

## ***Improving Natural Rubber Latex Film Softening due to Oil***

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*Natural rubber latex (NRL) gloves are generally accepted for their superior mechanical properties compared to synthetic gloves in many applications. However, their tolerance to polar solvents and oils is relatively poor. This study demonstrated improvement in tolerance of NR towards oils by introducing more crosslinks in NRL gloves. This was done by increasing sulphur content in the NRL latex mixture from which gloves were prepared. Evidence of better tolerance can be deduced from the much reduced mass uptake of oil into highly crosslinked NRL films and the lower diffusion rate of oil in the NRL films. The mass uptake of oil in NRL films can also be reduced by blending nitrile latex (XNBR) with NRL latex.*

**Keywords:** NR; XNBR; blends; swelling resistance; tensile strength; crosslink concentration; cooking oil

Natural rubber (NR) is a non-polar rubber that has excellent mechanical properties and barrier protection against infectious liquids and gases but relatively poor swelling resistance<sup>1</sup>. Currently, natural rubber latex gloves have entered the fast food industry where good swelling resistance is an essential requirement. NR latex gloves have poor swelling resistance and this limits their application in food containing oils and fats due to similar polarity. The swelling resistance of NRL films can be increased to a limited extent by increasing the crosslink concentrations of the NRL film<sup>1</sup> or by blending NRL with synthetic latices that have good swelling resistances. The swelling resistance can be measured based on the mass uptake of oil through the rubber material. The mass uptake can be defined as the amount

of oil absorbed in the rubber material for a certain period of time by immersing the rubber material in vegetable oils such as cooking oil<sup>2,3</sup>. The rubber generally absorbs vegetable oil slowly and reaches equilibrium absorption after about 100 days, during which time the rubber absorbs about an equal weight of oil<sup>1</sup>.

Rubber with the absorbed oil tends to be very soft, thus, it loses its physical properties such as tensile and tear strengths. The decrease in these strength properties is associated with the loosening of the cohesive bonds and low intermolecular forces between molecular chains since the rubber molecular chains are pushed apart by the oil molecules<sup>4</sup>. Thus, it is possible to limit oil absorption by

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introducing a dense network within the rubber by increasing addition of a rubber crosslinker. The other method is to blend a polar material such as carboxylated nitrile rubber (XNBR). It is a known fact that blending NR latex with XNBR latex improves some of its mechanical properties and oil resistance<sup>5</sup>. Even though blending of two different latices is a good solution to obtain a useful product with a good balance of properties, there are a few problems which may arise involving the preparation of latex such as immiscibility between the two latices<sup>5-7</sup>. Therefore, the physical structure must be characterised in order to understand the properties of the blends.

This paper describes a study of measuring the mass uptake of cooking oil absorbed into NR latex films of different crosslink concentrations and NR:XNBR latex blends and further correlates with their physical properties.

## MATERIALS AND METHODS

The NRL and XNBR latices in the study were of commercial grade latices, the types and general properties of the latices are described in *Table 1*. Toluene, potassium hydroxide and potassium laurate were of analar grades. All other materials in the study were of industrial grades as shown in *Tables 2, 3 and 4*.

### Preparation of NR Latex and NR Latex Blend Compounds

NRL films were prepared from latex compounds with varying amounts of sulphur as shown in *Table 2*<sup>8</sup>. The compounded latex mixtures were diluted to 40% total solid content and stirred for one hour. The compound was left to mature for at least 24 h at room temperature (28°C). After maturation, the latex compound was stirred for at least one

hour and allowed to stand at room temperature for at least one hour before the dipping process. Latex films were prepared from the NRL latex mixtures.

The blends of NR:XNBR were prepared at 80:20, 20:80 and 50:50 ratios. First, the XNBR latex was compounded with 0.5 p.p.h.r. zinc oxide (ZnO) and adjusted to pH 10 with 10% potassium hydroxide (KOH) before blending with the natural rubber latex compound. The NRL compound was prepared by adding ingredients as shown in *Table 3*. The NR compound was prepared separately by adding ingredients with two different sulphur contents (1.5 p.p.h.r. and 2.0 p.p.h.r.) as shown in *Table 4*. The NR and XNBR compounds were then allowed to stand overnight separately at ambient temperature before blending. Following that, the XNBR latex compound was slowly added into the NR compound. The NR:XNBR latex blend was stirred for half an hour and allowed to stand for at least one hour to ensure that there was no formation of trapped air bubbles. The NR:XNBR latex blends were prepared with 1.5 p.p.h.r. and 2.0 p.p.h.r. sulphur content.

### Preparation of NR Latex and NR Latex Blend Films

Clean ceramic plates were dried in the oven at 70°C for 30 minutes. The plates were then immersed into 30% calcium nitrate coagulant solution. The coated ceramic plates were dried in the oven at 70°C for 13 minutes. After that, the warmed coated ceramic plates were dipped in the latex blend (NR: XNBR) for a dwell time of 20 s and dried in the oven at 70°C for 5 minutes. The NR: XNBR films were leached in distilled water at a temperature of 60°C for 3 minutes. Later, the NR: XNBR films were dried in the oven at 80°C followed by 100°C and 110°C for 10 min each. The NR: XNBR films were dried and cured at two different

TABLE 1. TOTAL SOLIDS CONTENT, DRY RUBBER CONTENT, pH AND MST IN NR AND XNBR LATICES

Types of latex	Total solid content(%)	Dry rubber content (%)	pH	Mechanical stability time (s)
High ammoniated (HA) natural rubber	61.45	59.95	10.7	1380
XNBR (46% acrylonitrile)	44.90	45.00	8.2	1800

TABLE 2. FORMULATION FOR NR LATEX COMPOUNDS

Ingredients	Parts per hundred rubber (p.p.h.r.)						
	0.2	0.6	1.0	1.5	2.0	2.5	3.0
60% HA latex concentrate	100	100	100	100	100	100	100
50% Sulphur dispersion	0.2	0.6	1.0	1.5	2.0	2.5	3.0
50% Zinc dibutyl dithiocarbamate (ZDBC)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
50% Zinc oxide (ZnO)	0.2	0.2	0.2	0.2	0.2	0.2	0.2

TABLE 3. FORMULATION FOR XNBR COMPOUNDING BEFORE BLENDING WITH NR LATEX

Ingredients	Parts per hundred rubber (p.p.h.r.)
46% Carboxylated nitrile	100
50% Zinc oxide (ZnO)	0.5
10% Potassium hydroxide (KOH)	0.1

temperatures sequentially to ensure that all the water in the latex blend films diffused from the surface of the films slowly as well as to avoid the formation of blisters on the films. Cornstarch was applied on the blend films to ease stripping and prevent sticking.

#### Measurement of Crosslink Concentration of NR Latex Film by Equilibrium Volume Swelling Method

The measurement of crosslink concentration of NR latex films at different crosslink concentrations (0.2 p.p.h.r. to 3.0 p.p.h.r.) were determined and calculated based on Flory-Rehner equilibrium swelling<sup>9,10</sup>.

#### Measurement of Glass Transition Temperature ( $T_g$ )

The  $T_g$  of all the films including those soaked in cooking oil was evaluated using a Differential Scanning Calorimeter (DSC) according to the *ASTM D3418* test method<sup>11</sup>.

#### Measurement of Oil Uptake of NR Latex and NR Latex Blend Films

Circular shaped samples with a diameter of 23 mm were cut from the latex film and the thickness of the samples was measured with an accuracy of  $\pm 0.01$  mm. The initial weight of the cut sample was recorded before

TABLE 4. FORMULATION FOR NR LATEX COMPOUNDS AT 1.5 P.P.H.R. AND 2.0 P.P.H.R. SULPHUR CONTENT BEFORE BLENDING WITH XNBR LATEX

Ingredients	Parts per hundred rubber (p.p.h.r.)	
	1.5	2.0
60% NR latex	100	100
10% KOH	0.1	0.1
20% Potassium laurate	0.5	0.5
50% Sulphur	1.5	2.0
50% ZBDC	1.0	1.0
50% ZnO	0.5	0.5
50% Wingstay L <sup>®</sup>	0.5	0.5

immersing the cut samples into the swelling agent (palm oil) under room conditions. The oil swollen sample was blotted with filter paper to remove the excess oil on the surface and edges of the sample. Then the sample was re-weighed and re-immersed into cooking oil. The procedure was continued until there was minimal increase in weight. The results of these experiments were expressed as mass uptake of oil per unit area of the sample, ( $\text{g mm}^{-2}$ ) and calculated based on *Equation 1*.

$$\text{Mass uptake} = \frac{W_1 - W_0}{A_o} (\text{g mm}^{-2}) \quad \dots 1$$

$W_0$  and  $W_1$  are the weights of the sample before and after swelling, respectively.  $A_o$  is the surface area of the sample.

The diffusion coefficient,  $D$  of cooking oil through latex films were evaluated from the mass uptake against the square root of time. The diffusion coefficient is calculated according to the *Equation 2* below:

$$\frac{M_t}{M_\infty} = \frac{2}{l} (D.t/\pi)^{1/2} \quad \dots 2$$

Where,  $M_\infty$  is the amount of oil absorbed at infinite time,  $M_t$  is the total amount of oil which has crossed a unit area of the boundary interface at time  $t$  and  $l$  is half the thickness of

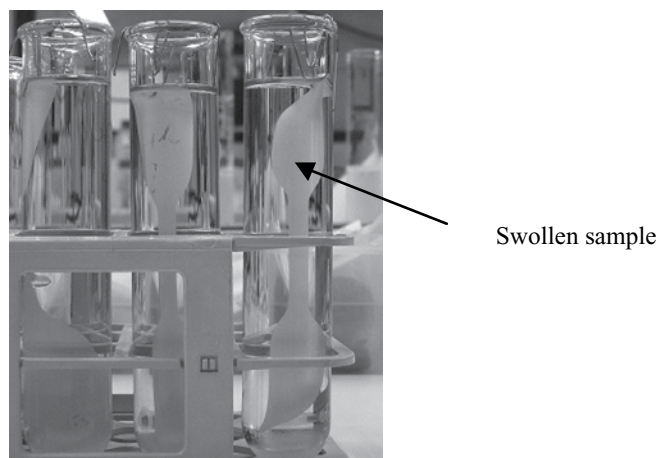
the film sample. The diffusion coefficient,  $D$  can be obtained from the initial slope of the graph of  $M_t$  against the square root of time together with the equilibrium concentration of oil in rubber<sup>9,10</sup>.

### Tensile Properties

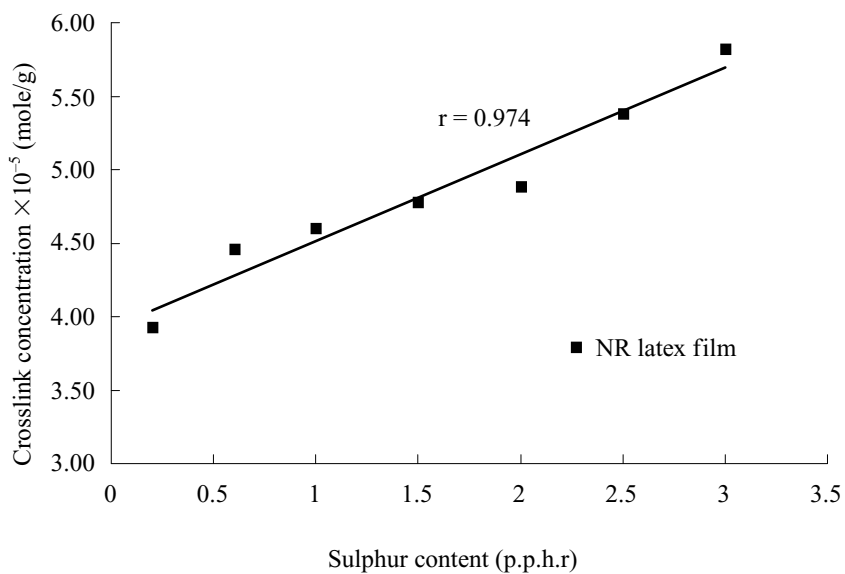
Tensile strength test samples were prepared by punching dumbbell-shaped test specimens out of the latex films. The test sample was immersed in a glass tube containing 70 mL of cooking oil for three days as shown in *Figure 1*. The tensile properties were measured by using the Instron tensile machine with a crosshead speed of 500 mm/min according to *ASTM D 412*<sup>12</sup>.

## RESULTS AND DISCUSSION

The crosslink concentration of NR latex films at different sulphur contents was evaluated by the equilibrium volume swelling method<sup>9,10</sup>. The correlation between the sulphur content and crosslink concentration is investigated because the number of crosslinks depend on the quantity of sulphur in the natural rubber compound. The correlation,  $r = 0.974$  as shown in *Figure 2* indicated a good correlation between the crosslink



*Figure 1. NRL films in cooking oil.*



*Figure 2. The crosslink concentration of NR latex films at different sulphur content.*

TABLE 5. EFFECTS OF CROSSLINK CONCENTRATIONS ON  $T_g$  OF NR LATEX FILMS

Crosslink concentration, $\times 10^{-5}$ , (mole/g)	$T_g$ ( $^{\circ}\text{C}$ )	
	Normal	Oil Swollen
3.93	-71.1	-69.6
4.46	-66.4	-70.0
4.60	-65.4	-70.0
4.78	-64.1	-69.3
4.89	-64.1	-66.6
5.38	-63.5	-66.0
5.82	-62.1	-66.5

concentration and sulphur content. Therefore, crosslink concentration increases with increasing sulphur content.

The behaviour of the glass transition temperature of the latex films suggests that the increase in crosslink concentration affected the mobility of the rubber molecules. Therefore, as the crosslink concentration increased the  $T_g$  also increased since the crosslink imposed restrictions on the molecular mobility of rubber molecules which is important in diffusion controlled processes such as swelling. The  $T_g$  of normal and oil swollen NR latex films at various crosslink concentrations are given in *Table 5*.

The  $T_g$  increased by about 20% when crosslink concentration was increased from  $3.93 \times 10^{-5}$  to  $5.82 \times 10^{-5}$  (mole/g). The result is in accordance with the theory that  $T_g$  increases with the increasing crosslink concentration, thus restricting molecular mobility<sup>13</sup>. A similar trend was observed for oil swollen NR latex films. However,  $T_g$  values of oil swollen samples were lower as compared to normal samples. The oil acts as a plasticiser to the latex films and lowers the  $T_g$  by creating free volume and enhancing the molecular mobility.

The value of  $T_g$  is important in rubber blends because it reflects the degree of compatibility between the two different polymers. A single  $T_g$  value is expected for two completely miscible polymers. The  $T_g$  of a polymer is influenced by the main backbone, chain flexibility, side group, polarity and steric hindrance. In the case of XNBR, the factors affecting  $T_g$  are polarity and the side group acrylonitrile (ACN). The higher the acrylonitrile content, the higher the polar attraction and the greater the hindrance to molecular mobility imposed by the side of acrylonitrile group. The  $T_g$  of normal latex samples increased as the XNBR content increased (as shown in *Table 6*), and the samples exhibited a single  $T_g$  which indicates that the blends were compatible with each other. However, the  $T_g$  value was not somewhere in between the two values of NR or XNBR. This is probably due to the higher percentage of NR in the blend, whereby, latex films with NR and XNBR were more flexible than XNBR with a decreased  $T_g$  value approaching that of NR. Oil swollen latex films of NR and XNBR produced two  $T_g$  values (*Table 6*), one value was nearing the  $T_g$  value of NR, while the second  $T_g$  value was towards the XNBR. This may be due to phase separation that occurred after exposure

TABLE 6. EFFECTS OF BLEND RATIOS ON  $T_g$  OF LATEX FILMS AT TWO DIFFERENT SULPHUR CONTENTS

Sulphur Content (p.p.h.r.)	(NR: XNBR) Blend ratio	Glass transition temperature ( $T_g$ ) (°C)		
		Normal	Oil Swollen	
			Value 1	Value 2
1.5	0:100	-21.5	Nil	-29.1
	20:80	-29.6	-70.7	-31.2
	50:50	-68.0	-68.8	-24.6
	80:20	-65.3	-67.8	-19.9
	100:0	-64.5	-69.3	Nil
2.0	0:100	-24.6	Nil	-27.7
	20:80	-30.9	-68.8	-30.7
	50:50	-67.0	-68.7	-25.4
	80:20	-64.3	-68.0	-24.5
	100:0	-64.1	-66.6	Nil

to oil. The swelling effect caused the rubber molecules to be pushed further apart.

The results of mass uptake of cooking oil into latex films are shown in *Figure 3*. NRL films of high estimated crosslink concentration tended to absorb less oil than those latex films of lower estimated crosslink concentration. The mass uptake of oil into the film increased progressively with time, until equilibrium was reached. In the study, the NRL films prepared from higher sulphur content were expected to be of higher crosslink concentration due to higher sulphur levels added to the films. Although the mass uptake of oil into NRL films can be reduced by increasing the crosslink formation in the films, increase in crosslink concentration generally contributes to stiffer films. Thus, a compromise between the stiffness for product application and oil resistivity should be the focus in producing NRL products of low oil absorbability. The dense network attributed to the formation of crosslinks which retarded the oil diffusion rate into the rubber matrix as the space and route for the oil between rubber molecules were limited with the reduction in

mobility of the rubber chains. Thus, highly crosslinked NRL films contained less oil to plasticise the rubber matrix and the NRL films remained intact during its application. It was found that the equilibrium state was achieved after about 22 h exposure to the cooking oil, as shown in *Figure 3*, when it was expected that the rubber matrix in the NRL films was highly saturated with oil, thus unable to accommodate excess oil from the surroundings.

Knowing that the extent of crosslinking governs the rate of oil diffusion into NRL films, it is interesting to further study the diffusion rate of NRL films at similar crosslink concentrations, with addition of XNBR. Maintaining the sulphur content at 1.5 p.p.h.r. in the NRL, several films that were prepared from different blending ratios of NRL and XNBR latex mixtures showed increased improvements in reduction in the mass uptake of oil (*Figure 4*). XNBR is a polar material, thus was expected to resist the oil much better than NR. It was interesting to note that the percent reduction in the equilibrium mass uptake of oil of these films

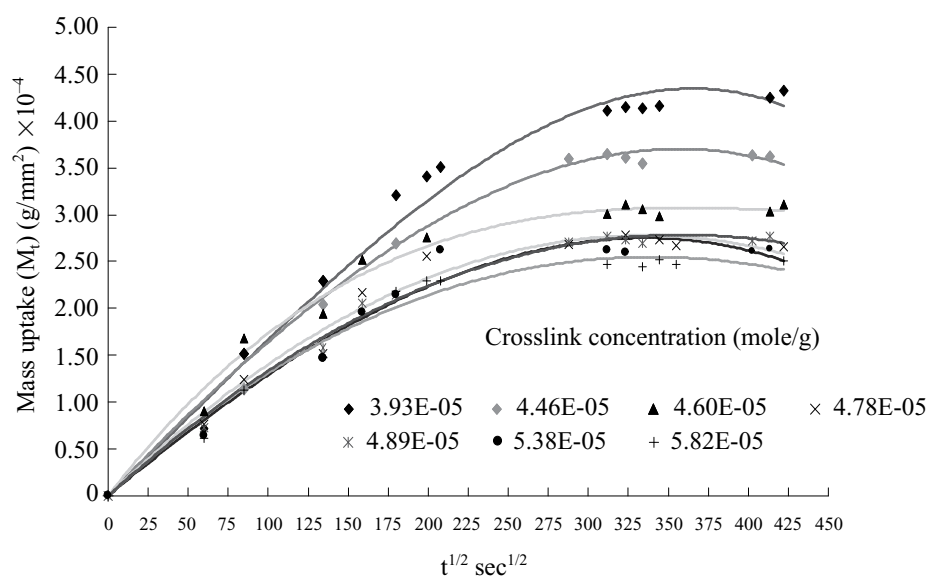


Figure 3. Mass uptake of cooking oil into NRL films.

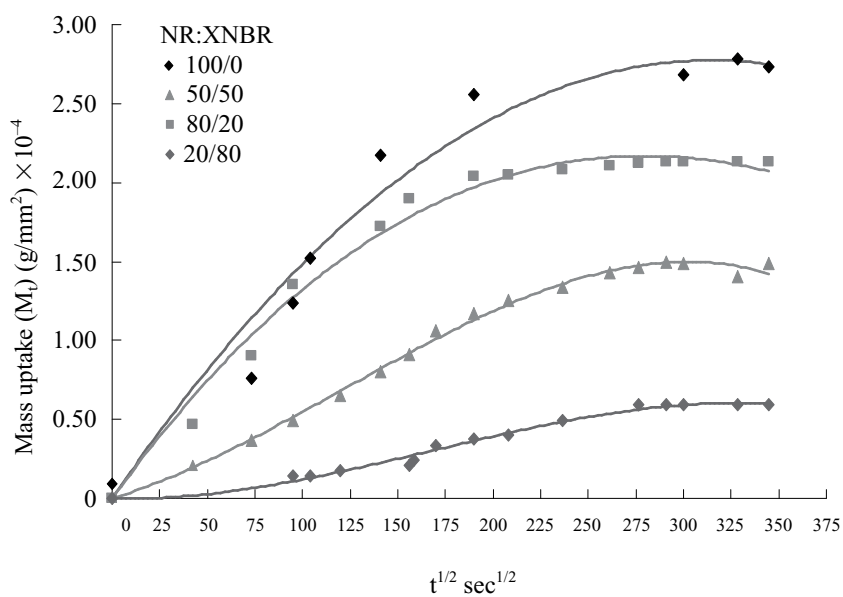


Figure 4. Mass uptake of oil into films prepared by blending NR and XNBR at 1.5 p.p.h.r. sulphur content.



was almost proportionate to the XNBR ratio; of about 22% for 80:20 (NR:XNBR), 45% for 50:50 (NR:XNBR) and 78% for 20:80 (NR:XNBR).

As seen in *Figure 3*, although the effect of sulphur content on swelling behaviour depends on the role of crosslinks in NRL, it was equally important in reducing the oil sensitivity of latex films. Our study, however, is contrasting the results indicated in *Figure 4* that the swelling behaviour also depends on the NR: XNBR ratio. Results for 50:50 blends of NR: XNBR as shown in *Figure 5* showed that the mass uptake of oil was comparable after short exposure duration, but upon longer exposure the blend with low sulphur content absorbed less oil. The trend was seen for the 80:20 NR to XNBR blends (*Figure 6*).

This is an unexpected finding since one would expect a high sulphur content to produce a higher crosslink concentration than low sulphur content and consequently resist the oil better. The same plots were repeated but on samples with lower NR content of 20 parts to 80 parts of XNBR. In these plots (*Figure 7*), the expected results due to the crosslinks were realised. Compared with the previous plots, the mass uptake of oil started immediately after exposure and increased at a different rate due to their crosslink concentrations until equilibrium where the film with lower sulphur content absorbed more oil than the higher one.

The obvious conclusion from these plots is that the polarity of the material is the foremost factor in reducing the oil resistivity and the network formation in the films is a secondary contributor to limit the mass uptake of oil in the latex film. This gives an advantage to a polar polymer as a good oil resistant material. However, the application needs high elasticity and does not require lengthy exposure to oil. Non-polar polymers such as NR with adequate

crosslink network may be a possible substitute. The diffusion coefficient ( $D$ ) calculated for the NRL and blended latex films are given in *Figure 8* and tabulated in *Table 7*, respectively. Consistent with the earlier results, NRL with highly crosslinked networks allowed less oil to diffuse through the films, thus low  $D$  values were calculated, supporting the restriction theory that high network density reduces oil uptake into these films. In the blend films, the content of XNBR determines the  $D$  values with high  $D$  for increased XNBR content.

It is well established that tensile strength is strongly dependent upon the crosslink concentration and it is also affected by other factors such as the amount of orientated crystallinity in the vulcanised stretched rubber. It can be seen that the tensile strength increases progressively up to  $4.6 \times 10^{-5}$  mole crosslinks per gram<sup>14</sup>. At a low crosslink concentration, the number of chain segments is low and thus unable to support high tensile force. It is easier for the rubber to react to deformation stress by viscous flow than by crystallisation. The stress is dissipated before it is sufficiently high to effect reorientation and crystallisation. As more crosslinks are introduced and crosslink concentration increases, the network can support large stresses and viscous flow is no longer feasible<sup>15</sup>. Consequently, the chain molecules are reoriented to affect crystallisation which enhances tensile strength. Subsequently, at crosslink concentration values greater than  $4.6 \times 10^{-5}$  mole crosslinks per gram, tensile strength begins to decrease with increasing crosslink concentration. This is due to the shortening of chain segments and tightening of the network which imposes restrictions on the reorientation of molecules. Consequently, the degree of crystallinity reduces and hence tensile strength decreases.

However, for oil swollen samples, the tensile strength of NRL films is gradually

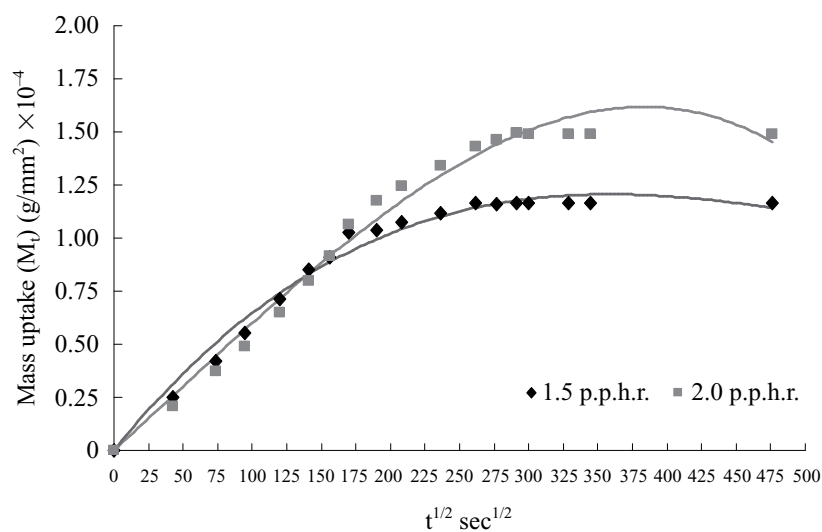


Figure 5. Effect of sulphur content in NRL films on the mass uptake of oil into blended latex film (50 NR: 50 XNBR).

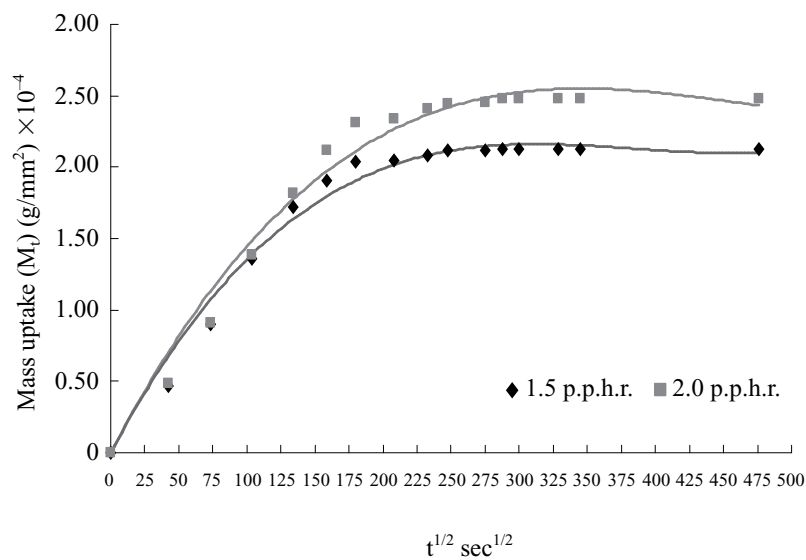


Figure 6. Effect of sulphur content in NRL on the mass uptake of oil into blended latex film (80 NR: 20 XNBR).

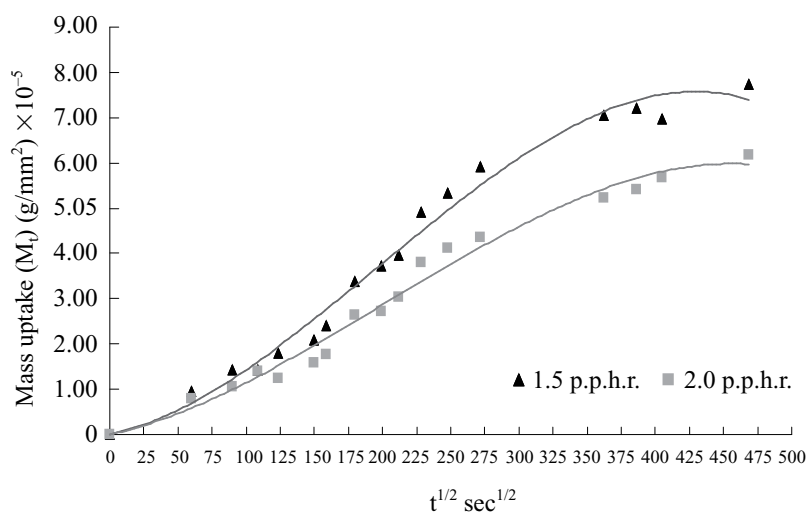


Figure 7. Effect of sulphur content in NRL on the mass uptake of oil into blended latex film (20 NR: 80 XNBR).

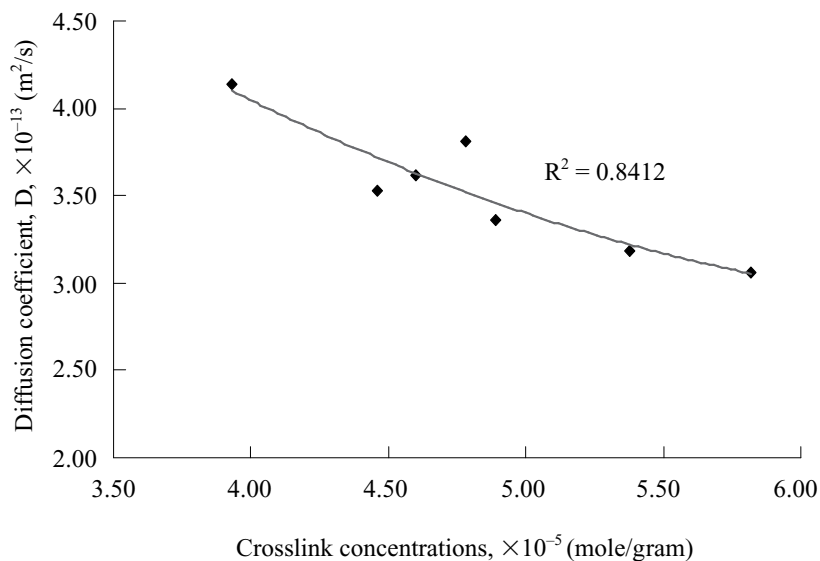


Figure 8. Effect of crosslink concentration on the diffusion coefficient of NRL films.

TABLE 7. DIFFUSION COEFFICIENT OF BLENDED LATEX FILMS  
(SULPHUR AT 1.5 P.P.H.R. AND 2.0 P.P.H.R.)

Sulphur content (p.p.h.r.)	NR:XNBR blends ratio	$(M_t/t^{1/2})$ $(\text{g/mm}^2 \text{ s}^{1/2}) \times 10^{-6}$	Diffusion coefficient, $D (\text{m}^2/\text{s}) \times 10^{-13}$
1.5	80:20	1.19	2.98
	50:50	0.61	1.10
	20:80	0.23	0.95
2.0	80:20	1.33	3.21
	50:50	0.60	1.96
	20:80	0.18	0.89

decreased after  $5.62 \times 10^{-5}$  mole crosslinks per gram because of the swelling effect by the oil. The effect of swelling was to reduce the tensile strength by reducing the hysteresis (energy dissipation). Besides that, swelling will increase the intermolecular distance thus reducing the molecular forces and consequently lowering the strength.

In the case of tensile strength of NR:XNBR latex blend films, the tensile strengths for NR:XNBR containing 1.5 p.p.h.r. and 2.0 p.p.h.r. show a same pattern for normal and oil swollen samples. Therefore, the discussion will concentrate on NR:XNBR containing 1.5 p.p.h.r. sulphur content only (*Figure 9*). There is a general trend where the tensile strength of rubber blend decreases as the NR component decreases to 50%. Beyond 50%, the tensile strength increases again. There are few factors affecting the tensile strength of NR: XNBR blend<sup>5,16,17</sup> such as:

- Extent of strain-crystallisation
- Energy dissipation (hysteresis) influenced by the  $T_g$  of the material
- Crosslink distribution between the two rubber phases
- Crosslinking at the interface of the two rubber components

The variations of the tensile strength as a function of blend ratios can be explained in

terms of the four factors mentioned. In the case of a normal sample, tensile strength is very high because of the strain-crystallisation effect. The crystals act as reinforcing fillers and increase the hysteresis of the rubber while enhancing tensile strength. However, for oil swollen samples, the tensile strength decreased by a factor of 4, due to poor swelling resistance of NR. When NR is swollen, the interaction forces between the molecules are lower than in the normal sample. In the oil swollen sample, strain-crystallisation cannot take place because the sample broke at a low strain level before reaching the critical strain for reorientation to align the molecules into a regular pattern to cause strain-crystallisation to take place.

In the case of XNBR, the high tensile strength is associated with high hysteresis associated with its high  $T_g$  ( $-21.5^\circ\text{C}$ ). The high percentage (71%) retention of XNBR latex film after exposure to cooking oil is associated with its very high swelling resistance due to its acrylonitrile content.

But when the two rubbers are blended, the crosslink distribution between the two rubber phases and crosslinking at the interface of the two rubber components are involved. Sulphur prefers to go into the NBR phase because of the polar nature of sulphur and NBR<sup>17,18</sup>. The results shown in *Figure 9* indicate that when

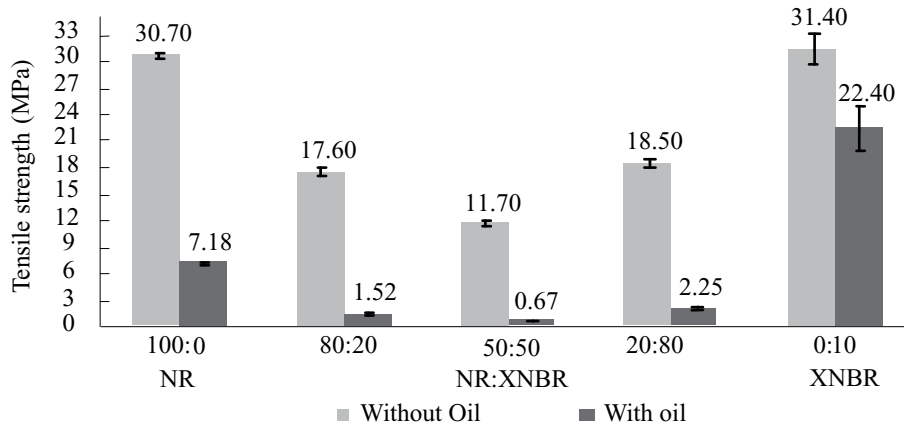


Figure 9. Effect of XNBR content of the tensile strength values of blended latex films at 1.5 p.p.h.r. sulphur content.

TABLE 8. TENSILE PROPERTIES OF NR LATEX FILMS

Crosslink concentration, (mole/g) $\times 10^{-5}$	*Tensile strength MPa		*Modulus at 100MPa		*Elongation at break (%)	
	Normal	Oil swollen sample	Normal	Oil swollen sample	Normal	Oil swollen sample
3.93	21.9	2.60	0.55	0.25	1010	590
4.46	28.6	5.80	0.60	0.39	1022	656
4.60	30.7	6.30	0.63	0.46	1030	650
5.62	30.7	7.10	0.67	0.48	980	650
4.89	28.9	6.60	0.62	0.51	1040	668
5.38	28.1	3.20	0.70	0.56	940	510
5.82	25.1	0.01	0.72	0.55	930	398

\* Values are mean of five samples

the NR phase is lower than the XNBR phase, the tensile strength decreases. The decrease in tensile strength might be attributed to the inability of the NR phase to strain crystallise to its fullest because the crosslink concentration is too low to support high stresses to cause reorientation and molecular alignment necessary for crystallisation. The lower crosslink concentration in the NR phase is also responsible for the low tensile strength of the

oil swollen sample. The NR phase is highly swollen because of its non-polar nature as well as its low crosslink concentration. Thus, the highly swollen NR phase provides sites for failure initiation. As the XNBR content increases to more than 50%, tensile strength increases again since the NR component which acts as failure initiation is outweighed by high polarity of XNBR to reduce swelling. The tensile strength increases again at 20:80 (NR:

XNBR). High  $T_g$  increases tensile strength by providing viscoelastic energy dissipation so that more energy or work input is required to rupture the molecular chains. The high retention of tensile strength of 20:80 NR: XNBR is associated with the higher polarity of XNBR which reduced swelling. The low mass uptake of oil helps to retain high tensile strength.

## CONCLUSION

The swelling resistance of NR latex films improved with increasing crosslink concentrations and the mass uptake of oil is more at low crosslink concentrations than at high crosslink concentrations. Thus, the swelling resistance can be increased by increasing the crosslink concentration and high numbers of crosslink at high crosslink concentrations restrict the diffusion of liquid into rubber by a physical barrier. Apart from crosslink concentration, improvement in the swelling resistance of NR latex can also be achieved by blending NR latex with polar latices such as XNBR. The swelling resistance of NR latex improved substantially. The improvement is associated with the increase in polarity attributed to the acrylonitrile (ACN) group. The swelling resistance increased with increasing XNBR ratio in the blend. Therefore, blending NR with XNBR might be an efficient method of improving the swelling resistance of NR latex. The tensile strength is affected by crosslink concentration. In the case of normal NRL films, tensile strength attained a maximum value at an optimum crosslink concentration. Considering the cost reduction and swelling resistance, the optimum acceptability of physical properties is concluded to be at 20:80 with 1.5 p.p.h.r. sulphur content and blending NR with XNBR is the effective method to enhance swelling resistance of NRL films because it is more effective than increasing crosslink

concentration. In the case of NR:XNBR blends at 50:50 and 80:20 ratios, it was found that the mass uptake of oil was less at 1.5 p.p.h.r. sulphur content as compared to 2.0 p.p.h.r. sulphur content.

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