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RESEARCH ARTICLE

Computational chemistry

M-polynomial and topological indices for the anti-tuberculosis drugs

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Abstract: Tuberculosis (TB) is one of the deadliest infectious diseases which is caused by the *Mycobacterium tuberculosis*. A group of first line anti-TB drugs namely isoniazid, rifampicin, pyrazinamide and ethambutol have been accepted for the treatment of drug susceptible tuberculosis. A topological index is a molecular structure descriptor which is a numerical value associated with chemical constitution for correlation of a chemical structure with its properties. The aim of this work is to investigate some degree-based topological indices for the above-mentioned anti-TB drugs using a polynomial approach. The molecular graphs of these anti-TB drugs structures were used to derive the M-Polynomials and then the derived formulas were used to calculate topological indices of the respective structures. This research could facilitate the design of new medicines against these pathogenic bacteria.

Keywords: Anti-TB drugs, *M*-polynomial, Randić index, topological indices, tuberculosis, Zagreb index.

INTRODUCTION

Tuberculosis (TB) is one of the deadliest infectious diseases, responsible for millions of deaths annually in the globe (Floyd *et al.*, 2018). The German Microbiologist, Robert Koch declared in 1882 that the TB is an airborne disease which caused by the rod shaped bacillus called *Mycobacterium tuberculosis* (MTB) (Cambau & Drancourt, 2014). This bacterium usually affects the lungs leading to severe coughing, fever, and chest pains; however, it can affect other organs in the body (except nails and hair) as well (Comas & Gagneux, 2009). TB is an airborne infection, and these bacilli are expelled into the air in the form of tiny droplet when the infected patients coughs, sneezes, or laughs, and these droplets may remain suspended in the air for several hours (Keshavjee & Farmer, 2012**)**. The infection process typically occurs after long and repeated exposure to infected individuals via inhalation of these droplets into the lungs (Feng *et al.*, 2020). According to the World Health Organisation (WHO), an untreated TB patient can infect 10–15 persons over the course of one year (WHO, 2002). Early diagnosis and effective treatment are the major challenges in controlling TB globally. A standard TB treatment regime has been recommended by the WHO, and active tuberculosis is treated with first line drugs which include isoniazid, rifampicin, pyrazinamide, and ethambutol for two months (British Thoracic Society, 1984). These anti TB drugs act as bactericidal or bacteriostatic agents against MTB by effecting inhibition of their cell wall, protein synthesis inhibition, nucleic acid inhibition or inhibition of the membrane energy metabolism. (Ma *et al*., 2010: Favrot & Ronning 2012).

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Synthesizing a drug molecule with desired properties is the key for targeting specific diseases (Gao *et al*., 2016; Zheng *et al*., 2019). Therefore, studying the properties of drug molecule is important in drug design. These properties of the compound could be interpreted by using well known topological indices in molecular graph theory or molecular topology.

Currently many researchers are focusing on calculating the topological indices for the chemical structures used in various applications to overcome the painstaking approach of computing a certain type of index of a specific category of graphs (Mobeen *et al*., 2016: Zuo *et al*., 2020). Furthermore, the role of topological indices in drug design research has been reported by various scientists (Rouvray, 1973; Estrada & Uriarte, 2001; Estrada *et al*., 2003; Gálvez *et al*., 2012; Zanni *et al*., 2015). Therefore, the study of topological indices of essential first line anti-TB drugs namely isoniazid, rifampicin, pyrazinamide, and ethambutol is important to evaluate their properties.

A graph $G = G(V, E)$ with the vertex set $V = V(G)$ and the edge set $E = E(G)$ is said to be a connected if there is a connection between any pair of vertices in the graph. The number of edges which are connected to that fixed vertex is called the degree of a vertex, v, and is denoted by $d_v(G)$ or d_v.

A topological index is a numerical quantity which is derived mathematically in a direct and unambiguous manner from the structural graph of a molecule. The first topological index which is a distance based (non-degree based) index was introduced by Wiener in 1947 and defined by the following formula

$$W(G) = \sum_{\{u,v\}\subseteq V(G)} d_G(u, v).$$

where $d_G(u, v)$ is the shortest distance between the vertices u and v in the graph G. Degree-based topological indices are another type of topological indices. Nowadays, the degree-based topological indices play a prominent role in molecular graph theory.

The Randić index and the Zagreb index are the mostly studied types of degree-based topological indices in drug design (Gao *et al*., 2013: Nilanjan De, 2018; Jude *et al*., 2019; Jude *et al*., 2020). The well-known Zagreb index which is the oldest degree-based topological index was introduced by Gutman and Trinajstić in 1972 during the analysis of the structure-dependency of total π-electron energy (Gutman & Trinajstić, 1972). The Zagreb index is presented in two different formats as the first Zagreb index, $M_1(G)$, and the second Zagreb index, $M_2(G)$. The second modified Zagreb index, ${}^{m}M_2(G)$, was introduced by Hao in 2011 (Hao, 2011).

Another old degree-based topological index called the Randić index, $R(G)$, was introduced by Milan Randić in 1975 (Randić, 1975). Another format of the Randić index called the generalized Randic index, $R_\alpha(G)$, was introduced in 1998 by Bollobs and Erds (1998) and Amic *et al*. (1998) independently (here α is an arbitrary real number). This has been studied extensively by both chemists and mathematicians (Hu *et al*., 2005) and the mathematical properties have been discussed by (Caporossi *et al*., 2005). When substituting $\alpha = -1/2$ in this formula, the (original) Randi´c index could be obtained.

There are many topological indices introduced and studied by mathematical chemists. The symmetric division degree index (or simply sdd-index), SDD(G), was proposed by Vukičević (2010) as a remarkable predictor of total surface area of polychlorobiphenyls. The forgotten topological index, F(G), was proposed by Furtula and Gutman in 2015, and is quite helpful for pharmaceutical and medical scientists to grasp the biological and chemical characteristics of new drugs (Gao *et al*., 2016). The harmonic index, H(G), was proposed by Fajtlowicz (1987) as another variant of the Randić index. The inverse sum index, I(G), was proposed by Balban (1982) and that is a significant predictor of the total surface area of octane isomers. The augmented Zagreb index, A(G), was introduced by Furtula *et al.* (2010) for computing the heat of formation of alkanes.

The definition for the above-described degree-based topological indices are expressed by $D(G) = \sum_{uv\in E(G)} f(d_u, d_v)$, where the function $f(d_u, d_v)$ for each of the topological indices are given in the Table 1:

The topological indices could be calculated by direct calculation or by using the algebraic polynomials. For instance, the first derivative of the Hosoya polynomial (Hosoya, 1988) could be used to compute the Wiener index. For computing the degree-based topological indices, the *M*-polynomial, introduced by Deutsch and Klavzar in 2015, is used. For a graph $G = G(V, E)$, the *M*-polynomial is defined by

$$M(G) = \sum_{i\le j} m_{ij}(G)x^i y^j,$$

where $m_{ij}(G)$, $i, j \geq 1$ is the number of edges $e = uv$ of G such that $\{d_u, d_v\} = \{i, j\}, u, v \in V(G)$.

Table 1: Description of some of the degree based topological indices.

Topological index	**Notation**	$f(d_u, d_v)$	**Reference**
First Zagreb index	$M_1(G)$	$d_u + d_v$	Gutman & Trinajstić, 1972
Second Zagreb index	$M_2(G)$	$d_u d_v$	Gutman & Trinajstić, 1972
Second modified Zagreb	${}^{m}M_2(G)$	$\frac{1}{d_u d_v}$	Hao, 2011
Generalized Randić index	$R_\alpha(G)$	$(d_u d_v)^\alpha$	Amic *et al*., 1998; Bollobás & Erdös 1998
Randić index	$R_{-1/2}(G)$	$\frac{1}{\sqrt{d_u d_v}}$	Randić, 1975
Symmetric division deg index	$SDD(G)$	$\frac{d_u^2 + d_v^2}{d_u d_v}$	Vukicevic, 2010
Forgotten topological index	$F(G)$	$d_u^2 + d_v^2$	Furtula & Gutman, 2015
Harmonic index	$H(G)$	$\frac{2}{d_u + d_v}$	Fajtlowicz, 1987
Inverse sum indeg index	$I(G)$	$\frac{d_u d_v}{d_u + d_v}$	Balaban, 1982
Augmented Zagreb index	$A(G)$	$\left(\frac{d_u d_v}{d_u + d_v}\right)^3$	Furtula *et al.*, 2010

Table 2: The derivation of some degree-based topological indices from the *M*-polynomial (Deutsch & Klavzar, 2015).

Topological index	Notation	Derivation from $M(G)$
First Zagreb index	$M_1(G)$	$(D_x + D_y)(M(G))\big\|_{x=y=1}$
Second Zagreb index	$M_2(G)$	$(D_x D_y)(M(G))\big\|_{x=y=1}$
Second modified Zagreb	${}^{m}M_2(G)$	$(S_x\, S_y)(M(G))\big\|_{x=y=1}$
Generalized Randić index	$R_\alpha(G)$	$(D_x^\alpha\, D_y^\alpha)(M(G))\big\|_{x=y=1}$
Randić index	$R_{-1/2}(G)$	
Symmetric division deg index	$SDD(G)$	$(D_x S_y + S_x D_y)(M(G))\big\|_{x=y=1}$
Forgotten topological index	$F(G)$	$({D_x}^2 + {D_y}^2)(M(G))\big\|_{x=y=1}$
Harmonic index	$H(G)$	$2S_x J(M(G))\big\|_{x=y=1}$
Inverse sum indeg index	$I(G)$	$S_x J D_x D_y(M(G))\big\|_{x=y=1}$
Augmented Zagreb index	$A(G)$	$S_x^3 Q_{-2} J {D_x}^3 {D_y}^3(M(G))\big\|_{x=y=1}$

The topological indices described-above could be calculated using the respective derivation formula of the *M*-polynomial $M(G)$ given in the Table 2:

Here $D_x(f(x,y)) = x\frac{\partial f(x,y)}{\partial x}$, $D_y(f(x,y)) = y\frac{\partial f(x,y)}{\partial y}$, $S_x(f(x,y)) = \int_0^x \frac{f(t,y)}{t}dt$, $D_x^{\alpha} = \sum_i n_i^{\alpha} k_i x^{n_i} y^{m_i}$ here $D_x = \sum_i k_i x^{n_i} y^{m_i}$, $S_y(f(x,y)) = \int_0^y \frac{f(x,t)}{t}dt$, $J(f(x,y)) = f(x,x)$, $S_xJ = S_x(f(x,x)) = \int_0^x \frac{f(t,t)}{t}dt$, and $Q_{\alpha}(f(x,y)) = x^{\alpha}f(x,y)$.

In this study, we calculate some of the well-known degree based topological indices (expressed in the above table) using the M-polynomial for the first line anti-TB drugs, namely, isoniazid, rifampicin, pyrazinamide and ethambutol.

MATERIALS AND METHODS

In this paper, we considered four anti-TB drugs namely isoniazid, rifampicin, pyrazinamide and ethambutol and calculated their topological indices. The molecular graphs of these drug structures were used to derive the *M*-Polynomials, and then the derived formulas were used to calculate topological indices of the respective structures. The calculated topological indices are given in Table 2.

The edge sets were portioned by observing the molecular graph of a structure and find the *M*-Polynomial. We denote $E(i,j)$ be the set of edge partitions of the graph G, where $E(i,j) = \{uv \in E(G): d_u = i \text{ and } d_v = j\}$. In a molecular representation (in a molecular structure), a dashed line indicates that the bond is extending behind the plane of the drawing surface; a bold-wedged line indicates that the bond is protruding out from the plane of the drawing surface and a solid line indicates that the bond exists in the plane of the drawing surface. In molecular graph theory, all these bonds are considered as single edges for the calculation except a bond with Hydrogen. Furthermore, the multiple edges are treated as single edge in molecular graph theory. We calculated the topological indices using the derivation formula for the respective -Polynomial. MATLAB is used to sketch $M(G)$.

RESULTS AND DISCUSSION

First, we considered the molecular graph of isoniazid (Figure 1).

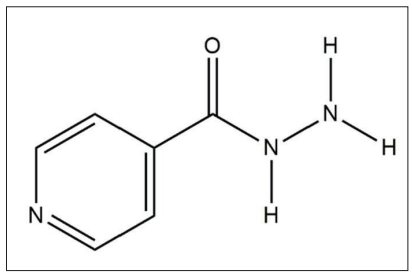

Figure 1: Molecular graph of isoniazid

Theorem 1: Let *G* be the molecular graph of isoniazid. Then the *M*-Polynomial of isoniazid is given by,

$$M(G) = xy^2 + xy^3 + 4x^2y^2 + 3x^2y^3 + x^3y^3.$$

Proof: Let *G* be the molecular graph of isoniazid which has 10 numbers of edges.

Let $E(i,j)$ be the set of edge partitions with the degree of end vertices i,j.

i.e., $E(i,j) = \{e = uv \in E(G): d_u = i \text{ and } d_v = j\}$. By observing the structure, we inferred four partitions of the edge set as follows:

$E(1,2) = \{e = uv\epsilon E(G): d_u = 1 \text{ and } d_v = 2\}$, $E(1,3) = \{e = uv\epsilon E(G): d_u = 1 \text{ and } d_v = 3\}$, $E(2,2) = \{e = uv\epsilon E(G): d_u = d_v = 2\}$ $E(2,3) = \{e = uv\epsilon E(G): d_u = 2 \text{ and } d_v = 3\}$ and $E(3,3) = \{e = uv\epsilon E(G): d_u = 3 \text{ and } d_v = 3\}$.

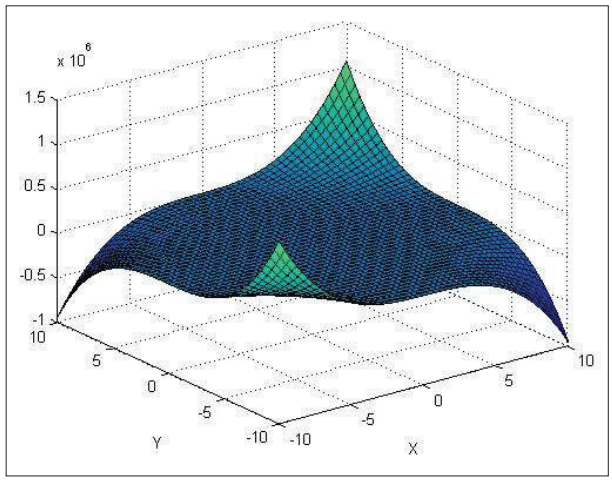

Figure 2: Plotting of *M*-polynomial for isoniazid

Also we get $|E(1,2)| = 1$, $|E(1,3)| = 1$, $|E(2,2)| = 4$, $|E(2,3)| = 3$ and Therefore, the *M* the *M*-polynomial of the molecular graph of isoniazid is

$$M(G) = xy^2 + xy^3 + 4x^2y^2 + 3x^2y^3 + x^3y^3.$$

Theorem 2: Let G be the molecular graph of isoniazid. Then, the first Zagreb index $M_1(G)$, second Zagreb index $M_2(G)$ second modified Zagreb index ${}^{m}M_2(G)$, generalized Randić index, $R_\alpha(G)$, Randić index $R_{-1/2}(G)$ (which is actually $R(G)$), symmetric division degree index SDD(G), forgotten topological index F(G), harmonic index H(G), inverse sum index index I(G), and the augmented Zagreb index A(G) are given by

1. $M_1(G) = 44.$
2. $M_2(G) = 48.$
3. ${}^{m}M_2(G) = \frac{22}{9}.$
4. $R_\alpha(G) = 2^\alpha + 3^\alpha + 4(4)^\alpha + 3(6)^\alpha + (9)^\alpha.$
5. $R_{-1/2}(G) = \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{3}} + \frac{3}{\sqrt{6}} + \frac{7}{3}.$
6. $SDD(G) = \frac{67}{3}.$
7. $F(G) = 104.$
8. $H(G) = \frac{141}{30}.$
9. $I(G) = \frac{631}{60}.$
10. $A(G) = \frac{5041}{64}.$

Proof: Let be the *M*-polynomial of the molecular graph of isoniazid. Then we get the following:

$$D_x\big(M(G)\big) = xy^2 + xy^3 + 8x^2y^2 + 6x^2y^3 + 3x^3y^3.$$

$$D_y\big(M(G)\big) = 2xy^2 + 3xy^3 + 8x^2y^2 + 9x^2y^3 + 3x^3y^3.$$

$$D_xD_y\big(M(G)\big) = 2xy^2 + 3xy^3 + 16x^2y^2 + 18x^2y^3 + 9x^3y^3.$$

$$S_x\big(M(G)\big) = xy^2 + xy^3 + 2x^2y^2 + \frac{3}{2}x^2y^3 + \frac{1}{3}x^3y^3.$$

$$S_y\big(M(G)\big) = \frac{1}{2}xy^2 + \frac{1}{3}xy^3 + 2x^2y^2 + x^2y^3 + \frac{1}{3}x^3y^3.$$

$$S_xS_y\big(M(G)\big) = \frac{1}{2}xy^2 + \frac{1}{3}xy^3 + x^2y^2 + \frac{1}{2}x^2y^3 + \frac{1}{9}x^3y^3.$$

$$D_x^\alpha\big(M(G)\big) = xy^2 + xy^3 + 4(2)^\alpha x^2y^2 + 3(2)^\alpha x^2y^3 + (3)^\alpha x^3y^3.$$

$$D_y^\alpha\big(M(G)\big) = 2^\alpha xy^2 + 3^\alpha xy^3 + 4(2)^\alpha x^2y^2 + 3(3)^\alpha x^2y^3 + (3)^\alpha x^3y^3.$$

$$D_x^\alpha D_y^\alpha\big(M(G)\big) = 2^\alpha xy^2 + 3^\alpha xy^3 + 4(4)^\alpha x^2y^2 + 3(6)^\alpha x^2y^3 + (9)^\alpha x^3y^3.$$

$$S_xD_y\big(M(G)\big) = 2xy^2 + 3xy^3 + 4x^2y^2 + \frac{9}{2}x^2y^3 + x^3y^3.$$

$$S_yD_x\big(M(G)\big) = \frac{1}{2}xy^2 + \frac{1}{3}xy^3 + 4x^2y^2 + 2x^2y^3 + x^3y^3.$$

$$J\big(M(G)\big) = x^3 + 5x^4 + 3x^5 + x^6.$$

$$S_xJ\big(M(G)\big) = \frac{1}{3}x^3 + \frac{5}{4}x^4 + \frac{3}{5}x^5 + \frac{1}{6}x^6.$$

$$JD_xD_y\big(M(G)\big) = 2x^3 + 19x^4 + 18x^5 + 9x^6.$$

$$S_xJD_xD_y\big(M(G)\big) = \frac{2}{3}x^3 + \frac{19}{4}x^4 + \frac{18}{5}x^5 + \frac{9}{6}x^5$$

$$D_x^3D_y^3\big(M(G)\big) = 8xy^2 + 27xy^3 + 256x^2y^2 + 648x^2y^3 + 729x^3y^3.$$

$$Q_{-2}JD_x^3D_y^3\big(M(G)\big) = 8x + 283x^2 + 648x^3 + 729x^4.$$

$$S_x^3Q_{-2}JD_x^3D_y^3\big(M(G)\big) = 8x + \frac{283}{8}x^2 + 24x^3 + \frac{729}{64}x^4.$$

By using the derived formulas of the *M*-polynomial, we find,

1. $M_1(G) = \big(D_x + D_y\big)\big(M(G)\big)|_{x=y=1} = 44.$
2. $M_2(G) = D_xD_y\big(M(G)\big)|_{x=y=1} = 48.$
3. $R_\alpha(G) = D_x^\alpha D_y^\alpha\big(M(G)\big)|_{x=y=1} = 2^\alpha + 3^\alpha$
4. $R(G) = R_{-1/2}(G) = D_x^{-1/2}D_y^{-1/2}\big(M(G)\big)|_{x=y=1}$
   $= \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{3}} + \frac{3}{\sqrt{6}} + \frac{7}{3}.$
5. $SDD(G) = \big(S_xD_y + S_yD_x\big)|_{x=y=1} = \frac{67}{3}.$
6. $F(G) = \big(D_x^2 + D_y^2\big)\big(M(G)\big)|_{x=y=1} = 104.$
7. $H(G) = 2S_yD_x\big(M(G)\big)|_{x=y=1} = \frac{141}{30}.$
8. $I(G) = S_xJD_xD_y\big(M(G)\big)|_{x=y=1} = \frac{631}{60}.$
9. $A(G) = S_x^3Q_{-2}JD_x^3D_y^3\big(M(G)\big)|_{x=y=1} = \frac{5041}{64}.$

Now we considered the molecular graph of rifampicin (Figure 3).

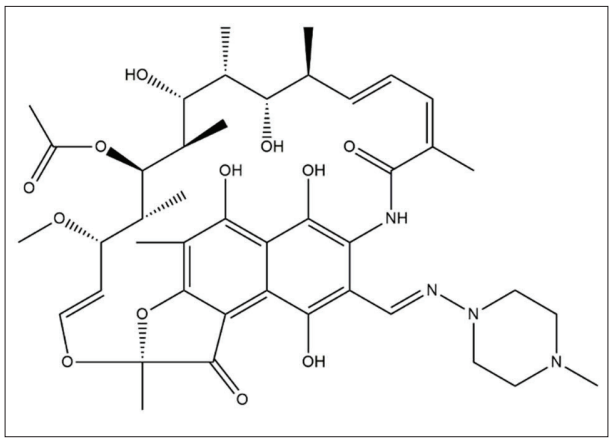

Figure 3: Molecular graph of rifampicin

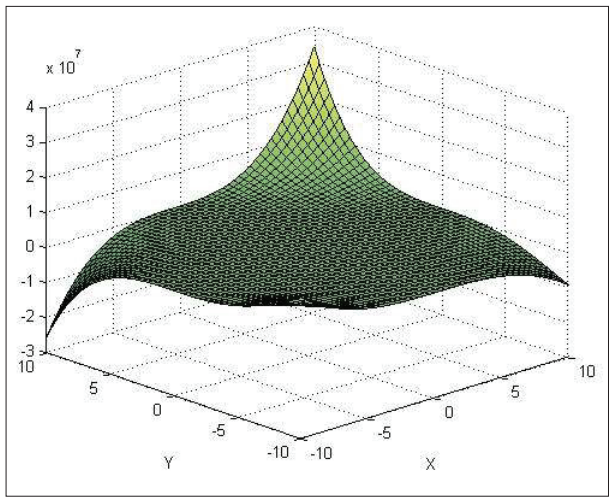

Figure 4: Plotting of *M*-polynomial for rifampicin

Theorem 3: Let *G* be the molecular graph of rifampicin. Then the *M*-Polynomial of rifampicin is given by,

$$M(G) = xy^2 + 16xy^3 + xy^4 + 5x^2y^2 + 17x^2y^3 + 2x^2y^4 + 20x^3y^3 + x^3y^4.$$

Proof: Let *G* be the molecular graph of rifampicin which has 63 numbers of edges.

By observing the structure, we inferred eight partitions of the edge set as follows:

$E(1,2) = \{e = uv \epsilon E(G): d_u = 1 \text{ and } d_v = 2\}$,
$E(1,3) = \{e = uv \epsilon E(G): d_u = 1 \text{ and } d_v = 3\}$,
$E(1,4) = \{e = uv \epsilon E(G): d_u = 1 \text{ and } d_v = 4\}$,
$E(2,2) = \{e = uv \epsilon E(G): d_u = d_v = 2\}$,
$E(2,3) = \{e = uv \epsilon E(G): d_u = 2 \text{ and } d_v = 3\}$,
$E(2,4) = \{e = uv \epsilon E(G): d_u = 2 \text{ and } d_v = 4\}$,
$E(3,3) = \{e = uv \epsilon E(G): d_u = d_v = 3\}$, and
$E(3,4) = \{e = uv \epsilon E(G): d_u = 3 \text{ and } d_v = 4\}$.

Also we get $|E(1,2)| = 1$, $|E(1,3)| = 16$, $|E(1,4)| = 1$, $|E(2,2)| = 5$, $|E(2,3)_5| = 17$, $|E(2,4)| = 1$, and $|E(3,4)| = 1$.

Therefore, the *M*-polynomial of the structure of rifampicin is

$$M(G) = xy^2 + 16xy^3 + xy^4 + 5x^2y^2 + 17x^2y^3 + 2x^2y^4 + 20x^3y^3 + x^3y^4.$$

Theorem 4: Let G be the molecular graph of rifampicin. Then, the first Zagreb index $M_1(G)$, second Zagreb index $M_2(G)$, second modified Zagreb index ${}^mM_2(G)$, generalized Randić index, $R_\alpha(G)$, Randić index $R_{-1/2}(G)$ (which is actually $R(G)$), symmetric division degree index $\mathrm{SDD(G)}$, forgotten topological index $\mathrm{F(G)}$, harmonic index $\mathrm{F(G)}$, inverse sum index index $\mathrm{I(G)}$, and the augmented Zagreb index are given by

1. $M_1(G) = 316$.
2. $M_2(G) = 384$.
3. ${}^mM_2(G) = \frac{229}{18}$.
4. $R_\alpha(G) = (2)^\alpha + 16(3)^\alpha + 6(4)^\alpha + 17(6)^\alpha + 2(8)^\alpha + 20(9)^\alpha + (12)^\alpha$.
5. $R(G) = \frac{2}{\sqrt{2}} + \frac{33}{2\sqrt{3}} + \frac{17}{\sqrt{6}} + \frac{29}{3}$.
6. $SDD(G) = 154$.
7. $F(G) = 868$.
8. $H(G) = \frac{647}{70}$.
9. $I(G) = \frac{7691}{105}$.
10. $A(G) = 102$

Proof: Let $M(G)$ be the *M*-polynomial of the molecular graph of rifampicin. Then we get the following:

$$D_x\big(M(G)\big) = xy^2 + 16xy^3 + xy^4 + 10x^2y^2 + 34x^2y^3 + 4x^2y^4 + 60x^3y^3 + 3x^3y^4.$$

$$D_y\big(M(G)\big) = 2xy^2 + 48xy^3 + 4xy^4 + 10x^2y^2 + 51x^2y^3 + 8x^2y^4 + 60x^3y^3 + 4x^3y^4$$

$$D_xD_y\big(M(G)\big) = 2xy^2 + 48xy^3 + 4xy^4 + 20x^2y^2 + 102x^2y^3 + 16x^2\,y^4 + 180x^3y^3 + 12x^3y^4$$

$$S_x\big(M(G)\big) = xy^2 + 16xy^3 + xy^4 + \tfrac{5}{2}x^2y^2 + \tfrac{17}{2}x^2y^3 + x^2y^4 + \tfrac{20}{3}x^3y^3 + \tfrac{1}{3}x^3y^4.$$

$$S_y\big(M(G)\big) = \tfrac{1}{2}xy^2 + \tfrac{16}{3}xy^3 + \tfrac{1}{4}xy^4 + \tfrac{5}{2}x^2y^2 + \tfrac{17}{3}x^2y^3 + \tfrac{1}{2}x^2y^4 + \tfrac{20}{3}x^3y^3 + \tfrac{1}{4}x^3y^4.$$

$$S_xS_y\big(M(G)\big) = \tfrac{1}{2}xy^2 + \tfrac{16}{3}xy^3 + \tfrac{1}{4}xy^4 + \tfrac{5}{4}x^2y^2 + \tfrac{17}{6}x^2y^3 + \tfrac{1}{4}x^2y^4 + \tfrac{20}{9}x^3y^3 + \tfrac{1}{12}x^3y^4.$$

$$D_x^{\alpha}\big(M(G)\big) = xy^2 + 16xy^3 + xy^4 + 5(2)^{\alpha}x^2y^2 + 17(2)^{\alpha}x^2y^3 + 2(2)^{\alpha}x^2y^4 + 20(3)^{\alpha}x^3y^3 + (3)^{\alpha}x^3y^4.$$

$$D_y^{\alpha}\big(M(G)\big) = (2)^{\alpha}xy^2 + 16(3)^{\alpha}xy^3 + (4)^{\alpha}xy^4 + 5(2)^{\alpha}x^2y^2 + 17(3)^{\alpha}x^2y^3 + 2(4)^{\alpha}x^2y^4 + 20(3)^{\alpha}x^3y^3 + (4)^{\alpha}x^3y^4.$$

$$D_x^{\alpha}D_y^{\alpha}\big(M(G)\big) = (2)^{\alpha}xy^2 + 16(3)^{\alpha}xy^3 + (4)^{\alpha}xy^4 + 5(4)^{\alpha}x^2y^2 + 17(6)^{\alpha}x^2y^3 + 2(8)^{\alpha}x^2y^4 + 20(9)^{\alpha}x^3y^3 + (12)^{\alpha}x^3y^4.$$

$$S_xD_y\big(M(G)\big) = 2xy^2 + 48xy^3 + 4xy^4 + 5x^2y^2 + \tfrac{51}{2}x^2y^3 + 4x^2y^4 + 20x^3y^3 + \tfrac{4}{3}x^3y^4.$$

$$S_yD_x\big(M(G)\big) = \tfrac{1}{2}xy^2 + \tfrac{16}{3}xy^3 + \tfrac{1}{4}xy^4 + 5x^2y^2 + \tfrac{34}{3}x^2y^3 + x^2y^4 + 20x^3y^3 + \tfrac{3}{4}x^3y^4.$$

$$J\big(M(G)\big) = x^3 + 21x^4 + 18x^5 + 22x^6 + x^7.$$

$$S_xJ\big(M(G)\big) = \tfrac{1}{3}x^3 + \tfrac{21}{4}x^4 + \tfrac{18}{5}x^5 + \tfrac{11}{3}x^6 + \tfrac{1}{7}x^7.$$

$$JD_xD_y\big(M(G)\big) = 2x^3 + 68x^4 + 106x^5 + 196x^6 + 12x^7.$$

$$S_xJD_xD_y\big(M(G)\big) = \tfrac{2}{3}x^3 + 17x^4 + \tfrac{106}{5}x^5 + \tfrac{98}{3}x^6 + \tfrac{12}{7}x^7$$

$$D_x^3D_y^3\big(M(G)\big) = 8xy^2 + 432xy^3 + 64xy^4 + 320x^2y^2 + 3672x^2y^3 + 1024x^2y^4 + 14580x^3y^3 + 1728x^3y^4$$

$$JD_x^3D_y^3\big(M(G)\big) = 8x^3 + 752x^4 + 3736x^5 + 15604x^6 + 1728x^7.$$

$$Q_{-2}JD_x^3D_y^3\big(M(G)\big) = 8x + 752x^2 + 3736x^3 + 15604x^4 + 1728x^5.$$

$$S_x^3Q_{-2}JD_x^3D_y^3\big(M(G)\big) = 8x + \tfrac{752}{2^3}x^2 + \tfrac{3736}{3^3}x^3 + \tfrac{15604}{4^3}x^4 + \tfrac{1728}{5^3}x^5.$$

By using the derived formulas of the *M*-polynomial, we find,

1. $M_1(G) = \big(D_x + D_y\big)\big(M(G)\big)|_{x=y=1} = 316.$
2. $M_2(G) = D_xD_y\big(M(G)\big)|_{x=y=1} = 384.$
3. ${}^{m}M_2(G) = S_xS_y\big(M(G)\big)|_{x=y=1} = \frac{229}{18}.$
4. $R_{\alpha}(G) = D_x^{\alpha}D_y^{\alpha}\big(M(G)\big)|_{x=y=1} = (2)^{\alpha} + 16(3)^{\alpha} + 6(4)^{\alpha} + 17(6)^{\alpha} + 2(8)^{\alpha} + 20(9)^{\alpha} + (12)^{\alpha}$
5. $R(G) = R_{-1/2}(G) = D_x^{-1/2}D_y^{-1/2}\big(M(G)\big)|_{x=y=1} = \frac{2}{\sqrt{2}} + \frac{33}{2\sqrt{3}} + \frac{17}{\sqrt{6}} + \frac{29}{3}.$
6. $SDD(G) = \big(S_xD_y + S_yD_x\big)|_{x=y=1} = 154.$
7. $F(G) = \big(D_x^2 + D_y^2\big)\big(M(G)\big)|_{x=y=1} = 868.$
8. $H(G) = 2S_yD_x\big(M(G)\big)|_{x=y=1} = \frac{647}{70}.$
9. $I(G) = S_xJD_xD_y\big(M(G)\big)|_{x=y=1} = \frac{7691}{105}.$
10. $A(G) = S_x^3Q_{-2}JD_x^3D_y^3\big(M(G)\big)|_{x=y=1} = 102 + \frac{3736}{3^3} + \frac{15604}{4^3} + \frac{1728}{5^3}.$

Now we considered the molecular graph of pyrazinamide (Figure 5).

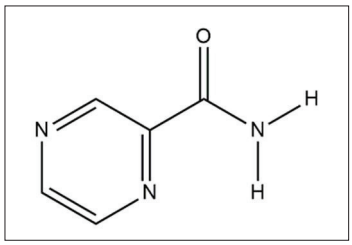

Figure 5: Molecular graph of pyrazinamide

Theorem 5: Let G be the molecular graph of pyrazinamide. Then the M-Polynomial of pyrazinamide is given by,

$$M(G) = 2xy^3 + 4x^2y^2 + 2x^2y^3 + x^3y^3.$$

Proof: Let be the molecular graph of pyrazinamide which has 9 numbers of edges.

By observing the structure, we inferred four partitions of the edge set as follows:

$E(1,3) = \{e = uv \epsilon E(G): d_u = 1 \text{ and } d_v = 3\}$,
$E(2,2) = \{e = uv \epsilon E(G): d_u = d_v = 2\}$,
$E(2,3) = \{e = uv \epsilon E(G): d_u = 2 \text{ and } d_v = 3\}$,
and $E(3,3) = \{e = uv \epsilon E(G): d_u = d_v = 3\}$.

Also we get, $|E(1,3)| = 2$, $|E(2,2)| = 4$, $|E(2,3)| = 2$ and $|E(3,3)| = 1$.

Therefore, the M-polynomial of the molecular graph of pyrazinamide is

$$M(G) = 2xy^3 + 4x^2y^2 + 2x^2y^3 + x^3y^3.$$

Theorem 6: Let G be the molecular graph of pyrazinamide. Then, the first Zagreb index $M_1(G)$, second Zagreb index $M_2(G)$, second modified Zagreb index ${}^{m}M_2(G)$, generalized Randić index, $R_\alpha(G)$, Randić index $R_{-1/2}(G)$ (which is actually $R(G)$), symmetric division degree index $SDD(G)$, forgotten topological index $F(G)$, harmonic index $H(G)$, inverse sum index index $I(G)$, and the augmented Zagreb index $A(G)$ are given by

1. $M_1(G) = 40.$
2. $M_2(G) = 43.$
3. ${}^{m}M_2(G) = \frac{19}{9}.$
4. $R_\alpha(G) = 2(3)^\alpha + 4(4)^\alpha + 2(6)^\alpha + (9)^\alpha.$
5. $R(G) = \frac{2}{\sqrt{3}} + \frac{2}{\sqrt{6}} + \frac{7}{3}.$
6. $SDD(G) = 21.$
7. $F(G) = 96.$
8. $H(G) = \frac{62}{15}.$
9. $I(G) = \frac{47}{5}.$
10. $A(G) = \frac{310}{2^3} + \frac{432}{3^3} + \frac{729}{4^3} = \frac{4233}{64}.$

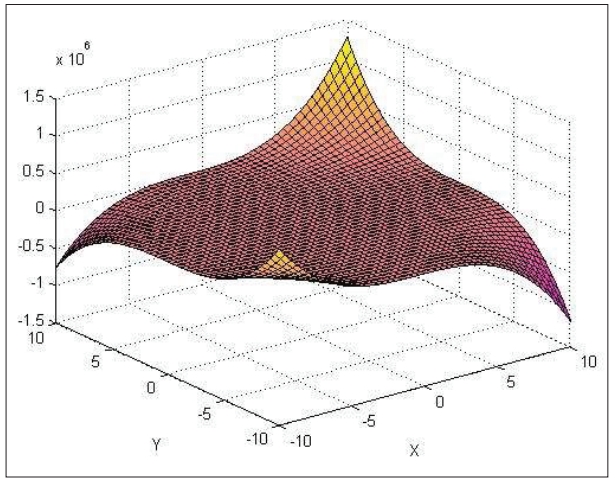

Figure 6: Plotting of M-polynomial for pyrazinamide

Proof: Let $M(G)$ be the -polynomial of the molecular graph of pyrazinamide. Then we get the following:

$$D_x(M(G)) = 2xy^3 + 8x^2y^2 + 4x^2y^3 + 3x^3y^3.$$

$$D_y(M(G)) = 6xy^3 + 8x^2y^2 + 6x^2y^3 + 3x^3y^3.$$

$$D_xD_y(M(G)) = 6xy^3 + 16x^2y^2 + 12x^2y^3 + 9x^3y^3.$$

$$S_x(M(G)) = 2xy^3 + 2x^2y^2 + x^2y^3 + \frac{1}{3}x^3y^3.$$

$$S_y(M(G)) = \frac{2}{3}xy^3 + 2x^2y^2 + \frac{2}{3}x^2y^3 + \frac{1}{3}x^3y^3.$$

$$S_xS_y(M(G)) = \frac{2}{3}xy^3 + x^2y^2 + \frac{1}{3}x^2y^3 + \frac{1}{9}x^3y^3.$$

$$D_x^\alpha\big(M(G)\big) = 2(3)^\alpha xy^3 + 4(2)^\alpha x^2y^2 + 2(2)^\alpha x^2y^3 + (3)^\alpha x^3y^3.$$

$$D_y^\alpha\big(M(G)\big) = 2(3)^\alpha xy^3 + 4(2)^\alpha x^2y^2 + 2(3)^\alpha x^2y^3 + (3)^\alpha x^3y^3.$$

$$D_x^\alpha D_y^\alpha\big(M(G)\big) = 2(3)^\alpha xy^3 + 4(4)^\alpha x^2y^2 + 2(6)^\alpha x^2y^3 + (9)^\alpha x^3y^3$$

$$S_xD_y\big(M(G)\big) = 6xy^3 + 4x^2y^2 + 3x^2y^3 + x^3y^3.$$

$$S_yD_x\big(M(G)\big) = \frac{2}{3}xy^3 + 4x^2y^2 + \frac{4}{3}x^2y^3 + x^3y^3.$$

$$J\big(M(G)\big) = 6x^4 + 2x^5 + x^6.$$

$$S_xJ\big(M(G)\big) = \frac{6}{4}x^4 + \frac{2}{5}x^5 + \frac{1}{6}x^6.$$

$$JD_xD_y\big(M(G)\big) = 22x^4 + 12x^5 + 9x^6.$$

$$S_xJD_xD_y\big(M(G)\big) = \frac{11}{2}x^4 + \frac{12}{5}x^5 + \frac{3}{2}x^6.$$

$$D_x^3D_y^3\big(M(G)\big) = 54xy^3 + 32x^2y^2 + 54x^2y^3$$

$$JD_x^3D_y^3\big(M(G)\big) = 310x^4 + 432x^5 + 729x^6.$$

$$Q_{-2}JD_x^3D_y^3\big(M(G)\big) = 310x^2 + 432x^3 + 729x^4.$$

$$S_x^3Q_{-2}JD_x^3D_y^3\big(M(G)\big) = \frac{310}{2^3}x^2 + \frac{432}{3^3}x^3 + \frac{729}{4^3}x^4.$$

By using the derived formulas of the *M*-polynomial, we find,

1. $M_1(G) = \big(D_x + D_y\big)\big(M(G)\big)|_{x=y=1} = 40.$.
2. $M_2(G) = D_xD_y\big(M(G)\big)|_{x=y=1} = 43.$
3. $^mM_2(G) = S_xS_y\big(M(G)\big)|_{x=y=1} = \frac{19}{9}.$
4. $R_\alpha(G) = D_x^\alpha D_y^\alpha\big(M(G)\big)|_{x=y=1} = 2(3)^\alpha + 4(4)^\alpha + 2(6)^\alpha + (9)^\alpha.$
5. $R(G) = R_{-1/2}(G) = D_x^{-1/2}D_y^{-1/2}\big(M(G)\big)|_{x=y=1} = \frac{2}{\sqrt{3}} + \frac{2}{\sqrt{6}} + \frac{7}{3}.$
6. $SDD(G) = \big(S_xD_y + S_yD_x\big)|_{x=y=1} = 21.$
7. $F(G) = \big(D_x^2 + D_y^2\big)\big(M(G)\big)|_{x=y=1} = 96.$
8. $H(G) = 2S_yD_x\big(M(G)\big)|_{x=y=1} = \frac{62}{15}.$
9. $I(G) = S_xJD_xD_y\big(M(G)\big)|_{x=y=1} = \frac{47}{5}.$
10. $A(G) = S_x^3Q_{-2}JD_x^3D_y^3\big(M(G)\big)|_{x=y=1} = \frac{310}{2^3} + \frac{432}{3^3} + \frac{729}{4^3} = \frac{4233}{64}.$

Finally, we considered the molecular graph of ethambutol (Figure 7).

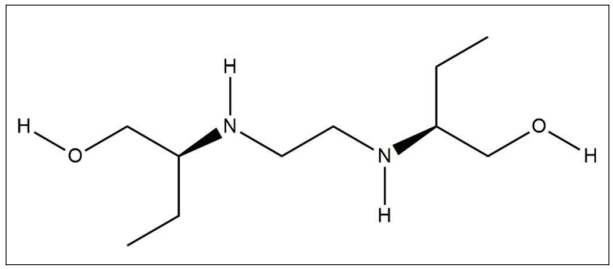

Figure 7: Molecular graph of ethambutol

Theorem 7: Let G be the molecular graph of Ethambutol. Then the *M*-Polynomial of isoniazid is given by,

$$M(G) = 4xy^2 + 3x^2y^2 + 6x^2y^3.$$

Proof: Let be the molecular graph of ethambutol which has 13 numbers of edges.

Let $E(i,j)$ be the set of edge partitions with the degree of end vertices i,j.

i.e., $E(i,j) = \{e = uv \in E(G): d_u = i \text{ and } d_v = j\}$. By observing the structure, we inferred three partitions of the edge set as follows:

$E(1,2) = \{e = uv\epsilon E(G): d_u = 1 \text{ and } d_v = 2\}$,
$E(2,2) = \{e = uv\epsilon E(G): d_u = d_v = 2\}$, and
$E(2,3) = \{e = uv\epsilon E(G): d_u = 2 \text{ and } d_v = 3\}$.

Also, we get $|E(1,2)| = 4$, $|E(2,2)| = 3$, and $|E(2,3)| = 6$.

Therefore, the *M*-polynomial of the molecular graph of ethambutol is

$$M(G) = 4xy^2 + 3x^2y^2 + 6x^2y^3.$$

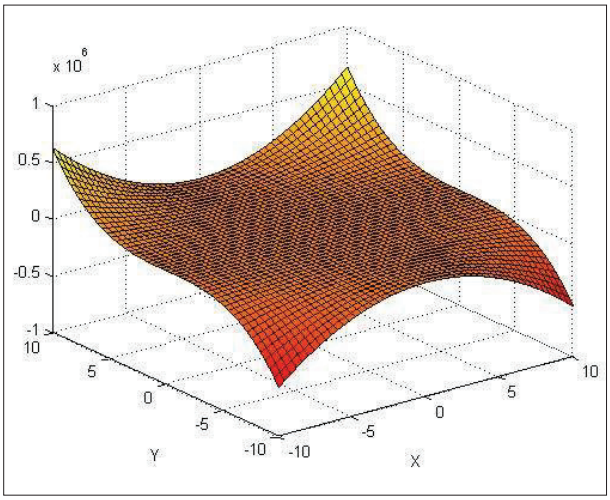

Figure 8: Plotting of *M*-polynomial for ethambutol

Theorem 8: Let *G* be the molecular graph of ethambutol. Then, the first Zagreb index $M_1(G)$, second Zagreb index $M_2(G)$ second modified Zagreb index ${}^{m}M_2(G)$, generalized Randić index, $R_\alpha(G)$, Randić index $R_{-1/2}(G)$ (which is actually $R(G)$), symmetric division degree index SDD(G), forgotten topological index F(G), harmonic index H(G), inverse sum index index I(G), and the augmented Zagreb index A(G) are given by

1. $M_1(G) = 54.$
2. $M_2(G) = 56.$
3. ${}^{m}M_2(G) = \frac{15}{4}.$
4. $R_\alpha(G) = 4(2)^\alpha + 3(4)^\alpha + 6(6)^\alpha.$
5. $R_{-1/2}(G) = 2\sqrt{2} + \sqrt{6} + \frac{3}{2}.$
6. $SDD(G) = 29.$
7. $F(G) = 122.$
8. $H(G) = \frac{197}{30}.$
9. $I(G) = \frac{193}{15}.$
10. $A(G) = 104.$

Proof: Let $M(G)$ be the *M*-polynomial of the molecular graph of ethambutol. Then we get the following:

$D_x\big(M(G)\big) = 4xy^2 + 6x^2y^2 + 12x^2y^3.$

$D_y\big(M(G)\big) = 8xy^2 + 6x^2y^2 + 18x^2y^3.$

$D_xD_y\big(M(G)\big) = 8xy^2 + 12x^2y^2 + 36x^2y^3.$

$S_x\big(M(G)\big) = 4xy^2 + \frac{3}{2}x^2y^2 + 3x^2y^3.$

$S_y\big(M(G)\big) = 2xy^2 + \frac{3}{2}x^2y^2 + 2x^2y^3.$

$S_xS_y\big(M(G)\big) = 2xy^2 + \frac{3}{4}x^2y^2 + x^2y^3.$

$D_x^\alpha\big(M(G)\big) = 4xy^2 + 3(2)^\alpha x^2y^2 + 6(2)^\alpha x^2y^3.$

$D_y^\alpha\big(M(G)\big) = 4(2)^\alpha xy^2 + 3(2)^\alpha x^2y^2 + 6(3)^\alpha x^2y^3.$

$S_xD_y\big(M(G)\big) = 8xy^2 + 3x^2y^2 + 9x^2y^3.$

$D_x^\alpha D_y^\alpha\big(M(G)\big) = 4(2)^\alpha xy^2 + 3(4)^\alpha x^2y^2 + 6(6)^\alpha x^2y$

$S_yD_x\big(M(G)\big) = 2xy^2 + 3x^2y^2 + 4x^2y^3.$

$J\big(M(G)\big) = 4x^3 + 3x^4 + 6x^5.$

$S_xJ\big(M(G)\big) = \frac{4}{3}x^3 + \frac{3}{4}x^4 + \frac{6}{5}x^5.$

$JD_xD_y\big(M(G)\big) = 8x^3 + 12x^4 + 36x^5.$

$S_xJD_xD_y\big(M(G)\big) = \frac{8}{3}x^3 + 3x^4 + \frac{36}{5}x^5.$

$D_x^3D_y^3\big(M(G)\big) = 32xy^2 + 192x^2y^2 + 1296x^2y^3.$

$JD_x^3D_y^3\big(M(G)\big) = 32x^3 + 192x^4 + 1296x^5.$

$Q_{-2}JD_x^3D_y^3\big(M(G)\big) = 32x + 192x^2 + 1296x^3.$

$S_x^3Q_{-2}JD_x^3D_y^3\big(M(G)\big) = 32x + 24x^2 + 48x^3.$

By using the derived formulas of the *M*-polynomial, we find,

1. $M_1(G) = \big(D_x + D_y\big)\big(M(G)\big)|_{x=y=1} = 54.$
2. $M_2(G) = D_xD_y\big(M(G)\big)|_{x=y=1} = 56.$
3. ${}^{m}M_2(G) = S_xS_y\big(M(G)\big)|_{x=y=1} = \frac{15}{4}.$
4. $R_\alpha(G) = D_x^\alpha D_y^\alpha\big(M(G)\big)|_{x=y=1} = 4(2)^\alpha + 3(4)^\alpha + 6(6)^\alpha.$
5. $R(G) = R_{-1/2}(G) = D_x^{-1/2}D_y^{-1/2}\big(M(G)\big)|_{x=y=1}$
   $= 2\sqrt{2} + \sqrt{6} + \frac{3}{2}.$
6. $SDD(G) = \big(S_xD_y + S_yD_x\big)|_{x=y=1} = 29.$

7. $F(G) = \left(D_x^2 + D_y^2\right)\left(M(G)\right)|_{x=y=1} = 122.$

8. $H(G) = 2S_yD_x\left(M(G)\right)|_{x=y=1} = \frac{197}{30}.$

9. $I(G) = S_xJD_xD_y\left(M(G)\right)|_{x=y=1} = \frac{193}{15}.$

10. $A(G) = S_x^3Q_{-2}JD_x^3D_y^3\left(M(G)\right)|_{x=y=1} = 104.$

CONCLUSION

This research is focused on calculating some degree-based topological indices for the anti TB drugs namely isoniazid, rifampicin, pyrazinamide and ethambutol. *M*-polynomial for these molecular structures was derived using the molecular graphs of these drugs molecules and the topological indices were calculated using the derived formulas of the *M*-polynomial. These finding could be useful to design and develop new drug molecules against this deadly disease.

Conflict of interest

There are no conflicts of interest.

REFERENCES

Amić D., Bešlo D., Lučić B., Nikolić S. & Trinajstić N. (1998). The vertex-connectivity index revisited. *Journal of Chemical Information and Computer Sciences* **38**: 819–822.
DOI: https://doi.org/10.1021/ci980039b

Balaban A.T. (1982). Highly discriminating distance based numerical descriptor. *Chemical Physics Letters* **89**: 399–404.
DOI: https://doi.org/10.1016/0009-2614(82)80009-2

Bollobás B. & Erdös P. (1998). Graphs of extremal weights. *Ars Combinatoria* **50**: 225–233.

British Thoracic Society (1984). A controlled trial of 6 months' chemotherapy in pulmonary tuberculosis Final report: Results during the 36 months after the end of chemotherapy and beyond. *British Journal of Diseases of the Chest* **78**: 330.
DOI: https://doi.org/10.1016/0007-0971(84)90165-7

Cambau E. & Drancourt M. (2014). Steps towards the discovery of *Mycobacterium tuberculosis* by Robert Koch, 1882. *Clinical Microbiology and Infection* **20**: 196–201.
DOI: https://doi.org/10.1111/1469-0691.12555

Caporossi G., Gutman I., Hansen P. & Pavlović L. (2003). Brief communication: graphs with maximum connectivity index. *Computational Biology and Chemistry* **27**: 85–90.
DOI: https://doi.org/10.1016/S0097-8485(02)00016-5

Comas I. & Gagneux S. (2009). The past and future of tuberculosis research. *PLoS Pathogens* **5**: e1000600.
DOI: https://doi.org/10.1371/journal.ppat.1000600

Deutsch E. & Klavzar S. (2015). M-polynomial and degree-based topological indices. *Iranian Journal of Mathematical Chemistry* **6**: 93–102.
DOI: https://doi.org/10.22052/ijmc.2020.224280.1492

Estrada E., Patlewicz G. & Uriarte E. (2003). From molecular graphs to drugs. a review on the use of topological indices in drug design and discovery. *Indian Journal of Chemistry Section A* **42**: 1315–1329.

Estrada E. & Uriarte E. (2001). Recent advances on the role of topological indices in drug discovery research. *Current Medicinal Chemistry* **8**: 1573–1588.

Fajtlowicz S. (1987). On conjectures of graffiti II. *Congressus numerantium* **60**: 189–197.

Favrot L. & Ronning D.R. (2012). Targeting the mycobacterial envelope for tuberculosis drug development. *Expert Review of Anti-infective Therapy* **10**: 1023–1036.
DOI: https://doi.org/10.1586/eri.12.91

Feng Z., Castillo-Chavez C. & Capurro A.F. (2000). A model for tuberculosis with exogenous reinfection. *Theoretical Population Biology* **57**: 235–247.
DOI: https://doi.org/10.1006/tpbi.2000.1451

Floyd K., Glaziou P., Zumla A. & Raviglione M. (2018). The global tuberculosis epidemic and progress in care, prevention, and research: an overview in year 3 of the End TB era. *The Lancet Respiratory Medicine* **6**: 299–314.
DOI: https://doi.org/10.1016/S2213-2600(18)30057-2 .

Furtula B., Graovac A. & Vukičević D. (2010). Augmented Zagreb index. *Journal of Mathematical Chemistry* **48**: 370–380.
DOI: https://doi.org/10.1007/s10910-010-9677-3

Furtula B. & Gutman I. (2015). A forgotten topological Index. *Journal of Mathematical Chemistry* **53**: 1184–1190.
DOI: https://doi.org/10.1007/s10910-015-0480-z

Gálvez J., Gálvez-Llompart M. & García-Domenech R. (2012). Molecular topology as a novel approach for drug discovery. *Expert Opinion on Drug Discovery* **7**: 133–153.
DOI: https://doi.org/10.1517/17460441.2012.652083

Gao W., Muzaffar B. & Nazeer W. (2017). K-Banhatti and K-hyper Banhatti indices of dominating David Derived network. *Open Journal of Mathematical Analysis* **1**: 13–24.
DOI: https://doi.org/10.30538/psrp-oma2017.0002

Gao W., Siddiqui M.K., Imran M., Jamil M.K. & Farahani M.R. (2016). Forgotten topological index of chemical structure in drugs. *Saudi Pharmaceutical Journal* **24**: 258–264.
DOI: https://doi.org/10.1016/j.jsps.2016.04.012

Gao W., Wang W. & Farahani M.R. (2016). Topological indices study of molecular structure in anticancer drugs. *Journal of Chemistry* **2016**: 1–8.
DOI: https://doi.org/10.1155/2016/3216327

Gutman I. & Trinajstić N. (1972). Graph theory and molecular orbitals total f-elecron energy of alternant hydrocarbons. *Chemical Physics Letters* **77**: 535–538.
DOI: https://doi.org/10.1016/0009-2614(72)85099-1

Hao J. (2011). Theorems about Zagreb indices and modified Zagreb indices. *MATCH Communications in Mathematical and in Computer Chemistry* **65**: 659–670.

Hosoya H. (1988). On some counting polynomials in chemistry. *Discrete Applied Mathematics* **19**: 239–257. DOI: https://doi.org/10.1016/0166-218X(88)90017-0

Hu Y., Li X., Shi Y., Xu T. & Gutman I. (2005). On molecular graphs with smallest and greatest zeroth-order general Randic index. *MATCH Communications in Mathematical and in Computer Chemistry* **54**: 425–434.

Jude T.P., Panchadcharam E. & Masilamani K. (2019). Computation of Zagreb and Randić indices of two biodegradable dendrimers used in cancer therapy. *Ceylon Journal of Science* **48**: 359–366. DOI: http://doi.org/10.4038/cjs.v48i4.7677

Jude T.P., Panchadcharam E. & Masilamani K. (2020). Computing Zagreb and Randi´c indices of PEG-cored dendrimers used for drug and gene delivery. *Journal of Chemistry* **2020**: 1–7. DOI: https://doi.org/10.1155/2020/2821510

Keshavjee S. & Farmer P.E. (2012). Tuberculosis, drug resistance, and the history of modern medicine. *The New England Journal of Medicine* **367**: 931–936. DOI: https://doi.org/10.1056/NEJMra1205429

Ma Z., Lienhardt C., McIlleron H., Nunn A.J. & Wang X. (2010). Global tuberculosis drug development pipeline: the need and the reality. *Lancet* **375**: 2100–2009. DOI: https://doi.org/10.1016/S0140-6736(10)60359-9

Mobeen M., Nazeer W., Rafique S. & Kang S. (2016). M-polynomial and related topological indices of nanostar dendrimers. *Symmetry* **8**: 97–108. DOI: https://doi.org/10.3390/sym8090097

Nilanjan De. (2018). Computing reformulated first Zagreb index of some chemical graphs as an application of generalized hierarchical product of graphs. *Open Journal of Mathematical Sciences* **2**: 338–350. DOI: https://doi.org/10.30538/oms2018.0039

Randić M. (1974). On Characterization of molecular branching. *Journal of the American Chemical Society* **97**: 6609–6615. DOI: https://doi.org/10.1021/ja00856a001

Rouvray D.H. (1973). The search for useful topological indices in chemistry: Topological indices promise to have far-reaching applications in fields as diverse as bonding theory, cancer research, and drug design. *American Scientist* **61**: 729–735. DOI: https://www.jstor.org/stable/27844077

Vukicevic D. (2010). Bond additive modeling 2 mathematical properties of max-min Rodeg index. *Croatica Chemica Acta* **54**: 261–273.

Wiener H. (1947). Structural determination of paraffin boiling points. *Journal of the American Chemical Society* **69**: 17–20. DOI: https://doi.org/10.1021/ja01193a005

World Health Organization. (2002). WHO Tuberculosis e Fact Sheet. Available at *https://www.who.int/news-room/fact-sheets/detail/tuberculosis*

Zanni R., Galvez-Llompart M., García-Domenech R. & Galvez J. (2015). Latest advances in molecular topology applications for drug discovery. *Expert Opinion on Drug Discovery* **10**: 945–957. DOI: https://doi.org/10.1517/17460441.2015.1062751

Zheng L., Wang Y. & Gao W. (2019). topological indices of hyaluronic acid-paclitaxel conjugates' molecular structure in cancer treatment. *Open Chemistry* **17**: 81–87. DOI: https://doi.org/10.1515/chem-2019-0009

Zuo M.X., Liu J-B, Iqbal H., Ali K. & Rizvi S.T.R. (2020). Topological indices of certain transformed chemical structures. *Journal of Chemistry* **2020**: 3045646. DOI: https://doi.org/10.1155/2020/3045646