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ORIGINAL ARTICLE

Fatty Acids in Heterocyclic Synthesis Part XII: Synthesis of Surfactants from Pyrazole, Isoxazole, Pyrimidine and Triazine, Incorporating the 1,3,4-Thiadiazole Moiety Having Dyeing and Antimicrobial Activities

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Abstract The titled compounds were prepared from 2-amino-5-heptadecyl[1,3,4]thiadiazole (**1**). Diazotization of (**1**) produced (**2**) which was coupled with active methylene compounds and gave azo $\rightleftharpoons$ hydrazono derivatives (**3A**, **3B**)$_{\mathbf{a-d}}$. It was found that there is regio-specificity for addition of different nucleophiles to these tautomers; thus, nitrogen nucleophiles such as hydrazine hydrate, hydroxylamine hydrochloride and thiourea were reacted via Azo tautomer (**3A**) to yield pyrazole, isoxazole and pyrimidine respectively (**5**-**7**), while carbon nucleophiles as phenylisocyanate was reacted via the hydrazono tautomer (**3B**) and produced triazine derivatives (**4**). Additionally, the diazonium chloride (**2**) was coupled with alkaline 2-naphthol and produced 2-(5-heptadecyl-[1,3,4]thiadiazol-2-yl) -1,2-dihydro-3-oxa-1,2-diaza-cyclopenta[a]naphthalene (**8**). UV–visible spectra of the synthesized colored compounds (**2**-**8**) showed λ_{max} at 374–398 nm, while screening these compounds in vitro against micro-organisms (including structure-activity relationship SAR study) revealed high antibacterial and moderate antifungal activities. Propoxylation of compounds **1**, **3**, **5**, **6**, **7** and **8** with 3, 5, 7 mol of propylene oxide produced nonionic surfactants **I**(**a**–**c**)–**IX**(**a**–**c**) having surface active properties so, it is clear that the tested surfactants can be used in the manufacture of dyes, drugs, cosmetics, emulsifiers, pesticides, luminphores for optical applications and many other industries with low toxicity to human beings and the environment owing to their high solubility and good biodegradability.

Keywords Dyes · Antiprotozoal · Antibacterial · Stearic acid · 2-Aminothiadiazole · Pyrazol-ylazo-thiadiazole · Azo-hydrazono tautomerism · Regiospecificity

Introduction

Five-membered, hetero-aromatic compounds containing imine (–C=N–) groups, such as imidazole [1], thiazole [2], triazole [3], oxadiazole [4], and thiadiazole [5–7] have long been of interest as luminophores for optical application and for dyeing, owing to their electron accepting nature [8].

1,3,4-Thiadiazoles were reported as being highly anti-inflammatory [9], anti-microbial [10], pesticidal [11], as having antiparasitic properties [12], and as being anticancer [13] and anticonvulsant agents [14–16]. Additionally, it is well known that some functionalized hydrazono derivatives present trypanocidal activity [17, 18]. Compounds containing 1,3,4-thiadiazole and hydrazone in one molecule are framework to act the structure pattern of lead-compound as a radical scavenger group [19–22].

Chemistry

In continuation to our research program on the development of new effective, cheap and safe biologically active heterocyclic compounds having surface active properties [23–30], herein we report the synthesis of pyrazole, isoxazole, pyrimidine and triazine from a simple starting material stearic acid. The versatile 2-amino-5-heptadecyl-1,3,4-thiadiazole [28] (**1**) was prepared by refluxing stearic

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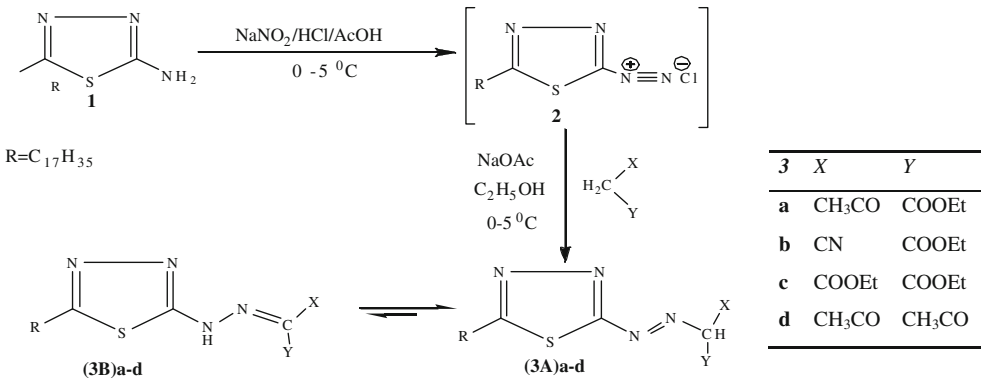
Scheme 1 Synthesis of (5-heptadecyl-[1,3,4]thiadiazol-2-ylazo/hydrazono) derivatives



3	X	Y
a	CH_3CO	COOEt
b	CN	COOEt
c	COOEt	COOEt
d	CH_3CO	CH_3CO

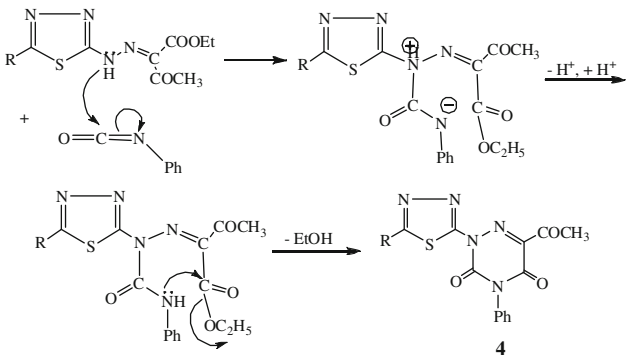
acid and thiosemicarbazide in boiling $POCl_3$. Diazotization of (**1**) with sodium nitrite and HCl/AcOH produced 5-heptadecyl-[1,3,4]thiadiazole-2-diazonium chloride (**2**) which was coupled smoothly with active methylene compounds as ethyl acetoacetate, ethyl cyanoacetate, diethylmalonate and acetylacetone via an electrophilic substitution reaction to afford azo (**3A**) $\rightleftharpoons$ hydrazono (**3B**) tautomers (**3a–d**) in a good yield (Scheme 1). These compounds can be used in dyeing and as an antiprotozoal agent [22].

Characteristic bands in IR spectra for **3a** revealed two carbonyl groups of the ester and ketone at 1742 and 1718 cm^{-1} respectively, for **3b** strong absorption at 2264 cm^{-1} for $\nu_{C\equiv N}$. For **3c** one strong band at 1742 cm^{-1} for two carbonyls of the ester, and for **3d** one carbonyl of the ketone at 1693 cm^{-1}. For all compounds (**3a-d**) there are weak and broad bands (3434–3277) cm^{-1} may be attributed to ν_{NH}, ν_{OH}. Also, ^{13}C-NMR shows a signal for C=N of the hydrazono tautomer at 133 ppm and another one at 85 ppm of the azo tautomer.

The mass spectrum of (**3a–d**) also proved this tautomerism, which showed [M^+-azo group ((–N=N–CH(X)(Y)))], and [M^+-imino group ((–N=C(X)(Y)))] for all the prepared compounds (**3a–d**).

It was found that the electrophilic reagent reacted regiospecifically with these tautomers thus, phenylisocyanate was reacted via the hydrazone tautomer **3Ba** to produce the highly substituted triazine, 6-acetyl-2-(5-heptadecyl-[1,3,4]thiadiazol-2-yl)-4-phenyl-2*H*-[1,2,4]-triazine-3,5-dione (**4**). The IR spectrum showed a sharp band for $\nu_{C=O's}$ at 1705 cm^{-1}, and ^{13}C-NMR showed δ ppm at 143.8, 155.6 for cyclic (2C=O) and 198.5 for ketonic (C=O) besides the other signals of aliphatic and aromatic carbon. Mass spectrum (M^+-2 = 551, 4.6%) and M^+-triazine moiety m/z = 324, 5.2%). The mechanism of the reaction is as follows (Scheme 2).

Nucleophilic reagents were reacted regiospecifically with the azo tautomer, thus nitrogen nucleophiles such as hydrazine, hydroxylamine hydrochloride and thiourea were

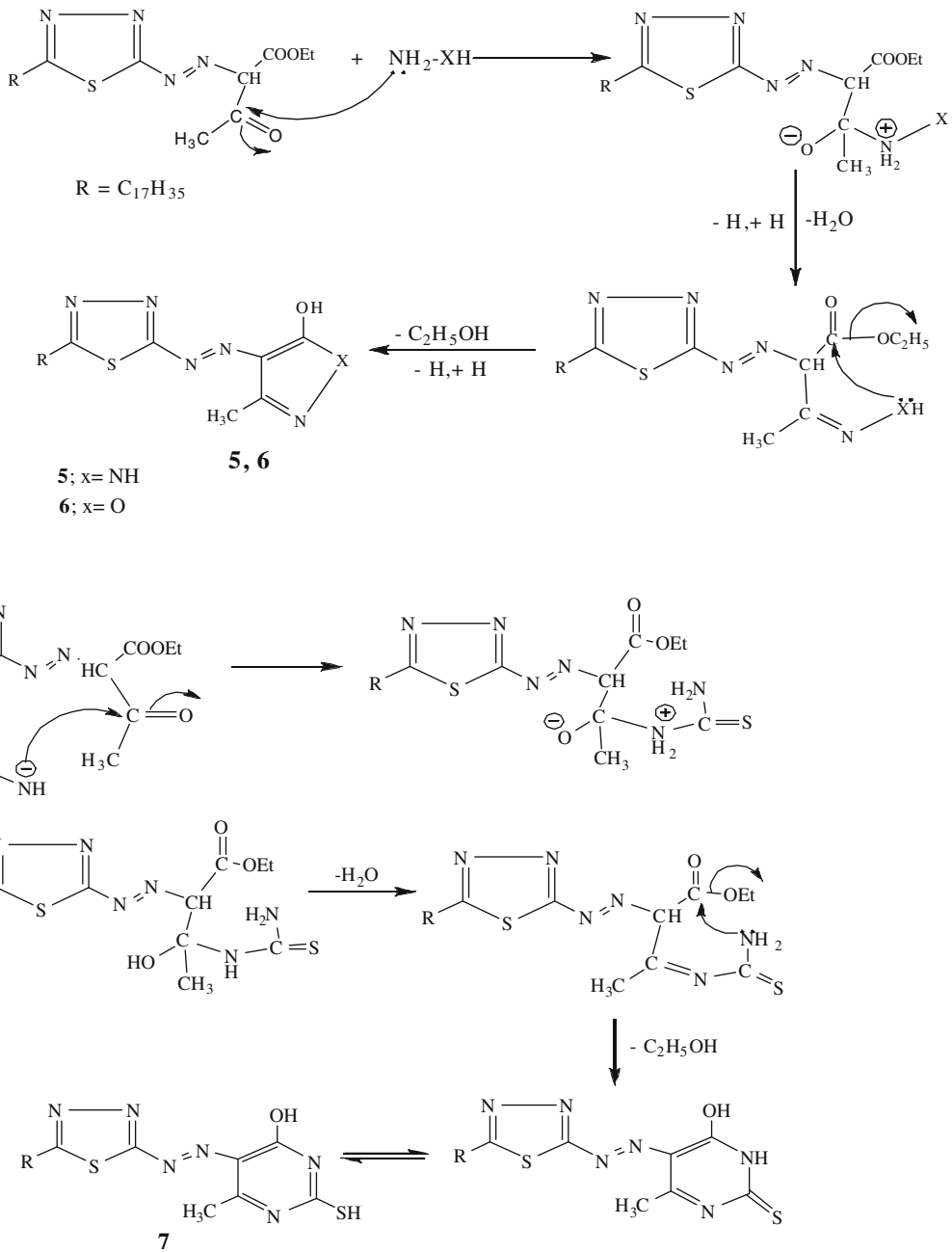


Scheme 2 Synthesis of 6-acetyl-2-(5-heptadecyl-[1,3,4]thiadiazol-2-yl)-4-phenyl-2*H*-[1,2,4] triazine-3,5-dione

reacted via the azo tautomer (**3Aa**) to produce 4-(5-heptadecyl-[1,3,4]thiadiazol-2-ylazo)-5-methyl-2*H*-pyrazol-3-ol (**5**), 4-(5-heptadecyl-[1,3,4]thiadiazol-2-ylazo)-3-methyl-isoxazol-5-ol (**6**), and 5-(5-heptadecyl-[1,3,4]thiadiazol-2-ylazo)-2-mercapto-6-methyl-pyrimidin-4-ol (**7**) respectively (Schemes 3 and 4). (These compounds containing the azo function can be utilized as dyeing materials). The mechanisms are as follows:

The IR spectrum of pyrazole (**5**) showed three bands at 3300, 3220 and 3120 cm^{-1} attributable to OH $\rightleftharpoons$ NH (tautomeric form), the mass spectrum showed (M^+-H_2O at 430, 1.3%), IR spectra for isoxazole (**6**) showed ν_{OH} at 3325 cm^{-1}, ^{13}C-NMR showed δ ppm at 100.5, 155.5, 158.9 for the 3C of isoxazole ring. The mass spectrum showed (M^+= 449, 0.9). The IR spectrum of pyrimidine (**7**) showed $\nu_{OH,\ NH}$'s at 3380, 3277 and 3176 cm^{-1}, $\nu_{C=S}$ at 1080 cm^{-1} and denoted a carbonyl group. ^{13}C NMR showed δ ppm at 183.1 for C–OH, 180.4 for C=S. The mass spectrum showed a molecular ion peak at (M^+ = 492, 4.4%). Coupling the diazonium salt (**2**) with an alkaline solution of 2-naphthol produced 2-(5-heptadecyl- [1,3,4]thiadiazol-2-yl)-1,2-dihydro-3-oxa-1,2-diaza-cyclopenta[a]naphthalene (**8**).

The IR spectra of compound (**8**) showed ν_{NH} at 3228 cm^{-1}, the mass spectrum showed (M^+ at 494, 0.5%) (Scheme 5).



Scheme 3 Synthesis of 4-(5-heptadecyl-[1,3,4]thiadiazol-2-ylazo)-5-methyl-2*H*-pyrazol-3-ol, and 4-(5-heptadecyl-[1,3,4]thiadiazol-2-ylazo)-3-methyl-isoxazol-5-ol

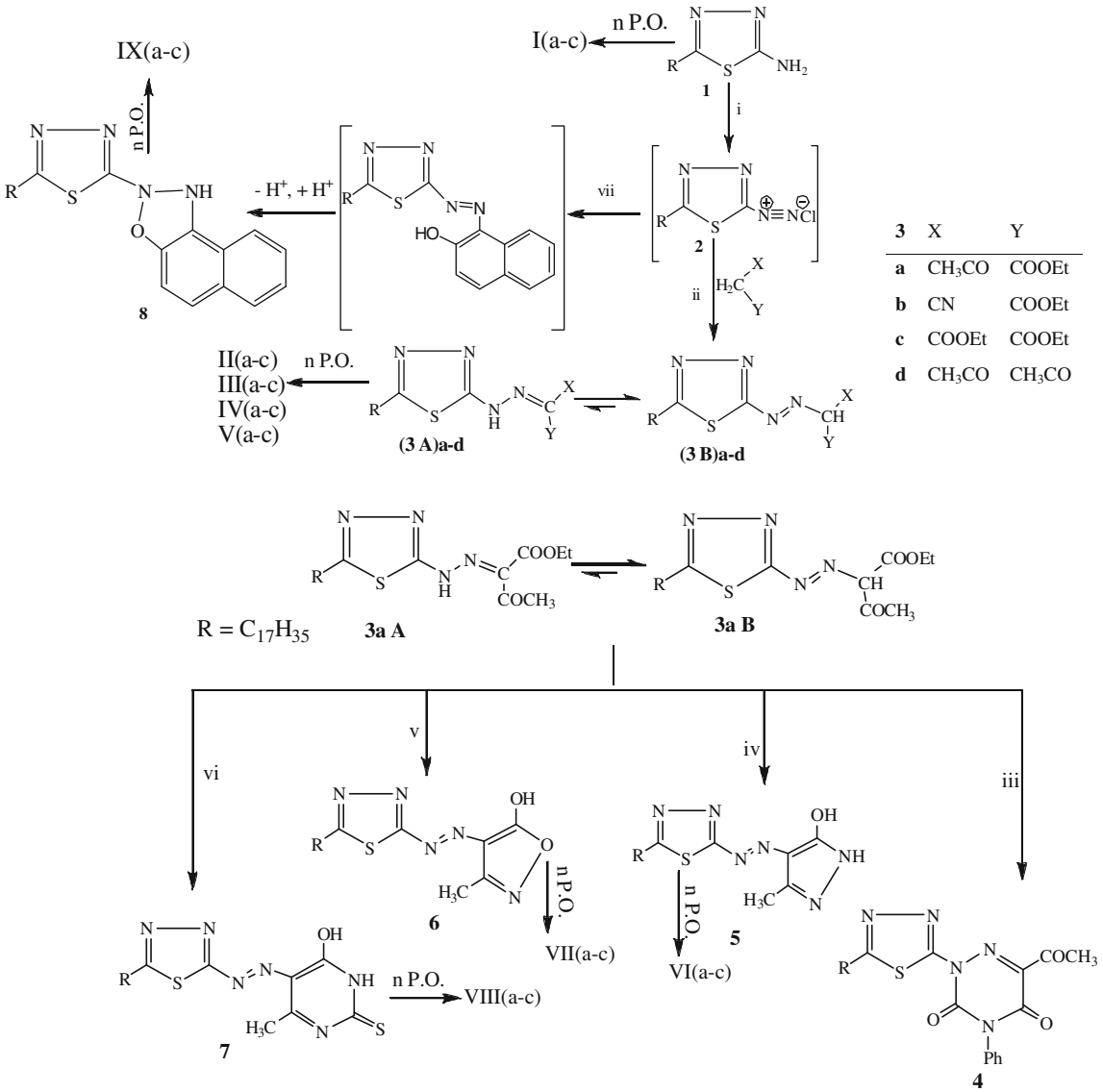
Scheme 4 Synthesis of 5-(5-heptadecyl-[1,3,4]thiadiazol-2-ylazo)-2-mercapto-6-methyl-pyrimidin-4-ol

Electronic Absorption Spectra

Non-conjugated 1,3,4-thiadiazole had no selective absorption above 220 nm, but conjugated substituted 2-amino-1,3,4-thiadiazole with lone pair caused bathochromic shifts. Band assignment of the absorption spectra of the prepared compounds were investigated by recording their spectra in chloroform at 25 °C (cf. Table 1; Fig. 1).

The first absorption was observed within wavelength range 248–264 nm, it may be assigned to local $\pi \rightarrow \pi^*$ electronic transition and it was characterized by high absorption value. The second band observed within wavelength range 290–310 nm, is attributed to the excitation of π electron within the –N=N– and that –C=N– bonds of 1,3,4-thiadiazole moiety of the molecule [31, 32].

The third band was mostly observed within the visible range 374–398 nm, this band may be assigned to electronic transition arising from charged transfer (CT) originating from the electron rich –N=N– group toward the electron poor heterocyclic thiadiazole moiety, i.e. due to the transition within the whole molecule (intramolecular charge transfer).



Scheme 5 Synthetic routes of non-condensed thiadiazoles. Conditions: (i) $NaNO_2$/HCl, stirring at 0–5 °C 2 h (ii) EtOH, AcONa, stirring at rt for 12 h (iii) PhNCO, dioxane, Et_3N, reflux 5 h (iv) $N_2H_4.H_2O$, dioxane, reflux 6 h; (v) $NH_2OH.HCl$, dioxane, AcONa, reflux for 6 h (vi) $(NH_2)_2CS$, EtONa, EtOH, reflux 7 h (vii) 2-naphthol in 10% NaOH solution, stirring at 0–5 °C for 0.5 h

Biological Activity[1]

Some of the synthesized compounds were screened in vitro against some bacteria, namely *Escherichia coli* and *Staphylococcus aureus*, and some fungi, namely *Aspergillus flavus* and *Candida albicans*. Tetracycline and Amphotericin B were taken as positive references for antibacterial and antifungal agents respectively.

The results are tabulated in Table 2, which shows that the samples have high antibacterial and moderate antifungal activities on the tested micro-organisms.

[1] Antibacterial and antifungal activity was investigated at the Micro Analytical Center, Faculty of Science, Cairo University using a modified Kirby–Bauer disc diffusion method [33, 34]

Table 1 λ_{max} values for synthesized compounds

Compound	λ_1 (nm)	λ_2 (nm)	λ_3 (nm)
1	252	–	–
3	256	310	376
4	264	306	374
5	252	306	376
6	248	306	378
7	254	306	376
8	248	290	398

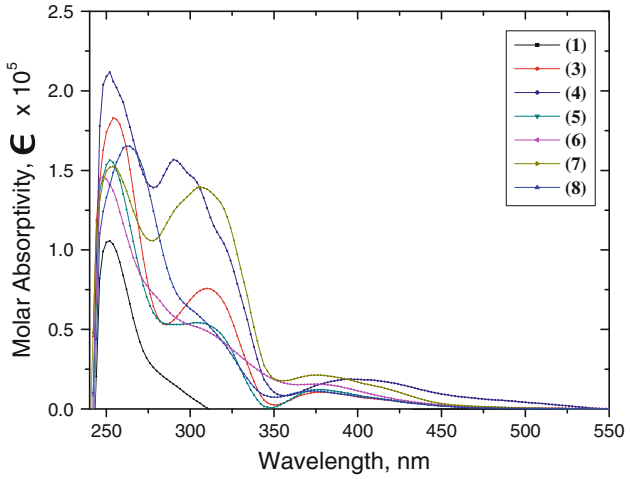


Fig. 1 UV–Vis absorption spectra of some synthesized compounds (1×10^{-5} M) in $CHCl_3$ at 25 °C

Structure-Activity Relationship (SAR) of Some Synthesized Thiadiazole Derivatives

As a part of our study on the effect of the synthesized thiadiazole derivatives on the microorganisms (bacteria & fungi), a structure-activity relationships (SAR) study was performed.

Herein, we focused on the effect of a certain substituent on the biological activity of the 2-aminothiadiazole (**1**). Also, the effect of construction of other heterocyclic ring condensed to the thiadiazole ring on the biological activity was also studied. Two bacteria strains [*Escherichia coli* (Gram-negative) & *Staphylococcus aureus* (Gram-positive)] and two fungi strains (*Aspergillus flavus* and *Candida albicans*) were selected to study these effects.

Introduction of a diazo group into the starting material has only a slight effect on the antibacterial activity (compound **3a**).

Introduction of a non-condensed triazine ring (in compound **4**) in the thiadiazole diminished activity against both bacterial strains and showed a good activity against *Aspergillus flavus*. Furthermore, addition of a pyrazole or isoxazole ring in a non-condensed way to thiadiazole (compounds **5** and **6**) demonstrated excellent antibacterial activity. Isoxazole derivatives (compound **6**) exhibited only moderate antifungal activity against *Candida albicans*.

Thiadiazolylpyrimidine (compound **7**) showed antibacterial and antifungal activities similar to the aminothiadiazole derivative (compound **1**).

Nonionic Surfactants from Some Synthesized Heterocyclic Compounds

The built up surfactant molecules contain heterocyclic thiadiazole are most important class of surface active

Table 2 Antimicrobial activity of some synthesized compounds

Sample	Inhibition zone diameter (mm/mg sample)							
	Escherichia coli (G^-)		*Staphylococcus aureus* (G^+)		*Aspergillus flavus* (Fungus)		*Candida albicans* (Fungus)	
	MIC	*A*	MIC	*A*	MIC	*A*	MIC	*A*
Control: DMSO	–	0.0	–	0.0	–	0.0	–	0.0
Tetracycline	200	31	200	30	–	–	–	–
Amphotericin B	–	–	–	–	200	16	200	19
1	100	14	200	15	400	0.0	400	0.0
3a	200	16	200	13	400	0.0	400	0.0
3b	100	11	200	14	200	12	400	0.0
3c	400	15	100	10	400	0.0	100	10
3d	200	12	400	16	400	0.0	400	0.0
4	400	0.0	400	0.0	200	14	400	0.0
5	200	17	400	27	400	0.0	400	0.0
6	400	24	100	16	400	0.0	100	12
7	200	15	100	13	400	0.0	400	0.0

A, antimicrobial activity of tested compounds; MIC, minimum inhibitory concentration; 0.0, not active; $A > 7$ mm, slightly active; $A > 15$ mm, moderately active; $A > 20$ mm, highly active

agents containing a heterocyclic moiety due to their dual characteristics, one due to conflict between the affinity of the hydrophobic and hydrophilic structure shows surface active properties and a second one that is due to the heterocyclic moiety confirmed with aid of a hydrophilic moiety (propylene oxide) give biological activity.

Propoxylation of some of the new compounds (**1**, **3**$_{(a–d)}$, **5**, **6**, **7**, and **8**) with various quantities of propylene oxide (3, 5, and 7 mol) produced nonionic surfactants **I(a–c)–IX(a–c)**, the structure of which was confirmed via IR [35] and ^{1}H-NMR spectra. IR-spectra showed a broad band in the region of (3500–2500) cm^{-1} (ν_{OH}) and two other bands in the regions (1100–1000) and (950–900) cm^{-1} for (νC–O–C ether linkage of the polypropoxy chain) besides the original bands of these compounds.^{1}H-NMR spectra showed the protons of the propyleneoxy groups which appear as broad multiple signals in the region of (3.2–3.7) ppm in addition to other signals of these compounds.

The surface active properties of the prepared propoxylated compounds **I(a–c)–IX(a–c)** were measured in a neutral medium by traditional procedures to evaluate the possible utilization of these compounds in various industrial fields.

The surface and interfacial tension were determined according to Findly [36]. The resulting data in (Table 3) show that the surface and interfacial tensions increased upon increasing the number of propylene oxide units added to the molecule [37]. All these compounds show high cloud points, when in hot water, which increased with an increasing number of moles of propylene oxide [38].

Also, the synthesized compounds exhibited efficient wetting properties—wetting time decreased with an increasing number of propylene oxide units. Emulsion stability decreased with an increasing number of propylene oxide units [39], while the foam height increases [40]. Thus, the surface active properties were independent of heterocyclic thiadiazole but dependent on the hydrophobic (C_{18}) and hydrophilic (propylene oxide units) properties, however, heterocyclic thiadiazole revealed biological activities of the synthesized molecules, i.e., these compounds are used as effective emulsifying agents in many fields, such as cosmetics, formulations, pesticides, dyes, textiles, etc.

Biodegradability of the Synthesized Surfactants

To evaluate how environmentally friendly the compounds are, the biodegradability of the synthesized compounds was evaluated, determined by a die-away test, followed by surface tension measurements [41]. The biodegradability data are given in (Table 4), within the experimental accuracy, all the prepared nonionic surfactants seem to degrade easily. The biodegradation of these compounds depends mainly on the propylene oxide chain length due to the same hydrophobic part. The results showed that in the first day 40–50% of the surfactants was biodegradable, after that they later decreased until the 6th day by which time they had disappeared. It means that these compounds are safe for human beings as well as the environment.

Experimental Protocols

The structural assignments of new compounds are based on their elemental analysis and spectral data (IR, ^{1}H NMR, ^{13}C NMR, Mass spectra).

All melting points are uncorrected and were determined by the open capillary method using a Gallen Kamp melting point apparatus.

IR-Spectra (KBr disk) of the synthesized compounds were recorded on FT/IR-BRUKER, Vector 22 (Germany), JASCO FT/IR-4100 (Japan), and JASCO FT/IR-460+(Japan) instruments. ^{1}H- and ^{13}C-NMR spectra were recorded in deuterated chloroform ($CDCl_3$) or dimethylsulfoxide (DMSO-d_6) as a solvent on a Varian Mercury VXR-300 spectrometer (300 MHz for ^{1}H NMR and 75 MHz for ^{13}C NMR) using TMS as internal reference and chemical shifts are expressed in δ(ppm). The mass spectra were recorded on a Shimadzu GCMS-QP-1000EX mass spectrophotometer at 70 eV. The electronic absorption spectra were recorded on a UV/Vis spectrophotometer, JASCO, Model V-350 (Japan), 200–900 nm.

Homogeneity of all compounds synthesized was checked by TLC. All the synthesized compounds gave satisfactory elemental analyses. Surface active properties were carried out at the Chemistry Department, Faculty of Science, at Benha University, Egypt.

Synthesis of 2-Amino-5-heptadecyl-[1,3,4]thiadiazole (1)

It was prepared according to our procedure reported in Ref. [28].

General Procedure for Synthesis of (5-Heptadecyl-[1,3,4]thiadiazol-2-ylazo/Hydrazono) Derivatives (3a-d)

A solution of **1** (0.01 mol) in concentrated hydrochloric acid (20 mL) and (10 mL) water was treated with a cold saturated solution of sodium nitrite (0.7 gm) for 1 h with stirring and cooling at 0–5 ^{o}C for 2 h. The clear diazonium salt solution (**2**) was then added dropwise to a solution of ethyl acetoacetate, ethyl cyanoacetate, diethylmalonate and

Table 3 Surface properties of some synthesized surfactants

Compound	No of moles	Surface tension (dyne/cm) 0.1 wt%	Interfacial tension (dyne/cm) 0.1 wt%	Cloud point °c 1.0 wt%	Wetting time (s) 0.1 wt%	Emulsion stability (min) 20 mol	Foam height (mm) 1.0 wt%
I(a–c)	3	31	10	85	50	44	60
	5	32	12	90	46	42	80
	7	34	14	>100	40	38	100
II(a–c)	3	33	9	81	53	45	50
	5	36	11	96	48	43	70
	7	39	13	>100	45	40	90
III(a–c)	3	30	8	81	44	50	80
	5	32	10	95	40	45	100
	7	35	13	>100	38	42	110
IV(a–c)	3	34	11	88	50	52	100
	5	36	13	94	48	49	120
	7	37	15	>100	44	43	150
V(a–c)	3	28	9	75	53	46	70
	5	30	10	86	47	38	80
	7	32	12	93	45	43	100
VI(a–c)	3	33	12	89	48	52	70
	5	35	14	97	43	48	80
	7	38	15	>100	35	41	110
VII(a–c)	3	28	10	78	42	55	80
	5	29	11	86	38	52	90
	7	31	14	94	32	46	110
VIII(a–c)	3	35	12	86	54	42	90
	5	36	13	94	50	38	110
	7	38	16	>100	46	35	120
IX(a–c)	3	30	10	83	49	46	50
	5	31	13	93	43	41	70
	7	33	15	>100	39	37	90

Table 4 Biodegradability of the synthesized surfactants

Compd.	No of moles	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
I(a–c)	3	53	66	75	85	95	–	–
	5	48	60	68	78	91	–	–
	7	45	50	62	74	83	93	–
II(a–c)	3	51	60	77	84	91	–	–
	5	46	54	68	71	84	91	–
	7	41	52	65	67	79	88	
III(a–c)	3	48	57	67	75	82	86	–
	5	45	51	58	69	76	84	–
	7	41	52	56	67	72	83	90
IV(a–c)	3	52	68	74	83	97	–	–
	5	49	62	66	78	84	90	–
	7	44	55	57	66	75	87	–
V (a–c)	3	60	69	77	85	90	96	–
	5	57	64	76	81	88	–	–
	7	54	61	73	79	90	–	–
VI(a–c)	3	55	67	78	86	94	–	–
	5	53	62	69	85	92	–	–
	7	50	60	66	82	90	–	–
VII(a–c)	3	46	57	67	75	82	88	–
	5	43	51	85	69	77	84	–
	7	41	50	56	67	72	85	90
VIII(a–c)	3	50	60	77	84	94	–	–
	5	46	54	68	71	84	91	–
	7	41	52	65	67	80	89	–
IX(a–c)	3	63	67	75	84	92	–	–
	5	55	64	69	80	88	92	–
	7	47	58	66	77	45	92	–

acetylacetone (0.01 mol) in ethanol (50 mL) containing sodium acetate (1 gm) at 0–5 °C. The pH of the coupling mixture, in each case, was maintained at 5–6 through the coupling process by adding sodium acetate. After the complete addition of the diazonium salt, the reaction mixture was stirred at room temperature over night. The precipitated products separated upon dilution with cold water (50 mL) and they were filtered off, washed with water several times, dried and recrystallized from ethanol.

Compound **3a** was obtained as yellowish brown powder in 77% yield, M.P. 80–82 °C; IR(KBr) ν (cm^{-1}): 3434 (NH), 2985, 2938 (aliphatic CH stretching), 1742, 1718 (2C=O), and 1647 (C=N stretching); ^{1}H-NMR spectrum (DMSO-d_6) showed signals at δ; 4.7 (s,H,NH) which disappeared on addition of D_2O, 3.8 (q, 2H, CH_2 ethoxy), 3.2 (t, 3H, CH_3 ethoxy), 2.9 (s, 3H, CH_3C=O), 1.2–1.6 (m, 32H, 16CH_2 of alkyl chain), 0.9 (t, 3H, terminal CH_3, 2.9 (s, 2H, CH_2CN), 1.6–1.2 (m, 32H, 16CH_2 of alkyl chain), 0.9 (t, 3H, terminal CH_3); ^{13}C NMR (DMSO-d_6) δ (ppm): 206, 177 (2C=O), 168, 173 (2C=N), 133.3 (C=N hydrazono tautomer), 85.6 (–CH–N=N azo tautomer), 61 (CH_2 ethoxy), 14.1 (CH_3 ethoxy), 25.2 (CH_3C=O), beside sp^3 carbons of aliphatic side chain 14.1 (terminal CH_3), 22.7, 28.5, 29.3 (2C), 29.6 (10C), 30.9, 31.9; MS *m/z* [% rel.int.]: 482 (M^+ +2, 2.86), 353(16.84), 312(13.37), 115(63.37), 57(100). Anal. Calcd. (%) for $C_{22}H_{38}N_4SO$: C; 64.98, H; 9.42, N; 13.78, S; 7.89. Found: C; 64.86, H; 9.23, N; 13.64, S; 7.60.

Compound **3b** was obtained as pale yellow crystals in 64% yield, M.P. 95–97 °C; IR(KBr) ν (cm^{-1}): 3277 (NH), 2984, 2938 (aliphatic CH stretching), 2264 (C $\equiv$ N), 1746 (C=O), and 1516 (C=N stretching); ^{1}H-NMR spectrum ($CDCl_3$) showed signals at δ; 5.2 (s,H,NH) which disappeared on addition of D_2O, 3.5 (q, 2H, CH_2 ethoxy), 3.1 (t, 3H, CH_3 ethoxy), 1.2–1.6 (m, 32H, 16CH_2 of alkyl chain), 0.9 (t, 3H, terminal CH_3), MS *m/z* [% rel.int.]: 464 (M^+ +1, 3.60), 268(9.10), 312(13.37), 115(84.80), 57(100). Anal. Calcd. (%) for $C_{24}H_{41}N_5O_2S$: C; 62.17, H; 8.91, N; 15.10, S; 6.92. Found: C; 62.34, H; 9.03, N; 15.35, S; 7.04.

Compound **3c** was obtained as yellow powder in 71% yield, M.P. 70–72 °C; IR(KBr) ν (cm^{-1}): 3261 (NH), 2985, 2938 (aliphatic CH stretching), 1742 (2C=O sharp), and 1626 (C=N stretching); the ^{1}H-NMR spectrum (DMSO-d_6) showed signals at δ; 4.3 (s,H,NH) which disappeared on addition of D_2O, 3.3 (q, 4H, $2CH_2$ ethoxy), 3.1 (t, 6H, $2CH_3$ ethoxy), 1.2–1.6 (m, 32H, $16CH_2$ of alkyl chain), 0.9 (t, 3H, terminal CH_3), MS *m/z* [% rel.int.]: 508 (M^+ -2, 0.05), 311(26.98), 128(45.68), 115(100). Anal. Calcd. (%) for $C_{26}H_{46}N_4O_4S$: C; 61.14, H; 9.08, N; 10.97, S; 6.28. Found: C; 61.22, H; 9.23, N; 10.66, S; 6.45.

Compound **3d** was obtained as brownish yellow crystals in 69% yield, M.P. 82–84 °C; IR(KBr) ν (cm^{-1}): 3177 (NH), 2919, 2850 (aliphatic CH stretching), 1693 (2C=O sharp), and 1577 (C=N stretching); the ^{1}H-NMR spectrum ($CDCl_3$) showed signals at δ; 4.9 (s,H,NH) which disappeared on addition of D_2O, 2.9 (s, 6H, $2CH_3C$=O), 1.2–1.6 (m, 32H, $16CH_2$ of alkyl chain), 0.9 (t, 3H, terminal CH_3), MS *m/z* [% rel.int.]: 450 (M^+, 0.04), 134(24.63), 115(46.67), 88(100). Anal. Calcd. (%) for $C_{24}H_{42}N_4O_2S$: C; 63.96, H; 9.39, N; 12.43, S; 7.11. Found: C; 64.07, H; 9.33, N; 12.55, S; 7.23.

Synthesis of 6-Acetyl-2-(5-heptadecyl-[1,3,4]thiadiazol-2-yl)-4-phenyl-2*H*-[1,2,4]triazine-3,5-dione (4)

To a mixture of equimolar amounts (0.01 mol) **3a** and phenyl isocyanate in 30 mL of 1,4-dioxane, a catalytic amount of triethylamine (0.5 mL) was added. The reaction mixture was heated under reflux for 5 h, concentrated, cooled at room temperature, poured onto cold water (50 mL) and neutralized with diluted HCl. The solid product that formed was collected by filtration, dried and recrystallized from 1,4-dioxane. Compound **4** was obtained as a brownish yellow powder in 68% yield, M.P. 89–91 °C; IR(KBr) ν (cm^{-1}): 2920, 2851 (aliphatic CH stretching), 1705 (C=O), and 1596 (C=N stretching); ^{1}H-NMR spectrum (DMSO-d_6) showed signals at δ; 6.6–7.3 (m, 5H, aromatic CH), 2.7 (s, 3H, CH_3-C=O), 1.2-1.6 (m, 32H, $16CH_2$ of alkyl chain), 0.88 (t, 3H, CH_3); ^{13}C NMR (DMSO-d_6) δ (ppm): 198.5 (C=O ketonic), 173, 168 (2C=O cyclic), 155, 143, 137 (3C=N), 128.0 (3C), 128.9 (2C), 135 (aromatic CH), 26.4(CH_3C=O), beside sp^3 carbons of the aliphatic side chain 14.1 (terminal CH_3), 22.7, 28.5, 29.3(2C), 29.6 (10C), 30.9, 31.9; MS *m/z* [% rel.int.]: 551 (M^+ -2, 4.6), 353(31.3), 141(88.7), 115(100). Anal. Calcd. (%) for $C_{30}H_{43}N_5O_3S$: C; 65.07, H; 7.83, N; 12.65, S; 5.79. Found: C; 65.26, H; 8.02, N; 12.97, S;5.98.

Synthesis of 4-(5-Heptadecyl-[1,3,4]thiadiazol-2-ylazo)-5-methyl-2*H*-pyrazol-3-ol (5)

Equimolar amounts (0.005 mol) of **3a** and hydrazine hydrate in 30 mL of 1,4-dioxane were heated under reflux for 6 h. The reaction mixture was concentrated and then triturated with ethanol. The solid produced was filtered off, dried and recrystallized from ethanol. Compound **5** was obtained as dark green crystals in 70% yield, M.P. 101–103 °C; IR(KBr) ν (cm^{-1}): 3300 (OH), 3220–3120 (NH), 2920, 2850 (aliphatic CH stretching), 1663 (C=N stretching); the ^{1}H-NMR spectrum (DMSO-d_6) showed signals at δ; 6.99 (s, 1H, OH) which disappeared on addition of D_2O, 4.7 (s,H,NH) which disappeared on addition of D_2O, 2.8 (s, 3H, CH_3-C=N), 1.2–1.6 (m, 32H, $16CH_2$ of alkyl chain), 0.88 (t, 3H, CH_3); ^{13}C NMR (DMSO-d_6) δ (ppm):) 177, 168, 142 (3C=N), 164 (C–OH), 101.4 (= C–N=N– of pyrazole ring), 12.2 (CH_3C=N), beside sp^3 carbons of aliphatic side chain 14.1 (terminal CH_3), 22.7, 28.5, 29.3(2C), 29.6 (10C), 30.9, 31.9; MS *m/z* [% rel.int.]: 430 (M^+ -H_2O, 1.3), 323 (19.3), 295 (92.4), 134 (100). Anal. Calcd. (%) for $C_{23}H_{40}N_6OS$: C; 61.57, H; 8.99, N; 18.73, S; 7.15. Found: C; 61.68, H; 8.91, N; 18.88, S; 7.23.

Synthesis of 4-(5-Heptadecyl-[1,3,4]thiadiazol-2-ylazo)-3-methyl-isoxazol-5-ol (6)

Equimolar amounts (0.005 mol) of **3a** and hydroxylamine hydrochloride in 30 mL of 1,4-dioxane containing sodium acetate (0.006 mol) was refluxed for 6 h. The reaction mixture was concentrated, cooled and then poured into cold water. The solid produced was filtered off, dried and recrystallized from acetic acid. Compound **6** was obtained as a pale green powder in 79% yield, M.P. 90–92 °C; IR (KBr) ν (cm^{-1}): 3325 (OH), 2920, 2850 (aliphatic CH stretching) and 1597 (C=N–O sharp); ^{1}H-NMR spectrum (DMSO-d_6) showed signals at δ; 4.02 (s, 1H, OH) which disappeared on addition of D_2O, 2.16 (s, 3H, CH_3C=N), 1.2–1.6 (m, 32H, $16CH_2$ of alkyl chain), 0.88 (t, 3H, CH_3); ^{13}C NMR (DMSO-d_6) δ (ppm): 206, 177 (2C=O), 171, 168, 155 (3C=N), 158.9 (C–OH), 100.5 (= C–N=N– of isoxazole ring), 10.0 (CH_3C=N), beside sp^3 carbons of aliphatic side chain 14.1 (terminal CH_3), 22.7, 28.5, 29.3(2C), 29.6 (10C), 30.9, 31.9; MS *m/z* [% rel.int.]: 449 (M^+, 0.9), 353(19.4), 312(17.6), 115(100). Anal. Calcd. (%) for $C_{23}H_{39}N_5O_2S$: C; 61.44, H; 8.74, N; 15.58, S; 7.13. Found: C; 61.67, H; 8.89, N; 15.79, S; 7.19.

Synthesis of 5-(5-heptadecyl-[1,3,4]thiadiazol-2-ylazo)-2-mercapto-6-methyl-pyrimidin-4-ol (7)

To a solution of **3a** (0.005 mol) in 40 mL of ethanolic sodium ethoxide solution (0.005 mol) of thiourea was added. The reaction mixture was boiled under reflux for 7 h, concentrated and the residue was triturated with cold water. The solid was collected by filtration, dried and recrystallized from ethanol. Compound **7** was obtained as a pale yellow powder in 74% yield, M.P. 98–100 °C; IR(KBr) ν (cm^{-1}): 3380 (OH), 3277–3176 (NH), 2919, 2850 (aliphatic CH stretching), 2682 (SH), 1614 (C=N stretching), 1080 (C=S); ^{1}H-NMR spectrum (DMSO-d_6) showed signals at δ; 5.56 (s, 1H, OH) which disappeared on addition of D_2O, 4.9 (s,H,NH) which disappeared on addition of D_2O, 2.12 (s, 3H, CH_3-C=N), 1.2–1.6 (m, 32H, 16CH_2 of alkyl chain), 0.88 (t, 3H, CH_3); ^{13}C NMR (DMSO-d_6) δ (ppm): 183.1 (C–OH), 180.4 (C=S), 168, 173, 164 (3C=N), 58.3 (= C–N=N– of pyrimidine ring), 17.8 (CH_3C=N), beside sp^3 carbons of aliphatic side chain 14.1 (terminal CH_3), 22.7, 28.5, 29.3(2C), 29.6 (10C), 30.9, 31.9; MS *m/z* [% rel.int.]: 492 (M^++2, 4.4), 239(11.6), 128(44.4), 115(100). Anal. Calcd. (%) for $C_{24}H_{40}N_6OS_2$: C; 58.50, H; 8.18, N; 17.06, S; 13.02. Found: C; 58.71, H; 8.29, N; 17.15, S;13.14.

Synthesis of 2-(5-Heptadecyl-[1,3,4]thiadiazol-2-yl)-1,2-dihydro-3-oxa-1,2-diaza-cyclopenta[a]naphthalene (8)

A solution of **1** (0.01 mol) in concentrated hydrochloric acid (20 mL) and (10 mL) water was treated with a cold saturated solution of sodium nitrite (0.7 gm) through 1 h with stirring and cooling at 0–5 °C for 2 h to form the diazonium salt (**2**). An alkaline solution of 2-naphthol (prepared by dissolving 1.44 gm in 30 mL of 10% NaOH) was added to the diazonium salt dropwise with continuous stirring for half an hour. A brown solid product was obtained, filtered off, dried and recrystallized from ethanol. Compound **8** was obtained as a yellowish orange powder in 79% yield, M.P. 88–90 °C; IR(KBr) ν (cm^{-1}): 3380 (OH), 3043 (aromatic CH), 2920, 2850 (aliphatic CH stretching), 1600 (N=N); ^{1}H-NMR spectrum ($CDCl_3$) showed signals at δ; 6.7–7.2 (m, 6H, 6H aromatic), 5.56 (s, 1H, OH) which disappeared on addition of D_2O, 1.2–1.6 (m, 32H, 16CH_2 of alkyl chain), 0.9 (t, 3H, CH_3); MS *m/z* [% rel.int.]: 491 (M^+ -3, 0.5), 239 (13.10), 115(39.20), 59 (100). Anal. Calcd. (%) for $C_{29}H_{42}N_4OS$: C; 70.40, H; 8.56, N; 11.32, S; 6.48. Found: C; 70.55, H; 8.88, N; 11.54, S; 6.77.

Preparation of Nonionic Surfactants from the Synthesized Heterocyclic Compounds

Propoxylation (Hydroxylation)

The hydrophobe of the synthesized compounds containing 0.5% KOH was stirred and heated to 70 °C while passing a slow stream of nitrogen through the system to flush out oxygen. Nitrogen addition was stopped and propylene oxide added dropwise with continuous stirring and heating under an efficient reflux system to retain propylene oxide. The reactions were conducted for different intervals of time ranging from 1 to 10 h. the apparatus was then filled with nitrogen, cooled and reaction vessel weighed. The amount of propylene oxide which was reacted and the average degree of propoxylation were determined through the increment in mass of the reaction mixture (increase in weight of the mixture after the addition of propylene oxide is the average amount of propoxylation) [42]. The selected average numbers of moles, n, were 3, 5 and 7.

Surface Active Properties of Surfactants

Surface and Interfacial Tensions [43]

Surface tension and interfacial tension were measured using a Du-Nouy tensiometer (Krüss type 8451), for various concentrations of the synthesized surfactants (0.05–10^{-6} mol/L) and at 25 °C.

Cloud Point

The cloud point, a measure of inverse solubility characteristic of nonionic surface active agents, was determined by the gradual heating of a solution in a controlled temperature bath, by determining the temperature at which the clear or nearly clear solutions become definitely turbid. Cooling the solutions until they become clear again, allowed us to check the reproducibility of this temperature [44].

Wetting Time

The wetting power of the tested surfactants were determined by immersing a sample of cotton fabric in a 1.0 wt% aqueous solution of the surfactants and measuring the sinking time in second [45].

Foaming Properties

The foamability was measured by the Ross-Miles method [46]. The foam production for a 1.0 wt% solution was measured by the foam height initially produced.

Emulsion Stability

The emulsion was prepared from 10 mL of a 20 mmol aqueous solution of surfactant and 5 mL of toluene at 40 °C. The emulsifying capacity was taken as the time it took for an aqueous volume separating from the layer to reach 9 mL counting from the moment of shaking [47].

Biodegradability

Samples which were taken daily or more frequently and these were filtered through filter paper before measuring the surface tension. Surface tension measurements were made periodically (each day) on each sample during the degradation test [48]. The biodegradation percentage (D) for each sample was calculated using the following equation.

$$D = [\gamma_t - \gamma_0/\gamma_{bt} - \gamma_0] \times 100$$

where γ_t = Surface tension at time t.

γ_0 = Surface tension at time zero (initial S.T).

γ_{bt} = Surface tension of the blank experiment at time t (without sample).

References

1. Yamamoto T, Uemura T, Tanimoto A (2003) Synthesis and chemical properties of π-conjugated poly(imidazole-2,5-diyl)s. Macromolecules 36:1047–1053
2. Yamamoto T, Arai M, Sasaki S (2003) Copolymers of thiophene and thiazole regioregulation in synthesis, stacking structure, and optical properties. Macromolecules 36:7986–7993
3. Yasuda T, Imase T, Sasaki S (2005) Synthesis, solid structure, and optical properties of new thiophene-based alternating π-conjugated copolymers containing 4-alkyl-1,2,4-triazole or 1,3,4-thiadiazole unit as the partner unit. Macromolecules 38:1500–1503
4. Liou G, Hsiao S, Chen W (2006) A new class of high T_g and organosoluble aromatic poly(amine−1,3,4-oxadiazole)s containing donor and acceptor moieties for blue-light-emitting materials. Macromolecules 39:6036–6045
5. Yasuda T, Imase T, Nakamura Y (2005) New alternative donor-acceptor arranged poly(aryleneethynylene)s and their related compounds composed of five-membered electron-accepting 1,3,4-thiadiazole, 1,2,4-triazole, or 3,4-dinitrothiophene units: synthesis, packing structure, and optical properties. Macromolecules 38:4687–4697
6. Hegmann T, Neumann B, Wolf R (2005) Liquid crystalline paracyclophanes and *ansa* compounds-series of polyether macrocycles incorporating diacetylene, phenyl, biphenyl, *p*-terphenyl and 2,5-diphenyl-1,3,4-thiadiazole rigid cores. J Mater Chem 15:1025–1034
7. Rees CW, Sivadasan S (2002) Synthesis of 1,3,4-thiadiazole oligomers. J Chem Soc Perkin Trans 1:1543–1547
8. Tao Y, Xu Q, Lu J, Yang X (2010) The synthesis, electrochemical and fluorescent properties of monomers and polymers containing 2,5-diphenyl-1,3,4-thiadiazole. Dyes and Pigments 84:153–158
9. Aamir M, Kumar S (2007) Synthesis and evaluation of anti-inflammatory, analgesic, ulcerogenic and lipid peroxidation properties of ibuprofen derivatives. Acta Pharm 57:31–45
10. Radwan MA, Ragal EA, Sabry NM, El-Shenawy SM (2007) Synthesis and biological evaluation of new 3-substituted Indole derivatives as potential anti-inflammatory and analgesic. Bioorg Med Chem 15:3832–3841
11. Ahmed SM, Ahmed F, Osman SM (1985) Preparation and characterization of derivatives of isoricinoleic acid and their antimicrobial activity. J Am Oil Chem Soc 62:1578–1580
12. Al-Qahtani A, Siddiqui YM (2009) Inhibition of growth of *Leishmania donovani* promastigotes by newly synthesized 1,3,4-thiadiazole analogs. J Saudi Pharm Soc 16:227–232
13. Bayrak H, Demirbas A, Karaoglu SA, Demirbas N (2009) Synthesis of some new 1,2,4-triazoles, their Mannich and Schiff bases and evaluation of their antimicrobial activities. Eur J Med Chem 44:1057–1066
14. Almasirad A, Tabatabai SA, Faizi M (2004) Synthesis and anticonvulsant activity of new 2-substituted-5-[2-(2-fluorophenoxy)phenyl]-1,3,4-oxadiazoles and 1,2,4-triazoles. Bioorg Med Chem 14:6057–6059
15. Rauf A, Sharma S, Gangal S (2008) One-pot synthesis, antibacterial and antifungal activities of novel 2,5-disubstituted-1,3,4-oxadiazoles. Chin Chem Lett 19:5–8
16. Oruc EE, Rallas S (2004) 1,3,4-thiadiazole derivatives. Synthesis, structure elucidation, and structure−antituberculosis activity relationship investigation. J Med Chem 47:6760–6767
17. Cerecetto H, Dimaio R (2000) Synthesis and antitrypanosomal evaluation of E-isomers of 5-nitro-2-furaldehyde and 5-nitrothiophene-2-carboxaldehyde semicarbazone derivatives. Structure–activity relationships. Eur J Med Chem 35:343–350
18. Cerecetto H, Dimaio R (2004) Design, synthesis and biological evaluation of new potent 5-nitrofuryl derivatives as anti-trypanosoma cruzi agents. Studies of trypanothione binding site of trypanothione reductase as target for rational design. Eur J Med Chem 39:421–431
19. Carvalho SA, Silva EF (2004) Synthesis and antitrypanosomal profile of new functionalized 1,3,4-thiadiazole-2-arylhydrazone derivatives, designed as non-mutagenic megazol analogues. Bioorg Med Chem Lett 14:5967–5970
20. Mahy PJ, Gaspard S, Mansuy D (1993) Phenylhydrazones as new good substrates for the dioxygenase and peroxidase reactions of prostaglandin synthase: Formation of iron(III)-.sigma.-phenyl complexes. BioChem 32:4014–4021
21. Prusis P, Dambrava M, Andrianov V (2004) Synthesis and quantitative structure-activity relationship of hydrazones of N-amino-N'-hydroxyguanidine as electron acceptors for xanthine oxidase. J Med Chem 47:3105–3110
22. Carvalho SA, Lopes FA (2008) Studies toward the structural optimizations of new brazillizone related trypanocidal 1,3,4-thiadiazole-2-arylhydrazone derivatives. Bioorg Med Chem 16:413–421
23. Amine MS, Eissa AMF, Elsawy AA, Shaaban AF, El Sayed R (2004) New heterocycles having double characters as

antimicrobial and surface active agents. Part 1: nonionic compounds from fatty acid isothiocyanate. Grasas y Aceites 55:370–377
24. Amine MS, Eissa AMF, El Sawy AA, Shabaan AF, El-sayed R (2003) New heterocycles having double characters as antimicrobial and surface active agents. Part 2: Anionic compounds from fatty acid isothiocyanate. Chem Indian J 1:313–319
25. Amine MS, Eissa AMF, Elsawy AA, Shaaban AF, El Sayed R (2004) New heterocycles having double characters as antimicrobial and surface active agents. Part 3: Non-ionic compounds from fatty acid hydrazide. OLAJ Szappan Kozmetika 53:124–128
26. Amine MS, Aly AA, El-Sayed R (2006) Synthesis and surface active properties of condensed and non-condensed quinazoline derivatives of industrial applications. Indian J Chem 45B:1020–1027
27. Amine MS, Hebash KA, Ahmed MHM, El-Sheikh AA (2006) New heterocyclic having double characters as antimicrobial and surface active agents. Part 5: new quinazoline derivatives from stearic acid. OLAJ Szappan Kozmetika 55:121–125
28. Amine MS, Ahmed MHM, Hebash KA, El-Sheikh AA (2007) New heterocycles having double characters as antimicrobial and surface active agents. Part 6: Novel thiadiazole from stearic acid. OLAJ Szappan Kozmetika 56:57–61
29. Amine MS, Ahmed MHM, Hebash KA, El-Sheikh AA (2010) Utilization of stearic acid in heterocyclic synthesis part 8 : synthesis of some new thiadiazoles and triazoles of industrial applications. OLAJ Szappan Kozmetika 59:30–34
30. Amine MS, Ahmed MHM, Hebash KA, El-Sheikh AA (2010) Utilization of fatty acids in heterocyclic synthesis part 9 : dual activity of novel triazoles as antimicrobial and surface active agents. OLAJ Szappan Kozmetika 59:49–55
31. Kornis G (1996) 1,3,4-Thiadiazoles, Comprehensive Heterocyclic Chemistry. In: Katritzky AR, Rees CW (eds) vol 4. Pergamon, Oxford pp 387–407
32. Koutentis PA, Constantinides CP (2008) 1,3,4-Thiadiazoles, Comprehensive Heterocyclic Chemistry. In: Katritzky AR (eds) vol 5. Pergamon, Oxford pp 573–600
33. Bauer AW, Kirby WM, Sherris C, Turck M (1966) Antibiotic susceptibility testing by a standardized single disk method. Am J Clinical Pathology 45:493–496
34. Pfaller MA, Burmeister L, Bartlett MA, Rinaldi MG (1988) Multicenter evaluation of four methods of yeast inoculum preparation. J Clin Microbiol 26:1437–1441
35. Ahmed MMH, Sallay P, Rusznak I, Farkas L (1996) Determination of the average ethoxylation degree. Tenside Surf Det 33:410–411
36. Findly A (1963) Practical physical chemistry, 6th edn. Longman, London, pp 1040–1069
37. Chlebicki J, Sokołowski A (1991) Adsorption of *n*-alkylthiooligooxypropylene glycols at aqueous solution-air interface. Colloids Surf 56:251–261
38. Ahmed MHM (2004) Preparation and surface active properties of novel succinic acid based surfactants. OLAJ Szappan Kozmetika 53:23–28
39. Takeshi H (1970) Studies of ester containing surfactant: preparation and properties of sodium sulphalkanoates. Bull Chem Soc 43:2236–2239
40. Seong KT, Toshiyaki K, Toshikozu NH, Ikeda JI (1996) Surface-active properties of novel cationic surfactants with two alkyl chains and two ammonio groups. J Am Oil Chem Soc 73:907–911
41. Eter ET, Richard RE, David A (1974) Biodegradable surfactants derived from corn starch. J Am Oil Chem Soc 51:486–494
42. Eissa AMF (2007) Synthesis and evaluation of some surface active agents from long chain fatty amine. Grasas y Aceites 58:379–389
43. Wiel JK, Smith FD, Stirton AJ, Bistine RG (1963) Long chain alkanesulphonates and 1-hydroxy-2-alkanesulphonates: Structure and property relations. J Am Oil Chem Soc 40:538–541
44. Durham K (1961) Properties of detergent solutions-amphipathy and adsorption. Surf Activity Deterg 1:1–28
45. Draves CZ, Clarkson R (1931) A new method for the evaluation of wetting agents. J Am Dye Stuff Report 20:201
46. Ross J, Milles GD (1941) Apparatus for comparison of foaming properties of soaps and detergents. Oil Soap 18:99–102
47. Scholnick F, Linfield WM (1977) Lactose-derived surfactants (III): fatty esters of oxyalkylated lactitol. J Am Oil Chem Soc 54:430–435
48. Falbe J (1986) Surfactants for consumer. 4:139–141

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