

Factory Production of Examination Gloves from Low Protein Latex

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Low protein latex (LOPROL) developed at the RRIM has been found to be suitable for factory scale production of examination gloves. Both prevulcanised and post vulcanised formulations can give satisfactory tensile properties; the latter requiring modifications of the formulations and compounding techniques. A post vulcanised formulation was used in the factory run. Unaged tensile strength of these gloves was in the region of 25 MPa – 27 MPa and a retention of more than 90% was obtained when they were aged at 70°C for 7 days and 100°C for 1 day.

Although the mechanical stability time of LOPROL has been reported to be lower than 650 s, continuous stirring of a compounded LOPROL caused a marginal increase in coagulum content after 7 days compared with HA latex treated in the same manner.

Short on-line wet leaching time of about 1 min gave soluble protein contents of the LOPROL gloves to be < 0.1 mg/g film. When these were dry leached for 30 s, the soluble protein contents further decreased to between 0.03 mg/g – 0.06 mg/g film.

Low protein latex is produced by enzyme deproteinisation of natural rubber latex. The properties of LOPROL (*Table 1*) was described in a previous paper¹.

It was reported then that with low accelerator levels, post-vulcanised LOPROL gave very low tensile properties. These properties have since been improved by modifications of the formulation and compounding technique and are now above international regulatory requirements.

In the case of prevulcanised LOPROL, very little problems were, however, encountered. Satisfactory tensile properties were easily achieved even with low accelerator sulphur systems.

This paper describes a factory trial production of examination gloves from

LOPROL undertaken at Sime Latex Products Sdn. Bhd. in Seremban.

PRODUCTION AND MANUFACTURING PROCESSES

Production of LOPROL

High ammonia LOPROL concentrate was produced at the Latex processing factory of the Rubber Research Institute of Malaysia (Experiment Station), Sungai Buloh. It was stored in 205 kg drums which were transported to the glove factory.

Compounding

The LOPROL compound for the factory trial was prepared using *Formulation B* of *Table 2*. The other two *Formulations (A and C)* were experimented only in the laboratory.

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TABLE 1. LATEX PROPERTIES

Properties	LOPROL	HA	ISO 2004
TSC (%)	63.0–65.0	61.0–62.0	61.5
DRC (%)	61.0–62.0	60.0–61.0	60.0
NRS (%)	2.0–3.0	0.5–2.0	2.0
pH	10–11	10–11	–
NH ₄ (%)	0.6–0.8	0.6–0.8	0.6
VFA(%)	0.01	0.01–0.02	<0.02
KOH (%)	0.3–0.4	0.6–0.7	0.6
Ash (%)	0.2–0.3	0.4–0.5	–
N ₂ (%)	0.06–0.10	0.34–0.5	–
Ace.Ext. (%)	2.5–3.0	3.0–4.0	–
Coag. (%)	0.001	0.001	0.05
Sludge (%)	0.003	0.015	0.10
P (%)	0.02	0.04	–
Mg (p.p.m.)	5–15	5–20	–
Mn (p.p.m.)	Nil – <1	<1	8
Cu (p.p.m.)	Nil – <1	3	8
Fe (p.p.m.)	3–4	5–10	–
Zn (p.p.m.)	Low	High	–
MST (se)	<650	>650	>650

TABLE 2. EXAMPLES OF LOPROL FORMULATIONS

Formulation	Dry weights/kg		
	A	B	C
62% LOPROL	100	100	100
10% KOH	0.3	0.3	0.3
20% K. laurate	0.3	0.15	0.3
25% Non-ionic	–	0.12	–
50% Sulphur	0.7	0.7	0.7
50% ZDEC	0.4	0.4	–
33.33% ZBUD	0.3	0.3	0.3
50% ZMBT	0.2	0.2	–
50% ZnO	0.5	0.5	0.5
50% Antioxidant	1.0	1.0	1.0

Formulations A and B are examples of postvulcanisable compounds and *Formulation C* for pre-vulcanised LOPROL.

The compound to be used in the trial was diluted to 45% total solids content before being matured for three days. The maturation step is necessary as it improves the tensile properties of LOPROL films. The longer the maturation time, the better are the tensile properties (see *Table 8*).

As it is anticipated that the MST of LOPROL will be lower and its development slower than in the case of normal centrifuged latex concentrate, a laboratory experiment that subjected the latices to continuous stirring of not more than 40 r.p.m. at room temperature was carried out to compare their stability against mechanical shear forces.

Results obtained (*Table 4*) show that the coagulum contents of LOPROL were comparable to those of the control HA latex concentrate, albeit slightly higher. Nonetheless, every precaution was taken during the trial to prevent destabilisation of LOPROL caused by mechanical agitation. The maximum time that the latex was stirred continuously was restricted to 30 min for every 24 h of maturation.

Coagulant Mixture and Wet Powder Slurry

Dry coacervant dipping based on freshly prepared calcium nitrate in water was used. The effect of varying the concentration of the coagulant on the thickness of LOPROL films

TABLE 3. EFFECT OF CONCENTRATION OF CALCIUM NITRATE ON THE THICKNESS OF EXAMINATION GLOVES

Concentration (%)	Thickness of palm (mm)
12	0.25-0.29
10	0.23-0.26
9	0.20-0.23
7	0.15-0.18

is shown in *Table 3*. As expected, increasing the coagulant concentration from 7 to 12 % resulted in > 60% increase in film thickness.

TABLE 4. EFFECT OF CONTINUOUS STIRRING OF LOPROL AND HA LATEX

Time (h)	Coagulum contents (%)	
	LOPROL ^a	HA Latex
0	0.003, 0.004	0.001, 0.001
24	0.003, 0.004	0.002, 0.002
48	0.003, 0.003	0.003, 0.002
96	0.003, 0.003	0.002, 0.003
120	0.004, 0.003	0.002, 0.003
144	0.004, 0.004	0.002, 0.002
168	0.007, 0.008	0.004, 0.004

^aRaw LOPROL (storage age of 16 months)
Coagulum content - 0.003%

As popularly practised, the wet powder slurry (freshly prepared) was made of bioabsorbable corn starch in water.

Dipping

Production of examination gloves was carried out on a typical line as shown in *Figure 1* using large sized unglazed formers.

LOPROL compound in the maturation tank was agitated for several minutes, filtered and placed in the dipping tank. It was continuously stirred once dipping was in progress.

Several factors have been found vital for successful dipping. They are namely:

- Keeping the temperature of LOPROL compound in the latex dip tank below 28°C. An efficient chiller is therefore essential
- Ensure thorough drying of the coagulant coated formers lest contamination of the latex tank occurs

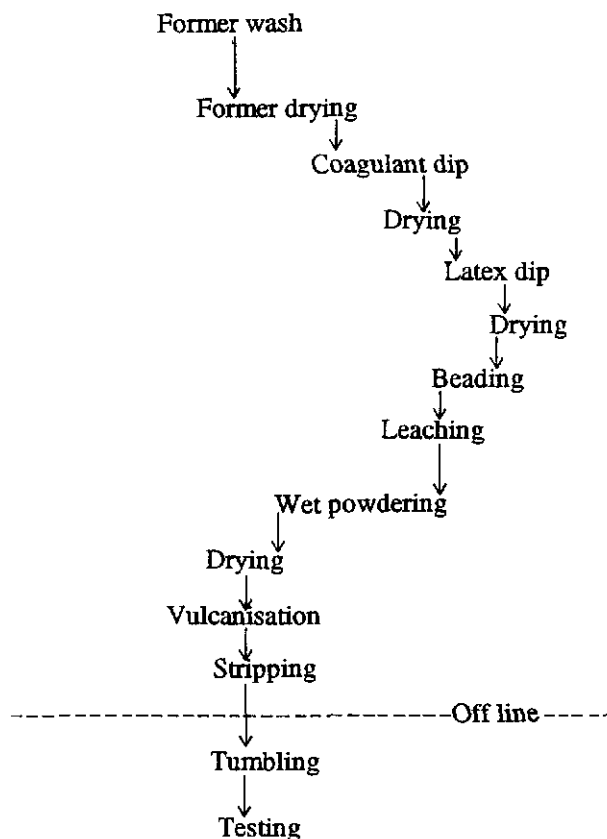


Figure 1. Sequence of operation for the manufacture of examination gloves.

- Optimise temperatures and duration of 'drying before vulcanisation' and 'vulcanisation'
- Optimise maturation time.

If the last two factors are taken care of, optimal vulcanisate properties would be obtained and very little powder would be required for detackifying.

Leaching

On line wet-gel leaching of the LOPROL gloves were done in two stages totalling about

1 min and 8 s. The leaching bath was kept at a constant temperature of $70^{\circ} \pm 5^{\circ}\text{C}$.

Tumbling

The process was extended to include tumbling for removal of excess powder and to even out powder contents on gloves.

Improvements in Tensile Properties of Post Vulcanisable LOPROL Films

Several factors were investigated in an effort to improve the tensile properties of the post-vulcanised LOPROL films, namely:

- Temperature of vulcanisation
- Amounts of accelerator
- Types of accelerator
- Activation of acceleration by zinc oxide
- Maturation time.

Temperature of Vulcanisation

Figures 2 and 3 show that the higher the temperature of vulcanisation, the lower are the tensile strength values of the films. The values were lowest when LOPROL and HA latex films obtained from post-vulcanisable compounds containing 0.27 p.h.r. ZBUD, 0.7 p.h.r. S and 0.5 p.h.r. ZnO were vulcanised at 120°C.

Similar observations, as shown in Figures 4 and 5, were obtained when sulphur systems containing 0.4 p.h.r. of ZDEC accelerator were used.

Lowering the temperature of vulcanisation did bring about an improvement in tensile strength of LOPROL films. However, the strength values remained in the region of 11 MPa – 13 MPa when the temperatures were lowered to 80° – 100°C, suggesting that lowering of temperature alone is not sufficient to achieve the required strength values.

Amount of Accelerator

Figures 6, 7 and 8 show that increasing the level of ZBUD from 0.27 p.h.r. to 0.6 p.h.r. gave higher tensile strength values for both LOPROL and HA latex films.

However, in the case of ZDEC, increasing its content from 0.4 p.h.r. to 0.7 p.h.r. did not affect the tensile strength values of both LOPROL and HA latex films (Figures 9 and 10).

Types of Accelerator

The use of ZBUD is preferred to ZDEC for LOPROL formulations. Alternatively, a combination of accelerators such as ZDEC/ZMBT/ZBUD in the order of 0.4 p.h.r., 0.2 p.h.r. and 0.1 p.h.r. has also been found to be suitable (Figure 11).

Activation by Zinc Oxide

Table 7 shows that increasing the amount of zinc oxide from 0.5 p.h.r. to 0.7 p.h.r. did not appear to increase the tensile strength appreciably.

Maturation Time

The state of precure of a latex compound is affected by maturation time and temperature, aqueous phase and the presence of non-rubbers^{3,4}. It has been shown that the degree of vulcanisation is lower in highly purified NR latex³, probably due to the absence of non-rubbers, and the necessary presence of added surface-active substances that could cause a slower rate of water removal during drying of the purified latex film. As a corollary, it is reasonable to assume that the state and rate of precure for LOPROL would be lower than those of normal HA latex concentrate regardless of the formulation used. This is confirmed by the results in Table 8 which showed a significant increase in tensile properties when the LOPROL compound was matured for a longer period.

Tensile Properties of LOPROL Gloves

Table 5 shows that the tensile properties of the gloves produced in this trial using a suitably formulated LOPROL compound were well above the minimum requirements of ASTM specifications for examination gloves.

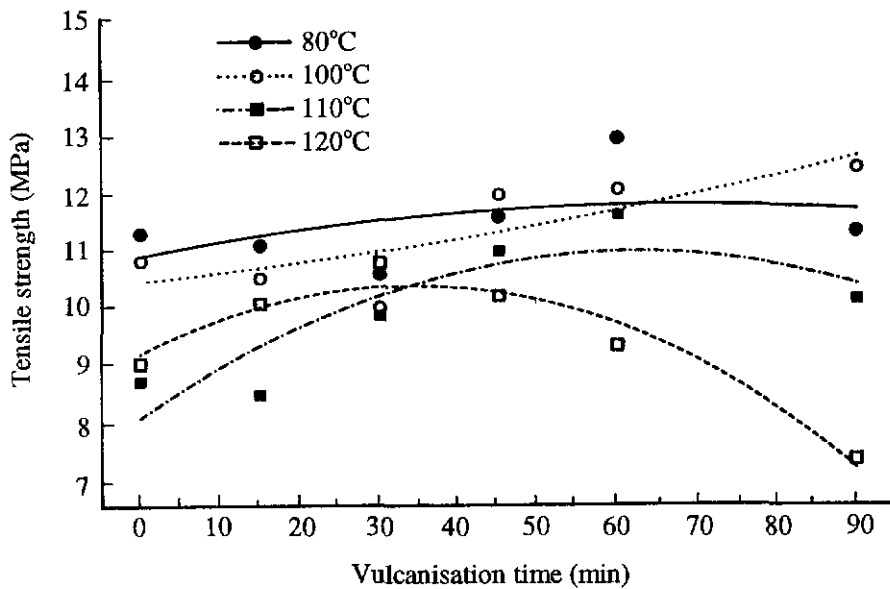


Figure 2. Effect of temperature on TS of Loprol films (ZBUD 0.27, S 0.7).

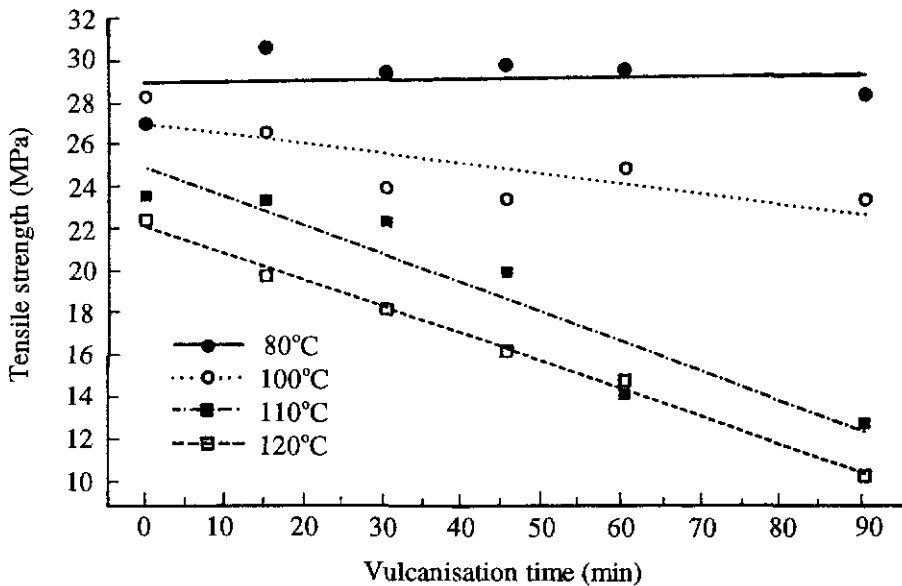


Figure 3. Effect of temperature on TS of HA latex films (ZBUD 0.27, S 0.7).

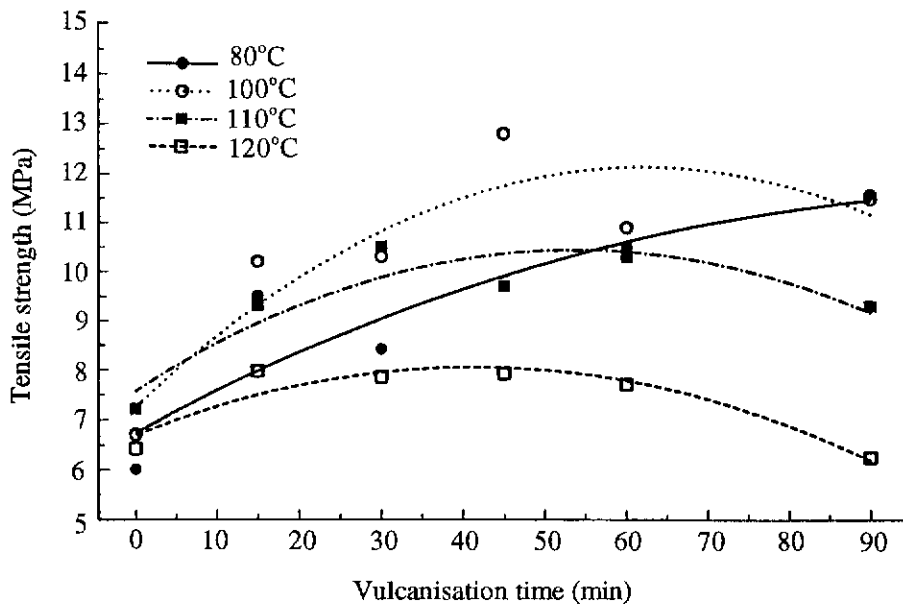


Figure 4. Effect of temperature on TS of Loprol films (ZDEC 0.4, S 0.7).

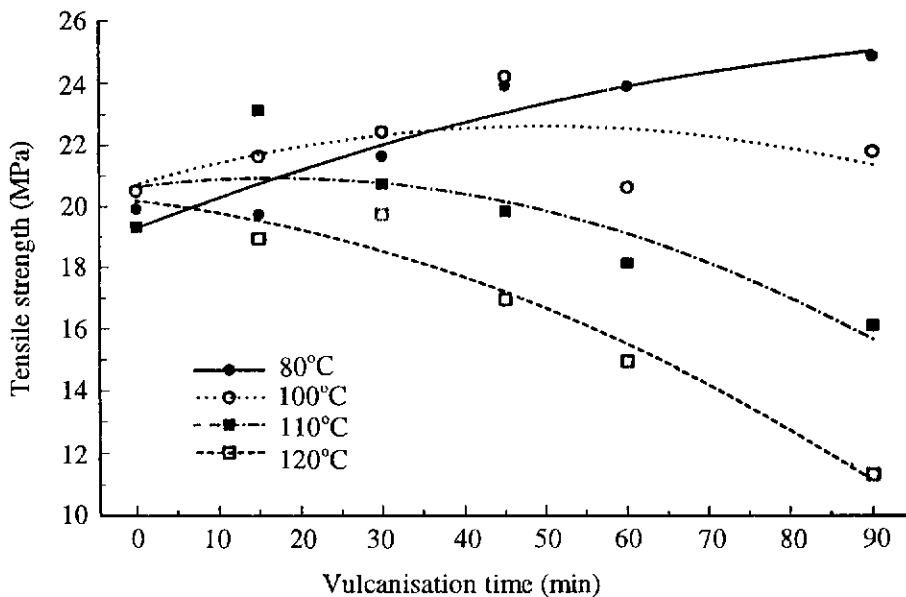


Figure 5. Effect of temperature on TS of HA latex films (ZDEC 0.4, S 0.7).

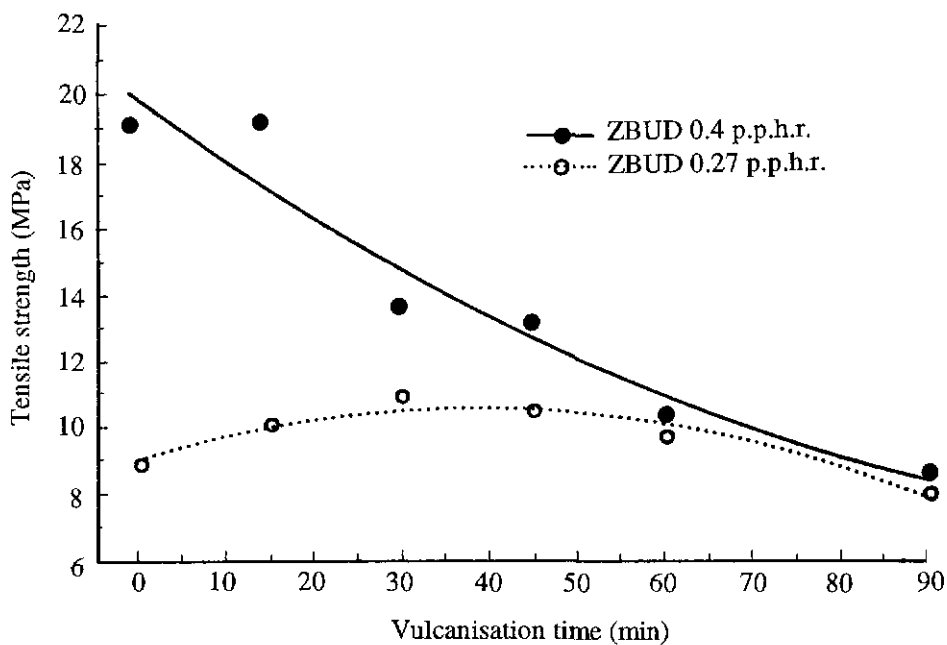


Figure 6. Effect of levels of ZBUD on TS of Loprol films at 120°C.

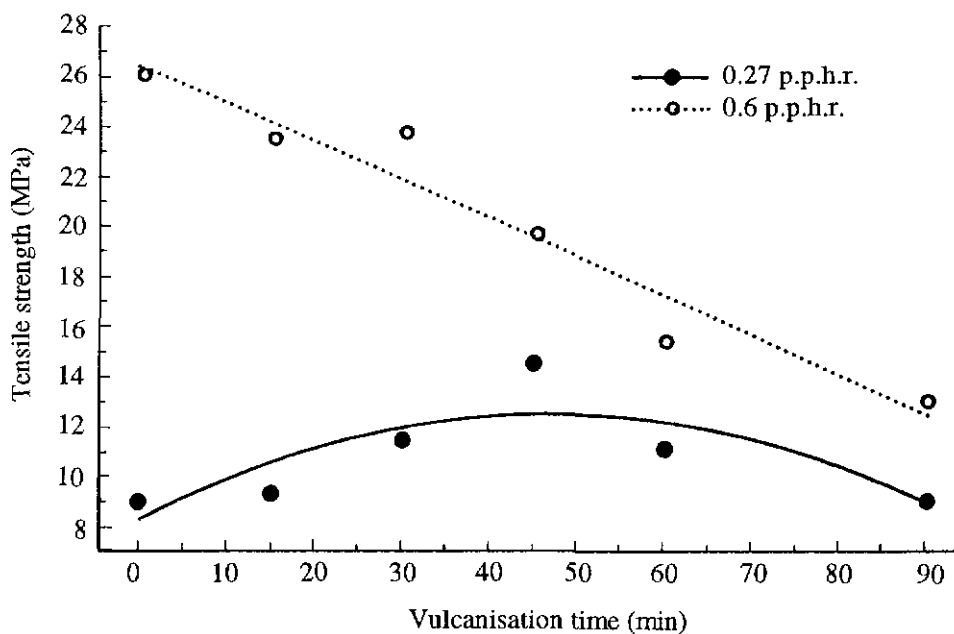


Figure 7. Effect of levels of ZBUD on TS of Loprol films at 110°C.

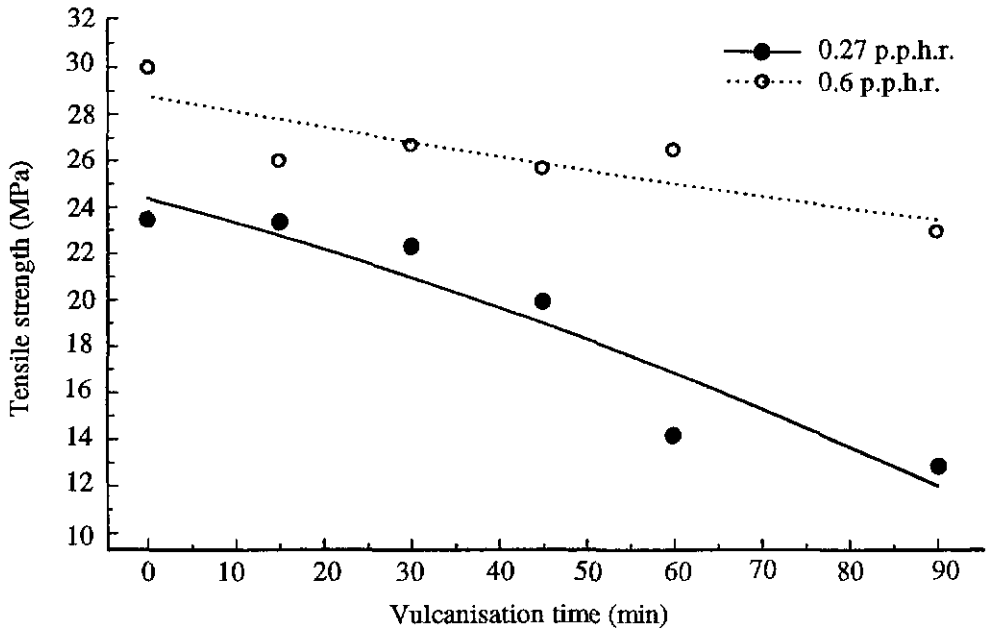


Figure 8. Effect of levels of ZBUD on TS of HA latex films at 110°C.

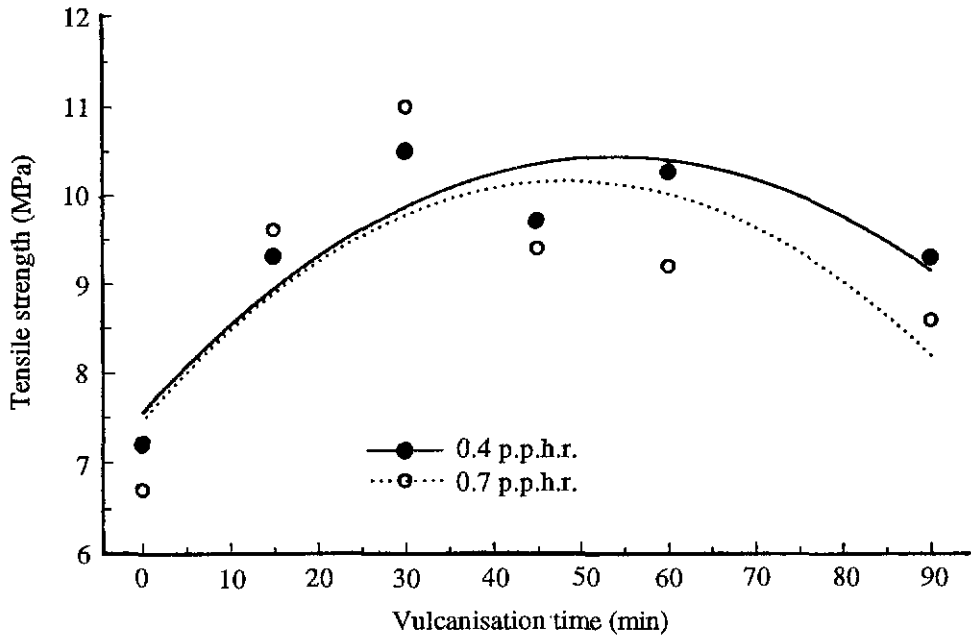


Figure 9. Effect of levels of ZDEC on TS of Loprol films at 110°C.

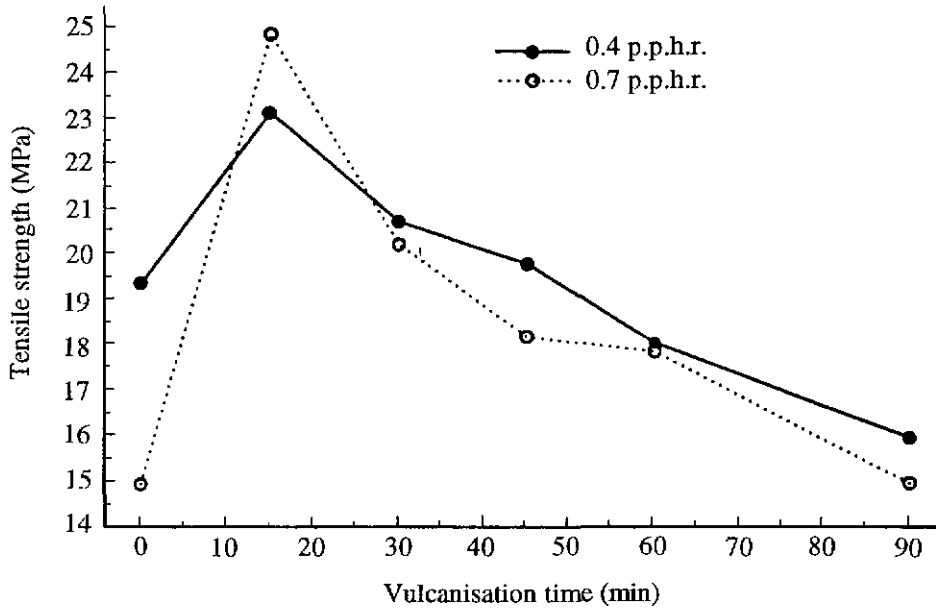


Figure 10. Effect of levels of ZDEC on TS of HA latex films at 110°C.

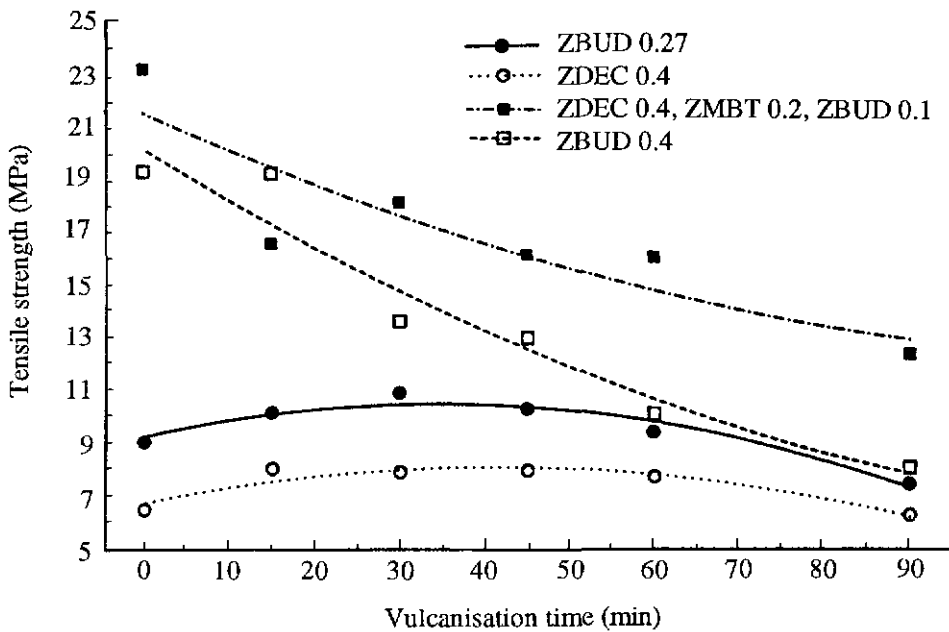


Figure 11. Effect of different accelerators on TS of Loprol films (vulc. temp. 120°C.)

TABLE 5. TENSILE PROPERTIES OF POST-VULCANISABLE LOPROL EXAMINATION GLOVES

	LOPROL	ASTM 3578-1991
A Unaged		
Tensile strength (MPa)	25 – 27	> 21
Elongation at break (%)	850 – 900	– 700
M300 (MPa)	1.15 – 1.25	–
M500 (MPa)	2.00 – 2.12	–
B Aged (7 days/70°C)		
Tensile strength (MPa)	23 – 25	> 16
Elongation at break	750 – 800	– 500
M300 (MPa)	1.3 – 1.4	–
M500 (MPa)	2.3 – 2.5	–
C Aged (1 day/100°C)		
Tensile strength (MPa)	23 – 27	> 16
Elongation at break (%)	790 – 830	–500
M300 (MPa)	1.2 – 1.4	–
M500 (MPa)	2.1 – 2.4	–

Extractable Protein (EP) Contents of LOPROL Gloves

As shown in *Table 6*, the EP contents of LOPROL Gloves are less than 0.1 mg/g of rubber film. These figures could be further lowered to 0.06 mg/g by a short dry film wash of 30 s.

CONCLUSION

The use of a low protein latex concentrate has been shown to be a viable process for large-scale production of gloves with reduced amounts of extractable proteins.

TABLE 6. SOLUBLE PROTEIN CONTENTS OF LOPROL EXAMINATION GLOVES

Gloves	Soluble protein (mg/g film)
LOPROL gloves (Wet leached 1 min 8 s/70°C)	0.09 – 0.10
LOPROL gloves (Wet leached 1 min 8 s/70°C) (Dry leached 30 s/RT) ^a	0.03 – 0.06
HIA latex gloves (Wet leached 3 min/70°C)	0.4 – 0.8

^aOff-line dry leaching of examination gloves

TABLE 7. EFFECT OF ZINC OXIDE ON THE TENSILE PROPERTIES OF LOPROL FILMS MADE FROM COMPOUNDED LOPROL MATURED FOR 3 DAYS

Vulcanisation time (100°C)	ZnO					
	0.5 p.h.r.			0.7 p.h.r.		
	TS (MPa)	EB (%)	M300% (MPa)	TS (MPa)	EB (%)	M300% (MPa)
0	25.5	940	1.0	24.6	920	1.0
15	25.4	930	0.97	26.4	990	0.99
30	24.5	950	1.0	24.4	950	0.95
45	29.5	1000	1.0	28.7	1000	0.90
60	27.4	990	1.0	26.8	990	0.90
90	27.5	1000	0.99	26.2	980	0.90

TABLE 8. EFFECT OF MATURATION DAYS ON TENSILE PROPERTIES OF LOPROL

Maturation (days)	Vulcanisation time	TS (MPa)	EB (%)	M300% (MPa)
2	0	28.9	940	1.19
	15	28.1	900	1.25
	30	28.0	910	1.21
	45	29.4	930	1.20
	60	26.7	920	1.20
	90	25.0	940	1.10
3	0	33.5	970	1.11
	15	33.9	970	1.20
	30	28.8	940	1.05
	45	28.6	930	1.10
	60	27.4	950	1.10
	90	27.9	950	1.11

HA latex

ZDEC 0.4, ZMBT 0.2 p.h.r.

Vulcanisation temperature: 100°C

Tensile strength (MPa)

Maturation (days) Vulcanisation time	Formulation 1		Formulation 2	
	1	3	1	3
0	24.2	25.5	23.2	24.6
15	26.2	25.4	23.6	26.4
30	24.5	24.5	19.4	24.4
45	21.8	29.5	22.0	28.7
60	20.3	27.4	21.6	26.8
90	18.8	27.6	16.0	26.2

LOPROL

Formulation 1 (ZBUD 0.3, ZDEC 0.4, ZMBT 0.2, ZnO 0.5)

Formulation 2 (ZBUD 0.3, ZDEC 0.4, ZMBT 0.2, ZnO 0.7)

Vulcanisation temperature: 100°C

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