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New Eco-Friendly 1-Alkyl-3-(4-phenoxybutyl) Imidazolium-Based Ionic Liquids Derivatives: A Green Ultrasound-Assisted Synthesis, Characterization, Antibacterial Activity and POM Analyses

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Abstract: In view of the emerging importance of the ILs as “green” materials with wide applications and our general interests in green processes, a series of a twenty five new 1-alkyl-3-(4-phenoxybutyl) imidazolium-based ionic liquids (ILs) derivatives is synthesized using a facile and green ultrasound-assisted procedure. Their structures were characterized by FT-IR, ¹H-NMR, ¹³C-NMR, ¹¹B, ¹⁹F, ³¹P, and mass spectrometry. Antimicrobial screens of some selected ILs were conducted against a panel of Gram-positive and Gram-negative bacteria. The antimicrobial activity of each compound was measured by determination of the minimal inhibitory concentration (MIC) yielding very interesting and promising results. Their antibacterial activities are reported, and, on the basis of the experimental and virtual POM screening data available, attempt is also made to elucidate the structure activity relationship.

Keywords: green procedure; ultrasound irradiation; ionic liquids; antimicrobial activity; Petra/Osiris/Molinspiration (POM) analyses

1. Introduction

Over the past two decades, Ionic liquids (ILs) have attracted considerable attention as friendly environmental substitutes for volatile organic solvents due to the several unique properties such as negligible vapor pressure, high thermal stability, easy recyclability, no flammability, and high ionic conductivity [1–4]. Generally, ILs are a group of low-melting-point salts containing organic cation, such as imidazolium, pyrrolidinium, or pyridazinium, paired with various anions, such as bromide or tetrafluoroborate [5].

Due to these unique properties, ILs have been widely synthesized and investigated as media for electrodeposition of metals [6–8], as a tool for lignocellulosic biomass fractionation [9], catalysis and biocatalysis [10–16], corrosion inhibition [17–20], food chemical science [21], and the nuclear industry [22].

Thus far, many chemists promoted to explore new procedures for the clean and efficient synthesis of ILs since the conventional syntheses of them are not benign [23]. Several modifications have been attempted including microwave irradiation, sonochemical reactions or solvent-free reactions. The use of these green technologies leads to many advantages, such as large reductions in reaction times, enhancements in conversions, sometimes in selectivity [24–27].

On the other hand, numerous studies have demonstrated the antimicrobial activity of various classes of ionic liquids against both environmental and clinically important microorganisms [28–33].

According to the above mentioned, and our ongoing research, interest in ionic liquids synthesis [34–36], we continued to combine the use of green technologies in the synthesis of new class of antimicrobial agents.

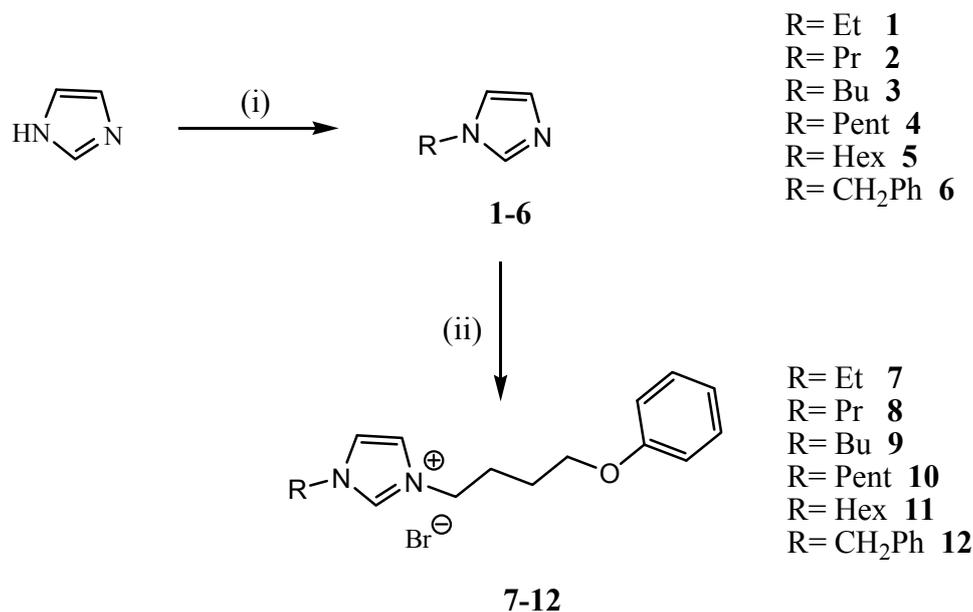
Some selected ILs were investigated for their anti-microbial activity against different pathogenic strains.

2. Results and Discussion

2.1. Chemistry

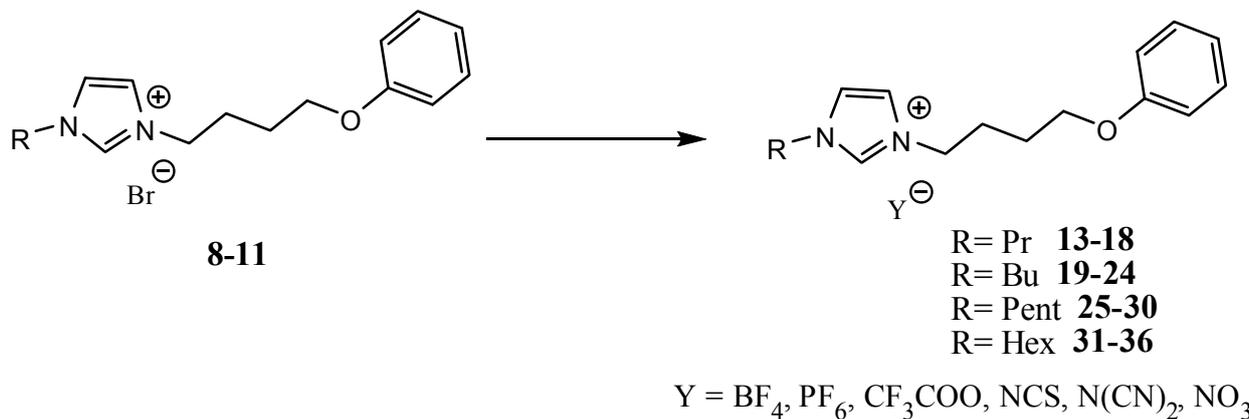
In continuation of our previous work dealing with the development of novel room temperature functionalized ionic liquids [37], herein, we report the synthesis of a variety of new imidazolium-based ionic liquids under both conventional and ultrasound irradiation methods (Schemes 1 and 2).

Scheme 1. Synthesis of a variety of new imidazolium-based ionic liquids under both conventional and ultrasound irradiation methods.



(i) N-alkylation of imidazole: RBr, (KOH/K₂CO₃), Acetonitrile, 80 °C, 16 h. R = Et, Pr, Bu, Pent, Hex, Benzyl. (ii) N-alkylation of N-alkylimidazole: conventional preparation (CP) and ultrasonic irradiation conditions (US). (CP): PhO(CH₂)₄Br, toluene, 80 °C, 18 h; (US): toluene, 80 °C, 5 h.

Scheme 2. Anion metathesis using conventional preparation (CP) and ultrasonic irradiation conditions (US). (CP): MY, dichloromethane, 70 °C, 3 h; (US): dichloromethane, 70 °C, 45 min. M = Na, K.



Initially, various 1-alkyl-1H-imidazole **1–6** were easily prepared by treatment of imidazole with alkyl bromide with K₂CO₃/KOH in Acetonitrile. The nucleophilic alkylation of N-alkylimidazoles **1–6** under standard conditions (toluene, 80 °C, 18 h), with different alkyl halides (1.1 eq) afforded the corresponding imidazolium halides in 78%–85% yield as oils after solvent removal by evaporation (Table 1).

Table 1. Reaction conditions and yields for the quaternization of N-alkylimidazole (7–12) using conventional preparation (CP) and ultrasound irradiation conditions (US).

Compound	R	Yield (%) of the Quaternization Step	
		CP ₁ ^a	US ^b
7	Et	79	85
8	Pr	80	87
9	Bu	78	89
10	Pent	79	88
11	Hex	80	87
12	CH ₂ Ph	79	86

^a Time (18 h), Temperature (80 °C) in toluene; ^b Time (5 h), Temperature (80 °C) in toluene.

Previous work reports that the hydrophobicity of an ionic liquid increases with the length of the alkyl chain on the imidazolium ring, and this increase tends to raise viscosity [38,39]. This why six anions were used in the metathesis step in order to obtain low melting point and less viscous ILs.

The next step in the synthesis involved an anion exchange halides by using a slight excess of the anions sodium tetrafluoroborate, potassium hexafluorophosphate, trifluoroacetic acid sodium, sodium dicyanamide, sodium thiocyanate, or sodium nitrate anions (Scheme 2).

The resulting pure products from these reactions were subsequently obtained by filtration of the metal halide salts, followed by filtrate evaporation and washing of the residue with dichloromethane followed by further filtration to remove any remaining metal salts. Finally, evaporation of the filtrate afforded the desired ionic liquids **13–36** in good yields (Table 2).

As already reported by our team, an anion exchange metathesis is easily performed by ultrasonic activation [34]. In a similar way, the preparation of ILs **13–36** was carried in a closed vessel and exposed to irradiation for 45 min at 70 °C using a sonication bath. The data presented in Table 2 indicated that very good yields were obtained in very short reaction times. As observed, the anion nature of the exchange agents did not affect product yields.

Table 2. Reaction conditions and yields for the anion metathesis reaction using conventional preparation (CP) and ultrasound irradiation conditions (US).

Compound	R	MY	Yield (%) for the Anion Metathesis	
			CP ₂ ^a	(US) ^b
13		NaBF ₄	95	96
14		KPF ₆	95	97
15	Pr	NaOCCF ₃	92	98
16		NaN(CN) ₂	94	97
17		NaNCS	92	97
18		NaNO ₃	94	95
19		NaBF ₄	94	98
20		KPF ₆	93	97
21	Bu	NaOCCF ₃	93	97
22		NaN(CN) ₂	92	96
23		NaNCS	93	95
24		NaNO ₃	92	96

Table 2. Cont.

Compound	R	MY	Yield (%) for the Anion Metathesis	
			CP ₂ ^a	(US) ^b
25		NaBF ₄	95	98
26		KPF ₆	93	96
27	Pent	NaOOCF ₃	95	97
28		NaN(CN) ₂	94	97
29		NaNCS	94	95
30		NaNO ₃	94	98
31		NaBF ₄	94	97
32		KPF ₆	93	96
33	Hex	NaOOCF ₃	95	97
34		NaN(CN) ₂	92	96
35		NaNCS	93	95
36		NaNO ₃	94	97

^a Time (3 h), Temperature (70 °C) in acetonitrile; ^b Time (45 min), Temperature (70 °C) in acetonitrile.

The structures of all the newly synthesized ionic liquids were confirmed by ¹H-NMR, ¹³C-NMR, ¹¹B-NMR, ¹⁹F-NMR, ³¹P-NMR, FT-IR, and LCMS analysis. All spectroscopic data are detailed in the experimental part.

2.2. Antimicrobial Activity

The short generation times of bacteria compared with other living organisms give a good starting point to examine the toxicity of ILs [40]. This has indirectly led to the realization that some ILs exhibit anti-microbial activity.

One of the objectives of the present study is therefore to investigate the anti-microbial activities of some synthesized ILs. For this, several types of human pathogens were selected to assess the potential toxicities of these ILs and their effectiveness as anti-microbial agents.

In this aim, the water soluble ILs 7–12 were tested *in vitro* for their antibacterial activity against Gram-positive bacteria including; *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Bacillus subtilis* and *Bacillus cereus*, as well as Gram-negative bacteria, including *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii*. These clinical isolates were selected based on their pathogenic properties. The antibacterial activity was measured by determination of MIC values in a range from 0 to 256 µg/mL and compared with those of some potent antibacterial compounds like mezlocillin, amikacin, tetracycline and nitrofurantion. MIC values are summarized (Table 3).

From the MIC values obtained, all compounds exhibited antibacterial activity with varying potential as well as spectrum. In general, all tested ILs (7–12) possessed congruent antibacterial activities against the growth of *E. coli*, *K. pneumoniae*, *S. aureus* and *S. pneumoniae* as compared with the standards mezlocillin, amikacin, tetracycline, and nitrofurantion while showed low activity (>128 µg/mL) against *P. aeruginosa* and *A. baumannii*.

Table 3. Antimicrobial activity of Ionic liquids 7–12 against eight bacterial strains.

Compounds	MIC ($\mu\text{g/mL}$)							
	<i>E. coli</i>	<i>K. pneumoniae</i>	<i>P. aeruginosa</i>	<i>A. baumannii</i>	<i>S. aureus</i>	<i>S. pneumoniae</i>	<i>B. subtilis</i>	<i>B. cereus</i>
7	64	64	>256	>256	64	64	128	>256
8	32	16	>256	>256	64	64	128	>256
9	16	16	>256	>256	32	16	128	>256
10	16	8	128	256	16	8	64	64
11	16	8	>256	128	8	8	16	32
12	16	32	>256	>256	64	32	64	>256
Mezlocillin	128	128	128	128	---	---	32	32
Amikacin	32	32	32	32	32	32	---	---
Tetracycline	16	16	---	16	---	8	4	4
Nitrofurantion	128	128	---	---	128	128	---	---

In particular, IL **11** exhibited the highest antibacterial activities in the series against most of the tested bacteria with MIC values ($<32 \mu\text{g/mL}$). Having MIC value of 8 for IL **11** against *K. pneumoniae*, *S. aureus*, and *S. pneumonia* makes it a good candidate as a potent antibacterial agent. Such relatively high antibacterial activity of IL **11** can be attributed to the presence of the hexyl chain which is absent in the IL **7** having lowest toxicity. This trend was also found in case of IL **9** and **10**. Therefore, it can be concluded that the biological activity of ILs **7–11** depends on the length of the alkyl chain and increased with increasing the hydrophobicity for the tested ILs.

Beside antibacterial activity, all tested ILs (**7–12**) showed broader spectrum revealed by detected antibacterial activity against Gram-positive and Gram-negative bacteria, particularly *S. aureus*, *S. pneumonia* and *E. coli*, *K. pneumonia*, respectively.

2.3. POM Analyses of Compounds 7–12

For a molecule to be a potential drug, besides having a good biological activity, it must have good pharmacokinetic properties in biological systems. To access the pharmacokinetic profile of the synthesized molecules, we used well validated *in silico* tools: Osiris, Petra and Molinspiration. These tools have been validated with almost 7000 drug molecules available on the market.

The analysis of theoretical toxicity risks for the similar ILs using the Osiris program showed that similar ILs were less toxic than standard clinical drugs and can be used as therapeutic agents.

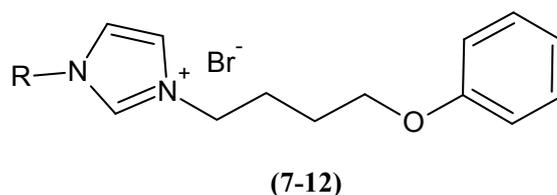
From the data evaluated in Table 4 indicates that, all structures are supposed to be non-mutagenic when run through the mutagenicity assessment system and, as far as irritating and reproductive effects are concerned, all the compounds are at low risk comparable with standard drugs used. The hydrophilicity character of each compound has been expressed in term of the $\log p$ value which correspond to the logarithm of its partition coefficient between n-octanol and water. It has been established that the absorption or permeation is greatly affected by the hydrophilicity (value of $\log p$). Accordingly, when $\log p$ is higher than 5, the absorption or permeation decrease.

On this basis, all the majority of compounds **7–12** is having $\log P$ values under the acceptable criteria should be active but they are not active because there is another crucial parameter which should be taken in consideration. It concerns the geometrical conformation of pharmacophore. The

absorption, distribution characteristics and bioactivity was proved to be dependent to the geometrical parameter and the aqueous solubility of a compound. Consequently, the bad absorption could presumably due to the low solubility of the tested ILs. Further, the Table 4 shows drug-likeness of compounds 7–12 which is not in the comparable zone with that of standard drugs used.

We have calculated overall drug-score (DS) for the compounds 7–12 and compared with that of standard drugs (AMP, GENTA, and AMPHO) used as shown in Tables 4 and 5. The DS combines drug-likeness, $\log p$, $\log S$, molecular weight, and toxicity risks, in one handy value that may be used to judge the compound's overall potential to qualify for a drug. The reported compounds 7–12 showed low to moderate DS as compared with standard drugs used.

Table 4. Osiris calculations of toxicity risks and drug-score of compounds 7–12.



Compd.	R	Toxicity Risks ^[a]				Drug-Score ^[b]			
		MUT	TUMO	IRRI	REP	CLP	S	DL	DS
7	Ethyl	■	■	■	■	2.38	-2.67	-0.66	0.60
8	Propyl	■	■	■	■	2.84	-2.94	-0.90	0.56
9	Butyl	■	■	■	■	3.31	-3.21	-3.16	0.43
10	Pentyl	■	■	■	■	3.77	-3.48	-5.85	0.39
11	Hexyl	■	■	■	■	4.23	-3.76	-10.23	0.36
12	Benzyl	■	■	■	■	3.31	-3.69	-0.91	0.41
Mezlocillin	---	■	■	■	■	-0.03	-2.53	15.14	0.66
Amikacin	---	■	■	■	■	-8.00	-0.23	1.73	0.35
Tetracycline	---	■	■	■	■	-1.02	-1.83	5.43	0.81
Nitrofurantion	---	■	■	■	■	-0.07	-2.50	0.67	0.78

■: not toxic; ■: slightly toxic; ■: highly toxic. ^[a] MUT: mutagenic; TUMO: tumorigenic; IRRI: irritant; REP: reproductive effective. ^[b] CLP: cLogP, S: Solubility, DL: Druglikness, DS: Drug-Score.

2.4. Molinspiration Calculations

cLog *P* (octanol/water partition coefficient) is calculated by the methodology developed by Molinspiration as a sum of fragment based contributions and correction factors (Table 4). The method is very useful and can be applied to all organic and some organometallic molecules. Molecular Polar Surface Area values (TPSA) were also measured using the above mentioned methodology. O- and N-centred polar fragments are considered. PSA has been shown to be a useful parameter for determination of drug absorption and especially intestinal absorption, bioavailability, and blood–brain barrier penetration. Prediction results of compounds 7–12 molecular properties (TPSA, GPCR ligand, and ICM) are valued (Table 5).

Table 5. Molinspiration calculations of compounds 7–12.

Compd.	MW (g/mol)	Physico-Chemical Properties ^[a]					Drug Likeness ^[b]				
		TPSA	O/NH	VIOL	VOL	GPC	ICM	KI	NRL	PI	EN
7	325	12.47	0	0	271	-0.06	-0.10	-0.18	-0.06	-0.22	0.01
8	339	12.47	0	0	287	0.04	-0.06	-0.13	0.03	-0.10	0.03
9	353	12.47	0	0	304	0.07	-0.06	-0.10	0.08	-0.05	0.05
10	367	12.47	0	0	321	0.10	-0.05	-0.07	0.12	0.01	0.07
11	381	12.47	0	0	338	0.12	-0.05	-0.05	0.13	0.03	0.06
12	387	12.47	0	0	325	0.09	-0.06	-0.01	0.08	0.04	0.04
Mezlocillin	539	173	3	2	434	-0.04	-0.43	-0.60	-0.58	0.66	0.10
Amikacin	585	332	17	3	510	0.32	-0.09	0.16	-0.10	0.78	0.45
Tetracycline	444	182	7	1	377	-0.15	-0.24	-0.53	-0.09	-0.04	0.52
Nitrofurantion	238	121	1	0	181	-1.36	-0.90	-1.21	-2.16	-1.45	-0.79

^[a] TPSA: Total polar surface area; O/NH: O---HN interaction; VIOL: number of violation; VOL: volume.

^[b] GPC: GPCR ligand; ICM: Ion channel modulator; KI: Kinase inhibitor; NRL: Nuclear receptor ligand; PI: Protease inhibitor; EI: Enzyme inhibitor.

The bioactivity properties were greatly affected by the electronic and steric factors. The obtained POM results confirm that most of these ILs could be used as potential antimicrobial activity after major modifications. Based on their great hydrosolubility properties, these compounds may be useful as solubilising substituents with potential anti-tumoral activity. These results prompt several pertinent observations: (i) This type of ILs can furnish an interesting model for studying the interaction of target-antibiotics complexes with cancer phosphates because the possible charge ($P=O^{\delta-} \cdots N^{\delta+}$) modification of pi-charge pharmacophore group; (ii) The future flexiblelipophyl-hydrosoluble drugs containing II moiety will enable us to prepare molecules for multi-therapeutic materials with high combined antibacterial/antiviral/antifungal/antitumoral activity.

3. Materials and Methods

3.1. Experimental

All new compounds were synthesized and characterized by ¹H-NMR, ¹³C-NMR, IR, and LCMS. ¹H-NMR (400 MHz) and ¹³C-NMR (100 MHz) spectra were measured in CDCl₃ at room temperature. Chemical shifts (δ) were reported in ppm to a scale calibrated for tetramethylsilane (TMS), which is used as an internal standard. The LCMS spectra were measured with a Micromass, LCT mass spectrometer. IR spectra were recorded in NaCl or KBr disc on a Shimadzu 8201 PC, FTIR spectrophotometer (ν_{\max} in cm⁻¹). The ultrasound-assisted reactions were performed using a high intensity ultrasonic processor SUB Aqua 5 Plus-Grant with temperature controller (750 W), microprocessor controlled-2004, the ultrasonic frequency of the cleaning bath used equal 25 KHz.

3.2. Synthesis

General procedures for the synthesis of imidazolium halides (7–12) using conventional method. To the solution of *N*-alkylimidazole (1 eq) in toluene, was added alkyl bromide (1.1 eq) at room temperature, followed by stirring at 80 °C for 18 h. The completion of the reaction was marked by the

separation of oil from the initially obtained clear and homogenous mixture of *N*-alkylimidazole and alkyl halide in toluene. The product was isolated by extraction to remove the unreacted starting materials and solvent. Subsequently, the imidazolium salt was washed with ethyl acetate. In each case, the IL/salt was finally dried at a reduced pressure to get rid of all the volatile organic compounds.

General procedure for the synthesis of imidazolium halides (**7–12**) using under Ultrasonic irradiation. Alkylimidazole (1 eq) and the appropriate alkyl bromide (1 eq) were placed in a closed vessel and exposed to irradiation for 5 h at 80 °C using a sonication bath. The product was then collected as described in the conventional procedure outlined earlier.

General procedure for the methathesis reaction of (**8–11**) leading to compounds (**13–36**) using conventional method. The quaternary salt (1 eq) was dissolved in dichloromethane to obtain a clear solution. To this solution of quaternary halide was added solution of sodium tetrafluoroborate, potassium hexafluorophosphate, trifluoroacetic acid sodium, sodium dicyanamide, sodium thiocyanate, or sodium nitrate (1.2 eq), followed by stirring at 70 °C for 3 h. The cooled reaction mixture was filtered through Celite to remove solid metal halide. The evaporation of dichloromethane leded quantitatively to the desired ionic liquids.

General procedure for the ultrasound-assisted methathesis reaction of (**8–11**) leading to compounds (**13–36**). Imidazolium-halides salts (1 eq) and NaBF₄, KPF₆, CF₃COONa, NaN(CN)₂, NaNCS or NaNO₃ (1 eq) were placed in a closed vessel and exposed to irradiation for 45 min at 70 °C using a sonication bath. The product was then collected as described in the conventional procedure outlined earlier.

3.3. Characterization

1-Ethyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium bromide (7). ¹H-NMR (CDCl₃, 400 MHz): δ = 1.40 (t, *J* = 7.2 Hz, 3H), 1.69 (quint, *J* = 7.6 Hz, 2H), 1.96 (quint, *J* = 7.6 Hz, 2H), 3.96 (t, *J* = 7.6 Hz, 2H), 4.23 (q, *J* = 7.2 Hz, 2H), 4.30 (t, *J* = 7.6 Hz, 2H), 6.87–6.91 (m, 3H, Ar-H), 7.22–7.27 (m, 2H, Ar-H), 7.93–7.99 (m, 2H), 9.55 (s, 1H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 15.0 (CH₃), 25.3 (CH₂), 26.3 (CH₂), 44.1 (CH₂), 48.4 (CH₂), 66.6 (CH₂), 114.3 (CH), 120.4 (CH), 122.1 (CH), 122.3 (CH), 129.4 (CH), 135.8 (CH), 158.3 (C); IR (NaCl) ν_{max} 3132 (C-H Ar), 1599–1471 (C=C), 1165(C-N), 1082 (C-O) cm⁻¹; LCMS (M⁺)-Br⁻ 245.2 found for C₁₅H₂₁N₂O⁺.

1-Propyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium bromide (8). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.88 (t, *J* = 7.2 Hz, 3H), 1.76 (quint, *J* = 7.6 Hz, 2H), 1.88 (sextet, *J* = 7.6 Hz, 2H), 2.07 (quint, *J* = 7.6 Hz, 2H), 3.93 (t, *J* = 7.6 Hz, 2H), 4.21 (t, *J* = 7.2 Hz, 2H), 4.40 (t, *J* = 7.6 Hz, 2H), 6.77–6.86 (m, 3H, Ar-H), 7.15–7.19 (m, 2H, Ar-H), 7.50–7.58 (m, 2H, Ar-H), 10.22 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 10.7 (CH₃), 23.6 (CH₂), 25.8 (CH₂), 27.3 (CH₂), 49.6 (CH₂), 51.3 (CH₂), 66.7 (CH₂), 114.4 (CH), 120.8 (CH), 122.3 (CH), 122.4 (CH), 129.5 (CH), 136.6 (CH), 158.5 (C); IR (NaCl) ν_{max} 3131 (C-H Ar), 1599–1470 (C=C), 1164(C-N), 1083 (C-O) cm⁻¹; LCMS (M⁺)-Br⁻ 259.2 found for C₁₆H₂₃N₂O⁺.

1-Butyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium bromide (9). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.88 (t, *J* = 7.2 Hz, 3H), 1.31 (sextet, *J* = 7.6 Hz, 2H), 1.78–1.82 (m, *J* = 7.6 Hz, 4H), 2.10 (quint, *J* = 7.6 Hz, 2H), 3.94 (t, *J* = 7.6 Hz, 2H), 4.25 (t, *J* = 7.2 Hz, 2H), 4.41 (t, *J* = 7.6 Hz, 2H), 6.79–6.86 (m, 3H, Ar-H), 7.17–7.21 (m, 2H, Ar-H), 7.47–7.58 (m, 2H, Ar-H), 10.22 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃,

100 MHz): δ = 13.4 (CH₃), 19.4 (CH₂), 25.8 (CH₂), 27.3 (CH₂), 32.1 (CH₂), 48.7 (CH₂), 49.6 (CH₂), 66.8 (CH₂), 114.4 (CH), 120.8 (CH), 122.2 (CH), 122.4 (CH), 129.5 (CH), 136.6 (CH), 158.5 (C); IR (NaCl) ν_{\max} 3133 (C-H Ar), 1600–1471 (C=C), 1166 (C-N), 1082 (C-O) cm⁻¹; LCMS (M⁺)-Br⁻ 273.3 found for C₁₇H₂₅N₂O⁺.

1-Pentyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium bromide (10). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.67 (t, J = 7.2 Hz, 3H), 1.04–1.15 (m, 4H), 1.62–1.72 (m, 4H), 1.97 (quint, J = 7.6 Hz, 2H), 3.79 (t, J = 7.6 Hz, 2H), 4.11 (t, J = 7.2 Hz, 2H), 4.28 (t, J = 7.6 Hz, 2H), 6.79–6.86 (m, 3H, Ar-H), 7.65–7.71 (m, 2H, Ar-H), 7.02–7.06 (m, 2H, Ar-H), 10.13 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 13.7 (CH₃), 21.8 (CH₂), 25.7 (CH₂), 27.2 (CH₂), 28.0 (CH₂), 29.7 (CH₂), 49.4 (CH₂), 49.8 (CH₂), 66.6 (CH₂), 114.2 (CH), 120.6 (CH), 122.2 (CH), 122.5 (CH), 129.3 (CH), 136.3 (CH), 158.4 (C); IR (NaCl) ν_{\max} 3132 (C-H Ar), 1600–1471 (C=C), 1164 (C-N), 1081 (C-O) cm⁻¹; LCMS (M⁺)-Br⁻ 287.3 found for C₁₈H₂₇N₂O⁺.

1-Hexyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium bromide (11). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.94 (t, J = 7.2 Hz, 3H), 1.14 (quint, J = 7.6 Hz, 2H), 1.39–1.41 (m, 4H), 1.69 (quint, J = 7.6 Hz, 2H), 1.77 (quint, J = 7.6 Hz, 2H), 1.96 (quint, J = 7.6 Hz, 2H), 3.96 (t, J = 7.6 Hz, 2H), 4.27 (quint, J = 7.2 Hz, 2H), 4.46 (t, J = 7.6 Hz, 2H), 6.87–6.91 (m, 3H, Ar-H), 7.22–7.27 (m, 2H, Ar-H), 7.93–7.99 (m, 2H, Ar-H), 9.55 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 13.9 (CH₃), 22.6 (CH₂), 24.8 (CH₂), 27.2 (CH₂), 27.3 (CH₂), 32.6 (CH₂), 33.9 (CH₂), 44.1 (CH₂), 48.3 (CH₂), 66.6 (CH₂), 114.3 (CH), 120.4 (CH), 122.1 (CH), 122.3 (CH), 129.4 (CH), 135.8 (CH), 158.3 (C); IR (NaCl) ν_{\max} 3132 (C-H Ar), 1598–1472 (C=C), 1165 (C-N), 1081 (C-O) cm⁻¹; LCMS (M⁺)-Br⁻ 301.3 found for C₁₉H₂₉N₂O⁺.

1-Benzyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium bromide (12). White crystals, Mp 153–155 °C, ¹H-NMR (CDCl₃, 400 MHz): δ = 1.77 (quint, J = 8, 2H), 2.07 (quint, J = 8 Hz, 2H), 3.91 (t, J = 8 Hz, 2H), 4.35 (t, J = 8 Hz, 2H), 5.52 (s, 2H), 6.77–6.88 (m, 3H), 7.17–7.55 (m, 9H), 10.45 (s, 1H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 25.7 (CH₂), 26.9 (CH₂), 49.7 (CH₂), 53.2 (CH₂), 66.7 (CH₂), 114.4 (CH), 120.8 (CH), 122.2 (CH), 122.6 (CH), 128.9 (CH), 129.4 (CH), 129.5 (CH), 133.0 (C), 135.5 (CH), 158.6 (C); IR (KBr) ν_{\max} 3130 (C-H Ar), 1599–1471 (C=C), 1164 (C-N), 1081 (C-O) cm⁻¹; LCMS (M⁺)-Br⁻ 307.3 found for C₂₀H₂₃N₂O⁺.

1-Propyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium tetrafluoroborate (13). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.88 (t, J = 7.2 Hz, 3H), 1.76 (quint, J = 7.6 Hz, 2H), 1.88 (sextet, J = 7.6 Hz, 2H), 2.07 (quint, J = 7.6 Hz, 2H), 3.93 (t, J = 7.6 Hz, 2H), 4.21 (t, J = 7.2 Hz, 2H), 4.40 (t, J = 7.6 Hz, 2H), 6.77–6.86 (m, 3H, Ar-H), 7.15–7.19 (m, 2H, Ar-H), 7.50–7.58 (m, 2H, Ar-H), 10.22 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 8.7 (CH₃), 21.6 (CH₂), 24.0 (CH₂), 25.3 (CH₂), 47.9 (CH₂), 49.6 (CH₂), 65.0 (CH₂), 112.6 (CH), 119.0 (CH), 120.7 (CH), 122.2 (CH), 127.7 (CH), 133.7 (CH), 158.5 (C); ¹⁹F-NMR (CDCl₃, 376.5 MHz): δ = -150.65; ¹¹B-NMR (CDCl₃, 128 MHz): δ = -0.96; IR (NaCl) ν_{\max} 3133 (C-H Ar), 1598–1472 (C=C), 1166 (C-N), 1084 (C-O) cm⁻¹; LCMS (M⁺)-BF₄⁻ 259.2 found for C₁₆H₂₃N₂O⁺.

1-Propyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium hexafluorophosphate (14). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.94 (t, J = 7.2 Hz, 3H), 1.80 (quint, J = 7.6 Hz, 2H), 1.87 (sextet, J = 7.6 Hz, 2H), 2.06 (quint,

$J = 7.6$ Hz, 2H), 3.98 (t, $J = 7.6$ Hz, 2H), 4.10 (t, $J = 7.2$ Hz, 2H), 4.25 (t, $J = 7.6$ Hz, 2H), 6.86–6.96 (m, 3H, Ar-H), 7.25–7.32 (m, 5H, Ar-H), 8.58 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 10.5$ (CH_3), 23.2 (CH_2), 25.7 (CH_2), 27.0 (CH_2), 49.8 (CH_2), 51.6 (CH_2), 66.7 (CH_2), 114.4 (CH), 120.9 (CH), 122.2 (CH), 122.3 (CH), 129.6 (CH), 135.2 (CH), 158.6 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): $\delta = -71.10$; $^{31}\text{P NMR}$ (CDCl_3 , 162 MHz): $\delta = -144.31$ (sep, $J = 712.8$ Hz); IR (NaCl) ν_{max} 3132 (C-H Ar), 1599–1471 (C=C), 1165(C-N), 1082 (C-O) cm^{-1} ; LCMS (M^+)- PF_6^- 259.2 found for $\text{C}_{16}\text{H}_{23}\text{N}_2\text{O}^+$.

1-Propyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium trifluoroacetate (15). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.88$ (t, $J = 7.2$ Hz, 3H), 1.75 (quint, $J = 7.6$ Hz, 2H), 1.83 (sextet, $J = 7.6$ Hz, 2H), 2.03 (quint, $J = 7.6$ Hz, 2H), 3.92 (t, $J = 7.6$ Hz, 2H), 4.14 (t, $J = 7.2$ Hz, 2H), 4.33 (t, $J = 7.6$ Hz, 2H), 6.79–6.88 (m, 3H, Ar-H), 7.18–7.22 (m, 3H, Ar-H), 7.40–7.47 (m, 2H, Ar-H), 10.10 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 10.5$ (CH_3), 23.4 (CH_2), 25.7 (CH_2), 27.2 (CH_2), 49.5 (CH_2), 51.3 (CH_2), 66.7 (CH_2), 114.3 (CH), 120.8 (CH), 122.1 (CH), 122.2 (CH), 129.4 (CH), 137.0 (CH), 158.5 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): $\delta = -75.42$; IR (NaCl) ν_{max} 3131 (C-H Ar), 1599–1469 (C=C), 1166 (C-N), 1079 (C-O) cm^{-1} ; LCMS (M^+)- CF_3CO_2^- 259.2 found for $\text{C}_{16}\text{H}_{23}\text{N}_2\text{O}^+$.

1-Propyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium dicyanoamine (16). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.91$ (t, $J = 7.2$ Hz, 3H), 1.79 (quint, $J = 7.6$ Hz, 2H), 1.82 (sextet, $J = 7.6$ Hz, 2H), 2.08 (quint, $J = 7.6$ Hz, 2H), 3.95 (t, $J = 7.6$ Hz, 2H), 4.19 (t, $J = 7.2$ Hz, 2H), 4.36 (t, $J = 7.6$ Hz, 2H), 6.81–6.88 (m, 3H, Ar-H), 7.18–7.22 (m, 3H, Ar-H), 7.45–7.51 (m, 2H, Ar-H), 9.28 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 8.8$ (CH_3), 21.6 (CH_2), 24.0 (CH_2), 25.4 (CH_2), 48.1 (CH_2), 49.8 (CH_2), 64.9 (CH_2), 112.6 (CH), 118.9 (CH), 120.6 (CH), 120.7 (CH), 127.6 (CH), 134.0 (CH), 156.6 (C); IR (NaCl) ν_{max} 3133 (C-H Ar), 1598–1472 (C=C), 1163 (C-N), 1080 (C-O) cm^{-1} ; LCMS (M^+)- $(\text{CN})_2\text{N}^-$ 259.2 found for $\text{C}_{16}\text{H}_{23}\text{N}_2\text{O}^+$.

1-Propyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium thiocyanate (17). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.89$ (t, $J = 7.2$ Hz, 3H), 1.78 (quint, $J = 7.6$ Hz, 2H), 1.86 (sextet, $J = 7.6$ Hz, 2H), 2.03 (quint, $J = 7.6$ Hz, 2H), 3.93 (t, $J = 7.6$ Hz, 2H), 4.12 (t, $J = 7.2$ Hz, 2H), 4.29 (t, $J = 7.6$ Hz, 2H), 6.79–6.87 (m, 3H, Ar-H), 7.16–7.22 (m, 3H, Ar-H), 7.39–7.46 (m, 2H, Ar-H), 9.50 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 8.8$ (CH_3), 21.6 (CH_2), 23.9 (CH_2), 25.3 (CH_2), 47.9 (CH_2), 49.6 (CH_2), 64.8 (CH_2), 112.5 (CH), 119.0 (CH), 120.5 (CH), 120.6 (CH), 127.6 (CH), 134.1 (CH), 156.6 (C); IR (NaCl) ν_{max} 3129 (C-H Ar), 1597–1469 (C=C), 1163 (C-N), 1079 (C-O) cm^{-1} ; LCMS (M^+)- SCN^- 259.2 found for $\text{C}_{16}\text{H}_{23}\text{N}_2\text{O}^+$.

1-Propyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium nitrate (18). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.75$ (t, $J = 7.2$ Hz, 3H), 1.63 (quint, $J = 7.6$ Hz, 2H), 1.74 (sextet, $J = 7.6$ Hz, 2H), 1.94 (quint, $J = 7.6$ Hz, 2H), 3.79 (t, $J = 7.6$ Hz, 2H), 4.07 (t, $J = 7.2$ Hz, 2H), 4.23 (t, $J = 7.6$ Hz, 2H), 6.66–6.74 (m, 3H, Ar-H), 7.03–7.07 (m, 3H, Ar-H), 7.42–7.50 (m, 2H, Ar-H), 9.92 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 10.6$ (CH_3), 23.4 (CH_2), 25.7 (CH_2), 27.1 (CH_2), 49.4 (CH_2), 51.2 (CH_2), 66.6 (CH_2), 114.3 (CH), 120.7 (CH), 122.3 (CH), 122.4 (CH), 129.3 (CH), 136.4 (CH), 156.4 (C); IR (NaCl) ν_{max} 3132 (C-H Ar), 1598–1470 (C=C), 1165 (C-N), 1081 (C-O) cm^{-1} ; LCMS (M^+)- NO_3^- 259.2 found for $\text{C}_{16}\text{H}_{23}\text{N}_2\text{O}^+$.

1-Butyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium tetrafluoroborate (19). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.90$ (t, $J = 7.2$ Hz, 3H), 1.33 (sextet, $J = 7.6$ Hz, 2H), 1.80–1.84 (m, $J = 7.6$ Hz, 4H), 2.12 (quint, $J = 7.6$ Hz, 2H), 3.96 (t, $J = 7.6$ Hz, 2H), 4.27 (t, $J = 7.2$ Hz, 2H), 4.43 (t, $J = 7.6$ Hz, 2H), 6.81–6.89 (m, 3H, Ar-H), 7.19–7.24 (m, 2H, Ar-H), 7.50–7.61 (m, 2H, Ar-H), 9.58 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 12.4$ (CH_3), 18.4 (CH_2), 24.8 (CH_2), 26.3 (CH_2), 31.1 (CH_2), 47.6 (CH_2), 48.7 (CH_2), 65.8 (CH_2), 113.4 (CH), 119.8 (CH), 121.2 (CH), 121.4 (CH), 128.5 (CH), 135.6 (CH), 157.5 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): $\delta = -150.35$; $^{11}\text{B-NMR}$ (CDCl_3 , 128 MHz): $\delta = -0.98$; IR (NaCl) ν_{max} 3130 (C-H Ar), 1599–1471 (C=C), 1164 (C-N), 1082 (C-O) cm^{-1} ; LCMS (M^+)- BF_4^- 273.3 found for $\text{C}_{17}\text{H}_{25}\text{N}_2\text{O}^+$.

1-Butyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium hexafluorophosphate (20). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.87$ (t, $J = 7.2$ Hz, 3H), 1.30 (sextet, $J = 7.6$ Hz, 2H), 1.77–1.81 (m, $J = 7.6$ Hz, 4H), 2.09 (quint, $J = 7.6$ Hz, 2H), 3.92 (t, $J = 7.6$ Hz, 2H), 4.23 (t, $J = 7.2$ Hz, 2H), 4.39 (t, $J = 7.6$ Hz, 2H), 6.77–6.86 (m, 3H, Ar-H), 7.15–7.20 (m, 2H, Ar-H), 7.46–7.57 (m, 2H, Ar-H), 8.78 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 12.8$ (CH_3), 18.8 (CH_2), 25.2 (CH_2), 26.8 (CH_2), 31.5 (CH_2), 48.0 (CH_2), 49.1 (CH_2), 66.2 (CH_2), 113.7 (CH), 120.2 (CH), 121.6 (CH), 121.6 (CH), 128.9 (CH), 136.0 (CH), 158.2 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): $\delta = -72.96$; $^{31}\text{P NMR}$ (CDCl_3 , 162 MHz): $\delta = -144.96$ (sep, $J = 712.8$ Hz); IR (NaCl) ν_{max} 3134 (C-H Ar), 1598–1469 (C=C), 1163 (C-N), 1080 (C-O) cm^{-1} ; LCMS (M^+)- PF_6^- 273.3 found for $\text{C}_{17}\text{H}_{25}\text{N}_2\text{O}^+$.

1-Butyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium trifluoroacetate (21). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.88$ (t, $J = 7.2$ Hz, 3H), 1.32 (sextet, $J = 7.6$ Hz, 2H), 1.78–1.83 (m, $J = 7.6$ Hz, 4H), 2.10 (quint, $J = 7.6$ Hz, 2H), 3.94 (t, $J = 7.6$ Hz, 2H), 4.24 (t, $J = 7.2$ Hz, 2H), 4.41 (t, $J = 7.6$ Hz, 2H), 6.78–6.88 (m, 3H, Ar-H), 7.16–7.22 (m, 2H, Ar-H), 7.47–7.59 (m, 2H, Ar-H), 8.99 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 13.1$ (CH_3), 19.1 (CH_2), 25.5 (CH_2), 27.1 (CH_2), 31.8 (CH_2), 48.3 (CH_2), 49.4 (CH_2), 66.5 (CH_2), 114.0 (CH), 120.6 (CH), 121.9 (CH), 121.9 (CH), 129.2 (CH), 136.3 (CH), 158.5 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): $\delta = -75.72$; IR (NaCl) ν_{max} 3132 (C-H Ar), 1599–1471 (C=C), 1165 (C-N), 1082 (C-O) cm^{-1} ; LCMS (M^+)- CF_3CO_2^- 273.3 found for $\text{C}_{17}\text{H}_{25}\text{N}_2\text{O}^+$.

1-Butyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium dicyanoamine (22). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.88$ (t, $J = 7.2$ Hz, 3H), 1.31 (sextet, $J = 7.6$ Hz, 2H), 1.78–1.82 (m, $J = 7.6$ Hz, 4H), 2.10 (quint, $J = 7.6$ Hz, 2H), 3.94 (t, $J = 7.6$ Hz, 2H), 4.25 (t, $J = 7.2$ Hz, 2H), 4.41 (t, $J = 7.6$ Hz, 2H), 6.79–6.86 (m, 3H, Ar-H), 7.17–7.21 (m, 2H, Ar-H), 7.47–7.58 (m, 2H, Ar-H), 10.22 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 13.4$ (CH_3), 19.4 (CH_2), 25.8 (CH_2), 27.3 (CH_2), 32.1 (CH_2), 48.7 (CH_2), 49.6 (CH_2), 66.9 (CH_2), 114.5 (CH), 120.8 (CH), 122.2 (CH), 122.4 (CH), 129.5 (CH), 136.6 (CH), 158.5 (C); IR (NaCl) ν_{max} 3130 (C-H Ar), 1600–1470 (C=C), 1164 (C-N), 1081 (C-O) cm^{-1} ; LCMS (M^+)- $(\text{CN})_2\text{N}^-$ 273.3 found for $\text{C}_{17}\text{H}_{25}\text{N}_2\text{O}^+$.

1-Butyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium thiocyanate (23). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.92$ (t, $J = 7.2$ Hz, 3H), 1.35 (sextet, $J = 7.6$ Hz, 2H), 1.82–1.86 (m, $J = 7.6$ Hz, 4H), 2.13 (quint, $J = 7.6$ Hz, 2H), 3.97 (t, $J = 7.6$ Hz, 2H), 4.28 (t, $J = 7.2$ Hz, 2H), 4.45 (t, $J = 7.6$ Hz, 2H), 6.79–6.86 (m, 3H, Ar-H), 7.17–7.21 (m, 2H, Ar-H), 7.47–7.58 (m, 2H, Ar-H), 8.99 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 13.4$ (CH_3), 19.4 (CH_2), 25.8 (CH_2), 27.3 (CH_2), 32.1 (CH_2), 48.7 (CH_2), 49.6 (CH_2), 66.8 (CH_2),

114.4 (CH), 120.8 (CH), 122.2 (CH), 122.4 (CH), 129.5 (CH), 136.6 (CH), 158.5 (C); IR (NaCl) ν_{\max} 3128 (C-H Ar), 1599–1471 (C=C), 1162 (C-N), 1079 (C-O) cm^{-1} ; LCMS (M^+)- SCN^- 273.3 found for $\text{C}_{17}\text{H}_{25}\text{N}_2\text{O}^+$.

1-Butyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium nitrate (24). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): δ = 0.90 (t, J = 7.2 Hz, 3H), 1.33 (sextet, J = 7.6 Hz, 2H), 1.80–1.84 (m, J = 7.6 Hz, 4H), 2.12 (quint, J = 7.6 Hz, 2H), 3.96 (t, J = 7.6 Hz, 2H), 4.27 (t, J = 7.2 Hz, 2H), 4.43 (t, J = 7.6 Hz, 2H), 6.81–6.89 (m, 3H, Ar-H), 7.19–7.24 (m, 2H, Ar-H), 7.50–7.61 (m, 2H, Ar-H), 8.89 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): δ = 13.0 (CH_3), 19.1 (CH_2), 25.4 (CH_2), 27.1 (CH_2), 31.7 (CH_2), 48.3 (CH_2), 49.3 (CH_2), 66.5 (CH_2), 113.9 (CH), 120.6 (CH), 121.8 (CH), 121.9 (CH), 129.1 (CH), 136.2 (CH), 158.5 (C); IR (NaCl) ν_{\max} 3131 (C-H Ar), 1598–1471 (C=C), 1163 (C-N), 1083 (C-O) cm^{-1} ; LCMS (M^+)- NO_3^- 273.3 found for $\text{C}_{17}\text{H}_{25}\text{N}_2\text{O}^+$.

1-Pentyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium tetrafluoroborate (25). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): δ = 0.87 (t, J = 7.2 Hz, 3H), 1.30–1.32 (m, 4H), 1.80–1.83 (m, 4H), 2.08 (quint, J = 7.6 Hz, 2H), 3.97 (t, J = 7.6 Hz, 2H), 4.15 (t, J = 7.2 Hz, 2H), 4.28 (t, J = 7.6 Hz, 2H), 6.85–6.92 (m, 3H, Ar-H), 7.23–7.27 (m, 2H, Ar-H), 7.35–7.42 (m, 2H, Ar-H), 8.90 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): δ = 11.9 (CH_3), 20.1 (CH_2), 23.9 (CH_2), 25.3 (CH_2), 26.3 (CH_2), 27.8 (CH_2), 47.9 (CH_2), 48.2 (CH_2), 64.9 (CH_2), 112.6 (CH), 119.0 (CH), 120.5 (CH), 120.6 (CH), 127.7 (CH), 133.8 (CH), 156.8 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): δ = -151.03; $^{11}\text{B-NMR}$ (CDCl_3 , 128 MHz): δ = -0.93; IR (NaCl) ν_{\max} 3135 (C-H Ar), 1601–1475 (C=C), 1165 (C-N), 1081 (C-O) cm^{-1} ; LCMS (M^+)- BF_4^- 287.3 found for $\text{C}_{18}\text{H}_{27}\text{N}_2\text{O}^+$.

1-Pentyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium hexafluorophosphate (26). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): δ = 0.78 (t, J = 7.2 Hz, 3H), 1.21–1.23 (m, 4H), 1.67–1.75 (m, 4H), 1.95 (quint, J = 7.6 Hz, 2H), 3.86 (t, J = 7.6 Hz, 2H), 4.02 (t, J = 7.2 Hz, 2H), 4.13 (t, J = 7.6 Hz, 2H), 6.76–6.85 (m, 3H, Ar-H), 7.14–7.25 (m, 4H, Ar-H), 8.42 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): δ = 12.0 (CH_3), 20.2 (CH_2), 24.0 (CH_2), 25.2 (CH_2), 26.4 (CH_2), 27.8 (CH_2), 48.0 (CH_2), 48.3 (CH_2), 65.0 (CH_2), 112.7 (CH), 119.1 (CH), 120.6 (CH), 120.7 (CH), 127.8 (CH), 133.2 (CH), 156.9 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): δ = -70.94; $^{31}\text{P NMR}$ (CDCl_3 , 162 MHz): δ = -144.26 (sep, J = 712.8 Hz); IR (NaCl) ν_{\max} 3132 (C-H Ar), 1599–1469 (C=C), 1167 (C-N), 1084 (C-O) cm^{-1} ; LCMS (M^+)- PF_6^- 287.3 found for $\text{C}_{18}\text{H}_{27}\text{N}_2\text{O}^+$.

1-Pentyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium trifluoroacetate (27). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): δ = 0.82 (t, J = 7.2 Hz, 3H), 1.21–1.29 (m, 4H), 1.74–1.82 (m, 4H), 2.05 (quint, J = 7.6 Hz, 2H), 3.93 (t, J = 7.6 Hz, 2H), 4.18 (t, J = 7.2 Hz, 2H), 4.34 (t, J = 7.6 Hz, 2H), 6.80–6.89 (m, 3H, Ar-H), 7.18–7.22 (m, 2H, Ar-H), 7.38–7.48 (m, 2H, Ar-H), 10.02 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): δ = 11.9 (CH_3), 20.1 (CH_2), 23.9 (CH_2), 25.4 (CH_2), 26.3 (CH_2), 28.0 (CH_2), 47.7 (CH_2), 48.1 (CH_2), 64.9 (CH_2), 112.5 (CH), 119.0 (CH), 120.2 (CH), 120.5 (CH), 127.6 (CH), 135.1 (CH), 156.7 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): δ = -75.36; IR (NaCl) ν_{\max} 3135 (C-H Ar), 1599–1473 (C=C), 1165 (C-N), 1082 (C-O) cm^{-1} ; LCMS (M^+)- CF_3CO_2^- 287.3 found for $\text{C}_{18}\text{H}_{27}\text{N}_2\text{O}^+$.

1-Pentyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium dicyanoamine (28). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.82$ (t, $J = 7.2$ Hz, 3H), 1.21–1.30 (m, 4H), 1.75–1.84 (m, 4H), 2.06 (quint, $J = 7.6$ Hz, 2H), 3.94 (t, $J = 7.6$ Hz, 2H), 4.15 (t, $J = 7.2$ Hz, 2H), 4.30 (t, $J = 7.6$ Hz, 2H), 6.79–6.87 (m, 3H, Ar-H), 7.17–7.21 (m, 2H, Ar-H), 7.38–7.47 (m, 2H, Ar-H), 9.56 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 11.9$ (CH_3), 20.0 (CH_2), 23.9 (CH_2), 25.4 (CH_2), 26.3 (CH_2), 27.8 (CH_2), 47.9 (CH_2), 48.2 (CH_2), 64.8 (CH_2), 112.5 (CH), 119.0 (CH), 120.5 (CH), 120.6 (CH), 127.6 (CH), 134.1 (CH), 156.6 (C); IR (NaCl) ν_{max} 3129 (C-H Ar), 1598–1471 (C=C), 1163 (C-N), 1079 (C-O) cm^{-1} ; LCMS (M^+)-(CN) $_2\text{N}^-$ 287.3 found for $\text{C}_{18}\text{H}_{27}\text{N}_2\text{O}^+$.

1-Pentyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium thiocyanate (29). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.85$ (t, $J = 7.2$ Hz, 3H), 1.24–1.33 (m, 4H), 1.78–1.87 (m, 4H), 2.09 (quint, $J = 7.6$ Hz, 2H), 3.97 (t, $J = 7.6$ Hz, 2H), 4.18 (t, $J = 7.2$ Hz, 2H), 4.33 (t, $J = 7.6$ Hz, 2H), 6.82–6.90 (m, 3H, Ar-H), 7.20–7.24 (m, 2H, Ar-H), 7.41–7.50 (m, 2H, Ar-H), 9.59 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 11.8$ (CH_3), 19.9 (CH_2), 23.8 (CH_2), 25.3 (CH_2), 26.2 (CH_2), 27.7 (CH_2), 47.8 (CH_2), 48.1 (CH_2), 64.7 (CH_2), 112.4 (CH), 118.9 (CH), 120.4 (CH), 120.5 (CH), 127.5 (CH), 134.0 (CH), 156.5 (C); IR (NaCl) ν_{max} 3132 (C-H Ar), 1599–1471 (C=C), 1165 (C-N), 1085 (C-O) cm^{-1} ; LCMS (M^+)-SCN $^-$ 287.3 found for $\text{C}_{18}\text{H}_{27}\text{N}_2\text{O}^+$.

1-Pentyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium nitrate (30). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.76$ (t, $J = 7.2$ Hz, 3H), 1.20–1.37 (m, 4H), 1.70–1.79 (m, 4H), 2.03 (quint, $J = 7.6$ Hz, 2H), 3.88 (t, $J = 7.6$ Hz, 2H), 4.17 (t, $J = 7.2$ Hz, 2H), 4.34 (t, $J = 7.6$ Hz, 2H), 6.74–6.83 (m, 3H, Ar-H), 7.12–7.16 (m, 2H, Ar-H), 7.44–7.57 (m, 2H, Ar-H), 10.07 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 13.7$ (CH_3), 21.9 (CH_2), 25.8 (CH_2), 27.2 (CH_2), 28.1 (CH_2), 29.8 (CH_2), 49.5 (CH_2), 49.9 (CH_2), 66.7 (CH_2), 114.3 (CH), 120.7 (CH), 122.2 (CH), 122.5 (CH), 129.4 (CH), 136.6 (CH), 158.5 (C); IR (NaCl) ν_{max} 3130 (C-H Ar), 1599–1471 (C=C), 1163 (C-N), 1082 (C-O) cm^{-1} ; LCMS (M^+)-NO $_3^-$ 287.3 found for $\text{C}_{18}\text{H}_{27}\text{N}_2\text{O}^+$.

1-Hexyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium tetrafluoroborate (31). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.98$ (t, $J = 7.2$ Hz, 3H), 1.18 (quint, $J = 7.6$ Hz, 2H), 1.43–1.45 (m, 4H), 1.73 (quint, $J = 7.6$ Hz, 2H), 1.81 (quint, $J = 7.6$ Hz, 2H), 2.00 (quint, $J = 7.6$ Hz, 2H), 4.00 (t, $J = 7.6$ Hz, 2H), 4.31 (quint, $J = 7.2$ Hz, 2H), 4.50 (t, $J = 7.6$ Hz, 2H), 6.91–6.95 (m, 3H, Ar-H), 7.26–7.31 (m, 2H, Ar-H), 7.97–8.01 (m, 2H, Ar-H), 9.32 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 14.1$ (CH_3), 22.8 (CH_2), 25.0 (CH_2), 27.4 (CH_2), 27.5 (CH_2), 32.8 (CH_2), 34.1 (CH_2), 44.3 (CH_2), 48.5 (CH_2), 66.8 (CH_2), 114.5 (CH), 120.4 (CH), 122.3 (CH), 122.5 (CH), 130.0 (CH), 136.2 (CH), 158.7 (C); $^{19}\text{F-NMR}$ (CDCl_3 , 376.5 MHz): $\delta = -148.25$; $^{11}\text{B-NMR}$ (CDCl_3 , 128 MHz): $\delta = -1.26$; IR (NaCl) ν_{max} 3129 (C-H Ar), 1602–1474 (C=C), 1165 (C-N), 1082 (C-O) cm^{-1} ; LCMS (M^+)-BF $_4^-$ 301.3 found for $\text{C}_{19}\text{H}_{29}\text{N}_2\text{O}^+$.

1-Hexyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium hexafluorophosphate (32). $^1\text{H-NMR}$ (CDCl_3 , 400 MHz): $\delta = 0.85$ (t, $J = 7.2$ Hz, 3H), 1.12 (quint, $J = 7.6$ Hz, 2H), 1.25–1.34 (m, 4H), 1.79–1.88 (m, 4H), 2.10 (quint, $J = 7.6$ Hz, 2H), 3.97 (t, $J = 7.6$ Hz, 2H), 4.18 (t, $J = 7.2$ Hz, 2H), 4.33 (t, $J = 7.6$ Hz, 2H), 6.83–6.91 (m, 3H, Ar-H), 7.21–7.25 (m, 2H, Ar-H), 7.42–7.51 (m, 2H, Ar-H), 9.24 (s, 1H, Ar-H); $^{13}\text{C-NMR}$ (CDCl_3 , 100 MHz): $\delta = 11.9$ (CH_3), 20.0 (CH_2), 23.9 (CH_2), 25.4 (CH_2), 26.4 (CH_2), 27.8

(CH₂), 32.2 (CH₂), 45.9 (CH₂), 48.2 (CH₂), 64.8 (CH₂), 112.5 (CH), 119.0 (CH), 120.5 (CH), 120.6 (CH), 127.6 (CH), 134.2 (CH), 156.7 (C); ¹⁹F-NMR (CDCl₃, 376.5 MHz): δ = -71.10; ³¹P NMR (CDCl₃, 162 MHz): δ = -144.16 (sep, *J* = 712.8 Hz); IR (NaCl) ν_{max} 3133 (C-H Ar), 1599–1471 (C=C), 1165 (C-N), 1083 (C-O) cm⁻¹; LCMS (M⁺)-PF₆⁻ 301.3 found for C₁₉H₂₉N₂O⁺.

1-Hexyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium trifluoroacetate (33). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.79 (t, *J* = 7.2 Hz, 3H), 1.07 (quint, *J* = 7.6 Hz, 2H), 1.20–1.29 (m, 4H), 1.75–1.84 (m, 4H), 2.05 (quint, *J* = 7.6 Hz, 2H), 3.92 (t, *J* = 7.6 Hz, 2H), 4.13 (t, *J* = 7.2 Hz, 2H), 4.28 (t, *J* = 7.6 Hz, 2H), 6.79–6.87 (m, 3H, Ar-H), 7.17–7.23 (m, 2H, Ar-H), 7.38–7.47 (m, 2H, Ar-H), 10.15 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 13.0 (CH₃), 21.1 (CH₂), 24.0 (CH₂), 26.5 (CH₂), 27.6 (CH₂), 28.9 (CH₂), 33.4 (CH₂), 47.0 (CH₂), 49.3 (CH₂), 65.9 (CH₂), 113.6 (CH), 120.1 (CH), 121.6 (CH), 121.7 (CH), 128.7 (CH), 135.3 (CH), 157.8 (C); ¹⁹F-NMR (CDCl₃, 376.5 MHz): δ = -75.41; IR (NaCl) ν_{max} 3133 (C-H Ar), 1599–1472 (C=C), 1162 (C-N), 1080 (C-O) cm⁻¹; LCMS (M⁺)-CF₃CO₂⁻ 301.3 found for C₁₉H₂₉N₂O⁺.

1-Hexyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium dicyanoamine (34). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.76 (t, *J* = 7.2 Hz, 3H), 1.04 (quint, *J* = 7.6 Hz, 2H), 1.20–1.37 (m, 4H), 1.70–1.79 (m, 4H), 2.03 (quint, *J* = 7.6 Hz, 2H), 3.88 (t, *J* = 7.6 Hz, 2H), 4.17 (t, *J* = 7.2 Hz, 2H), 4.34 (t, *J* = 7.6 Hz, 2H), 6.74–6.83 (m, 3H, Ar-H), 7.12–7.16 (m, 2H, Ar-H), 7.44–7.57 (m, 2H, Ar-H), 10.07 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 13.7 (CH₃), 21.9 (CH₂), 25.8 (CH₂), 27.2 (CH₂), 28.1 (CH₂), 29.8 (CH₂), 35.4 (CH₂), 49.5 (CH₂), 49.9 (CH₂), 66.7 (CH₂), 114.3 (CH), 120.7 (CH), 122.2 (CH), 122.5 (CH), 129.4 (CH), 136.6 (CH), 158.5 (C); IR (NaCl) ν_{max} 3133 (C-H Ar), 1599–1471 (C=C), 1165 (C-N), 1082 (C-O) cm⁻¹; LCMS (M⁺)-(CN)₂N⁻ 301.3 found for C₁₉H₂₉N₂O⁺.

1-Hexyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium thiocyanate (35). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.82 (t, *J* = 7.2 Hz, 3H), 1.10 (quint, *J* = 7.6 Hz, 2H), 1.21–1.29 (m, 4H), 1.74–1.82 (m, 4H), 2.05 (quint, *J* = 7.6 Hz, 2H), 3.93 (t, *J* = 7.6 Hz, 2H), 4.18 (t, *J* = 7.2 Hz, 2H), 4.34 (t, *J* = 7.6 Hz, 2H), 6.80–6.89 (m, 3H, Ar-H), 7.18–7.22 (m, 2H, Ar-H), 7.38–7.48 (m, 2H, Ar-H), 10.02 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 11.9 (CH₃), 20.1 (CH₂), 23.9 (CH₂), 25.4 (CH₂), 26.3 (CH₂), 28.0 (CH₂), 34.0 (CH₂), 47.7 (CH₂), 48.1 (CH₂), 64.9 (CH₂), 112.5 (CH), 119.0 (CH), 120.2 (CH), 120.5 (CH), 127.6 (CH), 135.1 (CH), 156.7 (C); IR (NaCl) ν_{max} 3128 (C-H Ar), 1602–1471 (C=C), 1164 (C-N), 1081 (C-O) cm⁻¹; LCMS (M⁺)-SCN⁻ 301.3 found for C₁₉H₂₉N₂O⁺.

1-Hexyl-3-(4-phenoxybutyl)-1H-imidazol-3-ium nitrate (36). ¹H-NMR (CDCl₃, 400 MHz): δ = 0.85 (t, *J* = 7.2 Hz, 3H), 1.14 (quint, *J* = 7.6 Hz, 2H), 1.24–1.33 (m, 4H), 1.78–1.87 (m, 4H), 2.09 (quint, *J* = 7.6 Hz, 2H), 3.97 (t, *J* = 7.6 Hz, 2H), 4.18 (t, *J* = 7.2 Hz, 2H), 4.33 (t, *J* = 7.6 Hz, 2H), 6.82–6.90 (m, 3H, Ar-H), 7.20–7.24 (m, 2H, Ar-H), 7.41–7.50 (m, 2H, Ar-H), 9.59 (s, 1H, Ar-H); ¹³C-NMR (CDCl₃, 100 MHz): δ = 11.8 (CH₃), 19.9 (CH₂), 23.8 (CH₂), 25.3 (CH₂), 26.2 (CH₂), 27.7 (CH₂), 34.2 (CH₂), 47.8 (CH₂), 48.1 (CH₂), 64.7 (CH₂), 112.4 (CH), 118.9 (CH), 120.4 (CH), 120.5 (CH), 127.5 (CH), 134.0 (CH), 156.5 (C); IR (NaCl) ν_{max} 3131 (C-H Ar), 1598–1470 (C=C), 1164 (C-N), 1081 (C-O) cm⁻¹; LCMS (M⁺)-NO₃⁻ 301.3 found for C₁₉H₂₉N₂O⁺.

3.4. Determination of Minimum Inhibitory Concentrations

Minimum inhibitory concentrations (MICs) were determined using the broth microdilution method based on recommended protocols employed by the Clinical and Laboratory Standards Institute [41]. Tested compounds were dissolved in sterile, distilled water and diluted to a final concentration of 512 µg/mL in Mueller-Hinton broth (Becton Dickinson, Franklin Lakes, NJ, USA) [42]. Two-fold serially diluted test compounds were dispensed into each of the 96 wells of a standard microdilution plates. The direct colony suspension method was used for inoculum preparation. Bacterial suspension was prepared by direct transfer of colonies from 24 h agar plates to Mueller Hinton broth. Bacterial suspensions were adjusted using bacterial counting chamber to contain approximately 1×10^8 CFU/mL. A 50 µL volume of each bacterial suspension was mixed with 50 µL serially diluted tested compound in 96 microdilution plate according to the microdilution method [43]. Uninoculated wells were prepared as control samples. Plates were incubated at 35 °C for 24 h. The minimum (inhibitory) bactericidal concentration was defined as the lowest concentration of test compound producing no visible growth. Confirmation for MIC, was achieved by transfer of aliquots from wells containing no growth on to nutrient agar plates and tested for colony formation upon subculturing. Given values of obtained MIC values are means of three independent experiments.

4. Conclusions

In summary, new eco-friendly 1-alkyl-3-(4-phenoxybutyl) imidazolium-based ionic liquids (ILs) derivatives were prepared by using ultrasound irradiation. Many advantages for the ultrasound assisted synthesis compared with the standard methods have been recorded. The ILs studied displayed a very promising antimicrobial activity. Their activities are greatly affected by the alkyl chain length. The study of the physicochemical properties, water content, biodegradability and solubility of the newly synthesized ionic liquids will be discussed in details in the forthcoming paper.

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Author Contributions

This work is part of a pharmacological field study carried out in Taibah University, Madinah, KSA. The Ionic liquids were prepared and characterised by Mouslim Messali, Mohamed R. Aouad, Adeeb Al-Sheikh Ali. The manuscript is written by Mouslim Messali. Taibi Ben Hadda and Belkheir Hammouti help in illustrations and drafting of manuscript. Mohamed R. Aouad, Wael S. El-Sayed, Adeeb Al-Sheikh Ali collected data in the field and help in compounds identification. The biological activity is carried out by Wael S. El-Sayed. Taibi Ben Hadda provided technical expertise in compiling POM data in to the manuscript. All the authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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