 150 ml. Lower the reciever and wash the end of the condenser with water. Immediately titrate the distillate with standardised 0.01 M H_2SO_4. Blank was carried through the entire procedure, but omitting the sample. Calculate the nitrogen content as follow :

$$\% N = \frac{2.8 \times (V_1 - V_2) \times M}{W}$$

where V_1 = ml of H_2SO_4 required for titration of the contents of the receiving flask

V_2 = ml of H_2SO_4 required for titration of the blank

M = Molarity of the H_2SO_4

W = grams of sample used

1.1.5 Determination of volatile matter

The volatile matter is primarily intended for the determination of moisture and the amount of any other material which is volatile at 100 ^{O}C in raw rubber.

The homogenized rubber was weight approximately 10 g (to the nearest 0.1 mg) and passed through the cold mill rolls set 0.5 mm. Then the test portion was placed on aluminium tray and heated in an oven at 100 $\pm$ 3 ^{O}C for 4 hours. At the end of heating, each test portion was inserted in a polythene bag and hang on the rack to cool down for half an hour in an air conditioned room, then each of test portion was removed from the bag and weighed. The volatile matter was calculated as follow :

$$\text{Volatile matter (\%)} = \frac{C - D}{C} \times 100$$

where C = weight of test portion before drying

D = weight of test portion after drying

1.1.6 Determination of initial plasticity and plasticity retention index

The plasticity retention index (PRI) test has been developed as a simple rapid method for measuring the resistance of raw rubber to oxidative breakdown on heating. The test involved measurement of the rapid plasticity of the rubber test pieces before and after a short period of heating in an air oven. The rapid plasticity is measured with the Wallace rapid plastimeter. A high value of PRI denotes high

resistance to oxidative breakdown. A test portion of 20 ± 5 g of the homogenized piece was passed twice through the rolls of a cool mill (doubling the sheeet between passes) with nip setting adjusted such that the final sheet thickness was 1.6-1.8 mm. The sheet which should be free from holds was immediately doubled and the two halves pressed lightly together by hand. Six test pellets were cut from the doubled sheet with the Wallace punch as illustrated below.
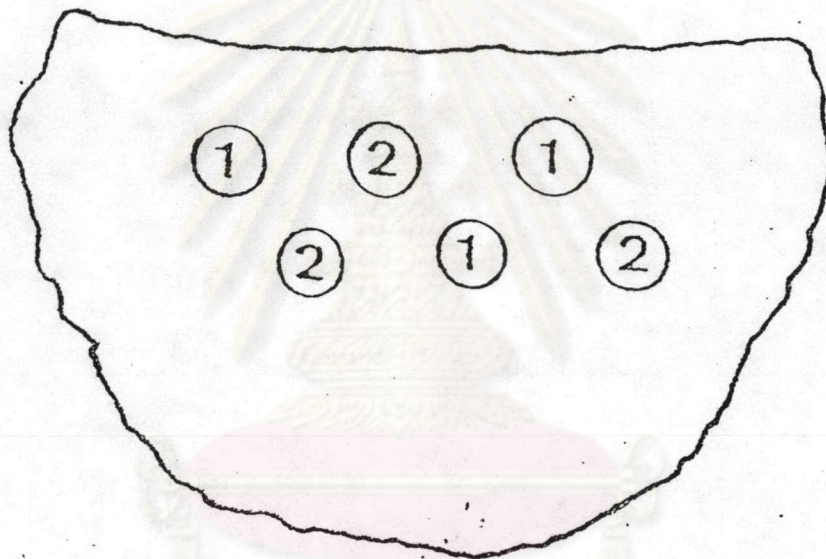
Punched pellets for

1) initial plasticity determination

2) aged plasticity determination

The test piece should be a disc of rubber of thickness between 3.2-3.6 mm and approximately 13 mm in diameter. The test pieces were divided into two sets each for plasticity determination before and after oven ageing. For ageing, the test pieces were heated in oven for

30 minutes at 140 ^{o}C. Then they were removed and allowed to cool to room temperatue. The pellet piece was sandwiched between two pieces of cigarette paper and pressed between the two plates to a fixed thickness of 1 mm with constant compressive force of 10 $\pm$ 0.1 kg$_f$ for 15 seconds. The thickness at the end of this period was measured by Wallace rapid plastimeter. The median of the three unaged and the three aged test pieces were used to calculate the PRI as follow:

$$PRI = \frac{Aged\ median\ plasticity\ value}{Unaged\ median\ plasticity\ value} \times 100$$

1.1.7 Characterization of viscosity-stabilized rubber

The accelerated storage-hardening test (A.S.H.T.) provided an indication of the propensity of solid natural rubber to increase its viscosity during storage as a result of the formation of cross-links between the rubber molecules. These cross-link formations are contributed largely from some condensation reactions involving aldehyde groups naturally present in the rubber molecules. A.S.H.T. involved the measurement of the Wallace rapid plasticity of test pieces before and after a short period of storage under condition which accelerated the storage-hardening reaction.

The homogenized piece was prepared similarly to same PRI test and divided into two sets, one set of three pellets was placed in the weighing bottle containing 6-8 g of P_2O_5 and storage-hardened at 60 $\pm$ 1 ^{o}C for 24 hours and the other set was left in the atmosphere at room temperature. After 24 hours all test pieces were determined for plasticity by Wallace plastimeter as well as PRI test. The accelerated

storage-hardening ($\triangle$P) should be expressed as:

$$\triangle P \quad = \quad P_H - P_O$$

where $\triangle P$ = difference in plasticity units between P_H and P_O

P_H = median plasticity value of 3 storage-hardened test pieces.

P_O = median plasticity value of 3 non-storage hardened

test pieces.

1.1.8 Determination of color

The color of the raw rubber was compared and matched as closely as possible with that of standard colored glasses. The numerically higher index values have deeper color. A test portion of 20 ± 5 g was taken from homogenized piece and prepared similarly to PRI test. The two test pieces were laminated together and pressed in the mould between two sheets of polyester or cellulose film using mould covers at not less than 3.5 MN/m^2 pressure on the cavity areas of the mould for 5 minutes at 150 ± 3 ^{O}C. The color of the test pieces was determined by matching as closely as possible to the appropriate color standard over a lighting box. The color was shown as index number of color glass.

1.1.9 Determination of Mooney viscosity (ASTM D1646, 1988)

The rubber sample 150 ± 5 g was homogenized by ten passed between the two-roll mill having a roll distance 2.5 ± 0.1 mm and temperature of the rolls 70 ± 5 ^{O}C. About 27 ± 3 g of homogenized

rubber was cut into two portions. One portion was placed in the lower die cavity and the roter was replaced, then the second portion was placed on the top and the die was closed immediately. The viscosity was reported as the Mooney unit, ML(1+4) 100 ^{O}C, the roter size (L for large), the number of minutes for warming up in the machine (1 minute), the number of minutes of actual test (4 minute) and temperature (100 ^{O}C).

1.1.10 Molecular weight averages and molecular weight distribution by gel permeation chromatography (GPC) (ASTM D3536, 1980)

Weight 0.01 g of rubber sample into a 20 ml vial with screw cap containing 10 ml of THF. The sample was dissolved at room temperature and aided by stirring until the dissolution was complete. The solution was filtered through a membrane filter with pore size 5 μm primarily to remove lint and other materials likely to obstruct the GPC column. About 100 μl of filtrate was filled in a syringe, expeled air from the syringe and injected into the sample injection position. The solution was introduced into series of four columns packed with styragel and having nominal exclusion limits of 10^4 ^{O}A, 10^5 ^{O}A, 10^6 ^{O}A and linear (Mw range 2,000 to > 10^7) by THF solvent at the flow rate 1 ml/min at 35 ^{O}C. The MW and MWD of the sample was determined by using polystyrene standard calibration graph (Mw standard range 8.5 x 10^3 – 1.06 x 10^7).
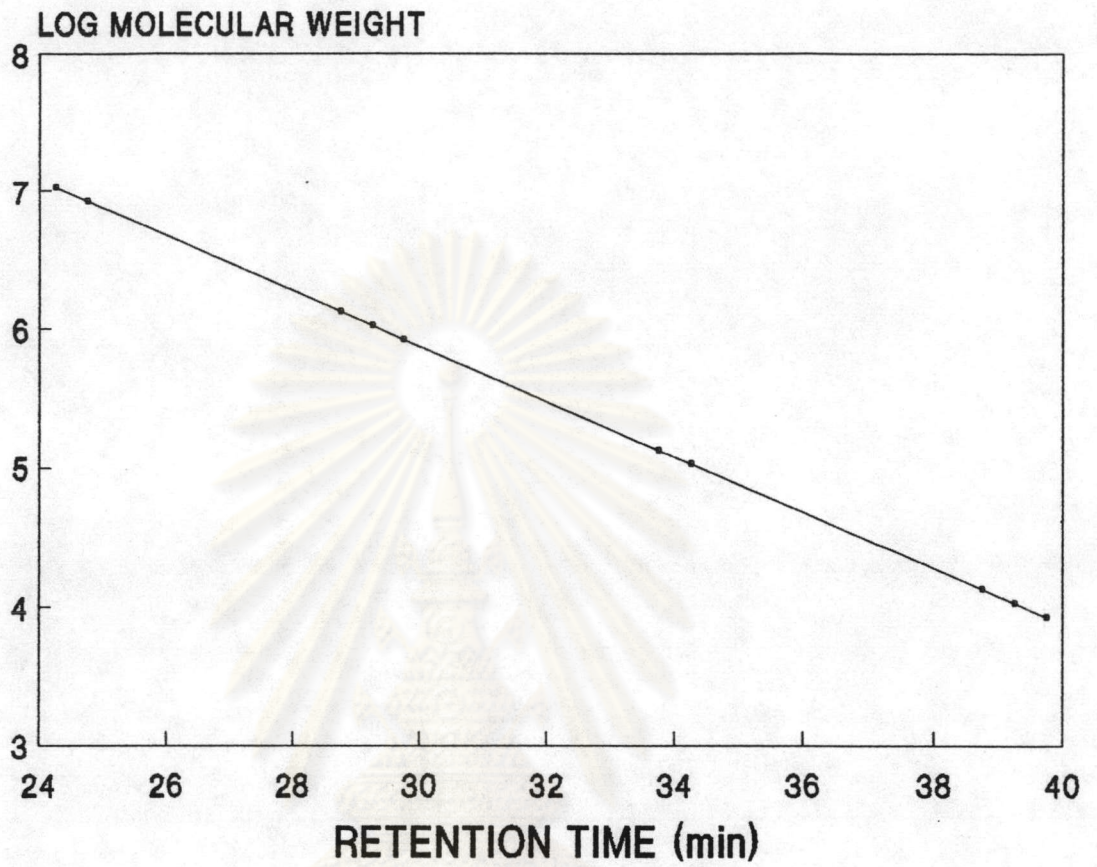
Figure A. 2.1   The molecular weight calibration curve of polystyrene standard

1.2 Test of the rubber valcanization

1.2.1 Preparation of rubber compounding

Preparation of rubber compound using sulfur as a vulcanizing agent is presently the most popular system. The compounding formulation in Table A. 2.1 was selected to prepare compounds for comparison of the cure characteristic and physical properties of CV-DPNR from each rubber clone and its control CV-rubber.

The rubber (300 g) was passed through a two-roll mill at room temperature. The homogenized rubber was added with the chemicals. The order of addition was the mixer of Hisil 233S, DEG, Shellflex and stearic acid followed by the mixer of wax, 22 CP 46 and zinc oxide, left the mixed sample until cooled and then added the mixer of MBTS, MBT, TMTM and finally sulfur. The compounding was stored at room temperature for 24 hours before cure characteristic test.

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Table A. 2.1 The compounding formulation chosen for assessing the cure characteristics behavior of natural rubber

Ingredient	Gram
Natural rubber	100.0
Hisil 233S	45.0
Zinc oxide active	3.0
22 CP 46	0.3
Wax	1.0
Stearic acid	1.2
DEG	3.5
Shellflex	1.5
Sulfur	2.0
MBTS	0.78
MBT	0.2
TMTM	0.12

Where

Hisil 233S (precipitated sillca) is reinforcing filler.

ZnO active and stearic acid are the activators of vulcanization.

MBTS (2-2 di-benzothiazyl disulfide), MBT (2-mercaptobenzothiazole), and TMMT (tetramethyl thiuram monosulfide) are accelerators of vulcanization.

22 CP 46 (2,2 methylene bis-4-methyl-6-p-butyl phenol) and wax are antioxidants.

DEG (diethylene glycol) is a depressor of sulface active absorption.

Shellflex is processing oil.

Sulfur is the crosslinking agent.

1.2.2 <u>Cure characteristic</u>

The cure characteristic of the compound rubber was run on a Rheometer model EK-100H (EEKONER, Taiwan) for 8 min at 155 ^{O}C. From the cure curve recorded (Figure A. 2.1), all the necessary reading was determined and reported.

The importance cure parameters were scorch time, cure rate, time to optimum cure and maximum modulus. Scorch time was the minimum safe time for processing the compounded rubber before the rubber was converted from a plastic to a vulcanized state where further processing is impossible. Cure rate determined the time to cure a given product to its optimum state.
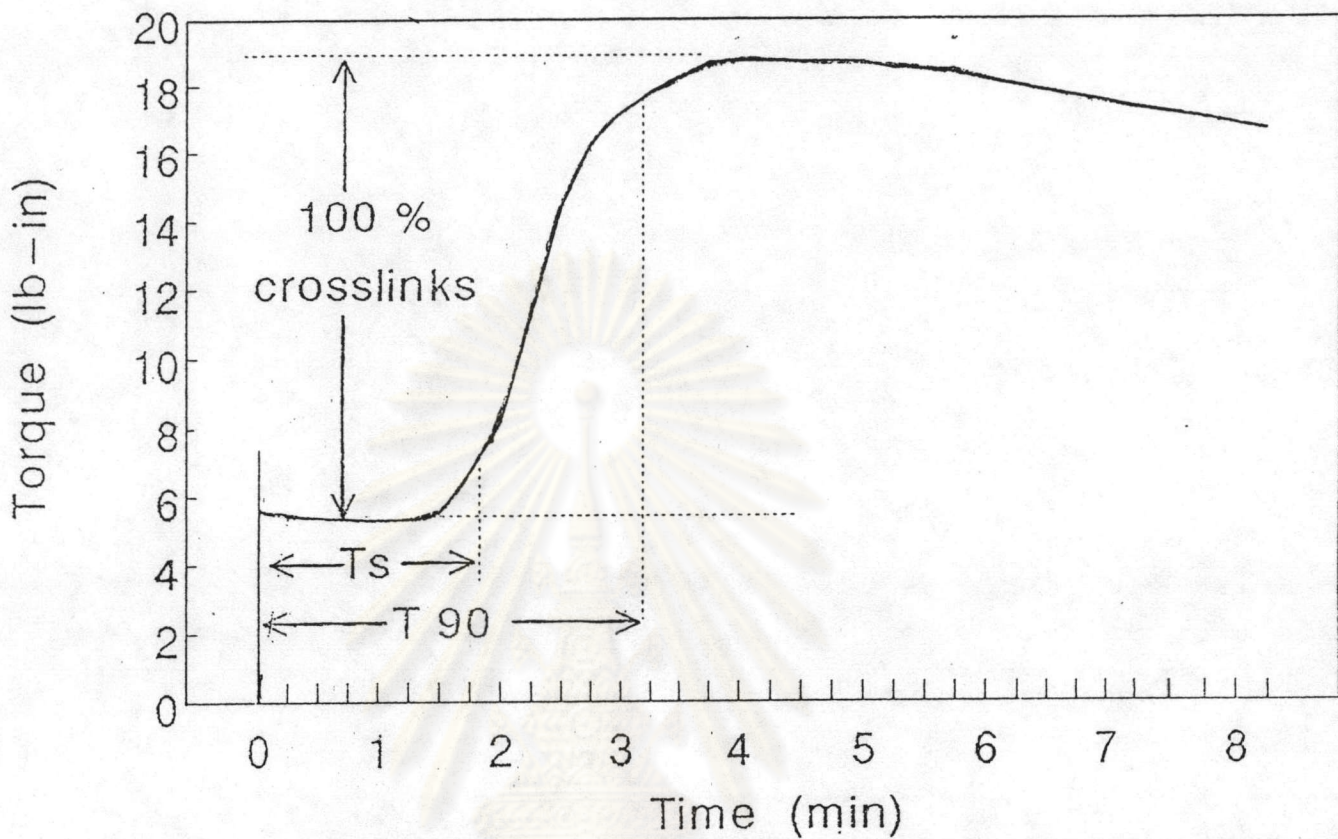
Figure A. 2.2 Rheometer curing curve.

1 = minimum viscosity or minimum modulus, M_L

2 = scorch point (1 torque unit rise above minimum viscosity),

   T_S-time

3 = maximum modulus, M_H

4 = 50 % crosslinks, T_{50}-time to 50 % crosslink

5 = optimum cure (90 % crosslinks), T_{90}-time to optimum cure

6 = cure rate, $T_{90} - T_S$

1.2.3 Test for physical properties of vulcanizates

1.2.3.1 Hardness (Shore A) (ASTM D1415, 1988)

The international hardness test is based on measurement of the penetration of a rigid ball into the rubber specimen under specified condition. The vulcanized rubber was prepared as a flat and smooth sheet having thickness sufficient to fit the gap of type A durometer. The plunger of durometer was pressed with the minor force on to the specimen, the scale was pointed and read as the hardness in shore A at room temperature. The median value of 5 different point distributed over the specimen was recorded.

1.2.3.2 Tensile strength, 300 % modulus and elongation at break (ASTM D412, 1987)

The four dumb-bell test pieces (Figure A. 2.3) were cut out from the vulcanized rubber by punching with die using a single stroke of a press. A reference of length 2.0 cm was marked and the thickness of the test pieces measured along the reference length by a micrometer dial gauge.

The two ends of the test piece were clamped into the two grips of the testing mechine. The test piece was stretched at a constant rate of moving grip of 500 ± 50 mm. The force per cross-section area of test piece required to stretch the sample to 300 % reference mark length and to breakage were automatically recorded as 300 % modulus and tensile strength (stress at break) respectively. The maximum stretching was recorded by a graph recorder and calculated as follows:

% Elongation at break = the number of graph peak X 10

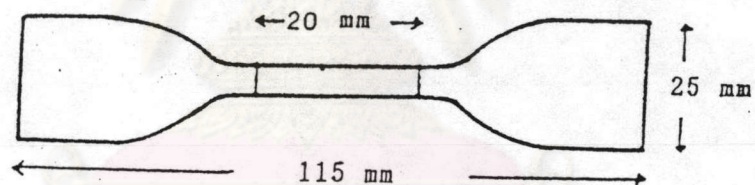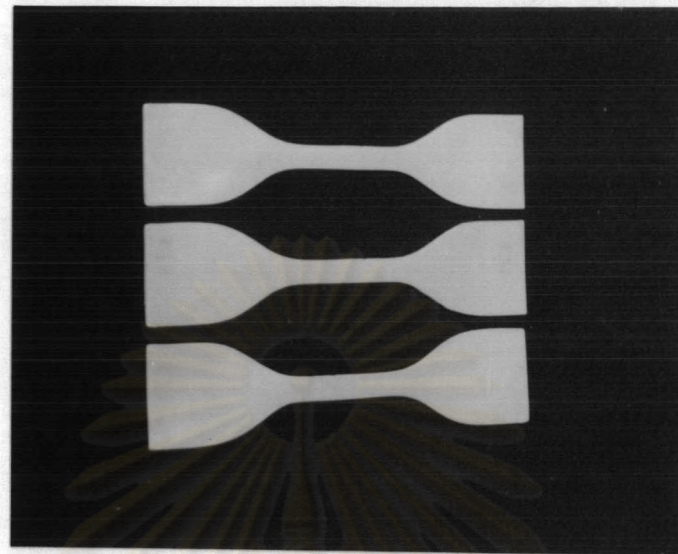Figure A. 2.3 Shape of dumb-bell test pieces

1.2.3.3 Tear strength test (ASTM D624, 1986)

The four test pieces (Figure A. 2.4) were cut out from the vulcanized rubber by punching with die using a single stroke of a press. The thickness of test pieces were measured by micrometer dial gauge and clamped into the grips of the test machine. The highest force per thickness of test piece to tear was recorded.

Figure A. 2.4 Shape of test pieces for tear strength test
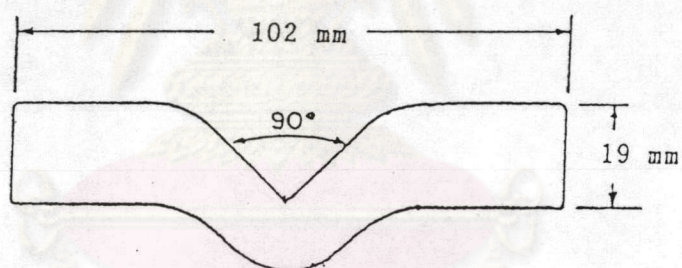
1.2.3.4 Specific gravity test

The test method was based on water replacement with test piece.
The weight of vulcanized rubber was weighed in the air and then
weighed again in the water. The specific gravity of vulcanizate was
calculated as follows:

$$\text{Specific gravity} = \frac{\text{Weight in air (g)}}{\text{Weight in air (g)} - \text{Weight in water (g)}}$$

APPENDIX 3

1. Raw rubber properties

1.1 Raw rubber properties of DPNR and its control prepared from 4 rubber clones, RRIM 600, PB 28/59, PB 5/51 and GT 1

Properties	RRIM 600		PB 28/59		PB 5/51		GT 1	
	Control CV–NR	CV–DPNR	Control CV–NR	CV–DPNR	Control CV–NR	CV–DPNR	Control CV–NR	CV–DPNR
Nitrogen content (%)	0.587 ± 0.004	0.070 ± 0.005	0.469 ± 0.131	0.056 ± 0.010	0.383 ± 0.003	0.036 ± 0.002	0.509 ± 0.003	0.094 ± 0.004
Ash content (%)	0.477 ± 0.033	0.195 ± 0.045	0.448 ± 0.137	0.205 ± 0.077	0.564 ± 0.068	0.173 ± 0.015	0.409 ± 0.039	0.261 ± 0.044
Dirt content (%)	0.023 ± 0.002	0.010 ± 0.006	0.013 ± 0.005	0.005 ± 0.002	0.042 ± 0.020	0.009 ± 0.000	0.021 ± 0.010	0.004 ± 0.001
Volatile matter (%)	0.349 ± 0.014	0.057 ± 0.028	0.525 ± 0.158	0.109 ± 0.019	0.280 ± 0.013	0.031 ± 0.006	0.454 ± 0.018	0.154 ± 0.040
P_0	34.78 ± 0.67	30.98 ± 0.86	44.54 ± 4.90	40.86 ± 2.04	66.95 ± 0.75	61.88 ± 2.45	44.65 ± 1.05	41.15 ± 0.11
PRI	89.43 ± 6.48	79.16 ± 3.33	78.14 ± 4.97	64.72 ± 2.71	77.68 ± 1.83	64.92 ± 2.47	79.88 ± 9.46	62.63 ± 1.76
ΔP	8.20 ± 0.99	2.78 ± 1.30	7.02 ± 0.59	2.87 ± 0.59	4.38 ± 0.46	1.98 ± 0.15	8.48 ± 0.33	4.55 ± 0.18
Mooney viscosity	60.48 ± 1.32	57.10 ± 1.11	68.64 ± 3.53	67.06 ± 3.21	98.63 ± 2.15	97.58 ± 0.57	78.13 ± 1.57	75.33 ± 1.52
Color	4.5 – 5	1.5 – 2	5 – 6	2.5 – 3.5	5 – 6	1.5 – 2	5 – 6	3.5 – 4

1.2 Raw rubber properties of commercial grades, TTR 5L, crepe and ribbed smoked sheet 1 (RSS 1)

Properties	TTR 5L	White–crepe	RSS 1
Nitrogen content (%)	0.146	0.394	0.532
Ash content (%)	0.197	0.161	0.208
Dirt content (%)	0.027	0.015	0.030
Volatile matter (%)	0.236	0.141	0.368
P_0	44.90	51.80	50.70
PRI	88.42	71.62	79.49
ΔP	41.00	16.50	30.70
Mooney viscosity	81.60	89.00	80.90
Color	3.5	4.5	16

2. Mooney viscosity before and after storage

2.1 Rubber from 4 clones

Time (month)	RRIM 600 CV–NR	RRIM 600 CV–DPNR	PB 28/59 CV–NR	PB 28/59 CV–DPNR	PB 5/51 CV–NR	PB 5/51 CV–DPNR	GT 1 CV–NR	GT 1 CV–DPNR
0	60.48	57.10	72.90	70.85	98.63	97.58	78.13	75.33
1								
2								
3								
4								
5								
6					104.05	103.50	82.23	75.38
7					105.10	103.90	80.80	75.50
8								
9	61.03	58.05	75.89	73.80				
10	62.20	56.60	74.70	70.40				

2.2 Commercial rubber grades

Time (month)	TTR 5L	White–crepe	RSS 1
0	81.60	89.00	80.90
1			
2			
3			
4			
5			
6			
7			
8			
9	85.60	92.60	91.80
10	86.08	92.30	92.70

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3. Cure characteristics of compound rubber

3.1 Cure characteristics of DPNR and its control from 4 rubber clones, RRIM 600, PB 28/59, PB 5/51 and GT 1

Cure Characteristics	RRIM 600		PB 28/59		PB 5/51		GT 1	
	Control CV-NR	CV-DPNR	Control CV-NR	CV-DPNR	Control CV-NR	CV-DPNR	Control CV-NR	CV-DPNR
Scorch time (min)	1.48 ± 0.06	1.64 ± 0.14	1.79 ± 0.54	2.01 ± 0.43	1.87 ± 0.06	2.14 ± 0.06	1.76 ± 0.10	2.08 ± 0.09
Cure time (min)	2.81 ± 0.22	2.48 ± 0.01	2.66 ± 0.06	2.53 ± 0.13	2.42 ± 0.05	2.71 ± 0.08	2.63 ± 0.18	2.65 ± 0.05
Torque rise (in.lb)	12.50 ± 1.61	14.05 ± 0.78	11.55 ± 3.85	10.78 ± 3.53	7.25 ± 0.34	6.20 ± 0.60	8.73 ± 1.24	6.30 ± 0.80
Cure rate (min)	1.18 ± 0.09	0.84 ± 0.14	0.88 ± 0.59	0.52 ± 0.31	0.55 ± 0.03	0.57 ± 0.02	0.87 ± 0.22	0.57 ± 0.06

3.2 Cure characteristics of commercial grades, TTR 5L, white-crepe and ribbed smoked sheet 1 (RSS 1).

Cure Characteristics	TTR 5L	White-crepe	RSS 1
Scorch time (min)	1.60	1.45	1.53
Cure time (min)	2.67	2.68	3.03
Torque rise (in.lb)	13.00	14.40	15.10
Cure rate (min)	1.07	1.23	1.50

4. Physical properties of vulcanizate rubber

4.1 Physical properties of CV—DPNR and its control from 4 rubber clones, RRIM 600, PB 28/59, PB 5/51 and GT 1

Physical Properties	RRIM 600		PB 28/59		PB 5/51		GT 1	
	Control CV—NR	CV—DPNR	Control CV—NR	CV—DPNR	Control CV—NR	CV—DPNR	Control CV—NR	CV—DPNR
Tensile strength (kg/cm^2)	140.18 $\pm$ 11.60	154.12 $\pm$ 10.21	107.32 $\pm$ 35.00	121.14 $\pm$ 42.15	107.94 $\pm$ 5.46	122.54 $\pm$ 21.25	123.66 $\pm$ 7.81	125.63 $\pm$ 6.50
Elongation at break (%)	624.50 $\pm$ 35.68	781.25 $\pm$ 7.40	675.30 $\pm$ 13.36	720.62 $\pm$ 19.08	723.48 $\pm$ 11.61	747.67 $\pm$ 29.93	720.07 $\pm$ 16.46	727.88 $\pm$ 20.68
Tear (kg/cm)	7.24 $\pm$ 1.82	9.22 $\pm$ 1.21	13.63 $\pm$ 3.94	14.34 $\pm$ 3.26	20.71 $\pm$ 2.01	27.52 $\pm$ 3.42	25.08 $\pm$ 4.92	27.42 $\pm$ 5.92
Hardness (Shore A)	65.00 $\pm$ 1.22	61.00 $\pm$ 0.71	64.60 $\pm$ 5.24	59.00 $\pm$ 2.97	57.50 $\pm$ 1.12	55.25 $\pm$ 0.83	63.75 $\pm$ 1.30	55.75 $\pm$ 0.83
300 % Modulus (kg/cm^2)	27.51 $\pm$ 1.70	20.81 $\pm$ 0.52	20.40 $\pm$ 6.09	16.95 $\pm$ 3.77	17.84 $\pm$ 0.63	15.83 $\pm$ 0.31	20.98 $\pm$ 0.85	20.93 $\pm$ 2.15
Sp gr	1.09 $\pm$ 0.05	1.13 $\pm$ 0.02	1.13 $\pm$ 0.00	1.10 $\pm$ 0.01	1.12 $\pm$ 0.00	1.11 $\pm$ 0.00	1.12 $\pm$ 0.01	1.11 $\pm$ 0.01

4.2 Physical properties of commercial grades, TTR 5L, white crepe and ribbed smoked sheet 1 (RSS 1)

Physical Properties	TTR 5L	White crepe	RSS 1
Tensile strength (kg/cm^2)	158.73	140.25	169.00
Elongation at break (%)	635.00	728.00	943.00
Tear (kg/cm)	8.18	4.46	6.98
Hardness (Shore A)	64	66	57
300 % Modulus (kg/cm^2)	331.03	26.39	28.50
Sp gr	1.13	1.16	1.13

APPENDIX 4

1.) Calculation of % nitrogen reduction at 5 min

Temperature (°C)	% N content at		% nitrogen reduction
	t = 0 min	t = 5 min	
30	0.570	0.293	48.60
35	0.560	0.236	57.93
40	0.576	0.210	63.49
45	0.566	0.200	64.60
50	0.580	0.221	61.82
55	0.566	0.267	53.97

Calculated the protein reduction in solid rubber from % nitrogen reduction by total protein = 6.25 x % N content. The weight of protein in solid rubber is very low, then we assume the total weight as weight of solid rubber.

% nitrogen reduction at 5 min

$$= \frac{(\text{nitrogen content}_{0\ min} - \text{nitrogen content}_{5\ min}) \times 100}{\text{nitrogen content}_{0\ min}}$$

At 50 °C, % nitrogen reduction at 5 min $= \dfrac{(0.580 - 0.221) \times 100}{0.580}$

$$= 61.90$$

2.) <u>Calculation of θ</u>

Speed (rpm)	Re	θ	%N reduction
57	120.28	15.33	70.28
37	772.75	42.64	79.77
50	1044.26	50.32	83.38
60	1255.11	55.63	83.07
80	1670.82	65.16	80.69
100	2088.52	73.67	79.37

* reaction : vessel of 11 cm diameter, impeller of 8.9 cm

2.1) Calculated the Reynolds Number, Re at each of speed from

$$Re = (\rho N L^2)/\mu$$

ρ = density of latex at 25 %DRC at pH 7-8

μ = viscosity of latex 25 %DRC at pH 7-8, 50 ^{O}C

N = agitator speed

L = impeller diameter

$$Re \text{ (at 50 rpm)} = \frac{(0.975 \text{ g/cm}^3)(50 \text{ rpm})(1/60 \text{ sec})(28 \text{ cm})\hat{}2}{(61 \times 10^{-2} \text{ g cm}^{-1} \text{ sec}^{-1})}$$

= 1044.26

2.2) Determine the intensity factor, θ at each speed

$$\theta = 1.1 \text{ Re}^{0.55}$$

$$\theta \text{ (at 50 rpm)} = 1.1 (1044.26)^{0.55}$$

= 50.32

VITA

Mr. Pongsatorn Koosakul was born on February 5, 1970, in Nakornphanom Province. He graduated with a Bachelor degree in Chemical Engineering from Faculty of Science, Chulalongkorn University in 1990 and continued study in Master degree at the same department.