

# Production of Low-Molecular-Weight Natural Rubber: Comparative Assessment of a Nonchemical Route

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**ABSTRACT:** The use of *Funtumia* latex and nitrobenzene as molecular weight depressants for natural rubber was studied. Portions of a given sample of natural rubber latex were treated with these materials, and this provided a means of ascertaining the amount of *Funtumia* latex in a blend with natural rubber that could produce a lowering of the molecular weight equivalent to that from known concentrations of nitrobenzene in natural rubber latex. The molecular weight of the products decreased to an equilib-

rium value after 10 h of reaction with nitrobenzene. The calculations revealed that a 27.9% substitution of natural rubber latex (300 mL) with *Funtumia* rubber latex achieved the same result as nitrobenzene in the same polymer at concentrations of 0.5–2.0 wt % of the dry rubber content of the latex after 10 h of reaction. © 2007 Wiley Periodicals, Inc. *J Appl Polym Sci* 106: 1291–1293, 2007

**Key words:** blends; latices; modification; rubber; viscosity

## INTRODUCTION

Soft-rubber compounds, especially spongy and frictioning rubbers and those used for rubber solutions, are characterized by low viscosities. This can be achieved by a high degree of mastication or by the use of peptizing agents to affect oxidative mastication on an open roller mill. On the other hand, natural rubber (NR) latex has been depolymerized with nitrobenzene<sup>1</sup> and phenyl hydrazine.<sup>2</sup> Blends of *Funtumia* and NR latices have also been reported<sup>3</sup> to produce low-viscosity rubber. *Funtumia* rubber latex has been judged to be an effective nonchemical peptizer for NR by the authors. The creaming of latex has been successfully carried out with tamarind powder<sup>4</sup> (a nonchemical creaming agent) instead of conventional sodium or ammonium alginate.

*Funtumia elastica* is one of the sources of wild rubber in Africa. This rubber was briefly exploited during World War II (1941–1942).<sup>5</sup> An experimental plot was established in 1985 at the Rubber Research Institute of Nigeria in Benin City. A mature tree is 9–12 m tall and has an average girth of 0.85 m.

In this study, the molecular weight of products obtained through depolymerization with nitrobenzene and blending with *Funtumia* latex was evaluated by a viscometric method to assess the effectiveness of *Funtumia* rubber latex as a molecular weight depressant for NR on a comparative basis.

## EXPERIMENTAL

### Materials

*F. elastica* latex was obtained from plantations established at the Rubber Research Institute of Nigeria. The NR latex was obtained from the NIG 805 clonal series of the Rubber Research Institute of Nigeria. Analytical grades of formic acid (BDH), toluene (M&B) (Dagenham, England), and nitrobenzene (BDH) (Poole, England) were used in the preparation and characterization of the rubber samples.

### Methods

By the nonchemical route, six blend compositions of NR and *Funtumia* rubber latices were prepared as shown in Table I. The samples were coagulated with formic acid, washed, and dried to obtain dry rubbers.

The chemical route involved the depolymerization of NR latex with nitrobenzene. NR latex [100 mL; 20% dry rubber content (DRC)] was stabilized with a 2% concentration of a nonionic surfactant [alkyl phenol poly(ethylene oxide)]. The nitrobenzene concentrations were 0.5, 1.0, 1.5, and 2.0 wt % of the DRC of the latex. The reaction, which was monitored after the 1st hour and subsequently every 2 h up to the 10th hour, proceeded at  $30 \pm 2^\circ\text{C}$  under oxygen. The resultant product was converted to dry rubber by coagulation with 2% formic acid.

The intrinsic viscosity ( $[\eta]$ ) of the products obtained through both the nonchemical and chemical routes was determined with an Ubbelohde-type

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**TABLE I**  
Composition of the *Hevea/Funtumia* Rubber Blends<sup>a</sup>

Material	Mix					
	A	B	C	D	E	F
NR latex	100	90	80	70	60	50
<i>Funtumia</i> rubber latex	—	10	20	30	40	50

<sup>a</sup> Scaled up by a batch factor of 3.

viscometer. The efflux times of solutions of dry rubber samples in toluene were taken at 30°C. Limiting viscosity values were converted to the viscosity-average molecular weight ( $M_v$ ) with the Mark–Houwink equation:

$$[\eta] = KM_v^\alpha \quad (1)$$

where the constants  $K$  and  $\alpha$  are  $3.31 \times 10^{-4}$  and 0.71, respectively, as reported by Subramaniam<sup>6</sup> or in the *Polymer Handbook* for the determination of  $[\eta]$  for different clones of rubber in toluene at 30°C.

## RESULTS AND DISCUSSION

Table II shows the molecular weights of the various rubber blends with 0–50% *Funtumia*. Clearly, there was a remarkable decrease in the molecular weight as the *Funtumia* concentration of the rubber blend increased. A plot of the molecular weight of the rubber blends versus the *Funtumia* concentration is shown in Figure 1. The linearly fitted equation for the plot, obtained with JMP statistical software (version 3) (SAS Institute Inc., Cary, NC), is given in eq. (2). The  $y$  and  $x$  axes represent the molecular weight and *Funtumia* concentration (%), respectively. The square of the correlation coefficient ( $r^2$ ) in eq. (3) indicates a high level of the goodness of fit:

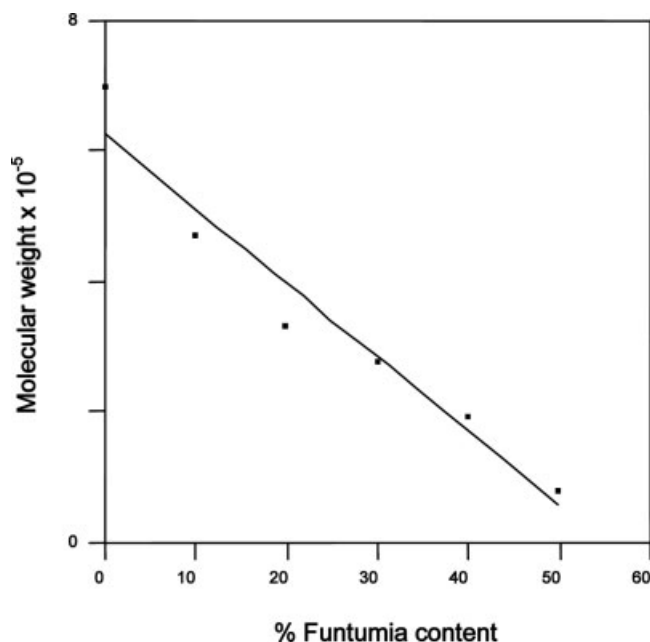
$$y = 6.30238 - 0.11403x \quad (2)$$

$$r^2 = 0.948658 \quad (3)$$

A weight-average molecular weight of  $7.2 \times 10^4$  for *Funtumia* rubber, as determined by gel permeation

**TABLE II**  
Effect of the *Funtumia* Latex Concentration on  $M_v$  of NR/*Funtumia* Rubber Blends

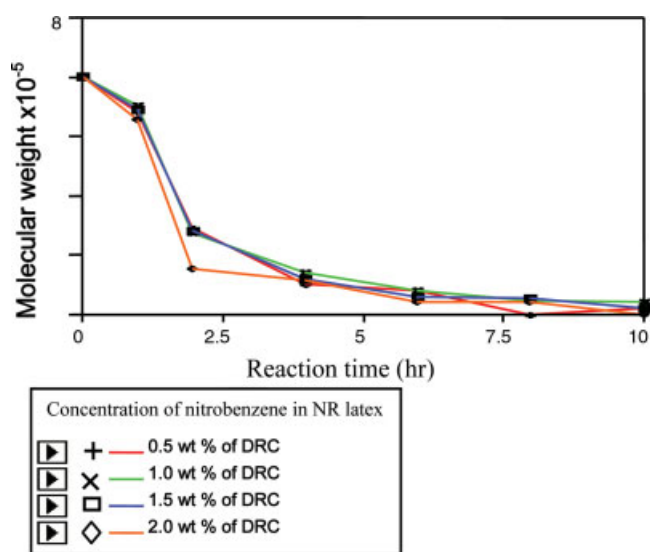
<i>Funtumia</i> (%) in the NR/FR latex blend	$M_v \times 10^{-5}$
0	7.02
10	4.75
20	3.36
30	2.79
40	1.97
50	0.82



**Figure 1** Variation of the molecular weight with the *Funtumia* concentration (%).

chromatography, has been reported elsewhere, and its molecular structure is known to be *cis*-polyisoprene.<sup>7</sup> Thus, the molecular weight of *Funtumia* rubber is many times lower than that of NR, and this is thought to be a major factor responsible for the observed lowering of the molecular weight of the NR/*Funtumia* rubber blend as the *Funtumia* concentration increases.

Data on the molecular weight of the rubber samples obtained after different stages of depolymeriza-



**Figure 2** Effects of the concentration of nitrobenzene and the reaction time on the molecular weight of NR. [Color figure can be viewed in the online issue, which is available at [www.interscience.wiley.com](http://www.interscience.wiley.com).]

TABLE III  
Effects of the Nitrobenzene Concentration and Reaction Time on the Depolymerization of the NR Latex

Concentration of nitrobenzene (wt % of the DRC of the latex)	$M_v \times 10^{-5}$						
	0.0 h	1.0 h	2.0 h	4.0 h	6.0 h	8.0 h	10.0 h
0.5	7.02	6.43	4.46	3.52	3.42	3.02	3.12
1.0	7.02	6.53	4.38	3.72	3.42	3.24	3.22
1.5	7.02	6.46	4.42	3.62	3.32	3.28	3.12
2.0	7.02	6.29	3.79	3.58	3.22	3.22	3.02

tion with nitrobenzene have been plotted against the reaction time (Fig. 2). The plots show that the molecular weights of the samples decreased to an equilibrium value as the reaction time increased. The leveling of the molecular weights occurred between 8 and 10 h of reaction, and at this time, the molecular weight were found to be nearly equal, regardless of the concentration of nitrobenzene used. After 10 h of reaction, the mean value of  $M_v$  of the rubber samples depolymerized with the quoted concentrations of nitrobenzene was  $3.12 \times 10^5$ . This mean value was plugged into eq. (2) to ascertain the *Funtumia* concentration in the NR/*Funtumia* rubber blend that caused the same molecular weight reduction as an increase in the concentration of nitrobenzene. The calculation revealed that 27.9% *Funtumia* rubber in the rubber blend produced the same result as nitrobenzene (1–2 wt % of the DRC of the latex) after 10 h of reaction (Table III).

Concentrations higher than 2.0 wt % of the DRC of the latex posed the problem of getting rid of the residual chemical at the end of the reaction. It is more advantageous to work with a lower dosage of nitrobenzene and an increased reaction time (at least 10 h).

### CONCLUSIONS

A 27.9% concentration of *Funtumia* rubber in a *Funtumia*/NR blend reduced the molecular weight of NR from  $7.02 \times 10^5$  to  $3.12 \times 10^5$  (a 55.6% reduc-

tion). This proportion of *Funtumia* rubber latex in the blend produced the same reduction in the molecular weight of NR as the reaction of nitrobenzene (1–2 wt % of the DRC of the latex) with NR latex over a period of 10 h. This study has shown a method of quantifying the amount of *Funtumia* latex in a blend with NR latex that can yield a lowering of the molecular weight equivalent to that from a given concentration of nitrobenzene in NR latex.

The advantage of this method over chemical peptizers is that it uses a natural product or, more specifically, latex from a different botanical source to reduce the molecular weight of NR. Residual chemicals could have adverse effects on the aging properties of the sample. Therefore, a nonchemical molecular weight depressant for NR, such as *Funtumia* rubber, is likely to be better tolerated.

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