

## Poly-2-[(4-methylbenzylidene)amino]phenol: Investigation of thermal degradation and antimicrobial properties

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**ABSTRACT:** A new polyphenol (poly-2-[(4-methylbenzylidene)amino]phenol) (P(2-MBAP)) containing an azomethine group was synthesized by oxidative polycondensation reaction of 2-[(4-methylbenzylidene)amino]phenol (2-MBAP) with NaOCl, H<sub>2</sub>O<sub>2</sub>, and O<sub>2</sub> oxidants in an aqueous alkaline medium. The structures of 2-MBAP and P(2-MBAP) were characterized by UV-vis, FT-IR, and <sup>1</sup>H NMR spectra. While the monomer decomposed completely up to 350°C and 57.2% of the polymer decomposed up to 1000°C. The thermal degradation of P(2-MBAP) was also supported by the Thermo-IR spectra recorded in the temperature range of 25–800°C. Electrical conductivity of the polymer was observed to increase 10<sup>8</sup> fold after doping with I<sub>2</sub>. Antimicrobial activities of the P(2-MBAP) and 2-MBAP against *Sarcina lutea*, *Enterobacter aerogenes*, *Escherichia coli*, *Enterococcus faecalis*, *Klebsiella pneumoniae*, *Bacillus subtilis*, *Candida albicans*, and *Saccharomyces cerevisiae* were also investigated. The number average molecular weight ( $M_n$ ), weight average molecular weight ( $M_w$ ) and polydispersity index (PDI) of the polymers were determined by gel permeation chromatography (GPC). © 2014 Wiley Periodicals, Inc. *J. Appl. Polym. Sci.* **2015**, *132*, 41758.

**KEYWORDS:** polycondensation; properties and characterization; thermal properties

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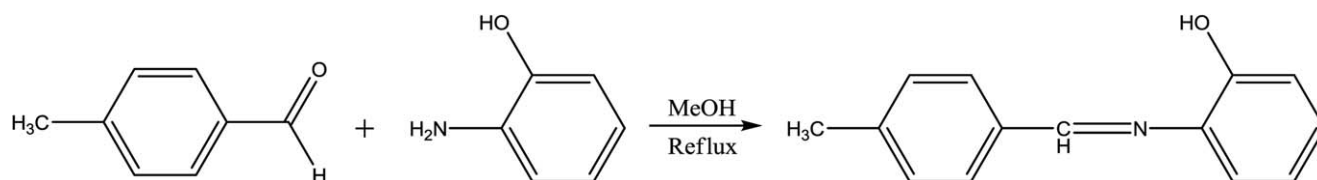
### INTRODUCTION

Schiff base polymers, also known as polyazomethines containing azomethine (-HC=N-) groups, have drawn attention as a type of high performance polymers because of their extensive applications in advanced technology areas.<sup>1,2</sup> Polyazomethines have been extensively used in light emitting diodes, field effect transistors, solar cells, catalysts, and antimicrobial materials because of their thermal resistance and semi-conductor, electronic, opto-electronic, and antimicrobial properties.<sup>3–8</sup> The first polyazomethine was synthesized by Adams *et al.* in 1923 from the reaction of teraphthaldehyde with benzidine and anisidine.<sup>9</sup>

Polyphenols which are polyazomethines having active hydroxyl group; they have drawn the attention of researchers for a long time because of their properties such as para-magnetism, thermal stability, mechanical resistance, ability to form bonds with metals, high energy resistance, semi-conductor, and optical characteristics.<sup>8,10,11</sup> Because of these superior properties, the azomethine group containing polyphenols has found extensive applications in areas such as thermal stabilizers and photoconducting, as well as antistatic and flame-resistant materials.<sup>12–16</sup> There are also other studies in the literature in which polyazomethines having hydroxyl groups have been used as catalysts.<sup>17</sup> The main synthesis method of polyazomethines is condensation

polymerization of diamines and dialdehydes or diketones. Oxidative polycondensation which is the most commonly used method in the polymerization of an azomethine group containing polyphenols, covers the simple reaction of -OH groups with active functional groups such as -NH<sub>2</sub>, -CHO, and -COOH in the presence of oxidants such as NaOCl, H<sub>2</sub>O<sub>2</sub>, and O<sub>2</sub> in an aqueous alkaline medium. The usage of these types of oxidants which are cheap, easily available, and have simple structures has some advantages, such as ease of separation from the reaction medium, that enable polymers to be obtained with improved solubility and thermal stabilities and giving environmentally friendly by-products.<sup>18</sup> It has been determined that polyazomethines having active hydroxyl groups synthesized by this method show antimicrobial activity and have potential for use as antimicrobial agents.<sup>8</sup>

Antimicrobial agents have low molecular weights such as disinfectants or bactericides and the ability to kill pathogenic microorganisms.<sup>19</sup> Phenol derivative compounds, cationic compounds, and quaternary ammonium salts are low molecular weight compounds that have antimicrobial effects and can be used as disinfectants. However, these low molecular weight compounds have many disadvantages, such as being harmful to the environment and only affecting the bacteria for a short time.<sup>20</sup> These problems



Scheme 1. Synthesis of 2-MBAP.

can be prevented by attaching the groups that have antimicrobial effects to polymers or by synthesizing polymers containing groups having antimicrobial effects.<sup>19</sup> It was emphasized in the literature that the molecular weight was linked to the antimicrobial properties.<sup>21</sup> Polymeric materials have superior properties such as nonvolatility, chemical stability, and very slow penetration through human and animal skin in comparison with low molecular weight compounds that have antimicrobial effects.<sup>19</sup> Additionally, increasing the productivity and selectivity, as well as safer handling are also advantages of polymeric agents against low molecular weight compounds.<sup>21</sup> Polymeric antimicrobial agents are also used to increase the productivity and activity of other agents and decrease their toxicity and harmful effects on the environment.<sup>22</sup> For this reason, the importance of synthesizing polymers having antimicrobial effects and developing the antimicrobial properties of polymers is widely emphasized in the literature.<sup>23</sup>

In this study, the effects of oxidant types as well as polymerization temperature and time on P(2-MBAP) yield were investigated. The synthesized 2-MBAP and P(2-MBAP) were characterized by FT-IR, UV-Vis, <sup>1</sup>H NMR, TG-DTA, and GPC techniques. In addition the, thermal degradation steps of the polymer were monitored by FT-IR spectroscopy, and the results obtained from TG curves were used to support the results from this technique. Additionally, the microbial activities of the Schiff base and polymer were investigated.

## EXPERIMENTAL

### Materials and Method

2-aminophenol, *p*-tolualdehyde, methanol, ethanol, ethyl acetate, acetone, *n*-heptan, 1,4-dioxane, *N*-methylpyrrolidone (NMP), dimethylformamide (DMF), dimethyl sulfoxide (DMSO), tetrahydrofuran (THF), potassium hydroxyde (KOH), hydrochloric acid (HCl, 37%), and I<sub>2</sub> were obtained from Merck Chemical (Germany). Sodium hypochlorite (NaOCl) (30% aqueous solution) was obtained from Birpa Chemical (Turkey). All these materials were used without purification. The antimicrobial activity of the monomer and polymer were assayed against *Sarcina lutea* ATCC 9341NA, *Enterobacter aerogenes* ATCC 13048, *Escherichia coli* ATCC 39628, *Enterococcus faecalis* ATCC 29212, *Klebsiella pneumonia*, *Bacillus subtilis* ATCC 6633, *Saccharomyces cerevisiae*, and *Candida albicans* obtained from Celal Bayar University, Biology Dept. and Sutcui-mam University Medical Faculty, Microbiology Laboratory.

### Synthesis of Monomer

2-MBAP was synthesized by a condensation reaction of 2-aminophenol and *p*-tolualdehyde (Scheme 1). Then, 0.01 mol

aminophenol was dissolved in 15 mL methanol and a solution of 0.01 mol *p*-tolualdehyde in 10 mL methanol was added drop by drop for 30 min into the aminophenol solution that was continuously stirred under a reflux condenser at 60°C. Yellow crystals formed approximately 6 h later, were separated by filtering and then crystallized from methanol again and dried in a vacuum desiccator before being weighed. Yield: 85%; melting point: 121°C.

### Synthesis of Polymer

P(2-MBAP) was synthesized by oxidative polycondensation of 2-MBAP in the presence of the oxidants NaOCl (15%), H<sub>2</sub>O<sub>2</sub> (30%), and O<sub>2</sub> in an aqueous alkaline medium (Scheme 2). 2-MBAP (0.211 g, 1 mmol) was dissolved in aqueous KOH solution (10%, 1 mmol). The reaction was accomplished in a 50 mL flask with three necks attached to which were a reflux condenser, thermometer, and funnel for the addition of oxidants under a nitrogen atmosphere. After dissolution of the monomer and reaching the determined reaction temperature, 1 mmol NaOCl or H<sub>2</sub>O<sub>2</sub> was added drop by drop within 20 min. When O<sub>2</sub> was used as the oxidant, O<sub>2</sub> having a flow rate of 0.55 Lh<sup>-1</sup> was passed through the reaction medium for determined the polymerization time. Reactions were carried out at various time and temperatures. After the reaction was completed, the polymerization medium was neutralized with HCl (37%) and the precipitated product was washed with hot water (3×25 mL) to remove mineral salts and unreacted monomer before being dried at 70°C in a vacuum oven and weighed.

Polymer yield (yield, %) was calculated according to the following equation:

$$\text{Yield (\%)} = \frac{W_p}{W_m} \quad (1)$$

where  $W_p$  is the polymer weight and  $W_m$  is the monomer initial weight.

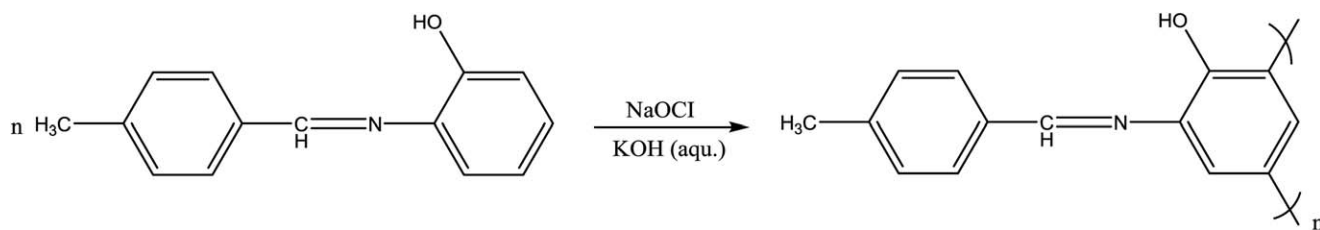
### Characterization

UV-Vis spectra of 2-MBAP and P(2-MBAP) were obtained a using Shimadzu UV-1700 PharmaSpec UV-Visible Spectrophotometer in DMSO at a wavelength range of 210–700 nm.

FTIR spectra of the 2-MBAP and P(2-MBAP) were recorded by using Perkin Elmer Fourier Transform Infrared Spectrometer in the 4000–650 cm<sup>-1</sup> frequency range.

<sup>1</sup>H NMR spectra of the compounds were recorded by using Bruker Avance 500 MHz Nuclear Magnetic Resonance at 25°C in DMSO using tetramethylsilane as the internal standard.

TG/DTG and DTA curves were recorded by using EXSTAR TG/DTA S11 7300 under dynamic nitrogen atmosphere in the



Scheme 2. Synthesis of P-2-MBAP.

temperature range of 30–1000°C (heating rate: 10°C/min, platinum crucible).

$M_n$ ,  $M_w$ , and PDI values of the polymer were determined by using Shimadzu Prominence GPC with Nucleogel GPC 103-5 VA300/7.7 column attached (eluent: dimethylformamide, flow rate: 0.5 mL min<sup>-1</sup>, calibrated with polystyrene standards).

The pellets of the polymer synthesized having thicknesses of 3 mm and diameters of 10 mm were prepared under hydraulic pressure of 1687.2 kg/cm<sup>2</sup> and these pellets were used for the measurement of surface resistivity. The surface resistivity of the samples was determined using the two-point probe technique by using Thurlby 1503 Multimeter. From the measured surface resistivity values, the electrical conductivity values of the polymer were calculated using the following equation:

$$\sigma = \frac{l}{Ra} \quad (2)$$

where  $\sigma$  is the conductivity of the polymer,  $R$  (ohm cm<sup>-2</sup>) is the measured surface resistivity and  $l$  (cm) and  $a$  (cm<sup>2</sup>) represent the thickness and the area of the prepared pellet, respectively.

#### Solubility Test

The solubility tests for 2-MBAP and P(2-MBAP) were carried out by putting 1 mg of sample in 1 mL solvent and the results are given in Table I. 2-MBAP was completely soluble in all the solvents whereas organic solvents having high polarity such as DMF, DMSO, NMP, 1,4-dioxane, and THF dissolved P(2-MBAP).

#### Antimicrobial Test

The antimicrobial assay was accomplished using Mueller-Hinton agar and Sabouraud dextrose agar by the agar-well diffusion method.<sup>24</sup> The culture suspensions of bacteria and yeast were prepared with standardized inoculums, 10<sup>8</sup> and 1 × 10<sup>6</sup> cfu mL<sup>-1</sup>, respectively.<sup>25</sup> After inoculation of the media, they were cooled to 45°C, mixed by gentle shaking and poured in to sterile petri dishes. All of the compounds were dissolved in DMSO at a concentration of 100 µg and 200 µg/100 µL and loaded to 6 mm in diameter wells prepared with the help of a sterile cork

borer. Nystatine (100 U) and Chloramphenicol (30 µg) were used as the standard and DMSO as the solvent control. The plates of the monomer and polymer were incubated at 36°C and 30°C for 24 h. After incubation, the diameters of the zones of inhibition were measured and evaluated.

## RESULTS AND DISCUSSION

### Effect of Synthesis Conditions on Polymerization of 2-MBAP

The oxidative polycondensation reaction of 2-MBAP was performed in an alkaline aqueous medium by using oxidants NaOCl, H<sub>2</sub>O<sub>2</sub>, and O<sub>2</sub>, and the optimum reaction conditions were determined. First, to monitor the effects of oxidants types on P(2-MBAP) yield, experiments were performed at various temperatures and time periods. P(2-MBAP) was synthesized by the addition of the oxidants at concentrations of [NaOCl]<sub>0</sub> = [H<sub>2</sub>O<sub>2</sub>]<sub>0</sub> = 0.1 mol L<sup>-1</sup> or O<sub>2</sub> with a flow rate of 0.5 L h<sup>-1</sup> into a 2-MBAP solution prepared at an initial concentration of [2-MBAP]<sub>0</sub> = [KOH]<sub>0</sub> = 0.1 mol L<sup>-1</sup>. When an oxidant was added into the yellow solution of 2-MBAP in an alkaline aqueous medium, the color of the solution immediately turned brown. When the polymerization reactions performed under the same conditions were completed, it was observed that the highest yield was obtained using NaOCl as the oxidant; thus, it was used as oxidant for the other studies (Table II).

The effects of polymerization temperature and time on the yield of the polymer synthesized using the NaOCl oxidant were investigated at 70°C, 80°C, and 90°C for various time periods, and the results are shown in Figure 1. It was observed that, polymerization yield increased with increasing polymerization time at all temperatures. The highest yield (37.1%) was obtained in the polymerization carried out at 80°C for 6 h. The effects of polymerization time and temperature on the yield are in agreement with data reported in the literature.<sup>8</sup>

### Structure of P(2-MBAP)

The values of  $M_n$ ,  $M_w$ , and PDI of P(2-MBAP) synthesized using NaOCl, H<sub>2</sub>O<sub>2</sub>, and O<sub>2</sub> oxidants were calculated from a PS standard calibration curve of GPC measurements as given in Table II. It was observed that P(2-MBAP) synthesized using

Table I. Solubility of 2-MBAP and P(2-MBAP) in Various Solvents

	Ethanol	Methanol	Acetone	1,4-dioxane	DMF	DMSO	NMP	Ethyl Acetate	Heptane	THF
2-MBAP	+	+	+	+	+	+	+	+	+	+
P(2-MBAP)	±	±	±	+	+	+	+	-	-	+

(+): soluble, (±): partially soluble, (-): insoluble

**Table II.** Effect of Oxidants Types on Yield (%),  $M_n$ ,  $M_w$ , PDI, and Conductivity Values of P(2-MBAP)

Oxidant	Yield (%)	$M_n$	$M_w$	PDI	Conductivity (S/cm)	
					Initial	Doped
NaOCl	37	5075	17717	3.49	$1.8 \times 10^{-14}$	$1.5 \times 10^{-6}$
H <sub>2</sub> O <sub>2</sub>	14	2095	2243	1.07	$9.4 \times 10^{-15}$	$7.8 \times 10^{-6}$
O <sub>2</sub>	23	1064	1562	1.46	$2.8 \times 10^{-15}$	$1.4 \times 10^{-6}$

$[2\text{-MBAP}]_0 = [\text{KOH}]_0 = [\text{NaOCl}]_0 = [\text{H}_2\text{O}_2]_0 = 0.1 \text{ mol L}^{-1}$  and flow rate of O<sub>2</sub> = 0.46 L h<sup>-1</sup>, doping time: 24 h.

NaOCl had the highest molecular weight and the values of  $M_n$ ,  $M_w$ , and PDI were 5075, 17,717, and 3.49, respectively. It can be concluded that NaOCl was an ideal oxidant in terms of giving the highest molecular weight and yield.

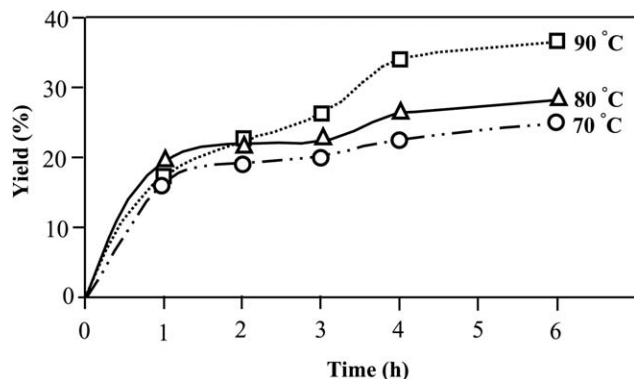
P(2-MBAP) synthesized with different oxidants were doped with I<sub>2</sub> vapor at 20°C for 168 hours, but it was observed that, the conductivity values of P(2-MBAP) did not change with the doping time at the end of 24 hours. As can be seen from Table II that the conductivity values of P(2-MBAP) were, in descending order, H<sub>2</sub>O<sub>2</sub>>NaOCl>O<sub>2</sub>. As the conductivity of doped P(2-MBAP) did not significantly change with type of oxidant used in the polymerization, the experiments were carried out with NaOCl as the oxidant.

UV-Vis spectra of 2-MBAP and P(2-MBAP) were recorded in the wavelength range of 260–700 nm when using solutions in DMSO, and are given in Figure 2. Two peaks at wavelengths of 295 and 341 nm were observed in the 2-MBAP spectrum. These peaks can be attributed to the  $\pi-\pi^*$  transitions of benzene (-C=C-) and  $n-\pi^*$  transitions of -CH=N- functional groups, respectively. These peaks were observed, with small shifts, at 286 and 401 nm in the P(2-MBAP) spectrum. It was also observed that the spectrum of P(2-MBAP) showed an extension up to 700 nm while the spectrum of 2-MBAP ended at 400 nm. Thus, it may be concluded that the shift observed from 341 to 401 nm of -CH=N- and the extension of P(2-MBAP) spectrum may have been a result of the extended conjugated  $\pi$  system in the polymer backbone.<sup>26</sup>

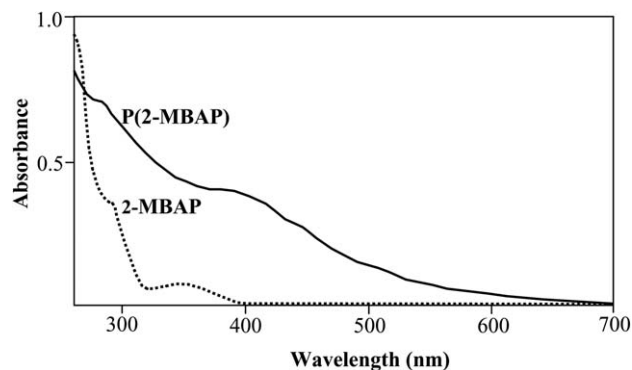
FTIR spectra of 2-MBAP and P(2-MBAP) are presented in Figure 3. When the FTIR spectra of 2-MBAP and P(2-MBAP)

were compared, the peaks because of -OH groups -OH groups were observed at 3278 and 3360 cm<sup>-1</sup>, respectively. While aliphatic -C-H stretching vibrations were observed at 2980 and 2810 cm<sup>-1</sup> in the 2-MBAP spectrum and the same vibration was observed at 2951 cm<sup>-1</sup> in the P(2-MBAP) spectrum. Characteristic peaks of the -CH=N- vibrations were observed at 1618 and 1630 cm<sup>-1</sup> in the spectra of 2-MBAP and P(2-MBAP), respectively. It has been indicated that the shift observed from 1618 to 1630 cm<sup>-1</sup> of -CH=N- was because of polymeric conjugation.<sup>27</sup> The peaks observed at 1587, 1509, and 1479 cm<sup>-1</sup> corresponded to the -C=C- vibrations of 2-MBAP. These vibrations were observed at 1574, 1497, and 1456 cm<sup>-1</sup> in the P(2-MBAP) spectrum. The peaks observed at 1374 cm<sup>-1</sup> for the monomer and 1365 cm<sup>-1</sup> for the polymer correspond to the -C-H in plane bending vibrations, and the peaks at 1284 and 1282 cm<sup>-1</sup> can be assigned to the -C-O- stretching vibrations.

<sup>1</sup>H-NMR spectra of the monomer and polymer were recorded in DMSO-d<sub>6</sub> to clarify their structure, and they are given in Figures 4 and 5, respectively. The peaks belong to the protons of characteristic -OH and -CH=N- functional groups were observed at  $\delta=9.95$  ppm and 8.69 ppm and  $\delta=9.91$  ppm and 8.83 ppm in spectra of 2-MBAP and P(2-MBAP), respectively. The peaks observed in 2-MBAP spectrum at  $\delta=7.97$  (d, 2H, Ar-Ha); 7.33 (d, 2H, Ar-Hb); 7.20 (d, 1H, Ar-Hf); 7.10 (t, 1H, Ar-Hd); 6.96 (d, 1H, Ar-Hc); and 6.88 (t, 1H, Ar-He) ppm belong to protons of aromatic structure. The peaks indicating the aromatic structure of P(2-MBAP) were observed at  $\delta=7.82$  (d, 1H, Ar-Ha); 7.41 (d, 1H, Ar-Hb); 7.34 (s, 1H, Ar-Hd); 7.11 (s, 1H, Ar-Hc) ppm. The shift observed in the peak values of the polymer compared to those of the monomer indicate the



**Figure 1.** The effect of temperature and polymerization time on % yield of P(2-MBAP) obtained with NaOCl oxidant ( $[2\text{-MBAP}]_0 = [\text{KOH}]_0 = [\text{NaOCl}]_0 = 0.1 \text{ mol L}^{-1}$ ).



**Figure 2.** UV-Vis spectra of 2-MBAP and P(2-MBAP).

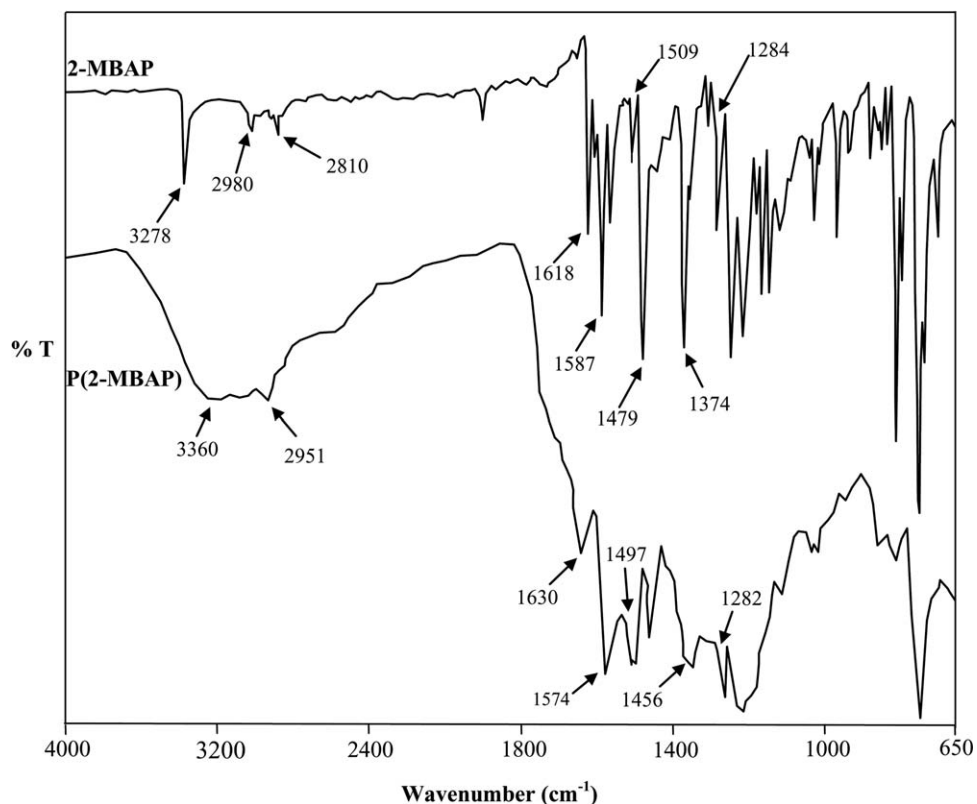


Figure 3. FTIR spectra of 2-MBAP and P(2-MBAP).

polyconjugated structure.<sup>27</sup> Because of the absence of Hc and He protons of 2-MBAP in polymer spectrum, newly formed Hd and Hf peaks as singlet in P(2-MBAP) spectrum while they are a triplet and doublet in the monomer's spectrum clarified

polymerization mechanism. These results indicate that the polymerization mechanism proceeds through C-C coupling at ortho and para positions to phenolic OH groups.<sup>27</sup> The broadening of P(2-MBAP) in the range of 6–8 ppm could be attributed to the

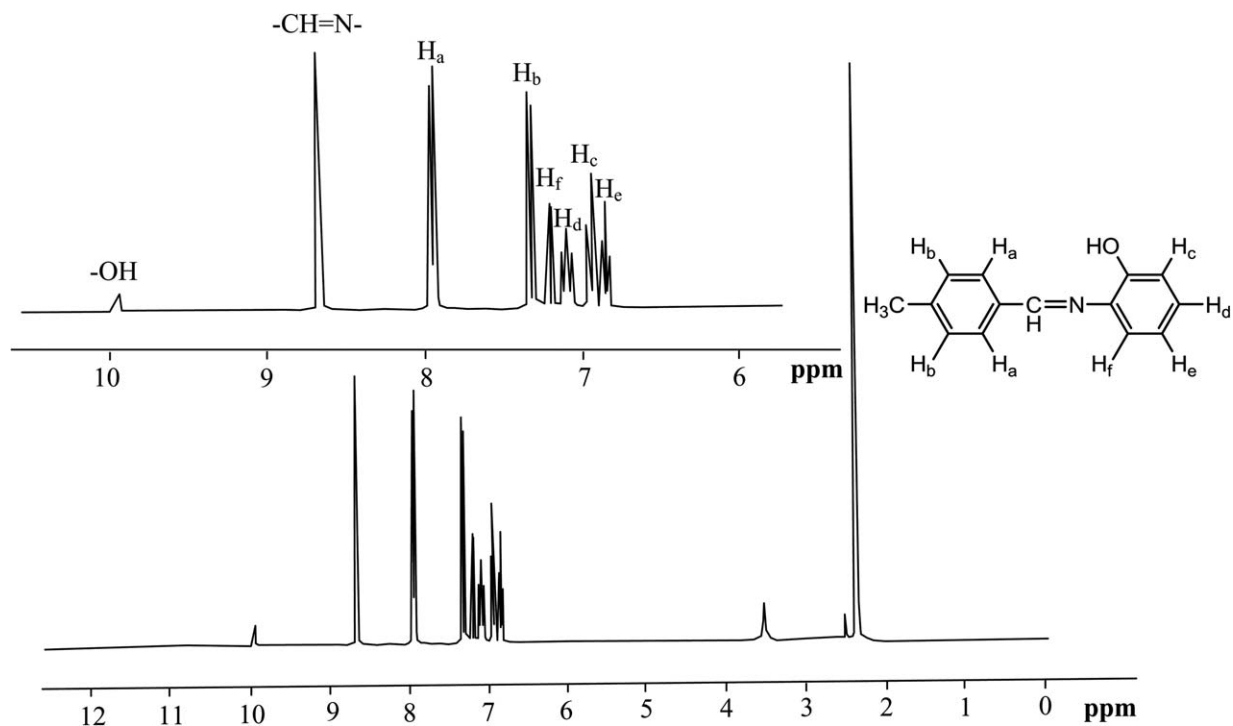


Figure 4. <sup>1</sup>H NMR spectrum of 2-MBAP.

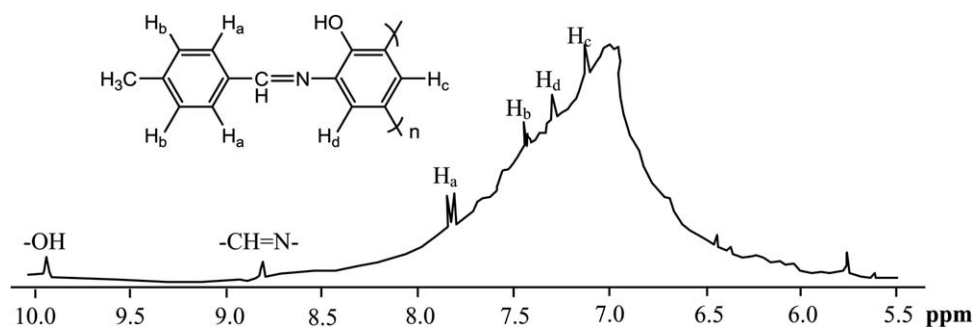


Figure 5.  $^1\text{H}$  NMR spectrum of P(2-MBAP).

aromatic protons overlapping of P(2-MBAP) having broad molecular weight distribution.

### Thermal Degradation of P(2-MBAP)

Thermal analysis curves of 2-MBAP and P(2-MBAP) are presented in Figure 6. The thermal degradation process of 2-MBAP was also supported by the thermo-IR analysis in the temperature range of 25–800°C (Figure 7). It was observed from the TG curve of 2-MBAP that degradation occurs in two steps. In the first step, 0.3% weight loss between 30°C and 150°C corresponds to the removal of adsorbed water and the maximum endothermic peak at 110°C in DTA curve corresponds to this degradation step. In the second step, the major degradation of the monomer functional groups occurs in the range 150–350°C,

the fast degradation started at about 175°C and finished at about 350°C. It was observed that 99.6% of the monomer decomposed without leaving any carbon residue in one step up to 350°C.

According to the thermal analysis curves of P(2-MBAP), weight loss of P(2-MBAP) occurred in three steps. In the first step, 4.5% (calculated: 4.1%) weight loss was observed between 30°C and 172°C. This weight loss could be attributed to the removal of 0.5 mol water of crystallization.<sup>28,29</sup> The maximum

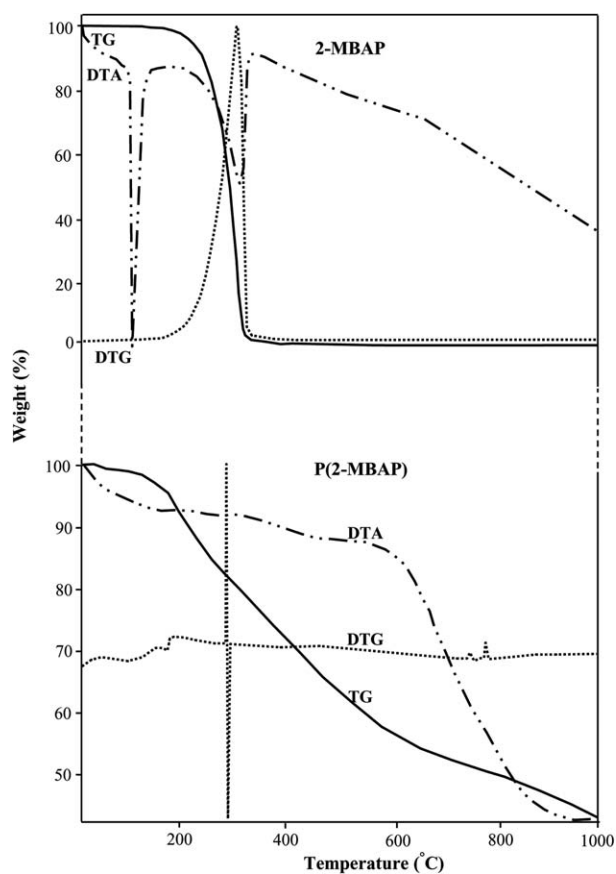


Figure 6. TG/DTG and DTA curves of 2-MBAP and P(2-MBAP).

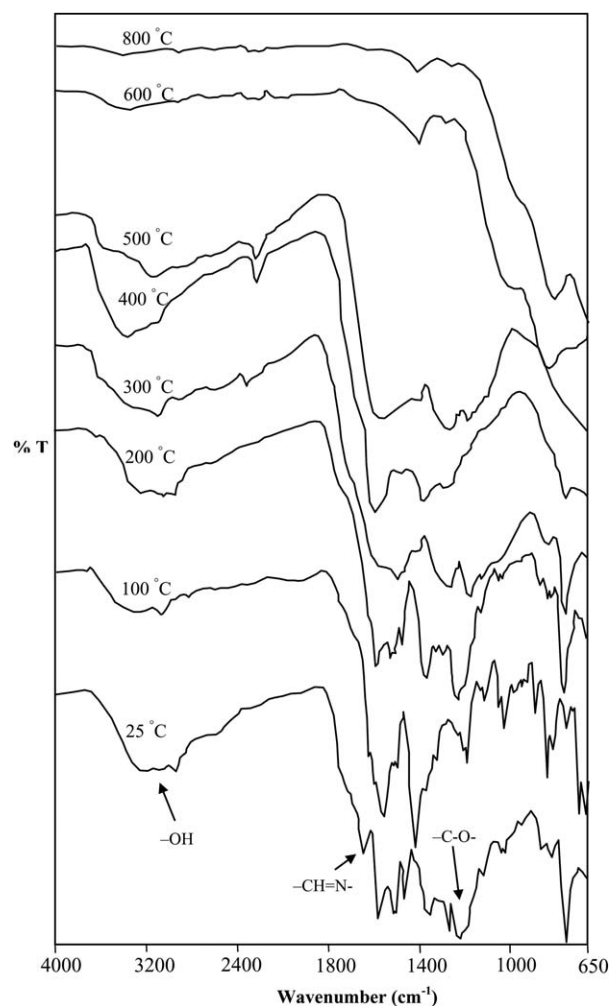
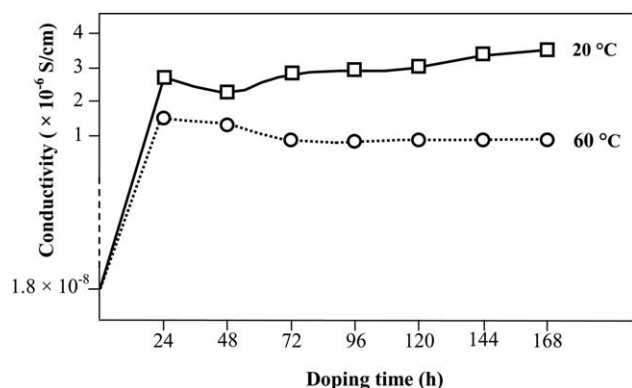


Figure 7. FTIR spectra of P(2-MBAP) heated in the temperature interval of 25–800°C.



**Figure 8.** The effect of temperature and doping time of  $I_2$  on conductivity of P(2-MBAP).

endothermic peak at 136°C in the DTA curve corresponds to this degradation step. In the second step, the weight loss was determined to be 14.7% (calculated: 12.3%) in the temperature range of 172–301°C, and we consider that this could be because of the degradation of  $-CH=N-$  functional group. Moreover, when the thermo-IR spectra were examined, the intensity of the vibration of the  $-CH=N-$  functional group decreased with increasing temperature and it was not observed at all over 300°C. This result shows that the characteristic  $-CH=N-$  functional group for 2-MBAP and P(2-MBAP) is not resistant to high temperatures. This observation was also supported by the complete degradation of the Schiff base in the temperature range of 150–350°C. In the third step of P(2-MBAP), 38% (calculated: 41.3%) weight loss was recorded in the temperature range of 301–1000°C. This weight loss was suggested to belong to the degradation of benzene ring to which an alkyl group is attached. Decreasing the number of aromatic  $-C=C-$  stretching bands and the loss of aliphatic C-H stretching bands in the thermo-IR spectrum within the temperature range of 400–1000°C are consistent with the results obtained from the TG curve. The maximum peaks of DTA belong to the degradation of azomethine functional group and benzene rings are determined 281°C and 598°C, respectively. It was concluded that the weight losses obtained from TG curves are consistent with theoretical calculations.

It was shown from the comparison of the thermal analysis results for the 2-MBAP and P(2-MBAP) that only 57.2% of the P(2-MBAP) degraded which left 42.8% as carbon residue up to 1000°C; while, the 2-MBAP had degraded completely by 350°C. This result is also supported by the thermo-IR spectra containing aromatic  $-C=C-$  stretching thereabouts  $1400\text{ cm}^{-1}$  at 600°C and 800°C. Additionally, it was observed from the thermo-IR spectra that the peaks corresponding to  $-OH$  and  $C-O$  vibrations which are characteristic for polyphenols were preserved up to 1000°C. It can be concluded by taking into account these results that because of the long conjugated band systems, the thermal resistance of the synthesized P(2-MBAP) is very high compared to that of the monomer.<sup>29</sup>

#### Doping with $I_2$

The changes in conductivity of P(2-MBAP) after doping with  $I_2$  vapor were monitored at 20°C and 60°C and the results are

**Table III.** Antimicrobial Properties of 2-MBAP and P(2-MBAP)

Microorganism	2-MBAP		P(2-MBAP)	
	100 µg	200 µg	100 µg	200 µg
<i>S. lutea</i> ATCC 9341NA	20	20	12	20
<i>E. aerogenes</i> ATCC 13048	20	20	18	20
<i>E. coli</i> ATCC 39628	11	12	11	12
<i>E. faecalis</i> ATCC 29212	15	16	15	16
<i>K. pneumonia</i> <sup>a</sup>	16	21	16	18
<i>B. subtilis</i> ATCC 6633	13	13	13	17
<i>C. albicans</i> <sup>a</sup>	-	-	-	-
<i>S. cerevisiae</i>	-	-	-	-

<sup>a</sup>Clinical isolate.

shown in Figure 8. As can be seen in Figure 8, the initial conductivity value of  $1.8 \times 10^{-14}$  S/cm of P(2-MBAP) remarkably increased to  $1.5 \times 10^{-6}$  S/cm at 20°C and  $2.8 \times 10^{-6}$  S/cm at 60°C after doping for 24 hours, and no significant changes were observed with longer doping times. It has been reported in the literature that the highly electronegative N atoms of Schiff Base polymers coordinate with  $I_2$  molecules and this coordination enables the doping of the polymer.<sup>30,31</sup> The increase in conductivity of P(2-MBAP) after doping with  $I_2$  by increasing the temperature is similar to that of conductive polymers. This could be explained by the increase in charge transfer efficiency between polymer chain and  $I_3^-$  dopant anions with temperature.<sup>32</sup>

#### Antimicrobial Properties of 2-MBAP and P(2-MBAP)

The 2-MBAP and P(2-MBAP) were tested for antimicrobial activity against some standard strains and clinical isolates using the conventional well diffusion method. The antimicrobial activities of 2-MBAP and P(2-MBAP) against *S. lutea*, *E. aerogenes*, *E. coli*, *E. faecalis*, *K. pneumoniae*, *B. subtilis*, *C. albicans*, and *S. cerevisiae* were investigated (Table III). The results show that 2-MBAP and P(2-MBAP) have strong antibacterial effects in a certain level against the tested microorganisms. Whereas, it was observed that 2-MBAP and P(2-MBAP) did not demonstrate antifungal activity against the *S. cerevisia* and *C. albicans*. 2-MBAP and P(2-MBAP) revealed the inhibitory effect against all bacteria of both gram positive and gram negative and have an inhibitory activity in a broad spectrum of microorganisms.

#### CONCLUSIONS

The synthesis of a new azomethine group containing a polyphenol derivative was performed using the oxidative polycondensation method using  $H_2O_2$ ,  $O_2$ , and  $NaOCl$  as the oxidants. It was also determined that the parameters of the reaction period and temperature had an effect on the polymer yield. The polymer had high thermal stability according to the thermal analysis curves. This result indicates that the polymer can be used in materials requiring high thermal stability. The antimicrobial activity showed by the polymer against different bacteria indicates that it can be used as an antibacterial agent. Additionally, since the conductivity of the synthesized

polymer increases after doping, it can be concluded that polymer has a potential for use in preparation of conductive materials.

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