Oxidative Cyclization of Some Aldehyde Semicarbazones Induced by Metallic Salts

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The oxidative cyclization of some aldehyde semicarbazones **1O** with four different oxidizing agents has been effected. The structure of the semicarbazones and the nature of cyclizing agent affected the rate and yield of cyclization but they did not show any influence on the regiochemistry of reaction. In fact, 1,2,4-triazoline **2O** was the only heterocyclic ring obtained by the cyclization reaction.

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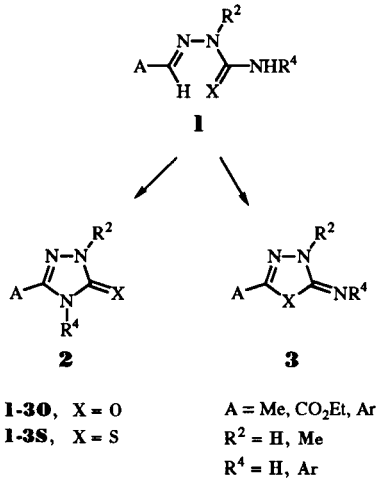
Ring synthesis by cyclization of opportune linear compounds is one of the most common and popular methods to prepare heterocyclic compounds. Ring synthesis is particularly useful as the number of heteroatoms in the ring increases. So, for example, aldehyde semi- and thiosemicarbazones are suitable substrates for the preparation of five- or six-membered heterocyclic rings containing three heteroatoms. The route of the cyclization reaction can be affected by the structure of the starting substrate [1] as well as by the nature of cyclizing agent [2,3].

We have recently [1] studied the substituent effects on oxidative cyclization of aldehyde thiosemicarbazones with alcoholic solutions of ferric chloride and found that thiosemicarbazones **1S** N-2 substituted lead to 1,2,4-triazoline **2S** and/or to 1,3,4-thiadiazoline **3S** heterocyclic rings depending on the nature of the aldehyde residue **A**.

Scheme 1



1-3O, X = O
1-3S, X = S

A = Me, CO_2Et, Ar
R^2 = H, Me
R^4 = H, Ar

In order to gain further information on the course of the oxidative cyclization reaction, we have studied the behaviour of some aldehyde semicarbazones **1Oa-i** with different cyclizing agents such as a ferric chloride in ethanol, lead tetraacetate in acetic acid, and cupric and ferric perchlorate in acetonitrile. The aforesaid cyclizing agents have been chosen because some of them, *i.e.* ferric chloride [1,4] and lead tetraacetate [5,6], were previously used in the cyclization reactions of aldehyde semi- and thiosemicarbazones. Further, there are such differences among the four systems used that we foresaw that the regiochemistry and/or reactivity might significantly change.

The oxidation of benzaldehyde and/or thiophenaldehyde semicarbazones was previously performed with various cyclizing agents. Formation of the 1,3,4-oxadiazole ring **3O** was observed with sodium hypobromite [7], iodine-potassium iodide in aqueous sodium carbonate [8], lead tetraacetate in acetic acid [5,6], lead dioxide in acetic or formic acids [9] and bromine in acetic acid containing sodium acetate [5,10], as the oxidant. Cyclization of semicarbazones leading to triazole ring **2O** was observed with ferric chloride in ethanol [4] or bromine in acetic acid [5] as oxidant.

Results.

Formally the oxidative cyclization of the aldehyde semicarbazones **1Oa-i** could lead to 1,2,4-triazoline-5-one derivatives **2Oa-i** and to the 1,3,4-oxadiazoline **3Oa-i** derivatives. However, data reported in Table show that only the formation of compounds **2O** has been observed independently of the cyclizing agent.

This result is different from that obtained by the corresponding thiosemicarbazones **1S** which gave either 1,2,4-triazoline-5-thione **2S** and 1,3,4-thiadiazoline **3S** derivatives or derivatives of this latter ring [1]. Further it should be noted that the route to the cyclization reaction of semicarbazones with ferric chloride seems to be unrelated to the structure of the starting compounds. In fact, the formation of 1,2,4-triazole **2O** (R^2 = R^4 = H) was also observed in the reaction of semicarbazones **1O**, unsubstituted on the N-2 nitrogen atom, with ferric chloride [4]. In contrast the ring formation induced by lead tetraacetate is dependent on the structure of the aldehyde semicarbazones [6]. In fact, the formation of 1,3,4-oxadiazole **3O** (R^2 = R^4 = H) had been observed in the reaction of com-

Table

Yields of 1,2,4-Triazole Derivatives **20a-i**

20	A	R^2	R^4	$FeCl_3$		$Pb(OAc)_4$		$Cu(ClO_4)_2$		$Fe(ClO_4)_3$	
				time hours	%	time hours	%	time minutes	%	time minutes	%
a	Me	Me	Ph	2 1/2	72	5	–[a]	1	87	1	82
b	CO_2Et	Me	Ph	18	–	2 1/2	52	1440	8	240	–
c [b]	Ph	Me	Ph	8 1/2	54	8 1/2	52	2	83	20	71
d	*p*-$MeOC_6H_4$	Me	Ph	6	58	2	74	1	86	1	53
e	*p*-MeC_6H_4	Me	Ph	6	68	2	64	1	83	1	64
f	*p*-$NO_2C_6H_4$	Me	Ph	6	–	4	45	60	69	240	44
g	Ph	Me	*p*-$MeOC_6H_4$	6	66	2	70	1	50	1	45
h	Ph	Me	*p*-MeC_6H_4	6	50	2	45	1	94	1	40
i	Ph	Me	*p*-$NO_2C_6H_4$	6	–	2	30	20	10 [c]	20	5 [c]

[a] The only isolated product (yield 67%) was acetanilide. [b] $FeCl_3$ in CH_3CN, 5 hours 75%. [c] Unisolated by-products were present in the mixture of reaction.

pounds **1O**, unsubstituted on the N-2 nitrogen atom, with lead tetraacetate.

Some considerations are necessary in order to explain the regiochemistry of heterocyclization of aldehyde semicarbazones.

If the regiochemistry of the studied reaction dependent only on the different nucleophilicity of the oxygen and nitrogen atoms of functional groups (C=**O**, CO-**N**) of semicarbazone derivatives, the substitution of the hydrogen atom for a methyl group on N-2 should not cause variation of the regiochemistry because the above substitution should not be able to change the order of nucleophilicity of the two atoms.

If the regiochemistry of the heterocyclization reaction depended only on thermodynamic factors, then the more aromatic [11] 1,2,4-triazo ring **2O** should always be obtained.

Further, it should be noted that the effect of cyclizing agent on regiochemistry cannot be explained by means either of the nucleophilicity of functional groups or of the stability of the heterocyclic rings.

Data reported in the Table show that the oxidizing agents used did not affect the regiochemistry of heterocyclization but they do influence a variation in the semicarbazone reactivity and also in the yield of the reaction. Among the cyclizing agents used, lead tetraacetate was slightly more efficient than ferric chloride, while acetonitrile solutions of ferric or cupric perchlorate displayed a strong increase of the reactivity.

The oxidation of semicarbazones **1O** with lead tetraacetate requires some remarks. Compounds **1Oa** did not give heterocyclization products but only scission products (acetoanilide) were isolated. In contrast to results obtained with other cyclizing agents, semicarbazone **1Ob** was more reactive than semicarbazone **1Oc**. The behaviour, in our opinion, could be due to some specific interaction between the carboxylic group and the oxidizing agent. Data relative to the reaction of semicarbazones **1Oa-c** with ferric chloride or perchlorate and cupric perchlorate show that the compound **1Oa** is the most reactive one, in contrast to **1Ob** which does not undergo cyclization.

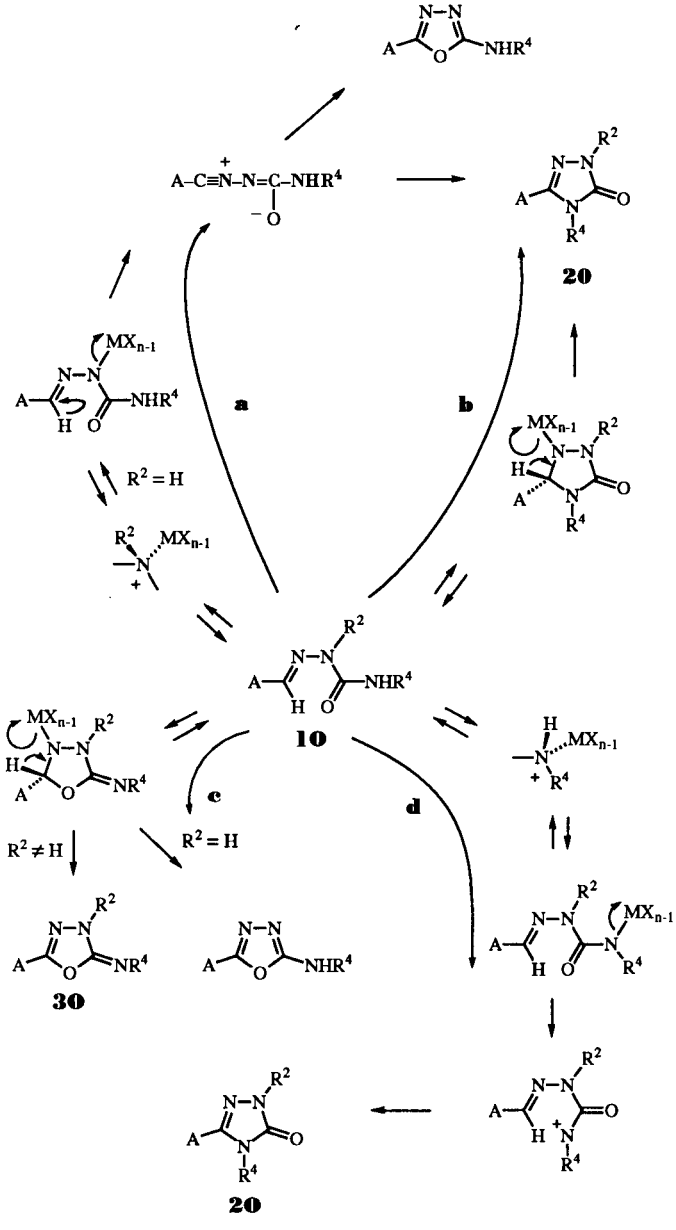
The different reactivity of the semicarbazones **1Oa-c** can be attributed to the different electronic properties of the residue **A** linked to the aldehyde carbon atom. So the reactivity of semicarbazones increases when **A** is a group able to increase the electronic density on the C=N double bond, for example methyl or phenyl groups. In contrast the reactivity of semicarbazones decreases when **A** is an electron-withdrawing group, for example a carboxylic group. The above behaviour was confirmed by studying the reactivity of the semicarbazones of some substituted benzaldehydes **1Oc-f**.

It is interesting to note that the reactivity of semicarbazones is also influenced by variation of the electronic density on the N-4 nitrogen atom. In fact, semicarbazones **1Og,h** having an electron-donating (OMe) or -repelling (Me) substituent on the phenyl group linked to N-4, are more reactive than semicarbazones **1Oc,i** bearing a phenyl group either unsubstituted, **1Oc**, or substituted with an electron-withdrawing substituent, **1Oi**. The fact that substrate activation can be obtained by similar substitution on either the aldehyde phenyl group or the N-4 phenyl group implies that the simple nucleophilic attack of the N-4 nitrogen atom on the C=N double bond cannot be the only rate determining step of the reaction. If nucleophilic attack was the only determing step of the heterocyclization reaction, a residue **A** able to decrease the electron-density on the C=N double bond should have a

substrate activation effect, *i.e.* just the opposite of what we observed.

The fact that the cyclizing agent causes a variation of the reactivity of semicarbazones indicates that the metallic salt is operative in a rate determining stage of the oxidative cyclization. However, the effect of oxidizing agents is not easy to explain. The oxidation potential [12] of iron(III) is higher than that of copper(II), but the latter is slightly more efficient than the former. Further the result of the oxidation of **10c** with an acetonitrile solution of ferric chloride (see Table) seems to indicate that also the anionic species of the metallic salt plays a role in the heterocyclization reaction of semicarbazones. Some pathways through which the oxidation of semicarbazones **10** may occur are shown in Scheme 2.

Scheme 2



The mechanism through which the oxidation of unsubstituted semicarbazones occurs consists of reversible electrophilic attack of the metallic acid on the basic N-2 nitrogen atom, reversible deprotonation followed by oxidation into nitrilimine intermediate which rapidly cyclizes (route **a**). When the N-2 nitrogen atom carries a methyl group mechanism **a** could in principle still occur by demethylation but surely alternative pathways are faster. Gibson [10] suggested the formation of a nitrilimine intermediate as the product-governing species in the reaction of semicarbazones with bromine. Butler [13] invoked a 1,5-electrocyclization or a 5-endo dig type process of a nitrilimine species in the formation of the 1,3,4-oxadiazole ring by reaction of semicarbazones with lead tetraacetate. It should be noted that route **a** does not seem to be able to explain the fact that the semicarbazone of the benzaldehyde gives the 1,3,4-oxadiazole with lead tetraacetate and 1,2,4-triazole with ferric chloride.

Different pathways (routes **b** and **c**) through which the cyclization of semicarbazones may occur consist in the reversible formation of cyclic intermediates followed by oxidation to triazole derivatives (route **b**) or oxadiazolo derivatives (route **c**). However, two observations suggest dismissing this idea. The first one is that, in contrast to thiosemicarbazones [1], no evidence exists of the presence of a cyclic structure of semicarbazones in acid solution. The second observation is related to the effect of the substituents. An electron-withdrawing group **A** should favour both the formation of a cyclic intermediate (nucleophilic attack on the C=N double bond) and the oxidation step (rupture of C-H and M-N bonds). In practice the observed effect of such a group **A** is exactly the opposite. An alternative mechanism which might explain the experimental data is route **d**. This consists of: (i) reversible electrophilic attack of metallic acid on the N-4 nitrogen atom; (ii) reversible deprotonation of the salt; (iii) heterolytic rupture of the M-N bond with formation of a nitrogen electrophilic cation; (iv) cyclization due to electrophilic attack of a nitrogen cation on the C=N double bond. The formation of an amino cation, $ArN^{\pm}$, has been suggested in the oxidation of thiosemicarbazones, of 2,4,6-tris(1,1-dimethylethyl)aniline [14] and also in the solvolysis of substituted *N*-chloroanilines [15]. The stages i and iii are favoured by groups R^4 able to delocalize a positive charge on the nitrogen atom. Stage iv is favoured by the presence of groups **A** able to increase the electron density on the C=N double bond. So if both stages iii and iv are rate determining, the observed effects of substituents and oxidizing agents are consistent with the above mechanism.

The different regiochemistry observed in the oxidation of the benzaldehyde semicarbazone with ferric chloride

and lead tetraacetate solutions may be explained considering that the routes **a** and **d** are in competition in the case of the reaction of unsubstituted semicarbazones.

Finally, the differences observed in oxidative cyclization of semi- and thiosemicarbazones can be attributed to the higher nucleophilicity of sulphur as compared to that of oxygen. Accordingly in the case of thiosemicarbazone heterocyclization, route **c** (attack of sulphur on C=N double bond) can effectively compete with route **d**.

EXPERIMENTAL

Melting points were determined with a Kofler hot-stage apparatus and are uncorrected; ir spectra (nujol mull) were recorded on a Perkin-Elmer infrared spectrophotometer (model 297); uv spectra (ethanol) were determined with a JASCO 7800 spectrophotometer; ^{1}H nmr spectra were recorded on a Bruker AC-E Series 250 MHz spectrometer. Chemical shifts are reported as δ values (ppm) relative to TMS as internal standard. Flash chromatography was performed on Merck silica gel (0.040-0.063 mm) by using mixtures of cyclohexane-ethyl acetate in varying ratios as the eluent. 2-Methyl-4-phenylsemicarbazide and the corresponding semicarbazone of benzaldehyde **10c** were prepared by methods described in the literature [16] as follows.

General Method for the Preparation of Semicarbazides.

To a stirred solution of methylhydrazine (50 mmoles) in anhydrous benzene (25 ml) an equimolar amount of phenylisocyanate, in anhydrous benzene (50 ml), was added dropwise at room temperature. After standing overnight semicarbazide was filtered off.

2-Methyl-4-(*p*-methoxyphenyl)semicarbazide.

This compound was obtained in a yield of 81%, mp 104° [17]; ir: 3370, 3300, 3200 (NH), 1640 (C=O) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 3.02 (s, 3H NCH_3), 3.69 (s, 3H OCH_3), 4.73 (s, 2H NH), 6.79, 7.42 (2d, 4H AB J = 8.86 Hz *p*-$MeOC_6H_4$), 8.81 (s, 1H NH).

2-Methyl-4-(*p*-methylphenyl)semicarbazide.

This compound was obtained in a yield of 80%, mp 138-140° [17]; ir: 3340, 3310, 3200 (NH), 1640 (C=O) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 2.21 (s, 3H *p*-CH_3), 3.02 (s, 3H NCH_3), 4.75 (s, 2H NH), 7.02, 7.40 (2d, 4H AB J = 8.33 Hz *p*-MeC_6H_4), 8.87 (s, 1H NH).

2-Methyl-4-(*p*-nitrophenyl)semicarbazide.

This compound was obtained in a yield of 87%, mp 195-196° [17]; ir: 3360, 3330, 3310 (NH), 1730 (C=O) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 3.07 (s, 3H NCH_3), 4.91 (s, 2H NH), 7.88, 8.12 (2d, 4H AB J = 8.33 Hz *p*-$NO_2C_6H_4$), 9.70 (s, 1H NH).

General Method for the Preparation of Semicarbazones **1O**.

To a stirred solution or suspension of semicarbazide (3 g) in hot ethanol (50 ml), acidified with acetic acid (2 ml), an equimolar ethanol solution (40 ml) of carbonyl compounds was added portionwise. After stirring overnight semicarbazones was collected, washed with water then crystallized from ethanol.

2-Methyl-4-phenylsemicarbazone of Acetaldehyde (**1a**).

This compound was obtained in a yield of 83%, mp 63-64°; ir: 3370 (NH), 1670 (C=O) cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 2.06 (d, 3H J = 5.18 Hz CH_3-CH=), 3.25 (s, 3H NCH_3), 6.92 (q,1H J = 5.18 Hz CH_3-C*H*=), 7.03 (t, 1H J = 7.77 Hz ArH), 7.29 (t, 2H J = 7.77 Hz ArH), 7.52 (d, 2H J = 7.77 Hz ArH), 8.67 (s, 1H, NH).

Anal. Calcd. for $C_{10}H_{13}N_3O$: C, 62.81; H, 6.85; N, 21.97. Found: C, 62.61; H, 6.88; N, 22.27.

2-Methyl-4-phenylsemicarbazone of Ethyl Glyoxylate (**1b**).

This compound was obtained in a yield of 80%, mp 76-77°; ir: 3460, 3420, 3260 (NH), 1700 (C=O) cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 1.38 (t, 3H OCH_2CH_3 J = 7.0 Hz), 3.36 (s, 3H NCH_3), 4.35 (q, 2H OCH_2CH_3 J = 7.0 Hz), 6.91 (s, 1H CH), 7.09 (t, 1H J = 7.2 Hz 1H ArH), 7.34 (t, 2H J = 7.2 Hz ArH), 7.54 (d, 2H J = 7.2 Hz ArH), 8.87 (s, 1H NH).

Anal. Calcd. for $C_{12}H_{15}N_3O_3$: C, 57.82; H, 6.07; N, 16.86. Found: C, 57.93; H, 6.04; N, 16.50.

2-Methyl-4-phenylsemicarbazone of *p*-Methoxybenzaldehyde (**1d**).

This compound was obtained in a yield of 97%, mp 121°; ir: 3360 (NH), 1670 (C=O) cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 3.42 (s, 3H NCH_3), 3.86 (s, 3H *p*-OCH_3), 6.96, 7.62 (2m, 4H AA'BB' J = 8.74 Hz *p*-$MeOC_6H_4$), 7.00-7.10 (m, 1H ArH), 7.29-7.37 (m, 2H ArH), 7.50-7.58 (m, 2H ArH + 1H CH), 8.77 (s, 1H NH).

Anal. Calcd. for $C_{16}H_{17}N_3O_2$: C, 67.83; H, 6.05; N, 14.83. Found: C, 67.95; H, 6.01; N, 14.75.

2-Methyl-4-phenylsemicarbazone of *p*-Methylbenzaldehyde (**1e**).

This compound was obtained in a yield of 86%, mp 142°; ir: 3360 (NH), 1675 (C=O) cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 2.40 (s, 3H *p*-CH_3), 3.42 (s, 3H NCH_3), 7.00-7.10 (m, 1H ArH), 7.20-7.26 (m, 2H AA'BB' J = 7.40 Hz *p*-MeC_6H_4), 7.29-7.38 (m, 2H ArH), 7.53-7.60 (m, 2H ArH, overlapped with 2H AA'BB' *p*-MeC_6H_4), 7.57 (s, 1H CH), 8.79 (s, 1H NH).

Anal. Calcd. for $C_{16}H_{17}N_3O$: C, 71.89; H, 6.41; N, 15.72. Found: C, 71.70; H, 6.47; N, 15.59.

2-Methyl-4-phenylsemicarbazone of *p*-Nitrobenzaldehyde (**1f**).

This compound was obtained in a yield of 88%, mp 216-218°; ir: 3360 (NH), 1675 (C=O) cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 3.48 (s, 3H NCH_3), 7.06-7.15 (m, 1H ArH), 7.31-7.40 (m, 2H ArH), 7.52-7.58 (m, 2H ArH), 7.62 (s, 1H CH), 7.82, 8.30 (2m, 4H AA'BB' J = 8.80 Hz *p*-$NO_2C_6H_4$), 8.66 (s, 1H NH).

Anal. Calcd. for $C_{15}H_{14}N_4O_3$: C, 60.40; H, 4.73; N, 18.78. Found: C, 60.22; H, 4.70; N, 18.85.

2-Methyl-4-(*p*-methoxyphenyl)semicarbazone of Benzaldehyde (**1g**).

This compound was obtained in a yield of 89%, mp 120°; ir: 3370 (NH), 1680 (C=O) cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 3.42 (s, 3H NCH_3), 3.80 (s, 3H *p*-OCH_3), 6.88, 7.45 (2m, 4H AA'BB' J = 8.80 Hz *p*-$MeOC_6H_4$-N), 7.38-7.47 (m, 3H, overlapped with 2H AA'BB', ArH), 7.57 (s, 1H CH), 7.60-7.90 (m, 2H ArH), 8.61 (s, 1H NH).

Anal. Calcd. for $C_{16}H_{17}N_3O_2$: C, 67.83; H, 6.05; N, 14.83. Found: C, 67.78; H, 5.98; N, 14.89.

2-Methyl-4-(*p*-methylphenyl)semicarbazone of Benzaldehyde (**1h**).

This compound was obtained in a yield of 85%, mp 142°; ir: 3370 (NH), 1675 (C=O) cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 2.32 (s, 3H *p*-CH_3), 3.43 (s, 3H NCH_3), 7.13, 7.43 (2m, 4H AA'BB' J = 8.24 Hz *p*-MeC_6H_4), 7.37-7.48 (m, 3H, overlapped with 2H AA'BB', ArH), 7.58 (s, 1H CH), 7.60-7.80 (m, 2H ArH), 8.69 (s, 1H

NH).

Anal. Calcd. for $C_{16}H_{17}N_3O$: C, 71.89; H, 6.41; N, 15.72. Found: C, 71.71; H, 6.46; N, 15.68.

2-Methyl-4-(*p*-nitrophenyl)semicarbazone of Benzaldehyde (**1i**).

This compound was obtained in a yield of 83%, mp 193-194°; ir: 3330 (NH), 1685 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 3.46 (s, 3H NCH_3), 7.42-7.50 (m, 2H ArH), 7.64-7.70 (m, 4H ArH + CH), 7.73, 8.22 (2m, 4H AA'BB' J = 9.17 Hz *p*-$NO_2C_6H_4$), 9.18 (s, 1H NH).

Anal. Calcd. for $C_{15}H_{14}N_4O_3$: C, 60.40; H, 4.73; N, 18.78. Found: C, 60.56; H, 4.75; N, 18.81.

General Method for Oxidative Cyclization of Semicarbazones.

Solutions of 2*M* anhydrous ferric chloride (Carlo Erba) in ethanol, of 1*M* lead tetraacetate (Janssen) in acetic acid, of 2*M* ferric perchlorate hydrate (Carlo Erba) and of 2*M* cupric perchlorate hexahydrate (Aldrich) in acetonitrile were prepared as oxidizing agents. To 5 mmoles of the semicarbazones (solution or suspension) in 50 ml of the appropriate solvent (ethanol, acetic acid or acetonitrile) a solution of the oxidizing agent (6 ml) was added. The mixture was refluxed and after cooling the solvent was removed under reduced pressure. Water (30 ml) was added and the mixture was extracted with chloroform. The organic layer was dried and the chloroform was removed under reduced pressure. The residue was subjected to chromatography with the appropriate eluent.

1,3-Dimethyl-4-phenyl-1,2,4-triazolin-5-one (**2a**).

This compound had mp 104-106° (111-112.5° [18]); ir: 1700 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 2.13 (s, 3H CH_3), 3.49 (s, 3H NCH_3), 7.26-7.31 (m, 2H ArH), 7.41-7.53 (m, 3H ArH); uv: nm λ max (log ε) 228 sh (3.64).

Anal. Calcd. for $C_{10}H_{11}N_3O$: C, 63.48; H, 5.86; N, 22.21. Found: C, 63.61; H, 5.90; N, 22.15.

1-Methyl-3-carboxyethyl-4-phenyl-1,2,4-triazolin-5-one (**2b**).

This compound had mp 126-127°; ir: 1740 (COOEt), 1720 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 1.25 (t, 3H OCH_2CH_3 J = 7.1 Hz), 3.63 (s, 3H NCH_3), 4.29 (q, 2H OCH_2CH_3 J = 7.1 Hz), 7.26-7.31 (m, 2H ArH), 7.45-7.53 (m, 3H ArH); uv: nm λ max (log ε) 264 (3.86).

Anal. Calcd. for $C_{12}H_{13}N_3O_3$: C, 58.29; H, 5.30; N, 16.99. Found: C, 58.40; H, 5.35; N, 16.87.

1-Methyl-3,4-diphenyl-1,2,4-triazolin-5-one (**2c**).

This compound had mp 178-179° (174-175° [15]); ir: 1705 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 3.61 (s, 3H NCH_3), 7.08-7.43 (m, 9H ArH); uv: nm λ max (log ε) 262 (3.98).

Anal. Calcd. for $C_{15}H_{13}N_3O$: C, 71.70; H, 5.21; N, 16.72. Found: C, 71.52; H, 5.18; N, 16.81.

1-Methyl-3-(*p*-methoxyphenyl)-4-phenyl-1,2,4-triazolin-5-one (**2d**).

This compound had mp 139°; ir: 1705 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 3.60 (s, 3H NCH_3), 3.78 (s, 3H *p*-OCH_3), 6.79, 7.23 (2m, 4H AA'BB' J = 8.98 Hz *p*-$MeOC_6H_4$), 7.20-7.26 (m, 2H ArH, overlapped with 2H AA'BB'), 7.37-7.44 (m, 3H ArH); uv: nm λ max (log ε) 266 (4.15).

Anal. Calcd. for $C_{16}H_{15}N_3O_2$: C, 68.31; H, 5.37; N, 14.94. Found: C, 68.5; H, 5.41; N, 14.82.

1-Methyl-3-(*p*-methylphenyl)-4-phenyl-1,2,4-triazolin-5-one (**2e**).

This compound had mp 174°; ir: 1710 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 2.32 (s, 3H *p*-CH_3), 3.60 (s, 3H NCH_3), 7.08, 7.19 (2m, 4H AA'BB' J = 8.10 Hz *p*-MeC_6H_4), 7.21-7.25 (m, 2H ArH), 7.37-7.46 (m, 3H ArH); uv: nm λ max (log ε) 262 (3.96).

Anal. Calcd. for $C_{16}H_{15}N_3O$: C, 72.43; H, 5.70; N, 15.84. Found: C, 72.75; H, 5.64; N, 15.64.

1-Methyl-3-(*p*-nitrophenyl)-4-phenyl-1,2,4-triazolin-5-one (**2f**).

This compound had mp 209-210°; ir: 1700 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 3.65 (s, 3H NCH_3), 7.22-7.28 (m, 2H ArH), 7.21-7.25 (m, 2H ArH), 7.46-7.53 (m, 3H ArH, overlapped with 2H AA'BB'), 8.14 (m, 2H AA'BB' J = 8.49 Hz *p*-$NO_2C_6H_4$); uv: nm λ max (log ε) 318 (3.94).

Anal. Calcd. for $C_{15}H_{12}N_4O_3$: C, 60.81; H, 4.08; N, 18.91. Found: C, 60.69; H, 4.12; N, 19.02.

1-Methyl-3-phenyl-4-(*p*-methoxyphenyl)-1,2,4-triazolin-5-one (**2g**).

This compound had mp 150°; ir: 1695 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 3.61 (s, 3H NCH_3), 3.83 (s, 3H OCH_3), 6.92, 7.14 (2m, 4H AA'BB' J = 6.76 Hz *p*-$MeOC_6H_4$), 7.24-7.37 (m, 5H ArH); uv: nm λ max (log ε) 261 (4.07).

Anal. Calcd. for $C_{16}H_{15}N_3O_2$: C, 68.31; H, 5.37; N, 14.94. Found: C, 68.52; H, 5.34; N, 14.85.

1-Methyl-3-phenyl-4-(*p*-methylphenyl)-1,2,4-triazolin-5-one (**2h**).

This compound had mp 165°; ir: 1700 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 2.38 (s, 3H *p*-CH_3), 3.61 (s, 3H NCH_3), 7.11, 7.22 (2m, 4H AA'BB' J = 8.34 Hz *p*-MeC_6H_4), 7.25-7.39 (m, 5H ArH); uv: nm λ max (log ε) 261 (3.98).

Anal. Calcd. for $C_{16}H_{15}N_3O$: C, 72.43; H, 5.70; N, 15.84. Found: C, 72.49; H, 5.75; N, 15.77.

1-Methyl-3-phenyl-4-(*p*-nitrophenyl)-1,2,4-triazolin-5-one (**2i**).

This compound had mp 199-200°; ir: 1705 (C=O) cm^{-1}; ^1H nmr (deuteriochloroform): δ 3.62 (s, 3H NCH_3), 7.42, 8.27 (2m, 4H AA'BB' J = 9.1 Hz *p*-$NO_2C_6H_4$), 7.27-7.39 (m, 5H ArH); uv: nm λ max (log ε) 262 (4.19).

Anal. Calcd. for $C_{15}H_{12}N_4O_3$: C, 60.81; H, 4.08; N, 18.91. Found: C, 60.60; H, 4.12; N, 18.95.

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