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# Reaction of Thiocarboxylic Acids with Conjugated Azoalkenes

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***Abstract:*** Thiocarboxylic acids smoothly attack conjugated azoalkenes at room temperature to give hydrazone 1,4-adducts that exhibit tautomerism with the corresponding enamino forms. These adducts when treated with sodium hydride in tetrahydrofuran at room temperature lead to 1-alkoxycarbonyl- or 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones. The same adducts in chloroform with trifluoroacetic acid under reflux produce 1-alkoxycarbonyl- or 1-aminocarbonyl-3-methyl-4-acylthio-5-alkoxypyrazoles. In acidic media with aqueous tetrahydrofuran the 1,4-adducts undergo hydrolysis affording 2-acylthio-3-oxobutanoate derivatives that exhibit enol-keto tautomerism. The 1-alkoxycarbonyl- and 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-one derivatives in methanol under reflux undergo solvolysis to give, after a few minutes, simple 3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones and, after a few hours, 4,4'-dithiobis(3-methyl-1*H*-pyrazol-5(2*H*)-ones), while 1-alkoxycarbonyl- and 1-aminocarbonyl-3-methyl-4-acylthio-5-alkoxypyrazole derivatives are resistant to the same reaction conditions even over several days. X-Ray diffraction studies of some 1-alkoxycarbonyl- and 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones have been performed in order to determine the structure of the pyrazole ring in all such compounds, as well as the conformational situation in the solid state of the substituents on N-1. These investigations confirm the reconsideration of the structure assignments frequently recurring in the literature for some 5- and 3-hydroxypyrazoles.

## INTRODUCTION

"The study of thio- and dithiocarboxylic acids is still a comparatively unexplored field in organic chemistry", especially with respect to the oxygen analogues.[1] The same consideration is also valid for the ester derivatives of the above-mentioned classes of compounds, in spite of the stronger nucleophilic character of sulfur in comparison to that of oxygen atom. This latter property, as well as the well known ability of the sulfur atom to exhibit 3*d*-orbital participation, suggests that the derivatives in question deserve much more attention. Thiocarboxylic esters may indeed represent interesting synthetic intermediates mainly due to the electronic effects ascribable to the sulfur atom enhancing the nucleophilic attack on the carbon atom of the carbonyl group more than that of the corresponding ester function.[2] Thiocarboxylic esters are largely used as protective groups of thiols and provide a convenient access to these compounds *via* alkaline hydrolysis or hydride reduction.[3] Furthermore thiolesters are of remarkable importance in biochemistry as intermediates in several metabolic transformations.

Since conjugated azoalkenes have been demonstrated to be powerful and versatile nucleophilic substrates able to give firstly, under very mild conditions, hydrazone derivatives by 1,4-conjugated addition and then

widely substituted pyrrole and pyrazole rings by internal cyclization, we decided to focus our attention on the study of the reaction of thiocarboxylic acids with the above-mentioned compounds.[4]

Thus, we here report the facile 1,4-addition of some thiocarboxylic acids to the azo-ene system of 1-alkoxycarbonyl- or 1-aminocarbonyl-azoalkenes with the successive cyclization of the hydrazone adduct intermediate, depending on the basic or acidic nature of the reaction media, to two different pyrazole rings: 1-alkoxycarbonyl- or 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones, and 1-alkoxycarbonyl- or 1-aminocarbonyl-3-methyl-4-acylthio-5-alkoxypyrazoles, respectively. In general, the cyclization processes are selective and free from significant side products. These pyrazole systems exhibit quite different chemical properties. In fact, the 1-alkoxycarbonyl- and 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-one derivatives manifest easy solvolytic cleavage at first of >N-CO- bond giving simple 3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones and then of the acylthio bond yielding 4,4'-dithiobis(3-methyl-1*H*-pyrazol-5(2*H*)-ones), while 1-alkoxycarbonyl- and 1-aminocarbonyl-3-methyl-4-acylthio-5-alkoxypyrazole derivatives are resistant in the same reaction conditions even after a long time. The hydrolytic cleavage of the hydrazone residue of the conjugate adduct is also examined and found to lead to 2-acylthio-1,3-ketoesters.

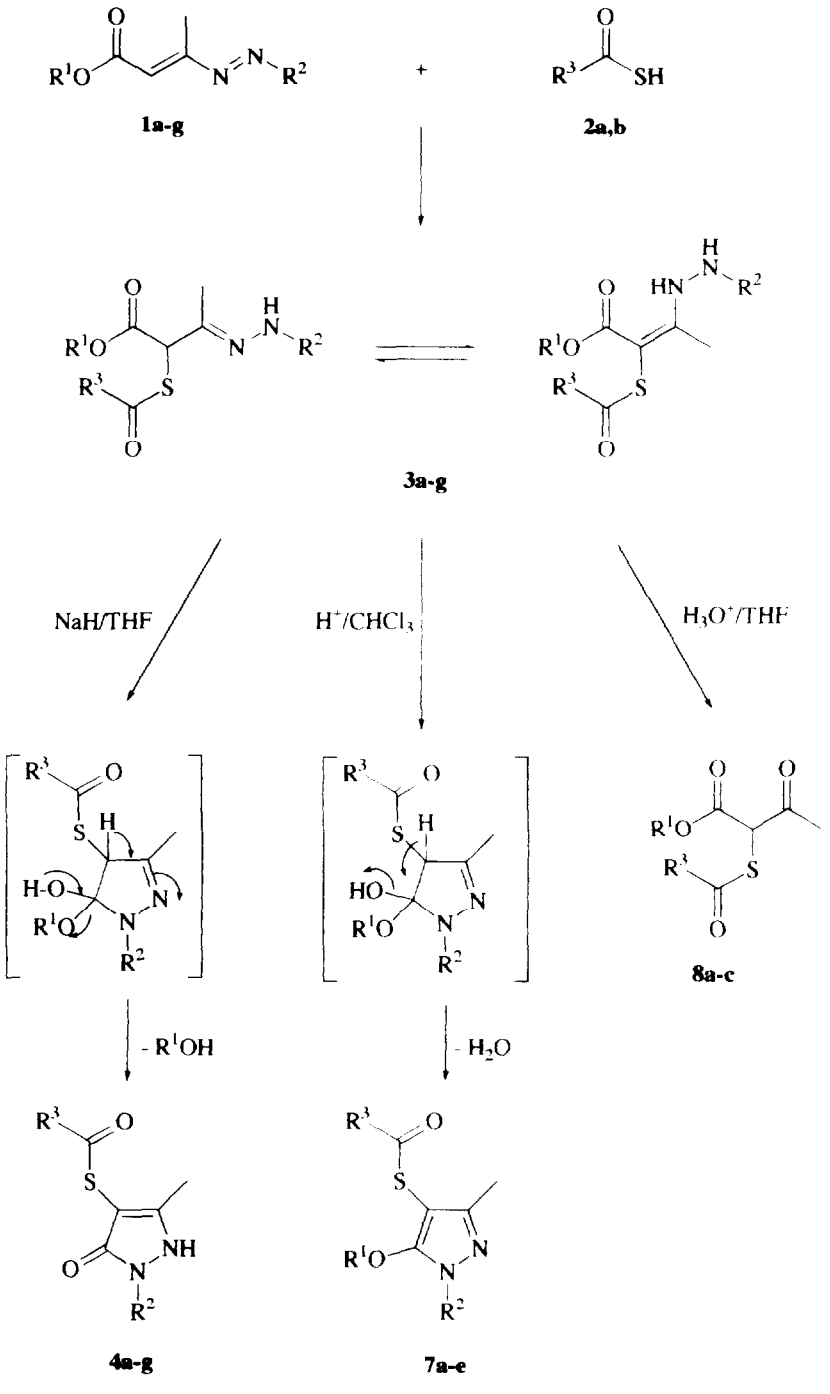
X-Ray structure determination of some 1-alkoxycarbonyl- and 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones are described in order to support the ketonic nature, rather than the enolic one, of the pyrazole heterocycles prepared. In our opinion, these studies confirm the timeliness of the reexamination of some structure assignments to named 5- and 3-hydroxypyrazoles previously reported in the literature. These structure attributions were frequently based on usual spectroscopic methods that, in these circumstances, offer unreliable and quite conflicting evidence about the real chemical nature of similar substances. In such an occurrence, we think it appropriate that the structure determination should be performed by means of various spectroscopic techniques integrated with the proper X-ray diffraction molecular elucidation, in order to avoid misunderstandings.[5]

## RESULTS AND DISCUSSION

Thiocarboxylic acids **2a,b** promptly react with conjugated azoalkenes **1a-g** in ethyl acetate at room temperature under magnetic stirring to form in a few minutes the hydrazone 1,4-adducts **3a-g** in high yields (see Scheme and Table 1). Although thiocarboxylic acid exist in a tautomeric equilibrium between "thiolo" and "thiono" form,[1] the reaction clearly takes place *via* conjugated Michael-type addition of the thiocarboxylic acid in "thiolo" form to the azo-ene system of conjugated azoalkene, by means of the nucleophilic attack by the sulfur atom.

In chloroform the hydrazone derivatives **3a-c** exhibit tautomerism into the corresponding enamino forms until the two tautomeric forms reach nearly the equimolecular ratio. This tautomerism is easy detected by $^1$H-NMR spectra in which the decrease of the CH (5.32-5.35 ppm) and NH (7.90-8.10 ppm) signals of the


"thiolo" "thiono"




**Scheme**

hydrazono-form and the simultaneous increase of the two NH (6.45-7.20 and 11.00 ppm) signals of the enamino-form are observed. This tautomerism is also supported by $^{13}$C-NMR spectra in which signals with relative intensities, varying in time at slightly different chemical shifts, imputable to the two tautomeric forms are revealed. Only the *E* isomer of the enamino form was observed and determined by IR absorption of NH and $^{1}$H-NMR spectra that show a strong deshielded NH proton, because an intramolecular hydrogen bond NH--O is present.[6]

For the 1,4-adducts **3d-g** only the hydrazono-form is detected and no tautomerism is observed in different solvents and after a long time. Yields and melting points of hydrazones **3a-g** are listed in Table 1.

Table 1. Yields and melting points of hydrazones **3a-g**.

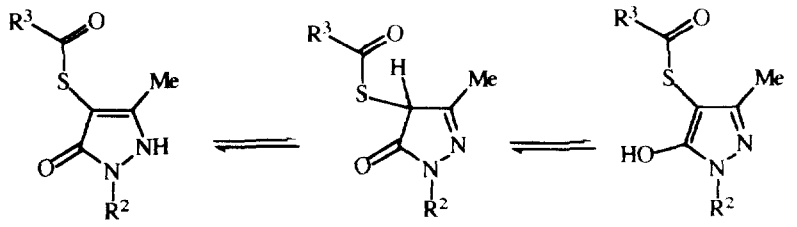
| Azoalkenes **1** | $R^1$ | $R^2$ | Thioacids **2** | $R^3$ | Hydrazones **3** | Yields (%) | Mps (°C) |
|---|---|---|---|---|---|---|---|
| **1a** | Et | $CO_2Me$ | **2a** | Ph | **3a** | 73 | 96-98 |
| **1b** | Et | $CO_2Et$ | **2a** | Ph | **3b** | 74 | 107-109 |
| **1c** | Me | $CO_2Bu^t$ | **2a** | Ph | **3c** | 78 | 80-81 |
| **1d** | Me | $CONH_2$ | **2a** | Ph | **3d** | 75 | 132-134 |
| **1e** | Et | $CONH_2$ | **2b** | Me | **3e** | 85 | 102-104 |
| **1f** | Me | CONHPh | **2a** | Ph | **3f** | 74 | 137-139 |
| **1g** | Et | CONHPh | **2b** | Me | **3g** | 73 | 106-108 |

The hydrazones **3a-g** when treated at room temperature with sodium hydride in tetrahydrofuran rapidly (1 h) react to give 1-alkoxycarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones **4a-c** or 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones **4d-g**. The reaction pathway likely implicates the nucleophilic attack by the >C=N-NH- nitrogen atom on the carboxylate group present in the azoalkene residue producing an heterocyclic intermediate from which the final pyrazol-5(2*H*)-ones **4a-g** arise by elimination of an alcohol molecule (see Scheme). Yields and melting points of pyrazol-5(2*H*)-ones **4a-g** are listed in Table 2.

Table 2. Yields and melting points of pyrazol-5(2*H*)-ones **4a-g**.

| Hydrazones **3** | Pyrazol-5(2*H*)-ones **4** | $R^2$ | $R^3$ | Yields (%) | Mps (°C) |
|---|---|---|---|---|---|
| **3a** | **4a** | $CO_2Me$ | Ph | 47 | 154-155 |
| **3b** | **4b** | $CO_2Et$ | Ph | 55 | 140-141 |
| **3c** | **4c** | $CO_2Bu^t$ | Ph | 54 | 179-181 |
| **3d** | **4d** | $CONH_2$ | Ph | 63 | 183-185 |
| **3e** | **4e** | $CONH_2$ | Me | 72 | 154-155 |
| **3f** | **4f** | CONHPh | Ph | 58 | 187-188 |
| **3g** | **4g** | CONHPh | Me | 71 | 239-240 |

However, an exact structure assignment to similar molecules by usual spectroscopic methods proves to be quite problematic mainly because of the following three tautomeric regioisomers theoretically possible and currently named "NH", "CH", and "OH" forms:




"NH" form "CH" form "OH" form

Likely, these difficulties justify the confusion existing in the literature about the real nature of similar compounds.[5] Therefore, we decided to carry out an exhaustive X-ray diffraction investigation of 1-*tert*-butoxycarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4c**), 1-aminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4d**) and 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4f**), in order to clarify the chemical structures of these compounds and to establish whether different substituents on the nitrogen atom in position 1 cause any difference in the molecular packing and/or in the preferential tautomeric conformation of these molecules.

The crystal structure of 1-aminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4d**) is pictured in Figure 1.

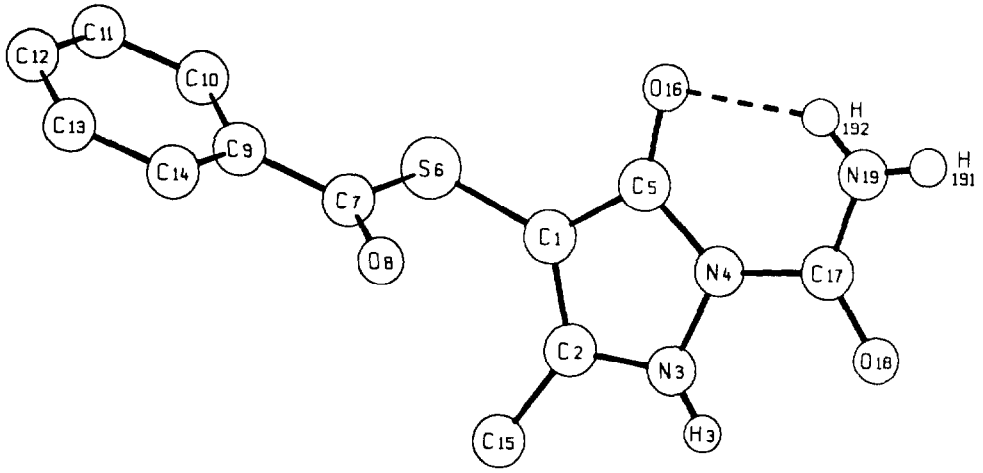



**Figure 1.** X-ray molecular structure of 1-aminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4d**) with the atom numbering system used in the crystallographic analysis.

The drawing clearly shows the 1*H*-pyrazol-5(2*H*)-one nature of the five-membered heterocycle, revealing the hydrogen atom on N(3) (corresponding to N(2) in the normal numbering) of the "NH" tautomeric form. The bond length C(5)-O(16) is 1.245(3) Å, typical for a nearly pure C=O double bond and quite different from the 1.43 Å appropriate for a C-O single bond. The bond length of C(1)-C(2) is 1.387(3) Å, in accordance with a C=C double bond. The 1*H*-pyrazol-5(2*H*)-one ring is perfectly planar, the maximum deviation from the least-squares plane passing through the five atoms is at C(5) [ 0.0093 Å], because of the three carbon atoms with $sp^2$ hybridization present in this ring system. The situation of other groups is quite regular. Unlike the analogous molecule previously studied by X-ray diffraction,[5] in this case no hydrogen-bonded water molecule is present, and therefore both hydrogen atoms of the 1-aminocarbonyl group are available for intramolecular hydrogen bondings. Thus, in accordance with the previous crystal structure determination,[5] an intramolecular hydrogen contact N(19)-H(192)---O(16)-C(5) (length 2.731(1) Å, angle 135.8°) is detected. This intramolecular organization is strengthened by two intermolecular hydrogen bondings that determine the molecular packing: N(3)-H(3)---O(16)-C(5) (2.714(1) Å) N(19)-H(191)---O(8)-C(7) (2.979(1) Å). All these data support the greater stability of this molecule in the "NH" tautomeric form.

The crystal structure of 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4f**) is depicted in Figure 2.

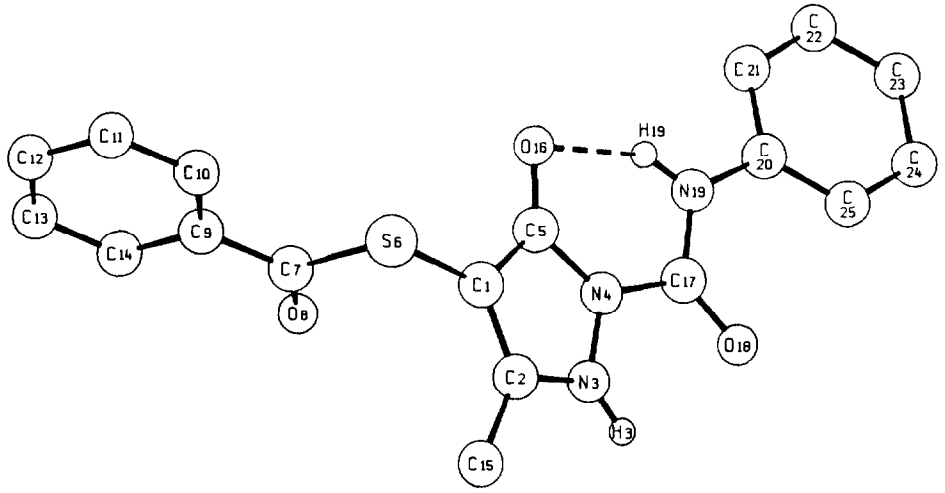



**Figure 2.** X-ray molecular structure of 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4f**) with the atom numbering system used in the crystallographic analysis.

The general arrangement of this molecule appears strictly similar to that of compound **4d** discussed above (see the supplementary material). The intramolecular hydrogen bond present between N(19)-H(19)---O(16)-C(5) (length 2.758(1) Å, angle 139.2°) remains nearly the same as above and the analogous molecule formerly examined.[5] In this case, only one intermolecular hydrogen bond between N(3)-H(3)---O(16)-C(5) (2.821(1) Å) is observed. However, these two last hydrogen effects should be sufficient to stabilize the "NH" tautomeric form for such a molecule.

The crystal structure of 1-*tert*-butoxycarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4c**) is shown in Figure 3.

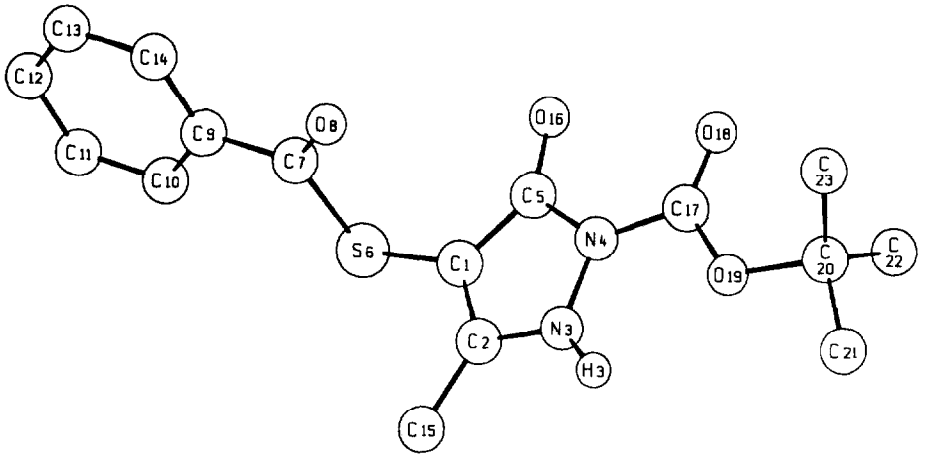


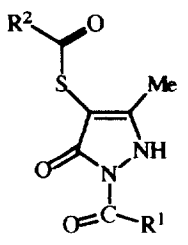

**Figure 3.** X-ray molecular structure of 1-*tert*-butoxycarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (**4c**) with the atom numbering system used in the crystallographic analysis.

Although the general situation of this molecule seems quite analogous to that of the two structures above-surveyed (see the supplementary material), it is noteworthy that no intramolecular hydrogen bonding is detected by X-ray diffraction investigation, while only one intermolecular hydrogen bond between N(3)-H(3)---O(16)-C(5) (2.655(1) Å) is revealed. In spite of this fact, even in such a circumstance the adoption of the "NH" tautomeric form is confirmed.

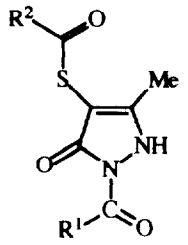
Moreover, it may be interesting to point out that the crystallographic analysis also shows the derivatives **4d** and **4f** in the solid state to be stabilized in *anti* conformation referred to the oxygen atom on the substituent group present on the nitrogen heteroatom in position 1 with respect to the oxygen atom in position 5 of the heterocycle ring, as pictured below. This preferred isomeric situation should be mainly ascribable to the intramolecular hydrogen bondings in the cases in which $R^1$=$NH_2$ or $R^1$=NHPh, according to our previous findings.[5] The absence of intramolecular hydrogen bonding when $R^1$=$OBu^t$, together with the considerable steric hindrance of the *tert*-butyl group, probably determines the *syn* conformation of the derivative **4c**. Clearly, the stereochemistry of these molecules may be subjected to change by solution in different solvents and/or by heating at temperatures higher than the ambient temperature.

In conclusion, our findings unequivocally demonstrate that the molecules here described exist exclusively in the "NH" tautomeric form, even in the absence of significative hydrogen bondings, and therefore suggest, once again, the necessity of a general reconsideration of the previous structural assignments reported in the literature for several hydroxy heterocycles, and, in particular, some 5- and 3-hydroxypyrazoles, that have been characterized only by means of standard spectroscopic methods. We believe that such assignments should be

supported, when possible, by X-ray crystal structure determination, in order to avoid misunderstandings ascribable to the different names attributed to the same heterocyclic compound.[5]



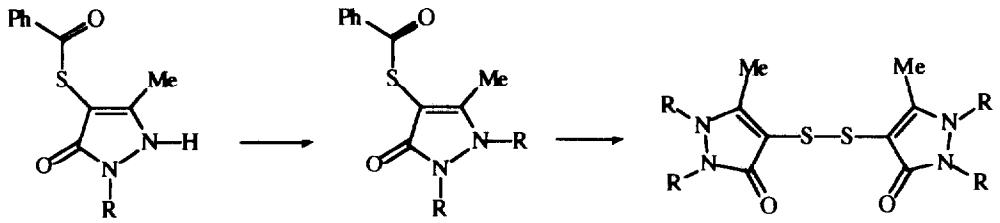
*syn* conformation



*anti* conformation

As a whole, these results are in good agreement with previous findings by some of us on an analogous matter, in which solely 1-aminocarbonyl-1*H*-pyrazol-5(2*H*)-one derivative furnished crystals suitable for X-ray structure determination, although for the molecules here reported we have not observed a neat enol-keto equilibrium, probably due to the recurrence of several concomitant phenomena.[5]

In fact, 1-alkoxycarbonyl- and 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones **4a-g** generally manifested facile solvolytic transformations. Since the subsequent solvolytic group loss leads substantially to the identical product, we report by way of example the treatment of 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one **4f**. When this compound was heated in methanol under reflux, after 20 min., 3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one **5a** was isolated in nearly quantitative yield by consequence of the solvolytic cleavage of the >N-CO- bond. When the heating of 1*H*-pyrazol-5(2*H*)-one **4f** was prolonged to 6 hours, 4,4'-dithiobis(3-methyl-1*H*-pyrazol-5-(2*H*)-one) **6a** was formed quantitatively in the reaction medium, as white crystals, owing to solvolysis of acylthio bond and the following formation of the dithio moiety.



**4f** R = CONHPh

**5a** R = H
**5b** R = COMe

**6a** R = H
**6b** R = COMe

The products **5a** and **6a** were characterized by routine spectroscopic techniques as such and as the acetyl derivatives **5b** and **6b**, respectively, prepared in accordance with well-known procedures, to be on the safe side.

The same hydrazones **3a-c,e-g** in chloroform in the presence of trifluoroacetic acid, under reflux for a few hours, afford 1-alkoxycarbonyl-3-methyl-4-acylthio-5-alkoxypyrazoles **7a-c** or 1-aminocarbonyl-3-methyl-4-acylthio-5-alkoxypyrazoles **7d,e** (see Scheme). The reaction intermediate should be the same as above, but in the acidic media loss of water is preferred with formation of 5-alkoxypyrazoles **7a-e**. Yields, melting points and reaction times of the 5-alkoxypyrazoles **7a-e** are listed in Table 3.

Hydrazone **3d**, treated under the same reaction conditions, provides the unespected 3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one **5a** instead of the relevant 1-aminocarbonyl-3-methyl-4-benzoylthio-5-methoxypyrazole. As for the synthesis of similar pyrazol-5(2*H*)-ones **4a-g** discussed above, the pyrazol-5(2*H*)-one **5a** is formed by the elimination of an alcohol molecule from the intermediate and by following cleavage of the >N-CO- bond. Unlike 3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones **4a-g**, 3-methyl-4-acylthio-5-alkoxypyrazoles **7a-e** generally manifested no solvolytic cleavage of the >N-CO- bond even when heated in methanol under reflux for a long time.

Table 3. Yields, melting points and reaction times of 5-alkoxypyrazoles **7a-e**.

| Hydrazones **3** | 5-Alkoxypyrazoles **7** | $R^1$ | $R^2$ | $R^3$ | Yields (%) | Mps (°C) | Reaction times (h) |
|---|---|---|---|---|---|---|---|
| **3a** | **7a** | Et | $CO_2Me$ | Ph | 98 | 123-125 | 6.0 |
| **3b** | **7b** | Et | $CO_2Et$ | Ph | 93 | 107-109 | 3.0 |
| **3c** | **7c** | Me | $CO_2Bu^t$ | Ph | 95 | 108-109 | 2.0 |
| **3e** | **7d** | Et | $CONH_2$ | Me | 73 | 123-125 | 4.0 |
| **3g** | **7e** | Et | CONHPh | Me | 85 | 121-123 | 10.0 |

Trifluoacetic acid in water and tetrahydrofuran under reflux for 24 hours effects the hydrolytic cleavage of >C=N- bond of hydrazones **3b,e,f** with formation of alkyl 2-acylthio-3-oxobutanoates **8a-c** (see Scheme). These derivatives exhibit enol-keto tautomerism as shown by $^1$H- and $^{13}$C-NMR spectroscopy (see Experimental). Yields, and melting points of 3-oxobutanoates **8a-c** are presented in Table 4.

Table 4. Yields and melting points of 3-oxobutanoates **8a-c**.

| Hydrazones **3** | 3-Oxobutanoates **8** | $R^1$ | $R^3$ | Yields (%) | Mps (°C) | Enol (%) |
|---|---|---|---|---|---|---|
| **3b** | **8a** | Et | Ph | 48 | oil | 80 |
| **3e** | **8b** | Et | Me | 47 | oil | 78 |
| **3f** | **8c** | Me | Ph | 51 | 47-49 | 90 |

In conclusion, this paper reports new and interesting reactions of thiocarboxylic acids with conjugated azoalkenes that selectively provide previously unknown derivatives bearing acylthio groups not usually accessible by other methods. The starting materials are of low cost and easily available: conjugated azoalkenes being readily synthesizable by smooth routine procedures and thiocarboxylic acids being commercial products. Besides, all these reactions are extremely simple to carry out because of mild reaction conditions, short reaction times, very simple work up procedures, and frequently afford the products in good to excellent yields. These reasons make the reactions here described highly useful also from the preparative point of view.[7]

## EXPERIMENTAL

Alkoxycarbonylazoalkenes (**1a-c**)[8] and aminocarbonylazoalkenes (**1d-g**)[9] were synthesized as previously reported. Thiobenzoic acid **2a** and thiolacetic acid **2b** were commercial materials (Aldrich) and were used without further purification. Melting points were determined in open capillary tubes with a Büchi (Tottoli) or Gallenkamp apparatus and are uncorrected. The products often decompose at melting point. IR spectra were obtained as liquid film or Nujol mull with a Perkin-Elmer 298 spectrophotometer. IR-FT spectra were performed with a Nicolet Impact 400 spectrophotometer. MS spectra were made with a Hewlett Packard 5995 C spectrometer. Elemental analyses were performed with a Fisons EA 1108 instrument. $^1$H NMR spectra at 60 MHz were recorded on Varian EM 360 L and at 200 MHz on Bruker AC 200 spectrometers and performed in $CDCl_3$ or in DMSO-$d_6$. Chemical shifts (δ) are reported in ppm downfield from internal TMS and coupling constants (J) in Hz. The abbreviations used are as follows: s, singlet; d, doublet, dd, doublet-doublet; t, triplet; q, quartet; m, multiplet; br, broad; $D_2O$ ex, $D_2O$ exchange. Densitometric analysis was made with a Scanning Densitometer Shimadzu CS-9000. Macherey-Nagel precoated silica gel SIL G-25UV$_{254}$ plates (0.25 mm) were employed for analytical thin layer chromatography (TLC) and silica gel Amicon LC 60 Å (35-70 mμ) for column chromatography. All new compounds showed satisfactory elemental analysis (C ±0.35, H ±0.30, N ±0.30).

**General procedure for the synthesis of hydrazones (3a-g).**

To a stirred solution of conjugated azoalkene **1a-g** (1 mmol) in ethyl acetate (5 ml) was added dropwise thiobenzoic acid **2a** or thiolacetic acid **2b** (1 mmol) in ethyl acetate (5 ml). After 5 min. at room temperature the conjugated azoalkene completely disappeared (monitored by silica gel TLC). The mixture was poured in a saturated aqueous solution of sodium hydrogen carbonate and extracted with ethyl acetate. The organic layer was dried over anhydrous sodium sulfate and, by evaporation of the solvent, the crude products **3a-g** were isolated. The products were further purified by chromatography on a silica gel column (elution with methylene chloride) and crystallized from ethyl acetate-petroleum ether (40-60 °C).

**Compound (3a).**

IR: 3215, 1740, 1720, 1665 cm$^{-1}$. Hydrazono form. $^1$H-NMR ($CDCl_3$): δ 1.29 (t, 3H, J=7.0 Hz, Me), 1.99 (s, 3H, Me), 3.81 (s, 3H, OMe), 4.25 (q, 2H, J=7.0 Hz, $OCH_2$), 5.32 (s, 1H, CH), 7.41-8.03 (m, 5H, Ph), 8.10 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 13.8 (Me), 14.0 (Me), 53.0 (OMe), 53.5 (CH), 62.3

($OCH_2$), 127.5, 128.7, 133.9 and 136.1 (Ph), 146.0 (C=N), 154.3 (N-C=O), 168.2 (C=O), 188.8 (S-C=O). Enamino form. $^1$H-NMR ($CDCl_3$): δ 1.19 (t, 3H, J=7.0 Hz, Me), 2.18 (s, 3H, Me), 3.78 (s, 3H, OMe), 4.16 (q, 2H, J=7.0 Hz, $OCH_2$), 7.20 (bs, 1H, NH, $D_2O$ ex), 7.41-8.03 (m, 5H, Ph), 11.00 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 14.2 (Me), 16.4 (Me-C=C), 53.1 (OMe), 60.4 ($OCH_2$), 81.5 (S-C=C), 127.4, 128.6, 133.2 and 136.9 (Ph), 156.5 (N-C=O), 169.3 (C=O), 170.0 (S-C=C), 191.5 (S-C=O).

**Compound (3b).**

IR: 3240, 3140, 1720, 1670, 1645 cm$^{-1}$. Hydrazono form. $^1$H-NMR ($CDCl_3$): δ 1.17-1.33 (m, 6H, Me), 1.98 (s, 3H, Me), 4.05-4.35 (m, 4H, $OCH_2$), 5.33 (s, 1H, CH), 7.40-8.05 (m, 5H, Ph), 7.90 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 13.8 (Me), 14.0 (Me), 14.4 (Me), 53.5 (CH), 62.1 ($OCH_2$), 62.3 ($OCH_2$), 127.4, 128.7, 133.8 and 136.9 (Ph), 145.6 (C=N), 153.6 (N-C=O), 168.2 (C=O), 188.9 (S-C=O). Enamino form. $^1$H-NMR ($CDCl_3$): δ 1.17-1.33 (m, 6H, Me), 2.20 (s, 3H, Me), 4.05-4.35 (m, 4H, $OCH_2$), 6.98 (bs, 1H, NH, $D_2O$ ex), 7.40-8.05 (m, 5H, Ph), 11.00 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 14.2 (Me), 14.4 (Me), 16.4 (Me-C=C), 60.5 ($OCH_2$), 62.3 ($OCH_2$), 81.8 (S-C=C), 127.5, 128.6, 133.1 and 136.1 (Ph), 156.1 (N-C=O), 169.3 (C=O), 170.1 (S-C=C), 191.5 (S-C=O).

**Compound (3c).**

IR: 3240, 1735, 1705, 1675, 1665 cm$^{-1}$. Hydrazono form. $^1$H-NMR ($CDCl_3$): δ 1.51 (s, 9H, $Bu^t$), 1.97 (s, 3H, Me), 3.80 (s, 3H, OMe), 5.35 (s, 1H, CH), 7.45-8.00 (m, 6H, Ph, NH). $^{13}$C-NMR ($CDCl_3$): δ 13.8 (Me), 28.1 ($CMe_3$), 53.0 (OMe), 53.4 (CH), 81.3 ($CMe_3$), 127.3, 128.8, 133.8 and 135.9 (Ph), 144.5 (C=N), 155.0 (N-C=O), 167.6 (C=O), 188.9 (S-C=O). Enamino form. $^1$H-NMR ($CDCl_3$): δ 1.49 (s, 9H, $Bu^t$), 2.20 (s, 3H, Me), 3.68 (s, 3H, OMe), 6.45 (bs, 1H, NH, $D_2O$ ex), 7.45-8.00 (m, 5H, Ph), 11.00 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 16.2 (Me-C=C), 28.1 ($CMe_3$), 51.6 (OMe), 80.4 ($CMe_3$), 81.7 (S-C=C), 127.4, 128.6, 133.1 and 136.7 (Ph), 152.3 (N-C=O), 169.6 (C=O), 170.7 (S-C=C), 191.4 (S-C=O).

**Compound (3d).**

IR: 3470, 3320, 3220, 1735, 1705, 1665 cm$^{-1}$. Hydrazono form. $^1$H-NMR ($CDCl_3$): δ 2.02 (s, 3H, Me), 3.80 (s, 3H, OMe), 5.27 (s, 1H, CH), 5.85 (bs, 2H, $NH_2$, $D_2O$ ex), 7.47-7.99 (m, 5H, Ph), 8.90 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 14.4 (Me), 53.1 (OMe), 53.5 (CH), 127.5, 128.8, 134.0 and 136.0 (Ph), 142.9 (C=N), 157.1 (N-C=O), 168.7 (C=O), 189.0 (S-C=O).

**Compound (3e).**

IR: 3470, 3360, 3280, 3150, 1750, 1705, 1690 cm$^{-1}$. Hydrazono form. $^1$H-NMR ($CDCl_3$): δ 1.27 (t, 3H, J= 7.0 Hz, Me), 1.94 (s, 3H, Me), 2.37 (s, 3H, Me), 4.21 (q, 2H, J= 7.0 Hz, $OCH_2$), 5.01 (s, 1H, CH), 5.70 (bs, 2H, $NH_2$, $D_2O$ ex), 9.19 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 14.0 (Me), 14.5 (Me), 30.0 (Me), 53.7 (CH), 62.2 ($OCH_2$), 143.0 (C=N), 157.7 (N-C=O), 168.0 (C=O), 192.7 (S-C=O).

**Compound (3f).**

IR: 3390, 3205, 3090, 1745, 1715, 1670 cm$^{-1}$. Hydrazono form. $^1$H-NMR ($CDCl_3$): δ 2.07 (s, 3H, Me), 3.84 (s, 3H, OMe), 5.36 (s, 1H, CH), 7.05-8.01 (m, 10H, Ph), 8.13 (bs, 1H, NH, $D_2O$ ex), 8.80 (bs, 1H, NH,

$D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 14.7 (Me), 53.2 (OMe), 53.6 (CH), 119.4, 123.4, 127.6, 128.8, 128.9, 134.1, 135.9 and 137.9 (Ph), 143.1 (C=N), 153.6 (N-C=O), 168.7 (C=O), 189.0 (S-C=O).

**Compound (3g).**
IR: 3380, 3205, 3095, 1735, 1720, 1695 cm$^{-1}$. Hydrazono form. $^1$H-NMR ($CDCl_3$): δ 1.30 (t, 3H, J= 7.0 Hz, Me), 2.06 (s, 3H, Me), 2.41 (s, 3H, Me), 4.25 (q, 2H, J= 7.0 Hz, $OCH_2$), 5.11 (s, 1H, CH), 7.00-7.50 (m, 5H, Ph), 8.15 (bs, 1H, NH, $D_2O$ ex), 9.68 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 14.0 (Me), 14.7 (Me), 30.1 (Me), 53.8 (CH), 62.3 ($OCH_2$), 119.3, 123.3, 128.9, and 138.0 (Ph), 143.2 (C=N), 153.8 (N-C=O), 168.0 (C=O), 192.7 (S-C=O).

**General procedure for the synthesis of 1-alkoxycarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones (4a-c) and 1-aminocarbonyl-3-methyl-4-acylthio-1*H*-pyrazol-5(2*H*)-ones (4d-g).**
To a stirred solution of hydrazones **3a-g** (1 mmol) in tetrahydrofuran (5 ml) was added sodium hydride (1.1 mmol) in small portions. After 1 h at room temperature the hydrazone had completely disappeared (monitored by silica gel TLC). The solvent was evaporated, the reaction mixture was dissolved in ethyl acetate and washed with aqueous 1% sulfuric acid. The organic layer was dried over anhydrous sodium sulfate and the solvent was evaporated under reduced pressure, affording the crude products **4a-g** which showed satisfactory purity and were further purified by crystallization from ethyl acetate-petroleum ether (40-60 °C).

**Compound (4a).**
IR: 3105, 1745, 1705, 1675, 1660 cm$^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 2.10 (s, 3H, Me), 3.91 (s, 3H, OMe), 7.54-8.00 (m, 5H, Ph), 12.80 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR (DMSO-$d_6$): δ 11.5 (Me), 54.1 (OMe), 85.5 (C4), 127.1, 129.2, 134.2 and 135.5 (Ph), 148.5 (C3), 156.5 (C=O), 159.6 (C5), 189.1 (S-C=O).

**Compound (4b).**
IR: 3050, 1755, 1680, 1630 cm$^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 1.31 (t, 3H, J=7.0 Hz, Me), 2.10 (s, 3H, Me), 4.36 (q, 2H, J=7.0 Hz, $OCH_2$), 7.54-8.00 (m, 5H, Ph), 12.70 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR (DMSO-$d_6$): δ 11.6 (Me), 14.1 (Me), 65.5 ($OCH_2$), 85.5 (C4), 127.1, 129.2, 134.2 and 135.5 (Ph), 148.0 (C3), 156.5 (C=O), 159.7 (C5), 189.1 (S-C=O).

**Compound (4c).**
IR: 3090, 1765, 1740, 1685, 1660 cm$^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 1.54 (s, 9H, $Bu^t$), 2.10 (s, 3H, Me), 7.50-8.00 (m, 5H, Ph), 12.60 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 11.4 (Me), 27.5 ($CMe_3$), 84.1 ($CMe_3$), 85.8 (C4), 127.0, 129.0, 134.0 and 135.5 (Ph), 146.5 (C3), 155.9 (C=O), 159.5 (C5), 189.1 (S-C=O).

**Compound (4d).**
IR: 3400, 3270, 3090, 1755, 1700, 1630 cm$^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 2.10 (s, 3H, Me), 7.50-8.00 (m, 5H, Ph), 7.98 and 8.18 (2bs, 2H, $NH_2$, $D_2O$ ex), 13.40 (bs, 1H, NH, $D_2O$ ex). $^{13}$C-NMR (DMSO-$d_6$): δ 11.3 (Me), 83.2 (C4), 126.9, 129.0, 133.8 and 135.7 (Ph), 144.4 (C3), 149.2 (C=O), 162.0 (C5), 189.7 (S-C=O).

**Compound (4e).**
IR: 3390, 3310, 3250, 3090, 1745, 1665, 1640 $cm^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 2.07 (s, 3H, Me), 2.29 (s, 3H, Me), 7.81 and 8.24 (2bs, 2H, $NH_2$, $D_20$ ex), 11.25 (bs, 1H, NH, $D_20$ ex). $^{13}$C-NMR (DMSO-$d_6$): δ 11.0 (Me), 28.9 (Me), 86.3 (C4), 143.8 (C3), 149.1 (C=O), 161.6 (C5), 195.0 (S-C=O).

**Compound (4f).**
IR: 3140, 3065, 1725, 1680, 1635, 1620 $cm^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 2.19 (s, 3H, Me), 7.10-8.05 (m, 11H, Ph, NH, $D_20$ ex), 11.10 (bs, 1H, NH, $D_20$ ex). $^{13}$C-NMR (DMSO-$d_6$): δ 11.1 (Me), 85.3 (C4), 119.7, 124.1, 127.0, 129.1, 133.7, 134.1, 135.5 and 136.7 (Ph), 146.1 (C3), 154.5 (C=O), 161.9 (C5), 189.0 (S-C=O).

**Compound (4g).**
IR: 3120, 3060, 1730, 1710, 1640, 1630 $cm^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 2.14 (s, 3H, Me), 2.48 (s, 3H, Me), 7.10-7.55 (m, 5H, Ph), 11.07 (bs, 1H, NH, $D_20$ ex), 13.55 (bs, 1H, NH, $D_20$ ex). $^{13}$C-NMR (DMSO-$d_6$): δ 10.9 (Me), 29.1 (Me), 87.1 (C4), 119.6, 124.4, 129.1 and 136.6 (Ph), 146.1 (C3), 153.8 (C=O), 161.7 (C5), 194.4 (S-C=O).

**Conversion of 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4f) into 3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (5a) and 4,4'-dithiobis(3-methyl-1*H*-pyrazol-5(2*H*)-one) (6a).**
1-Phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one **4f** (1 mmol) was dissolved in methanol (10 ml) and heated under reflux during 20 min. The solution was reduced to half volume by partial evaporation of the solvent, and then was stored in refrigerator until the crystallization of 3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one **5a** in nearly quantitative yield. 1-Phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one **4f** (1 mmol) was dissolved in methanol (15 ml) and heated under reflux for 6 h. The precipitate formed was filtered by suction providing 4,4'-dithiobis(3-methyl-1*H*-pyrazol-5(2*H*)-one) **6a** in nearly quantitative yield. Both products **5a** and **6a** were subjected to acetylation by routine procedure leading to the relevant acetyl derivatives **5b** and **6b**.

**Compound (5a).**
IR: 3435, 3135, 1690, 1620 $cm^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 2.06 (s, 3H, Me), 7.50-8.00 (m, 5H, Ph), 9.10 (bs, 1H, NH, $D_2O$ ex), 10.80 (bs, 1H, NH, $D_2O$ex). $^{13}$C-NMR (DMSO-$d_6$): δ 10.6 (Me), 82.3 (C4), 127.0, 129.1, 133.7 and 136.1 (Ph), 145.0 (C3), 159.3 (C5), 162.1 (C=O), 190.2 (S-C=O).

**Compound (5b).**
IR: 1770, 1740, 1675, 1555 $cm^{-1}$. $^1$H-NMR ($CDCl_3$): δ 2.30 (s, 3H, Me), 2.59 (s, 3H, COMe), 2.69 (s, 3H, COMe), 7.45-8.10 (m, 5H, Ph). $^{13}$C-NMR ($CDCl_3$): δ 13.8 (Me), 20.5 (COMe), 23.2 (COMe), 91.1 (C4), 127.8, 128.9, 134.1 and 135.8 (Ph), 150.0 (C3), 157.2 (C=O), 167.6 ($CH_3$-C=O), 170.7 (Me-C=O), 187.2 (S-C=O).

**Compound (6a).**
IR: 3090, 1610, 1590 $cm^{-1}$. $^1$H-NMR (DMSO-$d_6$): δ 1.78 (s, 3H, Me), 10.98 (bs, 2H, 2NH, $D_2O$ ex). $^{13}$C-NMR (DMSO-$d_6$): δ 9.5 (Me), 93.5 (C4), 144.7 (C3), 161.6 (C=O).

**Compound (6b).**
IR: 1780, 1740, 1550 $cm^{-1}$. $^1$H-NMR ($CDCl_3$): δ 2.20 (s, 3H, Me), 2.41 (s, 3H,COMe), 2.57 (s, 3H, COMe). $^{13}$C-NMR ($CDCl_3$): δ 13.6 (Me), 20.2 (COMe), 23.1 (COMe), 116.1 (C4), 149.6 (C3), 162.2 (C=O), 167.4 (MeC=O), 170.7 (MeC=O).

**General procedure for the synthesis of 1-alkoxycarbonyl-3-methyl-4-acylthio-5-alkoxypyrazoles (7a-c) or 1-aminocarbonyl-3-methyl-4-acylthio-5-alkoxypyrazoles (7d,e).**
To a solution of hydrazones **3a-c,e,g** (1 mmol) in chloroform (5 ml) was added trifluoroacetic acid (1 mmol) in chloroform (5 ml). The reaction was heated under reflux (2-10 h) until the hydrazone had completely disappeared (monitored by silica gel TLC). The solvent was evaporated, the reaction mixture was dissolved in ethyl acetate and washed with a saturated aqueous solution of sodium hydrogen carbonate. The organic layer was dried over anhydrous sodium sulfate and the solvent was evaporated affording the crude products **7a-e** that showed satisfactory purity. Further purification was obtained by crystallization from diethyl ether.

**Compound (7a).**
IR: 1725, 1635 $cm^{-1}$. $^1$H-NMR ($CDCl_3$): δ 1.41 (t, 3H, J=7.0 Hz, Me), 2.78 (s, 3H, Me), 3.65 (s, 3H, OMe), 4.44 (q, 2H, J=7.0 Hz, $OCH_2$), 7.45-8.00 (m, 5H, Ph). $^{13}$C-NMR ($CDCl_3$): δ 13.5 (Me), 14.1 (Me), 52.3 (OMe), 62.7 ($OCH_2$), 120.7 (C4), 126.7, 129.2 and 132.8 (Ph), 155.3 (C3), 159.3 (C5), 164.0 (C=O), 164.7 (S-C=O).

**Compound (7b).**
IR: 1730, 1630 $cm^{-1}$. $^1$H-NMR ($CDCl_3$): δ 1.17 (t, 3H, J=7.0 Hz, Me), 1.36 (t, 3H, J=7.0 Hz, Me), 2.72 (s, 3H, Me), 4.04 (q, 2H, J=7.0 Hz, $OCH_2$), 4.40 (q, 2H, J=7.0 Hz, $OCH_2$), 7.40-7.85 (m, 5H, Ph). $^{13}$C-NMR ($CDCl_3$): δ 13.2 (Me), 14.0 (Me), 14.8 (Me), 60.9 ($OCH_2$), 62.7 ($OCH_2$), 120.9 (C4), 126.1, 129.1 and 132.9 (Ph), 155.0 (C3), 159.1 (C5), 162.5 (C=O), 166.7 (S-C=O).

**Compound (7c).**
IR: 1730, 1640 $cm^{-1}$. $^1$HNMR ($CDCl_3$): δ 1.35 (s, 9H, $Bu^t$), 2.73 (s, 3H, Me), 3.90 (s, 3H, OMe), 7.40-7.95 (m, 5H, Ph). $^{13}$C-NMR ($CDCl_3$): δ 13.5 (Me), 28.7 ($C\underline{Me}_3$), 52.9 (OMe), 77.2 ($\underline{C}Me_3$), 120.1 (C4), 128.6, 129.1, 132.6 and 133.6 (Ph), 155.6 (C3), 159.7 (C5), 162.0 (C=O), 165.2 (S-C=O).

**Compound (7d).**
IR: 3470, 3360, 3170, 1725, 1685 $cm^{-1}$. $^1$H-NMR ($CDCl_3$): δ 1.39 (t, 3H, J=7.0 Hz, Me), 2.70 (s, 3H, Me), 2.77 (s, 3H, Me), 4.40 (q, 2H, J=7.0 Hz, $OCH_2$), 4.60 and 5.25 (2bs, 2H, $NH_2$, $D_2O$ ex). $^{13}$C-NMR ($CDCl_3$): δ 13.6 (Me), 14.1 (Me), 15.8 (Me), 62.6 ($OCH_2$), 109.9 (C4), 153.9 (C3), 159.3 (C5), 164.5 (C=O), 166.5 (S-C=O).

**Compound (7e).**
IR: 3340, 1730, 1680 $cm^{-1}$. $^1$H-NMR ($CDCl_3$): δ 1.40 (t, 3H, J=7.0 Hz, Me), 2.73 (s, 3H, Me), 2.79 (s, 3H, Me), 4.41 (q, 2H, J=7.0 Hz, $OCH_2$), 6.81 (bs, 1H, NH, $D_2O$ ex), 6.91-7.46 (m, 5H, Ph). $^{13}$C-NMR ($CDCl_3$): δ 13.7 (Me), 14.1 (Me), 15.9 (Me), 62.6 ($OCH_2$), 121.1 (C4), 118.1, 126.9, 128.7 and 129.6 (Ph), 153.7 (C3), 159.2 (C5), 161.3 (N-C=O), 166.7 (S-C=O).

**General procedure for the synthesis of alkyl 2-acylthio-3-oxobutanoates (8a-c).**
To a solution of the hydrazones **3b,e,f** (1 mmol) in tetrahydrofuran (2.5 ml) and $H_2O$ (2.5 ml) was added trifluoroacetic acid (1 mmol). The solution was heated 24 h under reflux until all of the hydrazone disappeared (monitored by silica gel TLC). The solvent was evaporated, the reaction mixture was dissolved in ethyl acetate and washed with a saturated aqueous solution of sodium hydrogen carbonate. The organic layer was dried over anhydrous sodium sulfate and the solvent was evaporated. The crude products **8a-c** were isolated by chromatography on a silica gel column (elution with methylene chloride) as oils, with the exception of **8c**.

**Compound (8a).**
IR: 1750, 1725, 1680, 1640 $cm^{-1}$. Keto form $^1$H-NMR ($CDCl_3$): δ 1.31 (t, 3H, J=7.0 Hz, Me), 2.43 (s, 3H, Me), 4.17-4.33 (m, 2H, $OCH_2$), 5.33 (s, 1H, CH), 7.43-8.04 (m, 5H, Ph). $^{13}$C-NMR ($CDCl_3$): δ 20.7 (Me), 28.5 (Me), 57.0 (CH), 62.7 ($OCH_2$), 127.4, 128.8, 133.5 and 135.5 (Ph), 166.0 (C=O), 188.9 (S-C=O), 198.2 (C=O). Enol form $^1$H-NMR ($CDCl_3$): δ 1.26 (t, 3H, J=7.0 Hz, Me), 2.21 (s, 3H, Me), 4.17-4.33 (m, 2H, $OCH_2$), 7.43-8.04 (m, 5H, Ph), 13.94 (bs, 1H, enol OH). $^{13}$C-NMR ($CDCl_3$): δ 14.0 (Me), 29.6 (Me), 61.6 ($OCH_2$), 88.3 (S-C=C), 127.4, 128.7, 134.2 and 136.4 (Ph), 172.0 (C=O), 183.9 (S-C=C), 189.5 (S-C=O).

**Compound (8b).**
IR: 1750, 1710, 1680, 1640 $cm^{-1}$. Keto form $^1$H-NMR ($CDCl_3$): δ 1.28 (t, 3H, J=7.0 Hz, Me), 2.34 (s, 3H, Me), 2.40 (s, 3H, Me), 4.24 (q, 2H, J= 7.0 Hz, $OCH_2$), 5.10 (s, 1H, CH). $^{13}$C-NMR ($CDCl_3$): δ 20.6 (Me), 28.4 (Me), 29.9 (Me), 57.0 (CH), 62.7 ($OCH_2$), 165.9 (C=O), 192.7 (S-C=O), 197.9 (C=O). Enol form $^1$H-NMR ($CDCl_3$): δ 1.26 (t, 3H, J=7.0 Hz, Me), 2.14 (s, 3H, Me), 2.34 (s, 3H, Me), 4.21 (q, 2H, J= 7.0 Hz, $OCH_2$), 13.60 (bs, 1H, enol OH). $^{13}$C-NMR ($CDCl_3$): δ 14.0 (Me), 29.3 (Me), 29.6 (Me), 61.7 ($OCH_2$), 89.5 (S-C=C), 171.8 (C=O), 183.5 (S-C=C), 193.9 (S-C=O).

**Compound (8c).**
IR: 1755, 1730, 1680, 1640 $cm^{-1}$. Keto form $^1$H-NMR ($CDCl_3$): δ 2.43 (s, 3H, Me), 3.83 (s, 3H, OMe), 5.32 (s, 1H, CH), 7.48-8.05 (m, 5H, Ph). $^{13}$C-NMR ($CDCl_3$): δ 28.5 (Me), 53.4 (OMe), 56.6 (CH), 127.5, 128.8, 134.3 and 136.2 (Ph), 166.6 (C=O), 189.5 (S-C=O), 197.7 (C=O). Enol form $^1$H-NMR ($CDCl_3$): δ 2.21 (s, 3H, Me), 3.77 (s, 3H, OMe), 7.48-8.05 (m, 5H, Ph), 13.80 (bs, 1H, enol OH). $^{13}$C-NMR ($CDCl_3$): δ 29.7 (Me), 52.6 (OMe), 88.0 (S-C=C), 127.5, 128.7, 133.6 and 136.2 (Ph), 172.4 (C=O), 184.2 (S-C=C), 189.5 (S-C=O).

**X-Ray analysis of 1-aminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4d).**
Intensity data were collected with an Enraf-Nonius CAD-4 diffractometer using graphite monochromated Mo-

Kα radiation, ω/2θ scan mode, range 2.88°<θ<24.98°. The unit cell parameters were determined by least-squares refinement on diffractometer angles for 25 automatically centered reflections 8.0°<θ<13°.

**Crystal data of 1-aminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4d).** $C_{12}H_{11}N_3O_3S$; mol. wt. 277.3; monoclinic; space group $P2_1/a$; a = 11.827(4) Å, b = 8.564(3) Å, c = 13.412(4) Å, β = 110.66(5)°, U = 1271(1) Å$^3$, $D_c$ = 1.45 Mg/m$^3$, Z = 4, λ = 0.71069 Å, μ (Mo-Kα) = 0.262 mm$^{-1}$, F(000) = 576, T = 298 K. Of 2221 indipendent reflections [R(int) = 0.029], 1632 having I > 2σ(I) were considered observed.

**Structure determination and refinement of 1-aminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4d).** The structure was solved by direct methods, and refined by full-matrix least-squares on $F^2$, using the SHELX program packages.[10] In refinements were used weights in accordance with the scheme $w = 1 / [\sigma^2(F^2_o) + (0.0763P)^2]$ where $P = (F^2_o + 2F^2_o) / 3$. All the hydrogen atoms were revealed in the Fourier difference maps, but not refined. The final agreement indices were $R_1$ = 0.0408 and $wR_2$ = 0.1079. Goodness of fit on $F^2$ = 3.55. Largest difference peak and hole was 0.272 and -0.267 eÅ$^{-3}$.

**X-Ray analysis of 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4f).** Intensity data were collected with an Enraf-Nonius CAD-4 diffractometer using graphite monochromated Mo-Kα radiation, ω/2θ scan mode, range 2.52°<θ<24.95°. The unit cell parameters were determined by least-squares refinement on diffractometer angles for 25 automatically centered reflections 7.5°<θ<11.5°.

**Crystal data of 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4f).** $C_{18}H_{15}N_3O_3S$; mol. wt. 353.4; ortorombic; space group Pbca; a = 9.105(2) Å, b = 11.542(4) Å, c = 32.354(5) Å, U = 3400(1) Å$^3$, $D_c$ = 1.38 Mg/m$^3$, Z = 8, λ = 0.71069 Å, μ (Mo-Kα) = 0.214 mm$^{-1}$, F(000) = 1472, T = 298 K. Of 2983 indipendent reflections, 1762 having I > 2σ(I) were considered observed.

**Structure determination and refinement of 1-phenylaminocarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4f).** The structure was solved by direct methods, and refined by full-matrix least-squares on $F^2$ using the SHELX program packages.[10] In refinements were used weights in accordance with the scheme $w = 1 / [\sigma^2(F^2_o) + (0.1388P)^2 + 7.42P]$ where $P = (F^2_o + 2F^2_o) / 3$. All the hydrogen atoms were revealed in the Fourier difference maps, but not refined. The final agreement indices were $R_1$ = 0.0762 and $wR_2$ = 0.210. Goodness of fit on $F^2$ = 1.047. Largest difference peak and hole was 0.674 and -0.516 eÅ$^{-3}$.

**X-Ray analysis of 1-*tert*-butoxycarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4c).** Intensity data were collected with an Enraf-Nonius CAD-4 diffractometer using graphite monochromated Mo-Kα radiation, ω/2θ scan mode, range 2.37°<θ<21.97°. The unit cell parameters were determined by least-squares refinement on diffractometer angles for 25 automatically centered reflections 8.0°<θ<13°.

**Crystal data of 1-*tert*-butoxycarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4c).** $C_{16}H_{18}N_2O_4S$; mol. wt. 334.4; ortorombic; space group Pbca; a = 11.353(3) Å, b = 25.412(5) Å, c = 11.694(3) Å, U = 3374(1) Å$^3$, $D_c$ = 1.32 Mg/m$^3$, Z = 8, λ = 0.71069 Å, μ (Mo-Kα) = 0.213 mm$^{-1}$, F(000) = 1408, T = 298 K. Of 2046 indipendent reflections, 1451 having I > 2σ(I) were considered observed.

**Structure determination and refinement of 1-*tert*-butoxycarbonyl-3-methyl-4-benzoylthio-1*H*-pyrazol-5(2*H*)-one (4c).** The structure was solved by direct methods, and refined by full-matrix least-squares on $F^2$ using the SHELX program packages.[10] In refinements were used weights in accordance with the

scheme $w = 1 / [\sigma^2(F^2_o) + (0.1150P)^2 + 6.0157P]$ where $P = (F^2_o + 2F^2_o) / 3$. All the hydrogen atoms were revealed in the Fourier difference maps, but not refined. The final agreement indices were $R_1 = 0.0625$ and $wR_2 = 0.1573$. Goodness of fit on $F^2 = 1.073$. Largest difference peak and hole was 0.548 and -0.390 eÅ$^{-3}$.

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