Synthesis of Dipiperazine Thiuramdisulphide (DPTD) and its application as a safe accelerator for the vulcanisation of natural rubber

Síntese do Tiuran Dissulfeto de di Piperazina (DPTD) e sua aplicação como um acelerador seguro para a Vulcanização de borracha natural

Síntesis de Tiuramisulfuro de Dipiperazina (DPTD) y su aplicación como acelerador seguro para la vulcanización del caucho natural

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ABSTRACT
Dipiperazine thiuramdisulphide (DPTD) prepared in the laboratory using piperazine, triethyl amine and carbon disulphide as reactants acts as an accelerator for the vulcanization of natural rubber. The DPTD synthesised in our laboratory was characterized by FTIR, CHNS and the estimation of amine value. Results of the MTT assay test shows that the DPTD is a safe (non-carcinogenic) chemical. For comparable dosages of the accelerator, the DPTD based latex and dry natural rubber (NR) vulcanisates show improved mechanical properties as compared to tetramethylthiuram disulphide (TMTD) based vulcanisates. DPTD may be considered as a safe replacement for the nitrosamine generating TMTD in natural rubber based formulations.

Keywords: vulcanisation, natural rubber, safe chemical, accelerator, nitrosamine.
RESUMO
O TIURAN DISSULFETO DE DI PIPERAZINA (DPTD) preparado em laboratório usando piperazina, trietil amina e dissulfeto de carbono como reagentes atua como um acelerador para a vulcanização da borracha natural. O DPTD sintetizado em nosso laboratório foi caracterizado por FTIR, CHNS e a estimativa do valor de amina. Os resultados do teste de ensaio MTT mostram que o DPTD é um produto químico seguro (não carcinogênico). Para dosagens comparáveis do acelerador, os vulcanizados de látex e de borracha natural seca (NR) à base de DPTD apresentam melhores propriedades mecânicas em comparação com os vulcanizados à base de dissulfeto de tetrametiltiuram (TMTD). O DPTD pode ser considerado um substituto seguro para o TMTD gerador de nitrosaminas em formulações à base de borracha natural.

Palavras-chave: vulcanização, borracha natural, produto químico seguro, acelerador, nitrosamina.

RESUMEN
El tiuramisulfuro de dipiperazina (DPTD) preparado en el laboratorio utilizando piperazina, trietilamina y disulfuro de carbono como reactivos actúa como acelerador de la vulcanización del caucho natural. El DPTD sintetizado en nuestro laboratorio se caracterizó por FTIR, CHNS y la estimación del valor de amina. Los resultados del ensayo MTT muestran que el DPTD es un producto químico seguro (no cancerígeno). Para dosis comparables del acelerador, los vulcanizados a base de látex y caucho natural seco (NR) con DPTD muestran mejores propiedades mecánicas que los vulcanizados a base de disulfuro de tetrametiltiuram (TMTD). El DPTD puede considerarse un sustituto seguro del TMTD, generador de nitrosaminas, en las formulaciones a base de caucho natural.

Palabras clave: vulcanización, caucho natural, producto químico seguro, acelerador, nitrosamina.

1 INTRODUCTION
The formation of carcinogenic nitrosamine at work place in the rubber industry is an unsolved problem. Nitrosamines are generally formed during the vulcanisation process. These are volatile at low temperatures. Nitrosamines are generally formed by the simple reaction of secondary amines with oxides of nitrogen. The oxides of nitrogen are formed by heating any compound containing nitrogen, even in air (nitrosation reaction). The secondary amines are produced by the breakdown of conventional accelerators such as thiurams, dithiocarbamates, sulphenamides, etc. Some of the conventional accelerators that generate nitrosamines are tetraethylthiuram disulphide (TETD), tetramethylthiuram disulphide (TMTD), tetrabutylthiuram disulphide (TBTD), dipentamethylenethiuram tetrasulphide (DPTT), N-oxydiethelene-2-benzothiazole sulphenamide (OBTS) and zinc diethyl dithiocarbamate (ZDC). Since1980 several
Nitrosamines have been classified as either carcinogens or mutagens. The target organs for the toxic effect of nitrosamines in human beings are lungs and liver.

Most of the nitrosamines formed during the vulcanisation of elastomers are carcinogenic. Some of the accelerators like N-cyclohexyl-2-benzothiazole sulphenamides (CBS), mercaptobenzothiazole (MBT), zinc mercaptobenzothiazole (ZMBT) and diphenylguanidine (DPG) are found to be non-regulated. This is because of the specific chemical structure of the nitrosamines formed. It is desirable to replace the carcinogenic rubber accelerators by the safe rubber accelerators without affecting their major activity in the vulcanization process.

Figure 1. – Structure of DPTD

Source: based on the primary data generated by our own research/investigations.

Some of the nitrosamines that are found in rubber industry are: N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA), N-nitrosodibutylamine (NDBA), N-nitrosopiperidine (NPIP), N-nitrosopyrrolidine (NPYR), N-nitrosomorpholine (NMOR) and N-nitrosoethylphenylamine (NEPhA). Nitrosamine are generally formed during vulcanisation using conventional accelerators like tetramethyl thiuram disulphide (TMTD). The methyl groups present in TMTD is not a constraint for the amine group to react with nitrogen oxide in the air to form N-nitroso dimethyl amine (NDMA). NDMA is a highly potent carcinogen associated with various health issues. The degree of carcinogenicity varies in accordance with the substituted group. It was reported that N-nitroso diethyl amine (NDEA) is the most potent carcinogen. NDMA and N-nitrosodiphenyl amine (NDPA) are 15,000 times less potent carcinogens compared to NDEA. During vulcanisation some or all the amines released from the accelerator can be converted to a suitable nitrosamine in the presence of a nitrosating agent.

The replacement of methyl group present in the TMTD with a bulky group such as piperazine may result in the formation of non-regulated nitrosamine. The synthesis of
novel dipiperazinethiuramdisulphide (DPTD) (Figure 1) and its application as a safe (non-regulated) accelerator in rubber formulations are discussed in this paper.

2 MATERIALS

Centrifuged Natural Rubber (NR) Latex (high ammonia (HA) type) as per ASTM D 1076 – 2010 was obtained from Central Experimental Station, Rubber Research Institute of India, Kottayam. The natural rubber (dry) used in this study having the Mooney Viscosity (ML (1 +4) 100 °C) 85, was obtained from the Rubber Research Institute of India, Kottayam.

Zinc oxide (ZnO) was supplied by M/s. Meta Zinc Ltd. Mumbai. VulcastabVL, zinc diethyl dithiocarbamate (ZDC), zinc 2-mercaptobenzothiazole (ZMBT), 2,2,4-trimethyl-1,2-dihydroquinoline (TQ), Dispersal F (sodiummethylene bis naphthalenesulphonic acid), tetramethylthiuramdisulfide (TMTD), tertiarybutylbenzothiazolesulphenamide (TBBS), styrenated phenol (SP), sulphur and stearic acid were supplied by M/s. Associated Rubber Chemicals (Kochi) Pvt. Ltd. Potassium hydroxide and potassium oleate were of the laboratory reagent grade.

Dipiperazine thiuramdisulphide (DPTD) was synthesized in the laboratory. The materials for the synthesis (piperazine, carbon di sulphide, iodine, triethyl amine and methanol) were supplied by M/s. Alpha Chemicals and Diagnostics Ltd., Kochi, India.

3 EXPERIMENTAL

3.1 SYNTHESIS OF DIPIPERAZINE THIURAMDISULPHIDE (DPTD)

The DPTD was prepared using the following method. Piperazine was dissolved in methanol. 100 ml of triethyl amine (TEA) was added to the solution drop by drop and cooled below 5°C. Carbon disulphide (60 ml) was added drop by drop with stirring. The trimethyl salt of piperazine was formed. 1:1 (molar) iodine in methanol was added with stirring. The precipitate formed was filtered, washed with water and dried. The proposed mechanism for the synthesis of DPTD is shown in Scheme 1.

![Scheme 1. – Reaction scheme for the synthesis of DPTD.](image-url)
4 CHARACTERIZATION

4.1 FTIR SPECTROSCOPY

FTIR spectroscopic analysis of the synthesised DPTD was conducted using Thermo Nicolet Avatar 370 FTIR spectrometer in the spectral range of 400 – 4000 cm\(^{-1}\) using horizontal attenuated total reflectance assembly.

4.2 CHNS ANALYSIS

Sulphur content was analysed using CHNS-O Analyser (Thermo Fisher Scientific, Model- Flash 2000, Detector-TCD (Thermal conductivity detector)).

4.3 AMINE VALUE

Amine value was determined by volumetric analysis using perchloric acid. DPTD was dissolved in ethyl alcohol. 20 ml of distilled water and two drops of phenolphthalein indicator were added to the solution. It was titrated against perchloric acid taken in the burette.

4.4 MTT ASSAY

Cytotoxicity of the newly synthesised DPTD was measured from the percentage viability of the cells by using the method of MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazoliumbromide) assay and the test procedure is based on ISO 10993-5. The MTT enters the cells and passes into the mitochondria where it is reduced to an insoluble, coloured (dark purple) formazan product. The cells are then solubilised with an organic solvent (dimethyl sulfoxide DMSO (Himedia)) and the released, solubilised formazan product was measured at 540 nm. Since reduction of MTT can only occur in metabolically active cells, the level of activity is a measure of the viability of the cells. Optical density was read at 540 nm using DMSO as blank in a microplate reader (ELISASCAN, ERBA). Control samples are the cells (L929 cells) to which the DPTD solution is not added.

The percentage viability of the cells was calculated using the formula:

\[
\text{Percentage viability} = \frac{\text{Optical density of test specimen}}{\text{Optical density of control}} \times 100
\]
4.5 PREPARATION OF THE MIXES

Mixing of the natural rubber latex based formulations was carried out using mechanical stirrer. The natural rubber latex was stirred and the ingredients were added in the order - stabilizer, anti-oxidant, activators, accelerators and the vulcanizing agent. The mix was kept for 24 hours for maturation. Films were cast using the mixes on a glass plate, dried and cured at 70 °C for 24 hours. The film vulcanizates prepared using TMTD is designated as C0 and the vulcanizates prepared using varying dosages of DPTD are designated as C1, C2, C3, C4, C5, C6 and C7 (Table 1).

Table 1. Formulation of Mixes (NR LATEX)

<table>
<thead>
<tr>
<th>Formulation*</th>
<th>C0</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR latex (g)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Potassium oleate (g)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ZnO Dispersion (phr)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SP emulsion (phr)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ZDC (phr)</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>TMTD (phr)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DPTD (phr)</td>
<td>0</td>
<td>0.25</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>ZMBT (phr)</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Sulphur (phr)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

*based on the dry weight of the rubber in the latex and the dry weight of the ingredients in the dispersion/emulsion.

Source: based on the primary data generated by our own research/investigations.

The dry natural rubber compounds were mixed on a laboratory size two-roll mill as per ASTM D 3182 at a friction ratio of 1:1.25. The formulation of the mixes is given in Table 2. The compounding ingredients were added as per the procedure given in ASTM D 3184.

Table 2. Formulation of the Mixes

<table>
<thead>
<tr>
<th>Formulation</th>
<th>CC</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR (g)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ZnO (phr)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Stearic acid (phr)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>TQ (phr)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>TBBS (phr)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>TMTD (phr)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DPTD (phr)</td>
<td>0</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>Sulphur (phr)</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Source: based on the primary data generated by our own research/investigations.
The cure characteristics of the mixes were obtained using RPA 2000 Rubber Processing Analyzer as per ASTM D 5289. The test specimens were prepared by moulding in an electrically heated hydraulic press at 200 kg/cm$^2$ at a temperature of 150 °C for the optimum cure time. The moulded samples were cooled quickly in water at the end of the curing cycle and kept for maturation.

5 TESTS ON VULCANIZATES

5.1 PROPERTIES

The tensile strength, tear strength, elongation at break and modulus at various elongations were measured using Shimadzu Universal Testing Machine (model AG-1 series (10 KN)) at a cross head speed of 500 mm/min, as per ASTM D 412.

The hardness (Shore A) of the samples was determined using Mitutoyo hardmatic hardness tester according to ASTM D 2240. Compression set at constant strain was measured according to Method B of ASTM D 395.

Resilience is the energy returned by the vulcanized elastomer when it is suddenly released from a state of strain or deformation. Rebound resilience was determined by vertical rebound method according to ASTM D 2632. The abrasion resistance of the samples were determined using a DIN Abrader (DIN 53, 516). Samples with standard diameter and thickness were kept on a rotating sample holder and a 10N load was applied. Abrasion loss was measured as per ASTM D 5963. The swelling index of the vulcanizates was determined by equilibrium swelling method. A Goodrichflexometer confirming to ASTM D 623 was used for measuring the heat build-up.

6 RESULTS AND DISCUSSION

6.1 FOURIER TRANSFORM INFRARED SPECTROSCOPY

IR spectrum of the newly synthesised DPTD (Figure 2) showed bands at 3445 cm$^{-1}$ representing N-H stretching. The peak at 3014 cm$^{-1}$ represents aromatic C-H stretching. The band at 2843 cm$^{-1}$ represents C-H stretching. The bands at 1368 and 1270 cm$^{-1}$ represent the stretching frequencies of C=S and peaks at 575 and 532 cm$^{-1}$ represents S-S stretching$^{13}$. 
6.2 CHNS ANALYSIS

Table 3 shows the results of CHNS analysis. The theoretical values of CHNS for DPTD are in very good agreement with the CHNS values obtained for the synthesised DPTD.

<table>
<thead>
<tr>
<th>% of constituents</th>
<th>Theoretical value</th>
<th>Experimental value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>37.2</td>
<td>36.7</td>
</tr>
<tr>
<td>H</td>
<td>5.5</td>
<td>5.1</td>
</tr>
<tr>
<td>N</td>
<td>17.3</td>
<td>16.6</td>
</tr>
<tr>
<td>S</td>
<td>39.7</td>
<td>37.5</td>
</tr>
</tbody>
</table>

6.3 AMINE VALUE

Amine value of the synthesised DPTD calculated from the titration is 10 %. The result is in agreement with the theoretical value.

6.4 CYTOTOXICITY

The cytotoxicity of the synthesised DPTD was evaluated by checking the cell viability through MTT assay. Cell morphology of control MTT assay and confluent
tested cell containing extract of DPTD were determined using phase contrast image as shown in Figure 3.

Figure 3. – Phase contrast image for determination of cell morphology of : (a) control of MTT assay (b) 6.25 (µg/mL) extract of DPTD (c) 25 (µg/mL) extract of DPTD (d) 100 (µg/mL) extract of DPTD

MTT assay of the controlled sample show large number of fibroblast cells. But in the case of confluent cells containing the extract of DPTD, considerable reduction in the number of viable cells was noticed. The reduction in the number of viable cells in the case of confluent cell containing the extract of DPTD was evident from the lower values of optical density as compared to the control cells after incubation for 24 hours. The samples containing the extract of DPTD was found to possess more than 80% of viable cells for all the concentrations (µg/mL) as shown in Figure 4. Thus the result of MTT assay shows that newly synthesised DPTD is a safe (non-cytotoxic) accelerator for the vulcanization of natural rubber.
Figure 4. – Cytotoxicity analysis of DPTD at different concentrations

Source: based on the primary data generated by our own research/investigations.

6.5 MECHANICAL PROPERTIES

The mechanical properties of control natural rubber vulcanizates prepared from latex based formulation (containing TMTD as one of the accelerators for vulcanization) and the vulcanizates containing varying dosages of the newly synthesised DPTD (as a safe substitute for TMTD) are shown in Table 4. The tensile strength, modulus and tear strength of the vulcanizates containing DPTD increased as the dosage of DPTD increased. At comparable dosages of the accelerators, the vulcanizates prepared using the safe accelerator (DPTD) shows better properties as compared to the vulcanizate prepared using TMTD. The properties further improved as the dosage of the safe accelerator was increased. In the case of the vulcanizates prepared using equal dosage (1 phr) of the accelerators, the vulcanizate prepared using the safe accelerator shows improved crosslink density.
Table 4. Properties of Vulcanizates (from NR latex) prepared using TMTD (C₀) and DPTD (C₁)

<table>
<thead>
<tr>
<th>Properties</th>
<th>C₀</th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>C₄</th>
<th>C₅</th>
<th>C₆</th>
<th>C₇</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus at 300 % elongation (MPa)</td>
<td>1.12</td>
<td>1.06</td>
<td>1.15</td>
<td>1.21</td>
<td>1.26</td>
<td>1.33</td>
<td>1.38</td>
<td>1.41</td>
</tr>
<tr>
<td>Elongation at break (%)</td>
<td>1049</td>
<td>1299</td>
<td>965</td>
<td>1387</td>
<td>1380</td>
<td>1287</td>
<td>1346</td>
<td>1290</td>
</tr>
<tr>
<td>Tear strength (N/mm)</td>
<td>25.1</td>
<td>24.6</td>
<td>25.3</td>
<td>25.9</td>
<td>26.5</td>
<td>27.3</td>
<td>27.9</td>
<td>28.6</td>
</tr>
<tr>
<td>Crosslink density x 10⁵ (mol/g)</td>
<td>3.20</td>
<td>3.22</td>
<td>3.24</td>
<td>3.27</td>
<td>3.31</td>
<td>3.36</td>
<td>3.38</td>
<td>3.41</td>
</tr>
</tbody>
</table>

Source: based on the primary data generated by our own research/investigations.

The mechanical properties of the dry natural rubber based vulcanizates prepared using the control (TMTD) and various dosages of the DPTD are shown in Table 5. As in the case of the latex based vulcanizates, the vulcanizates prepared from dry rubber too show improved tensile strength and modulus as the dosage of DPTD increased. This may be due to the increase in chemical crosslink density (Tables 4 and 5).

Table 5. Properties of vulcanizates (from NR dry rubber) prepared using TMTD and DPTD.

<table>
<thead>
<tr>
<th>Properties</th>
<th>C₀</th>
<th>D₁</th>
<th>D₂</th>
<th>D₃</th>
<th>D₄</th>
<th>D₅</th>
<th>D₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength (MPa)</td>
<td>21.55</td>
<td>20.70</td>
<td>21.91</td>
<td>23.04</td>
<td>23.49</td>
<td>24.27</td>
<td></td>
</tr>
<tr>
<td>Modulus at 300% elongation (MPa)</td>
<td>1.46</td>
<td>1.26</td>
<td>1.31</td>
<td>1.44</td>
<td>1.51</td>
<td>1.67</td>
<td></td>
</tr>
<tr>
<td>Elongation at break (%)</td>
<td>965</td>
<td>812</td>
<td>1122</td>
<td>1111</td>
<td>1127</td>
<td>1117</td>
<td></td>
</tr>
<tr>
<td>Tear Strength (N/mm)</td>
<td>27.58</td>
<td>26.23</td>
<td>26.87</td>
<td>27.77</td>
<td>28.01</td>
<td>28.45</td>
<td></td>
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<tr>
<td>Hardness (Shore A)</td>
<td>31</td>
<td>30</td>
<td>30</td>
<td>31</td>
<td>33</td>
<td>33</td>
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<td>Rebound resilience (%)</td>
<td>64</td>
<td>63</td>
<td>63</td>
<td>64</td>
<td>65</td>
<td>66</td>
<td></td>
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<tr>
<td>Compression set (%)</td>
<td>15.31</td>
<td>15.93</td>
<td>15.71</td>
<td>15.42</td>
<td>14.56</td>
<td>14.15</td>
<td></td>
</tr>
<tr>
<td>Abrasions loss (cm²/h)</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
<td>0.11</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Heat build up (°C)</td>
<td>5.1</td>
<td>4.6</td>
<td>4.4</td>
<td>4.3</td>
<td>4.2</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Crosslink density x 10⁵ (mol/g)</td>
<td>3.39</td>
<td>3.30</td>
<td>3.36</td>
<td>3.41</td>
<td>3.47</td>
<td>3.51</td>
<td></td>
</tr>
</tbody>
</table>

Source: based on the primary data generated by our own research/investigations.

Tear strength indicates the capacity of the vulcanizates to resist cutting, chipping and tearing action during service. Tear strength of the vulcanizates containing DPTD increased as the dosage of DPTD increased. Hardness is a measure of modulus of elasticity at low strain. The hardness increases marginally as the dosage of DPTD increased. Compression set is defined as the residual deformation of a material after the removal of an applied compression stress. Low set value means that the material has recovered nearly to its original height and there is very little residual deformation. The compression set value decreases with increase in the dosage of DPTD. The crosslink densities of the vulcanizates calculated from the equilibrium swelling measurement in toluene are shown in Tables 4 and 5. The crosslink density increases with increase the dosage of the safe accelerator. The observed improvement in the properties with the use
of the newly synthesised safe accelerator (DPTD) is marginally better in dry natural rubber based formulation.

7 CONCLUSION

Dipiperazine thiuramdisulphide (DPTD) could be prepared in the laboratory using piperazine, triethyl amine and carbon disulphide as reactants. The results of the characterization of the synthesised product by FTIR, CHNS and the estimation of amine value confirms the formation of DPTD. MTT assay test results shows that the newly synthesised DPTD is a safe (non-carcinogenic) chemical. DPTD acts as an accelerator for the vulcanization of latex and dry natural rubber based formulations. The mechanical properties of the vulcanizates improve as the dosage of DPTD is increased. For comparable dosages the DPTD based vulcanizates show improved mechanical properties in the case of both latex and dry natural rubber based vulcanizates as compared to the TMTD based vulcanizates. DPTD may be used as a safe (non-carcinogenic) replacement for TMTD.

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REFERENCES


