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EFFECT OF HETEROGENEOUS DISTRIBUTION OF CROSSLINK DENSITY ON PHYSICAL PROPERTIES OF RADIATION VULCANIZED NR LATEX FILM

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Abstract

Thus a study has been carried out to investigate the effect of particle to particle variation in crosslink density on physical properties of radiation vulcanized NR latex film. NR latex was irradiated in small bottle by γ-rays without vulcanization accelerator to provide latex rubber particles having homogeneous distribution of crosslink density. The doses were 30, 50, 100, 250, 300, 400, 500 and 600 kGy. Weight swelling ratio, gel fraction, tensile strength and elongation at break of the latex film from the mixed latex were measured. The vulcanization dose of this latex was 250 kGy. Then the two different latexes were mixed in a such way to adjust the average dose of 250 kGy to prepare a latex consisting of rubber particles having heterogeneous distribution of crosslink density. Tensile strength of the latex film was depressed by mixing. The reduction increased with increasing the decrease of gel fraction by mixing. However the reduction was not serious when the dose difference of two latexes was less than 200 kGy.

INTRODUCTION

The radiation vulcanization of NR latex in a big container by γ-rays without stirring leads to particle to particle variation in crosslink density. In other words, crosslink density of each particle differs according to the absorbed dose. Similar phenomena will occur in vulcanization by electron beams. The effect of the heterogeneous distribution of crosslink density among rubber particles in on the physical properties of NR latex film is interesting from basic science and application sides. This study can be performed only by means of radiation vulcanized NR latex. For instance solid crosslinked rubbers are unable to be blended homogeneously. Additional chemical crosslinking is unavoidable during film formation in sulfur vulcanized NR latex. In this paper radiation vulcanized NR latexes with various doses were mixed and their physical properties were evaluated to analyze the heterogeneous distribution of crosslink density among rubber particles.

EXPERIMENTAL

Materials and irradiation

A commercial high ammonia natural rubber latex (IOTEX dry rubber content, DRC 60%) from Malaysia exposed to γ-rays from Co-60 at a dose rate of 10 kGy/h in one liter plastic bottle. Irradiation doses were 30, 50, 100, 160, 250, 300, 400, 500 and kGy.

Blending of the irradiated latex

The following two series of blended latex were obtained.

(a) Blending two latexes with the same weight ratio, refereed as blended latex (1:1)

(b) Blending two latexes with the weight ratio so as to achieve 250 kGy of average dose, refereed as blended latex (250 kGy)

Measurements of physical properties

The film of about 0.7 mm thickness was prepared by casting about 20 g of latex onto a glass plate (12X18 cm). The films were dried in air at room temperature (about 20°C) until they became transparent and then immersed in 1 % aqueous ammonia solution (leaching) for 24 hours followed by drying at room temperature until transparent. Subsequently, the films were heated at 80°C for an hour. After cooling, the films were cut to dumbbell shape and conditioned at 20°C over night in a desiccator. The tensile strength of film was measured according to JIS K 6301 with Strograph-R1 tension meter (Toyoseiki Co. Ltd.). Gel fraction and was measured by the weight change after boiling the disk (φ 20 mm) of the film in toluene for 24 hours. An antioxidant (TNPP) was added to toluene to prevent oxidative degradation during boiling. Weight swelling ratio was measured by the weight increase of the dry gel after soaked in toluene for 24 hours. Number average molecular weight of chains between crosslinks was calculated from the data of weight swelling ratio.

RESULTS AND DISCUSSIONS

Mechanical properties of blended latex

Tensile strength (Tb), elongation at break (Eb), gel fraction (Gel), weight swelling ratio (Sw) and number average molecular weight of chains between crosslinks (Mc) were plotted against the dose in Figures 1 - 5, respectively. The optimum dose for the NR latex used in this experiment is around 250 kGy. Generally the Tb of blended latex (1:1) deviated from a plot of Tb of non-blended original latex. The deviation of the Tb of the blended latex (250 kGy) was more remarkable than the Tb of blended latex (1:1). These were also observed in Gel, Sw and Mc. However, negligible deviation was detected in plot of Eb against dose.

From these results it can be concluded that the physical properties of the blended latex can not be predicted by the absorbed average dose. Also it is clear that the blending of high and low quality latexes can improve the physical properties of low quality latex.

Optimum gel fraction and swelling ratio

Tb was plotted against Gel and Sw in figures 6 and 7, respectively, to estimate the optimum gel fraction and swelling ratio to achieve high tensile strength. Even the blended latex (250 kGy) high Tb can be achieved if Gel is around 96% and Sw is within 600 - 700%.

Effect dose difference in blended latex

Two latexes irradiated to lower and higher dose than 250 kGy were mixed so as to attain the average dose of 250 kGy. Physical properties of the blended latex differ, even the average dose is the same. Figure 8 shows the effect of higher dose on Tb. The Tb decreases with increasing higher dose. This means that Tb decreases with increasing the dose difference between lower and higher dose.

Improvement of physical properties by blending

Table 1 shows the effect of blending of low dose irradiated latex to the over-vulcanized latex on Tb. It can be seen that the blending is effective to improve the physical property of the over-vulcanized latex. This technique will be useful when the latex is irradiated to much due to dosimetry failure.

CONCLUSION

Blending of NR latex is the common technique in NR latex industry to minimize batch to batch variations in properties. In this paper the effect of the blending of radiation vulcanized NR latex was investigated and the following two important results were obtained.

1) Blending of high and low quality latexes tends to cause worsening of the physical properties of high quality latex.
2) However, blending of lower dose irradiated latex will be useful for improvement of the physical properties of over-irradiated latex.

Figure captions

Fig. 1 Relationship between dose and tensile strength

Fig. 2 Relationship between dose and elongation at break

Fig. 3 Relationship between dose and gel fraction

Fig. 4 Relationship between dose and weight swelling ratio

Fig. 5 Relationship between dose and number average weight of chains between crosslinks

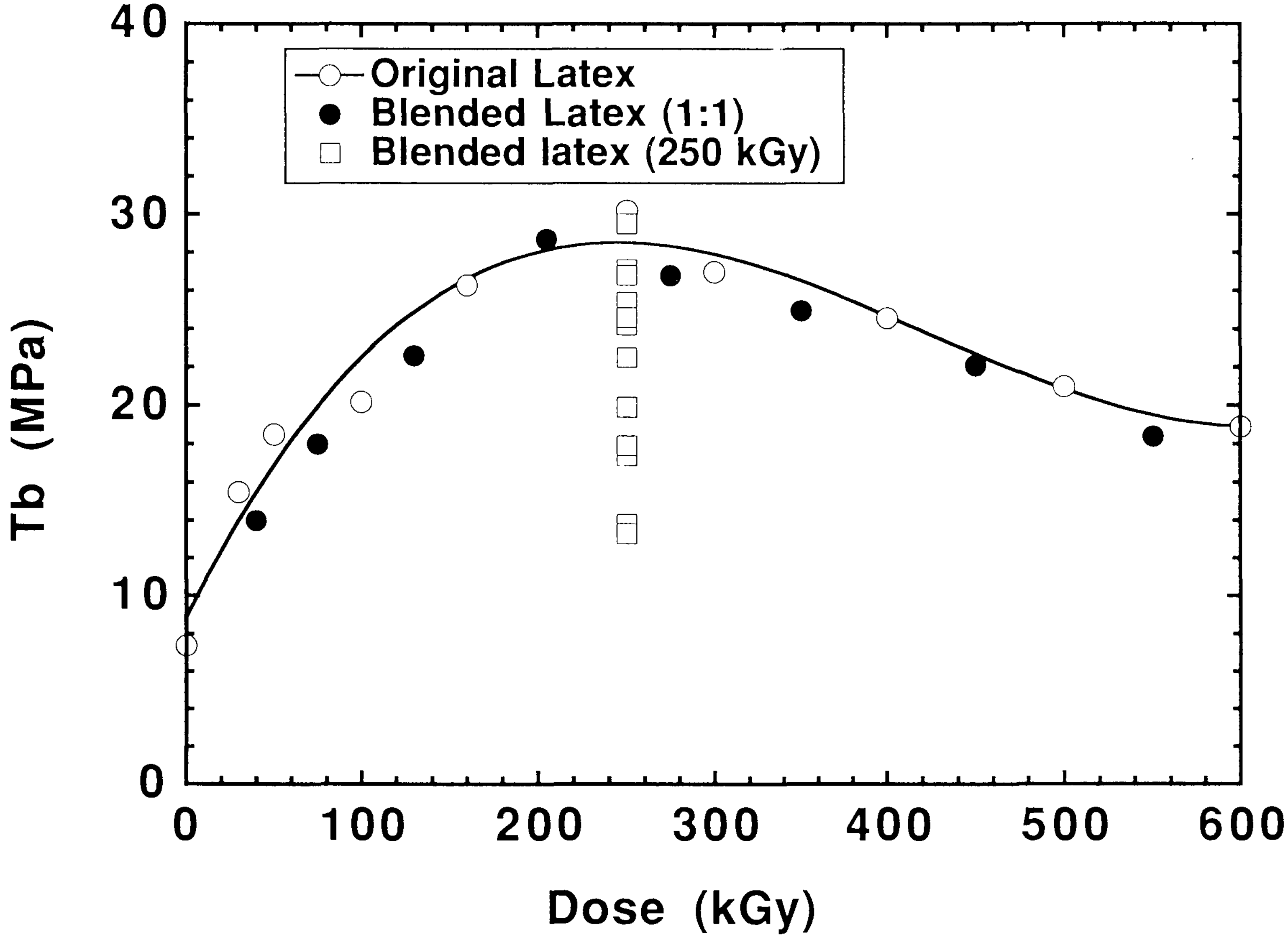
Fig. 6 Relationship between gel fraction and tensile strength

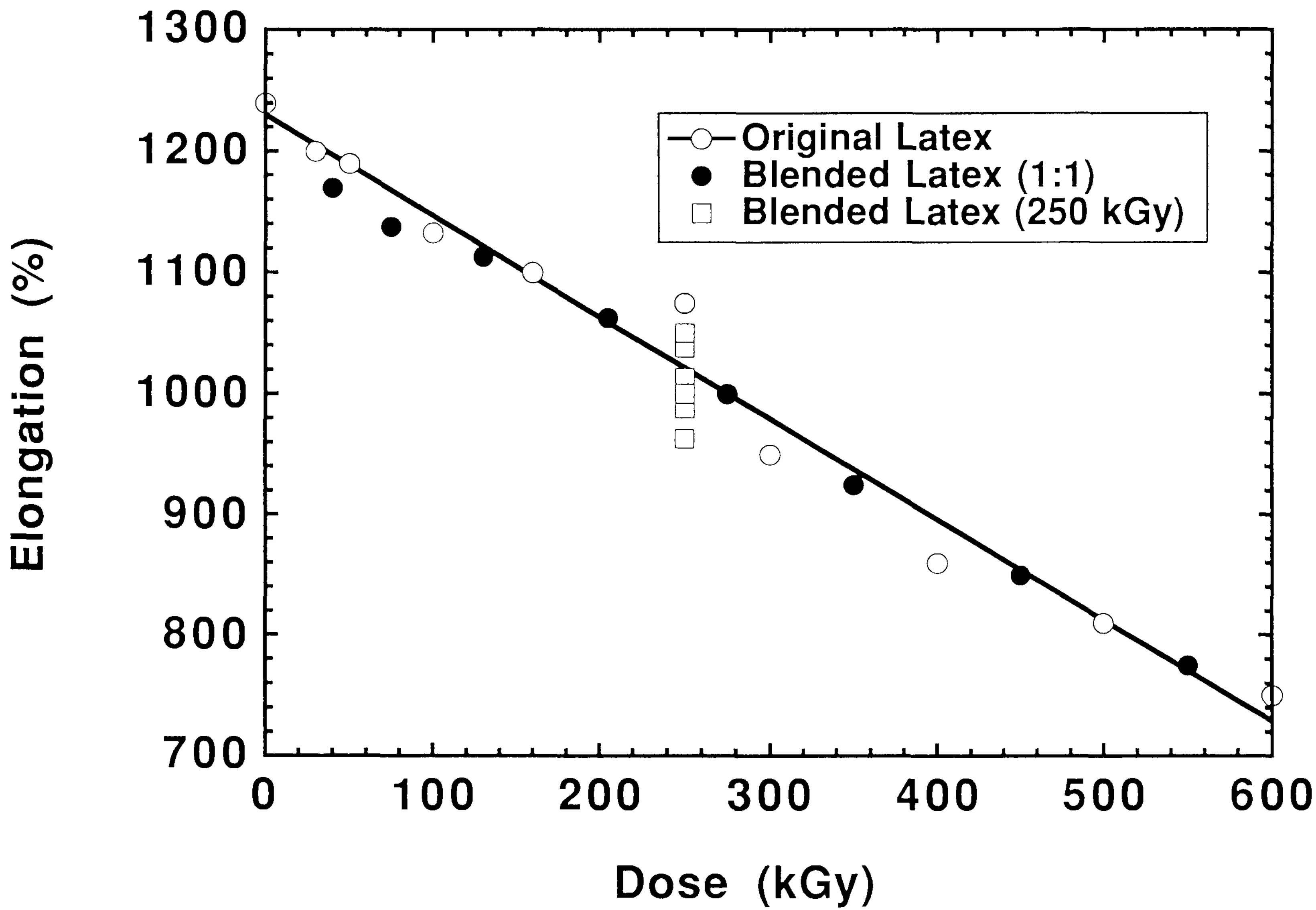
Fig. 7 Relationship between weight swelling ratio and tensile strength

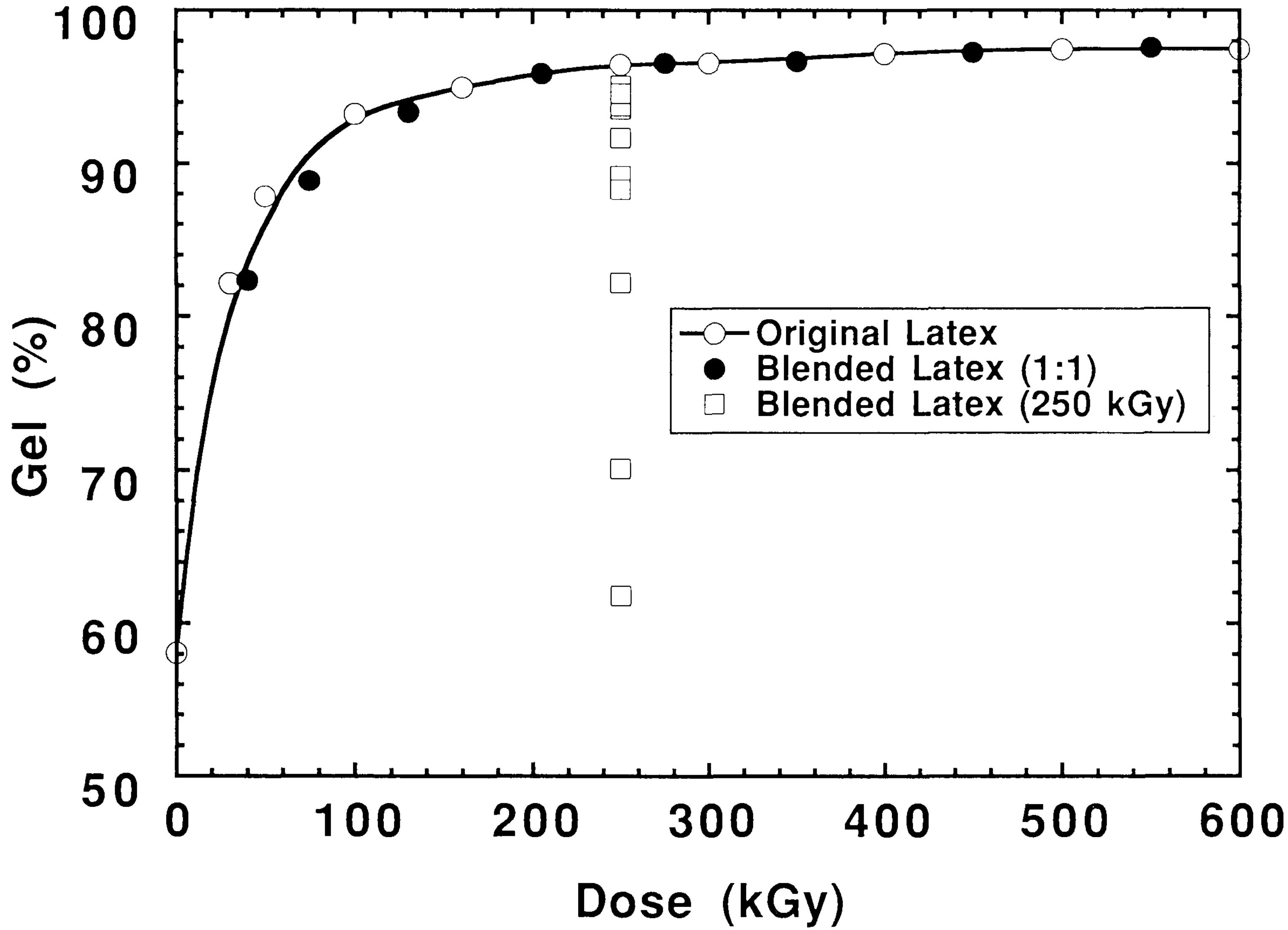
Fig. 8 Effect of higher dose on tensile strength of blended latex

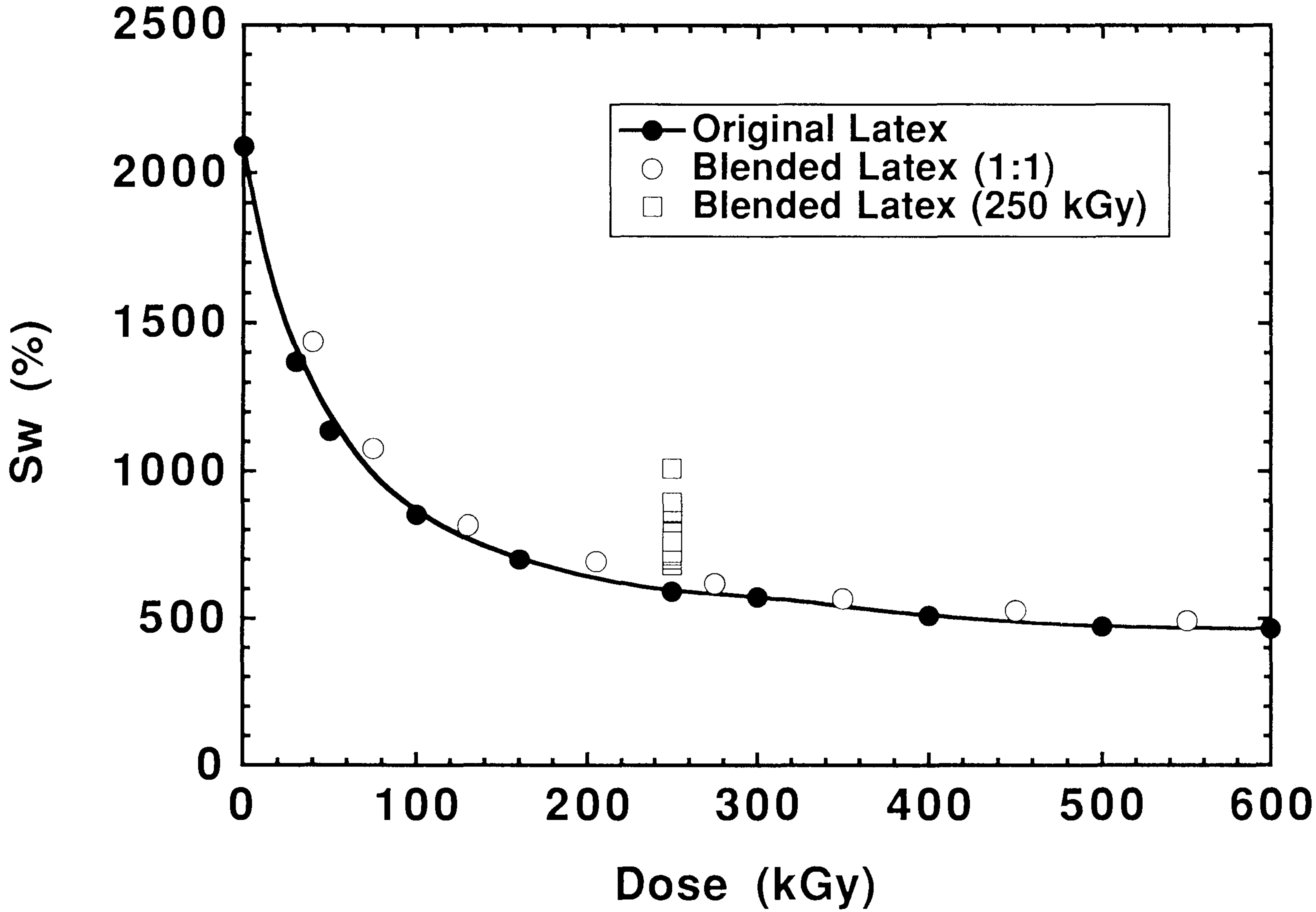
Table 1 Improvement of physical property of over-irradiated latex by blending with lower dose irradiated latex

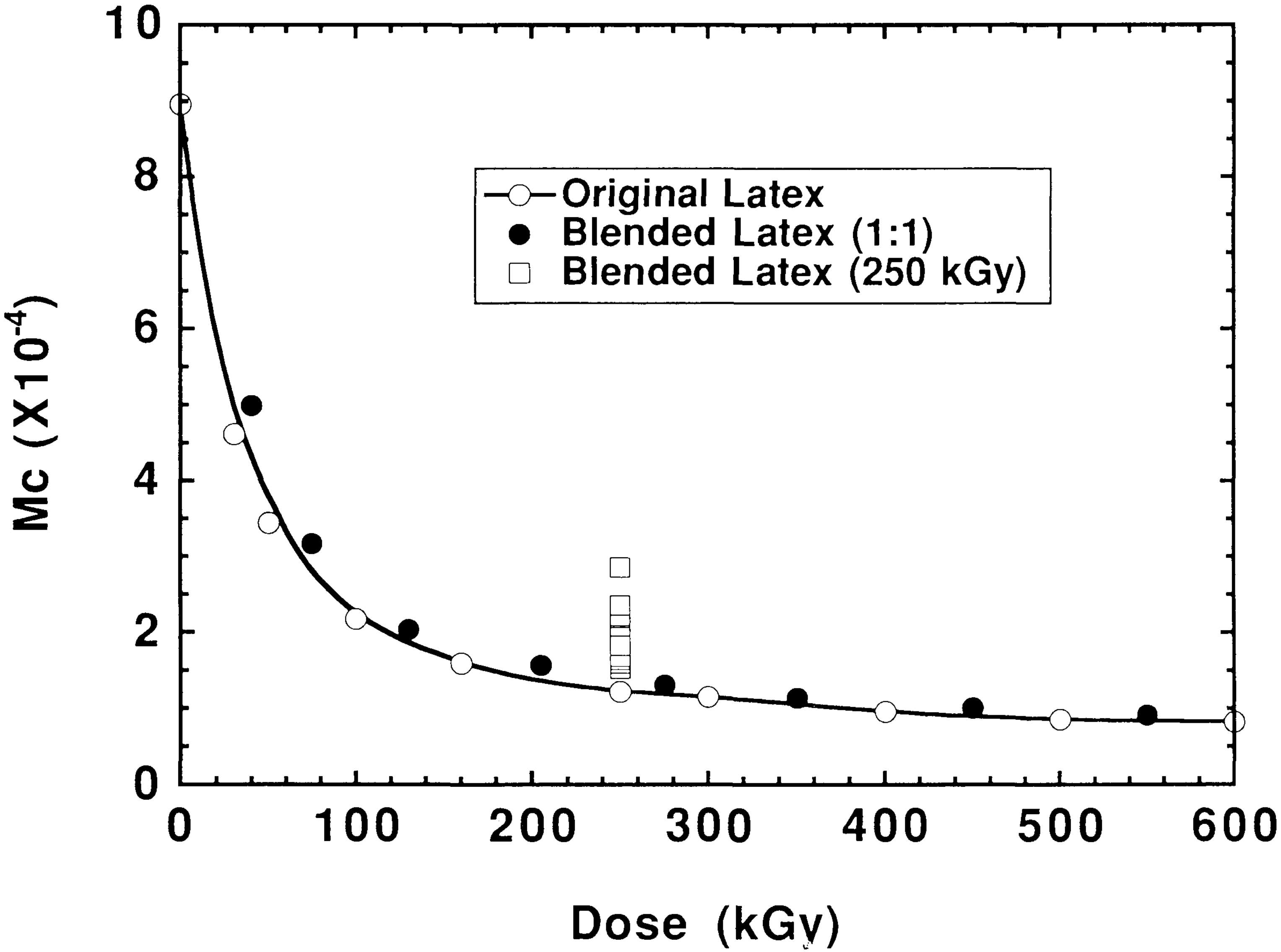
100 kGy	300 kGy	400 kGy	500 kGy	600 kGy	Tb (MPa)
	100%				27.0
25.0%	75.0%				29.5
		100%			24.3
50.0%		50.0%			26.8
			100%		20.7
62.5%			37.5%		25.4
				100%	18.0
70.0%				30.0%	24.6

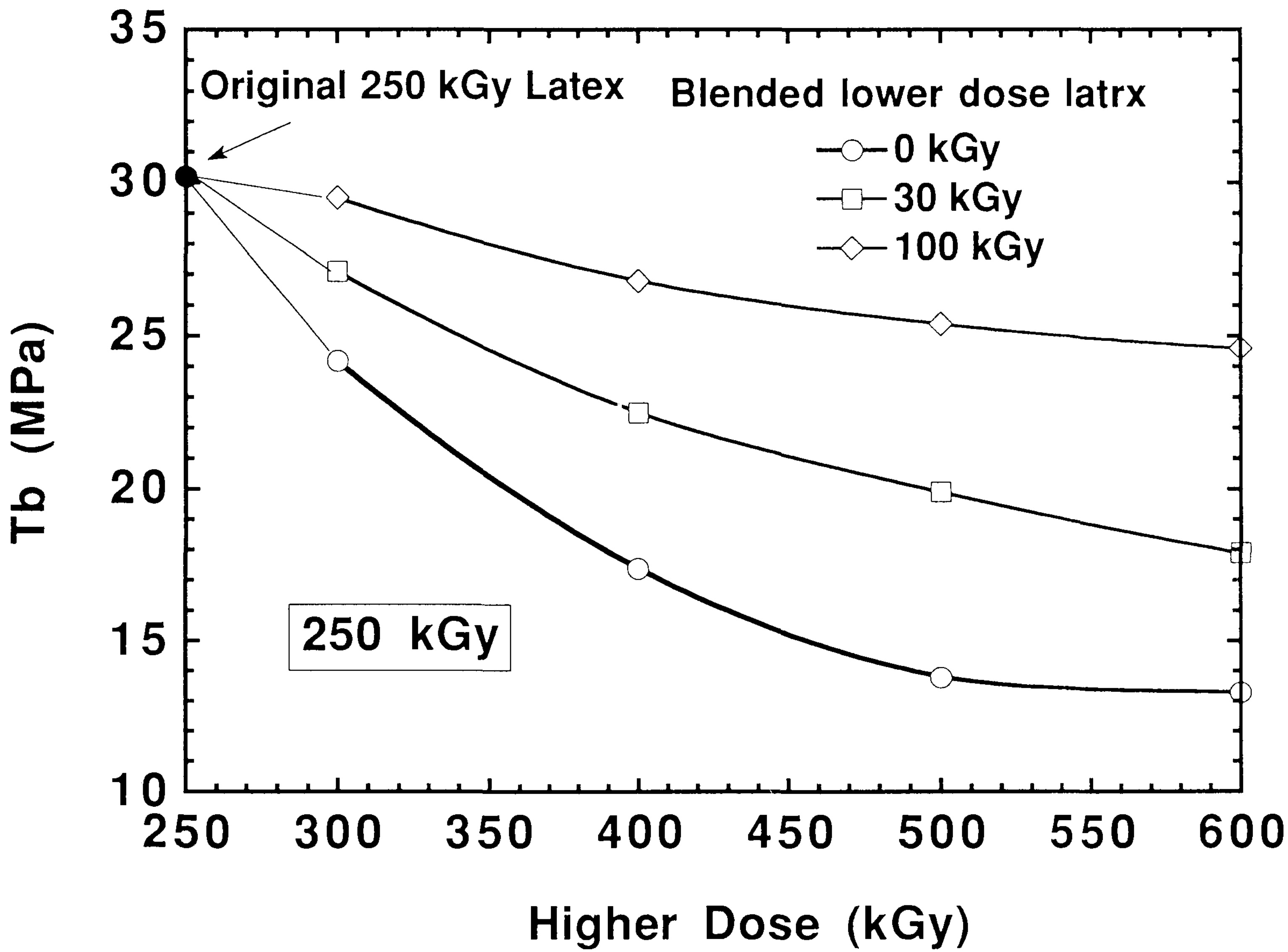

Original Latex
Blended Latex (1:1)
Blended latex (250 kGy)
Tb (MPa)
Dose (kGy)
0
10
20
30
40
0
100
200
300
400
500
600


Original Latex
Blended Latex (1:1)
Blended Latex (250 kGy)
Elongation (%)
1300
1200
1100
1000
900
800
700
0
100
200
300
400
500
600
Dose (kGy)

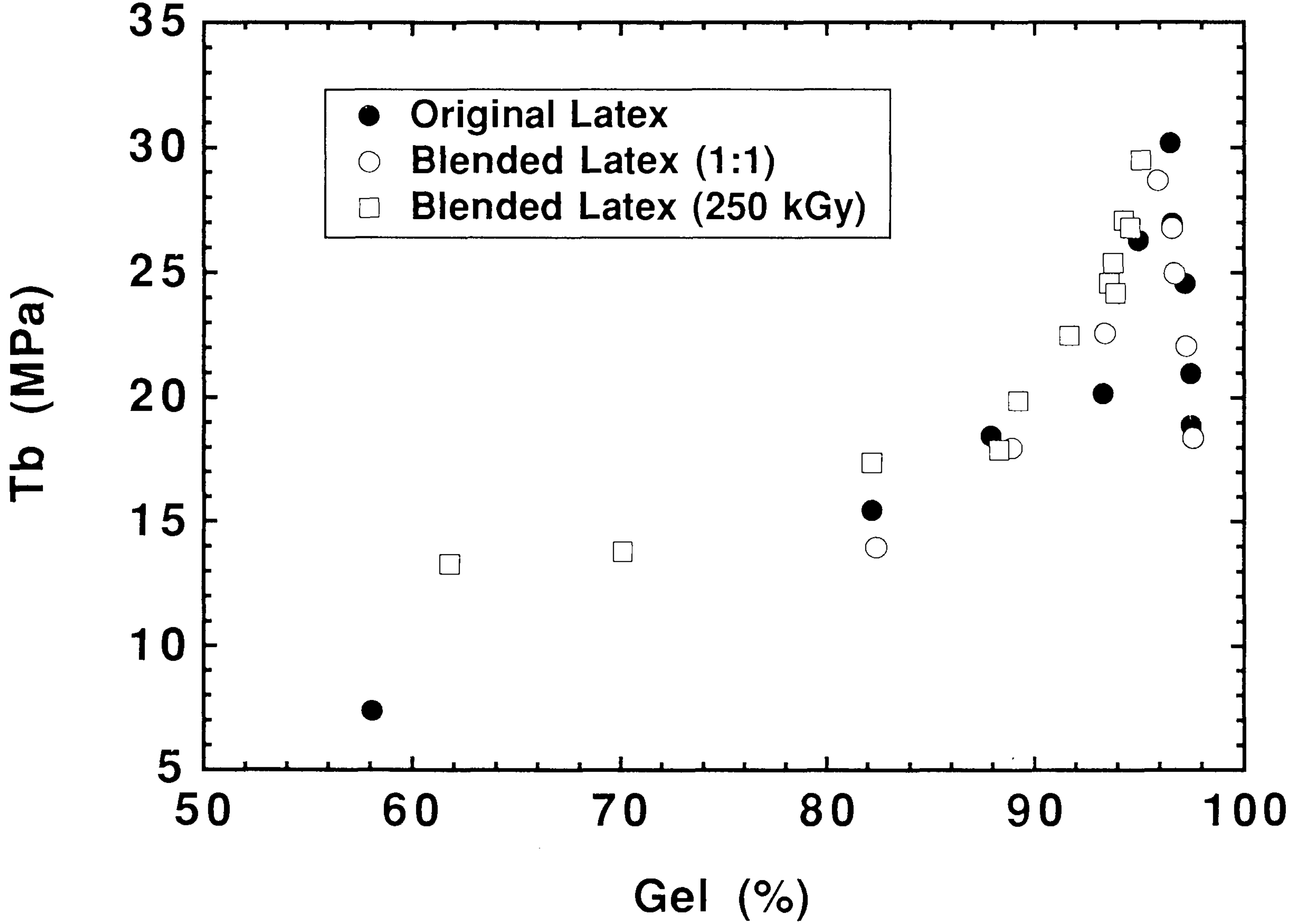

Gel (%)
100
90
80
70
60
50
0
100
200
300
400
500
600
Dose (kGy)
Original Latex
Blended Latex (1:1)
Blended Latex (250 kGy)

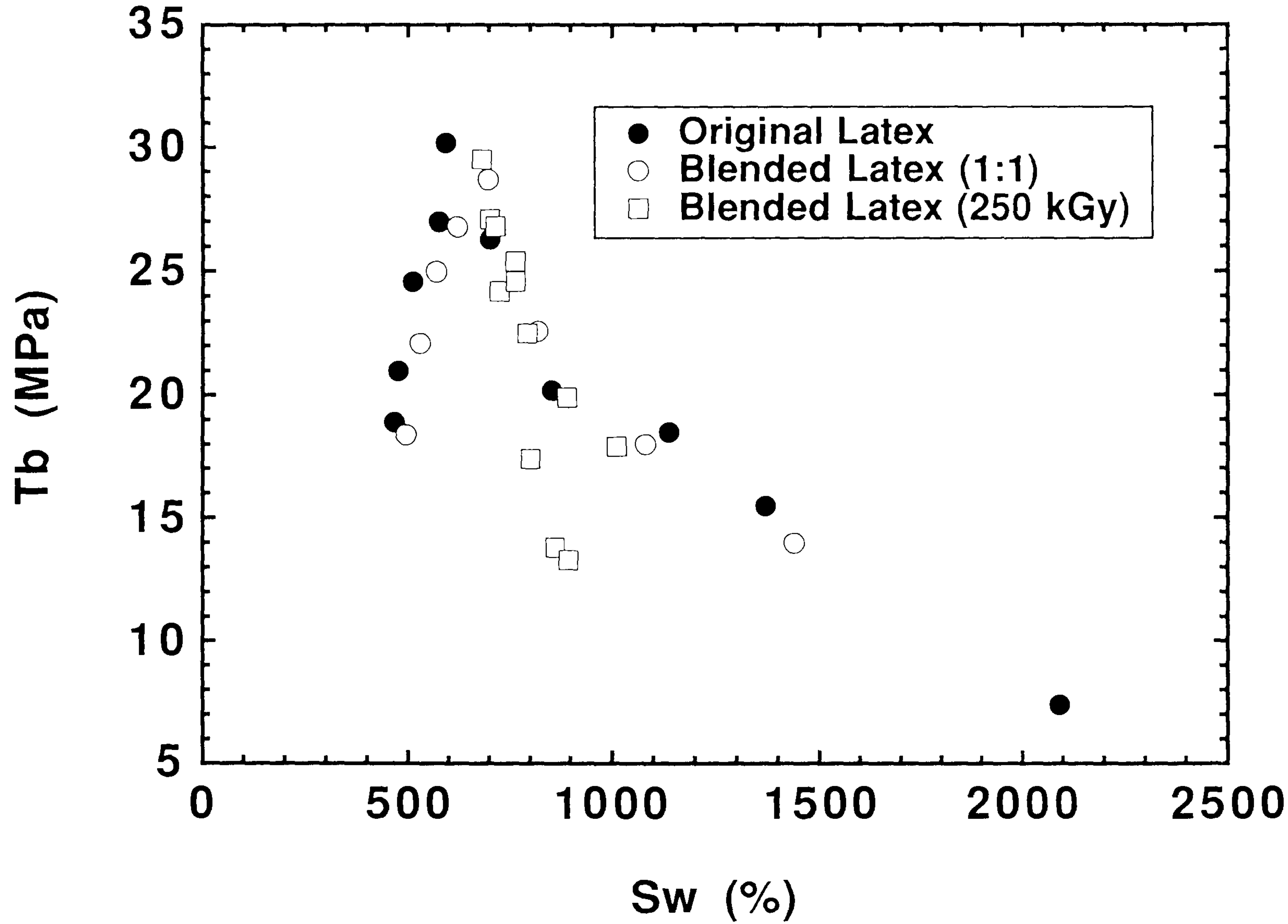

Original Latex
Blended Latex (1:1)
Blended Latex (250 kGy)
Sw (%)
Dose (kGy)
0
500
1000
1500
2000
2500
0
100
200
300
400
500
600


Original Latex
Blended Latex (1:1)
Blended Latex (250 kGy)
Mc (X10^{-4})
Dose (kGy)
0
2
4
6
8
10
0
100
200
300
400
500
600



Original 250 kGy Latex
Blended lower dose latrx
0 kGy
30 kGy
100 kGy
250 kGy
Tb (MPa)
Higher Dose (kGy)
35
30
25
20
15
10
250
300
350
400
450
500
550
600


Original Latex
Blended Latex (1:1)
Blended Latex (250 kGy)
Tb (MPa)
Gel (%)
35
30
25
20
15
10
5
50
60
70
80
90
100


Original Latex
Blended Latex (1:1)
Blended Latex (250 kGy)
Tb (MPa)
Sw (%)
35
30
25
20
15
10
5
0
500
1000
1500
2000
2500