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Abstract

Many pyrazolo[1,5-a]pyrimidine, thiazolidine and thiophene derivatives have been synthesized *via* the reaction of potassium 3-(4-chloro-phenylamino)-2-cyano-3-oxo-1-(phenylamino)prop-1-ene-1-thiolate **2** with many different reagents.

Key words: Pyrazolo[1,5-a]pyrimidine, thiazolidine and thiophene derivatives

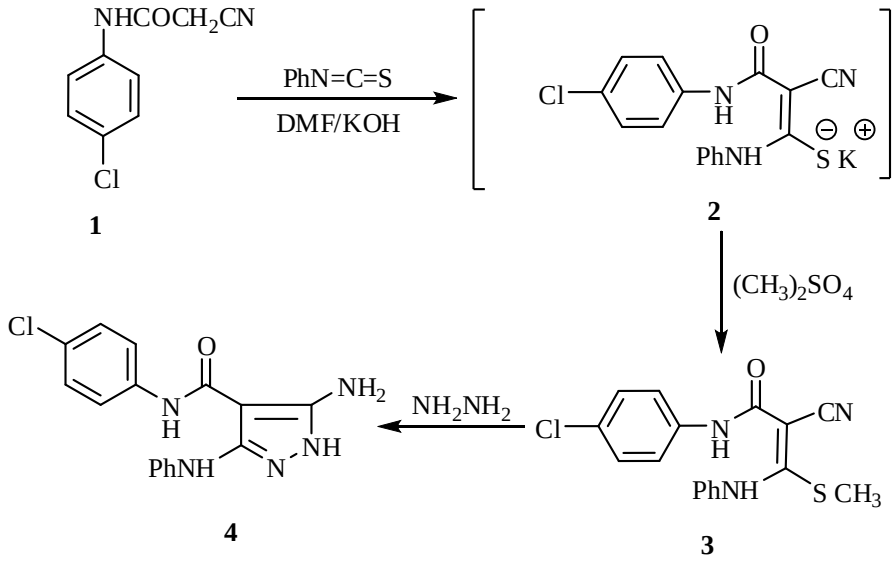
Introduction

The interesting pharmacological properties of thiophene, thiazole, pyrazolo[1,5-*a*]pyrimidine derivatives (1,2) in relation to the various changes in the structures of these compounds are important in the synthesis of some less toxic and more potent drugs. In continuation of our previous interest in the chemistry of azole derivatives from the readily obtainable inexpensive starting materials (3-8), we report here on the utility of cyanoacetanilide derivatives as building blocks for the synthesis of polysubstituted derivatives of pyrazole, pyrazolo[1,5-a]pyrimidine, thiophene and thiazole derivatives.

Results and Discussion

The cyanoacetanilide derivative **1** reacted with phenyl isothiocyanate in DMF in the presence of potassium hydroxide to give the corresponding potassium salt **2**. The ketene *N,S*-acetal derivative **3** was obtained on treatment the potassium salt **2** with dimethyl sulfate. Treatment of compound **3** with hydrazine hydrate in refluxing ethanol yielded the corresponding 5-aminopyrazole derivative **4** (9), (cf. Scheme 1 and experimental section).

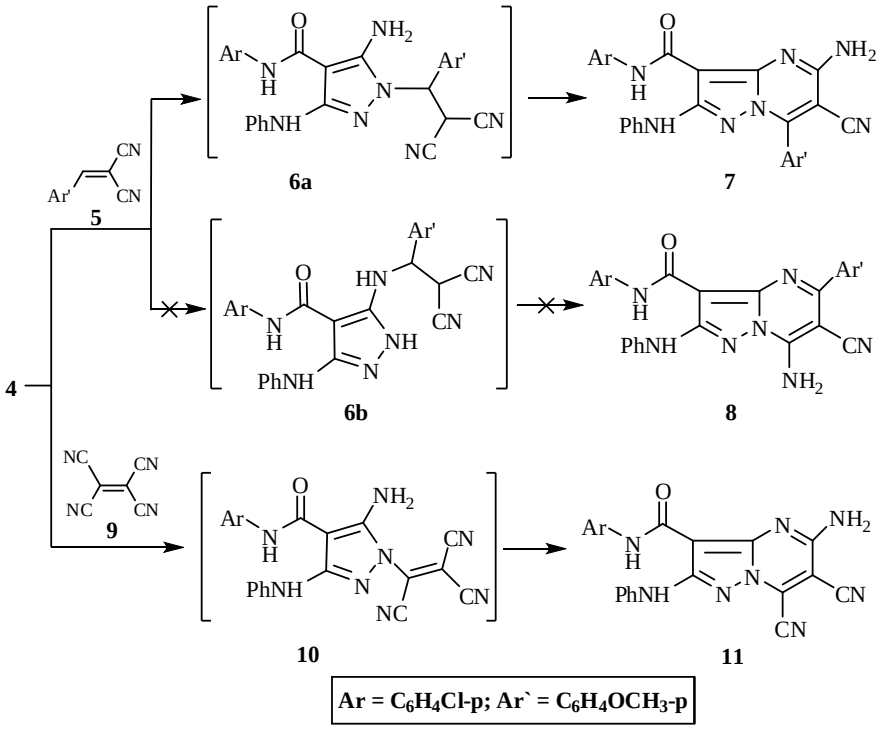
Scheme 1.



Pyrazolo[1,5-a]pyrimidines are considerable chemical and pharmacological importance as purine analogues and as such have useful properties as antimetabolites in purine biochemical reaction (10-12). The reactivity of aminopyrazole **4** towards some electrophilic reagents was investigated. Thus, compound **4** reacted with an equimolar amount of *p*-methoxybenzylidenemalononitrile **5** in refluxing ethanol catalyzed with piperidine yielded a single product for which structure **7** or **8** seemed possible. Structure **7** appears more likely than **8** on the basis that the ring nitrogen of pyrazole nucleus is the most nucleophilic one in the molecule. Formation of **7** was assumed to proceed via initial Michael type addition of the endocyclic NH in **4** to the electron deficient carbon in the α,β-unsaturated-cinnamonitrile system in **5** to form the intermediate 1:1 Michael adduct **6a** (13), which cyclized and auto-oxidized under the reaction conditions to yield the final product **7**. Both elemental and spectroscopic data of **7** are consistent with the assigned structure. Thus, its IR spectrum showed absorption peaks at ν 3438, 3306 and 2212 cm^{-1} corresponding to the presence of NH_2 and CN functional groups respectively. Its mass spectrum revealed a molecular ion peak at m/z (intensity %) 509 (32.4) corresponding to the molecular formula $C_{27}H_{20}ClN_7O_2$ with a base peak at m/z 383 [M-(ClC_6H_4NH)]. The ^{1}HNMR spectrum of compound **7** (DMSO-d_6) exhibited a singlet at δ 3.91 for the methoxy group with a singlet at δ 9.04 ppm observed for the NH_2 group.

Similar to its behavior towards α-substituted-cinnamonitrile, compound **4** reacted with tetracyanoethylene **9** in ethanol containing piperidine as a catalyst to produce pyrazolopyrimidine derivative **11** on the basis of analytical and spectral measurements. Thus, the IR spectrum of **11** revealed characteristic bands for NH_2 and CN functional groups. The formation of **11** proceeds via initial addition of the endocyclic NH followed by HCN elimination to give the intermediate **10** which then cyclized to afford the final product **11,** (cf. Scheme 2 and experimental section).

Scheme 2

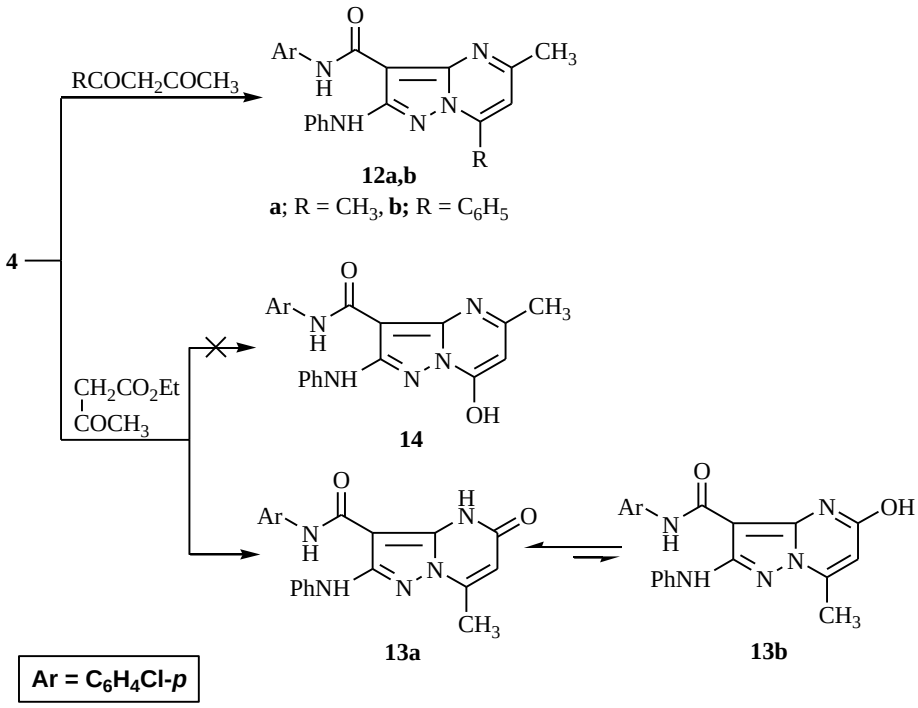


The basic strategy to synthesize pyrazolo[1,5-a]pyrimidines is based on the cyclocondensation of aminopyrazole **4** with β-diketone and β-keto-ester (11,14). Thus, condensation of **4** with symmetrical and unsymmetrical diketones in acetic acid under reflux conditions furnished the pyrazolopyrimidine derivatives **12a,b**. The structure of **12** was elucidated from their elemental analysis and spectroscopic data. The ^{1}HNMR spectrum of **12a** in (DMSO-d_6) showed two signals at δ 2.5 and 2.6 ppm corresponding for the two methyl groups of the pyrimidine ring and a signal singlet at δ 7.08 ppm for the proton at C_5 in the pyrimidine moiety. Mass spectrum

of **12b** showed a molecular ion peak at m/z (intensity %) 453 (21.5) corresponding to a molecular formula $C_{26}H_{20}ClN_5O$ with a base peak at 327 [M-(Cl.C_6H_4.NH)].

On the other hand, reaction of aminopyrazole **4** with ethyl aceto-acetate in acetic acid afforded two possible isomeric products **13** and **14**. Structure **14** was excluded on the basis of spectral data and analogy with previous work (15), compound **13** was found mainly in the keto form due to the presence of the carbonyl amide group which decreases the possibility of conjugation to form the enol form (16), (cf. Scheme 3 and experimental section).

Scheme 3.



Due to the possibility of existence in both tautomeric forms **13a,b**, therefore, we undertook a quantum chemical study in order to elucidate the tautomeric interconversions. Geometry optimization by *ab initio* quantum mechanical calculations were carried out, using several basis set effects using the GAUSSIAN 98 program (17). For all calculations the most stable tautomer corresponds to the keto form **13a**. The optimizational keto-enol tautomerization are illustrated in Fig. 1.

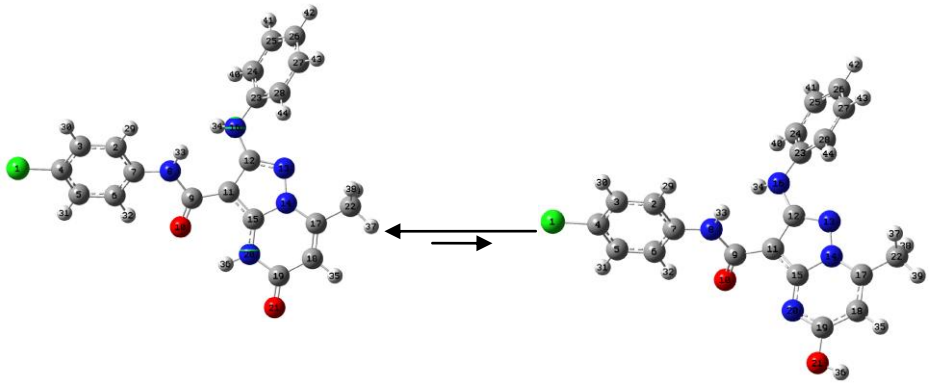


Fig. 1

The result of quantum mechanical calculations was shown in the following table.

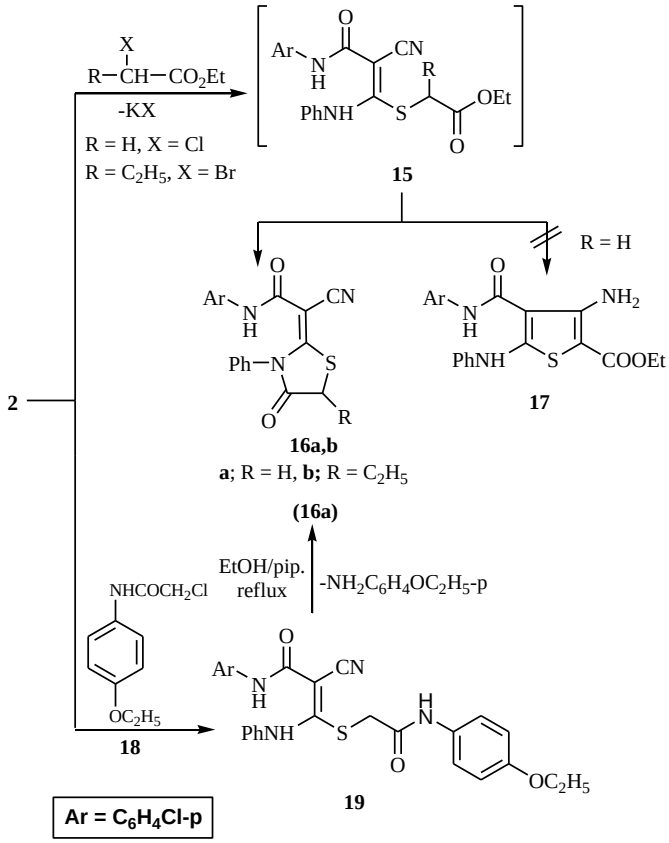
Method	Enol		Keto		Enol-ketone
	Energy	dipole	Energy	diploe	K.cal/mol
AM1	0.14175820	8.2	0.11937597	6.3	14.04
HF/31G	-1647.5729267	10.2	-1647.6159028	8.0	-26.97
6-31G pcm	-1647.6117603	12.7	-1647.6394335	10.3	-17.37
6-31 (d,p)	-1648.13380904	9.23	-1648.16340440	7.5	-19.0
DF	-1655.78513018	8.5	-1655.813602	6.8	-23.22
DFpcm	-1655.82820100	10.9	-1655.85188553	9.0	-14.8
HF16-31G	-1612.95750261	7.9	-1612.98084733	3.9	-14.9

The conjugation of the π-electrons of the carbonyl groups with the π-system of the molecular skeleton probably enhances the energy of the ketone, which leads to its predominance over the enol.

In this context, we report herein a convenient route to a variety of thiazolidine and thiophene derivatives. Thus, compound **2** was reacted with ethyl chloroacetate and ethyl 2-bromobutyrate to afford in each a single product identified as the thiazolidine derivatives **16a,b**, rather than the thiophene derivative **17** based on the elemental and spectral data. IR spectrum of **16a** showed the presence of CN stretching band at ν 2200 cm^{-1}. Also, ^{1}HNMR spectrum in (DMSO-d_6) exhibited two singlets at 4.03 and 9.5 corresponding for CH_2 and NH function groups respectively. The mass spectrum of compound (**16a**) showed a molecular ion peak at m/z (intensity %) 369 (35) in addition to other peaks were observed at m/z: 243 [66.2; M-(Cl.C_6H_4.NH.p)], 215 [100; (M- ClC_6H_4NH-*p* + CO)], 187 (7.5) and 120 (0.5;

PhNHCO). The formation of **16** was assumed to proceed through initial alkylation to give the thioether **15** as intermediate followed by intramolecular cyclization *via* C_2H_5OH elimination. Similarly, the thioether derivative **19** was obtained on treatment of the salt **2** with *N*-(4-ethoxy-phenyl)chloroacetamide **18** at room temperature. The structure of **19** was assigned by ^{1}HNMR spectrum in (DMSO-d_6) which exhibited signals at δ 1.37(t, 3H, CH_3), 3.77(s, 2H, SCH_2), 4.02(q, 2H, CH_2) and the presence of three D_2O exchangeable singlets at 9.7, 10.1 and 11.36 ppm. Cyclocondensation of compound **19** in ethanolic piperidine solution furnished a product **16a** through elimination of *p*-ethoxyaniline, this product is identical in all aspects (TLC, spectral data, m.p. and mixed m.p) with the thiazolidine derivative **16a**, (cf. Scheme 4 and experimental section).

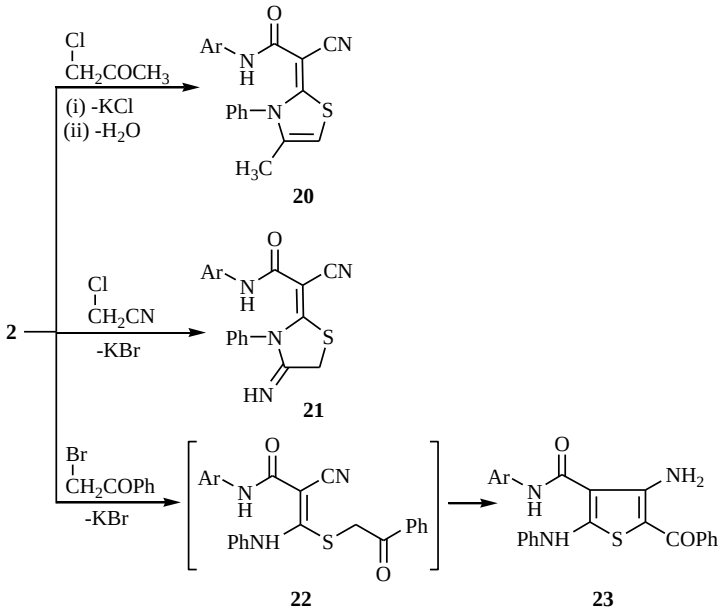
Scheme 4.



Moreover, when potassium salt **2** was treated with chloroacetone, the thiazole derivative **20** was obtained. The results of elemental analysis and spectral data are of good agreement with the proposed structure. The infrared spectrum of compound **20** showed the characteristic absorption band at ν 2222 cm^{-1} for the C≡N functional group. ^{1}HNMR spectrum of the reaction product revealed a signal at δ 1.87 ppm for CH_3 proton in addition to the presence of CH-thiazole at δ 6.96 ppm. The mass spectrum showed a molecular ion peak at m/z (intensity %) 367 (17.7), the base peak in the spectrum was found at m/z 241 [M-(ClC_6H_4NH)]. The formation of **20** was assumed to obtain through the initial alkylation followed by intramolecular cyclization and dehydration. The addition reaction of the intermediate **2** with chloroacetonitrile at room temperature furnished the iminothiazolidine derivative **21** in high yield. Its infrared spectrum showed a strong absorption band at ν 2174 cm^{-1} due to C≡N group in addition to the absorption bands characteristic for NH and C=O (amide) functional groups. Furthermore, ^{1}HNMR spectrum of the reaction product revealed a signal at δ 4.04 ppm for methylene protons in addition to the presence of two NH and aromatic protons signals. The formation of **21** was believed to proceed via the initial alkylation followed by heterocyclization (18) through nucleophilic addition of the NH to the cyano group.

Finally, treatment of compound **2** with phenacyl bromide gave the thioether derivative as intermediate **22**, followed by intramolecular cyclization to give the aminothiophene derivative **23**, *via* Thorpe-Ziegler reaction (19). The structure of compound **23** was confirmed by its infrared spectrum which indicated the absence of C≡N absorption band and the presence of characteristic absorption bands for NH_2 and C=O functional groups. In addition, ^{1}HNMR spectrum showed the absence of the methylene protons, (cf. Scheme 5 and experimental section).

Scheme 5.



Experimental Section

All melting points are uncorrected. IR spectra (KBr) were measured on Shimadzu 440 spectrometer, ^{1}H NMR spectra were obtained in DMSO on a Varian Gemini 200 (200 MHz) spectrometer using TMS as internal standard; Chemical shifts are reported as δ units. Mass spectra were obtained on GC MS\QP 1000 Ex mass spectrometer at 70 eV. Elemental analyses were carried out at the Microanalytical Center of Cairo University.

5-Amino-6-cyano-N-(4-chlorophenyl)-7-(4-methoxyphenyl)-2-(phenyl-amino)pyrazolo[1,5-a]pyrimidine-3-carboxamide (7)

To a solution of **4** (0.01 mole) in ethanol (30 mL), 4-methoxy-cinnamonitrile **5** (0.01 mole) and piperidine (0.5 ml) were added and the mixture was heated under reflux for 3h. The solid product thus formed was filtered off and recrystallized from acetic acid to give **7** as yellow crystals (60%), m.p. >300 °C. IR ν (cm^{-1}): 3438, 3306, 3200, 3150 (NH_2 + 2NH), 2212 (C≡N), 1650 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 3.90 (s, 3H, OCH_3), 6.97-8.01 (m, 13H, Ar-H) 9.04, 9.32, 10.15 (3s, 4H, NH_2 + 2NH; lost after D_2O exchange). Anal. Calcd. for $C_{27}H_{20}ClN_7O_2$ (509.5): C,; 63.59, H,; 3.92, N,; 19.23,. Found: C,; 63.50, H,; 3.80, N,; 19.10.

5-Amino-6,7-dicyano-N-(4-chlorophenyl)-2-(phenylamino)pyrazolo-[1,5-a]pyrimidine-3-carboxamide (11)

A mixture of compound **4** (0.01 mole), tetracyanoethylene **9** (0.01 mole), triethylamine (0.01 mole) in dioxane (10 mL) was heated under reflux for 30 min, then allowed to cool. The solid product thus formed after cooling was collected by filtration and recrystallized from acetic acid to yield compound **11** as brown crystals (55%), m.p. 290°C. IR ν (cm^{-1}): 3408, 3312, 3252, 3170 (NH_2 + 2NH), 2217 (C≡N), 1644 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 7.03-7.89 (m, 11H, Ar-H + NH_2), 9.43, 9.71 (2s, 2H, 2NH; exchangeable by D_2O). Anal. Calcd. for $C_{21}H_{13}ClN_8O$ (428.5): C,; 58.80, H,; 3.06, N,; 26.13,. Found: C,; 58.70, H,; 3.00, N,; 26.00.

Reaction of compound 4 with 1,3-dicarbonyl compounds

General procedure :

A mixture of compound **4** (0.01 mole) and 1,3-dicarbonyl compounds (0.01 mole) in glacial acetic acid (20 mL) was heated under reflux for 3h. The solid products obtained after cooling were filtered off and crystallized from the proper solvent to afford compounds **12a,b**, respectively.

***N*-(4-Chlorophenyl)-5,7-dimethyl-2-(phenylamino)pyrazolo[1,5-a]py-rimidine-3-carboxamide (12a)**

This compound was formed as yellow crystals from dimethylformamide (70%), m.p. >300°C. IR ν (cm^{-1}): 3274, 3180 (2NH), 1660 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 2.67, 2.77 (2s, 6H, $2CH_3$), 7.08 (s, 1H, pyrimidine-H), 7.42-7.79 (m, 9H, Ar-H), 9.35, 10.16 (2s, 2H, 2NH; exchangeable by D_2O). Anal. Calcd. for $C_{21}H_{18}ClN_5O$ (391.5): C,; 64.36 , H 4.59, N,; 17.87,. Found: C,; 64.30, H,; 4.50, N,; 17.80.

***N*-(4-chlorophenyl)-5-methyl-7-phenyl-2-(phenylamino)pyrazolo[1,5-a]pyrimidine-3-carboxamide (12b)**

This compound was formed as yellow crystals from dioxane (65%), m.p. >300°C. IR ν (cm^{-1}): 3310 (broad; 2NH), 1650 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 2.52 (s, 3H, CH_3), 6.98 (s, 1H, pyrimidine-H), 7.35-7.93 (m, 14H, Ar-H), 9.85, 10.07 (2s, 2H, 2NH; exchangeable by D_2O). Anal. Calcd. for $C_{26}H_{20}ClN_5O$ (453.5): C,; 68.79, H,; 4.41, N,; 15.43,. Found: C,; 68.70, H,; 4.30, N,; 15.40.

***N*-(4-Chlorophenyl)-5-hydroxy-7-methyl-2-(phenylamino)pyrazolo-[1,5-a]pyrimidine-3-carboxamide (13)**

A mixture of compound **4** (0.01 mole) and ethyl acetoacetate (0.01 mole) in glacial acetic acid (20 mL) was heated under reflux for 3hr. The solid product obtained on hot was filtered off and crystallized from dioxane to give compound **13** as yellow crystals (60%), m.p. 290°C. IR ν (cm^{-1}): 3366, 3240, 3180 (3NH), 1670, 1666 (2C=O; amide). ^{1}HNMR (DMSO-d_6): δ 2.52 (s, 3H, CH_3), 5.98 (s, 1H, pyrimidine-H), 6.99-7.74(m, 9H, Ar-H), 8.79, 9.85, 11.92 (3s, 3H, 3NH; exchangeable by D_2O). Anal. Calcd. for $C_{20}H_{16}ClN_5O_2$ (393.5): C,; 60.99, H,; 4.06, N 17.78,. Found: C,; 60.90, H,; 4.00, N,; 17.70.

Reaction of compound 2 with halo-reagents
General procedure :

To a suspension of finely powdered potassium hydroxide (0.01 mole) in dry *N*,*N*-dimethylformamide (10 mL), the anilide derivative **1** (0.01 mole) and then the phenyl isothiocyanate (0.01 mole) were added in portions for 1h. The reaction mixture was stirred at room temperature with α-halogenated compound (0.01 mole) and left at room temperature for 3h, then it was produced into ice/water and acidified with 0.1 N HC1 at pH 3-4. The resulting precipitate was filtered off, dried and recrystallized from the proper solvent to afford compounds **16a,b, 19, 20, 21, 23**.

***N*-(4-Chlorophenyl)-2-cyano-2-(5-ethyl-4-oxo-3-phenylthiazolidine-2-ylidene)acetamide (16a)**

This compound was formed as yellow crystals from ethanol (70%), m.p. 270°C. IR ν (cm^{-1}): 3332 (NH), 2200 (C≡N), 1738 (C=O; thiazole), 1652 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 4.03 (s, 2H, SCH_2), 7.14-7.60 (m, 9H, Ar-H), 9.59 (1s, 1H, NH; exchangeable by D_2O). Anal. Calcd. for $C_{18}H_{12}ClN_3O_2S$ (369.55): C,; 58.45, H 3.24, N,; 11.36,. Found: C,; 58.40, H,; 3.20, N,; 11.30.

***N*-(4-Chlorophenyl)-2-cyano-2-(4-oxo-3-phenylthiazolidine-2-ylidene)acetamide (16b)**

Yellow crystals from ethanol (60%), m.p. 250°C. IR ν (cm^{-1}): 3342(NH), 2928 (CH-aliph.), 2198 (C≡N), 1736 (C=O; thiazole), 1654 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 1.56 (t, 3H, CH_3), 2.1 (q, 2H, CH_2), 4.30 (q, 1H, CH), 7.19-7.962(m, 9H, Ar-H), 9.5 (1s, 1H, NH; lost exchangeable by D_2O). Anal. calcd. for $C_{20}H_{16}ClN_3O_2S$ (397.5): C,; 60.37, H,; 4.02, N,; 10.56,. Found: C,; 60.30, H,; 3.90, N,; 10.50.

***N*-(4-Chlorophenyl)-2-cyano-3-(2-(4-ethoxyphenylamino)-2-oxoethyl-thio)-3-(phenylamino)acrylamide (19)**

Yellow crystals (60%, benzene), m.p. 170°C. IR ν (cm^{-1}): 3200 (NH), 2900 (CH-aliph.), 2170 (C≡N), and 1660 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 1.33 (t, 3H, CH_3), 3.77 (2, 2H, SCH_2), 4.02 (q, 21H, CH_2), 6.85-7.42(m, 13H, Ar-H), 9.77, 10.14, 11.38 (3s, 3H, 3NH; exchangeable by D_2O). Anal. calcd. for $C_{26}H_{23}ClN_4O_3S$ (506.5): C,; 61.59, H,; 4.54, N,; 11.05,. Found: C,; 61.50, H,; 4.40, N,; 10.90.

***N*-(4-Chlorophenyl)-2-cyano-2-(4-methyl-3-phenylthiazol-2(3H)-ylidene)acetamide (20)**

Yellow crystals (50%, acetic acid), m.p. 270°C. IR ν (cm^{-1}): 3252 (NH), 2222 (C≡N), 1644 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 1.87 (s, 3H, CH_3), 6.96 (s, CH-thiazole), 7.28-7.71 (m, 9H, Ar-H), 8.86 (s, 1H, NH; exchangeable by D_2O). Anal. calcd. for $C_{19}H_{14}ClN_3OS$ (367.5): C,; 62.04, H,; 3.80, N,; 11.42,. Found: C,; 62.00, H,; 3.75, N,; 11.30.

***N*-(4-chlorophenyl)-2-cyano-2-(4-imino-3-phenylthiazolidin-2-ylidene)acetamide (21)**

Yellowish crystals (75%, ethanol), m.p. 250°C. IR ν (cm^{-1}): 3322 (broad, 2NH), 2174 (C≡N),1654(C=O; amide). ^{1}HNMR (DMSO-d_6): δ 4.04 (s, 2H, CH_2-thiazole), 7.03-7.79 (m, 9H, Ar-H), 9.59, 13.00 (2s, 2H, 2NH; exchangeable by D_2O). Anal. calcd. for $C_{18}H_{13}ClN_4OS$ (368.5): C,; 58.61, H,; 3.52, N,; 15.19,. Found: C,; 58.50, H,; 3.50, N,; 15.10.

4-amino-5-benzoyl-*N*-(4-chlorophenyl)-2-(phenyl-amino)thiophene-3-carboxamide (23)

Yellowish crystals (60%, acetic acid), m.p. 240°C. IR ν (cm^{-1}): 3394, 3282, 3150 (NH_2 + NH), 1672, (C=O), 1644 (C=O; amide). ^{1}HNMR (DMSO-d_6): δ 6.98-7.61 (m, 14H, Ar-H), 8.24, 9.39, 10.21 (3s, 4H, NH_2 + 2NH; exchangeable by D_2O). Anal. Calcd. for $C_{24}H_{18}ClN_3O_2S$ (447.5): C,; 64.35, H,; 4.02, N,; 9.38; found: C,; 64.30, H,; 4.00, N,; 9.30.

Formation of 16a from compound 19:

To a solution of **19** (0.01 mole) in ethanol (30 mL), the piperidine (0.01 mole) was added and the mixture was refluxed for 1 h. The solid product thus formed was collected by filtration and recrystallized to give **16a**.

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