PROPRIEDADES DA BASE ÁCIDA DE CETONAS NÃO
SATURADAS OBTIDAS DA REACÇÃO DA 5-FORMIL-8-
HIDROXIQUINOLINA COM ACETOFENONAS P-SUBSTITUÍDAS

ACID-BASE PROPERTIES OF α,β -UNSATURATED KETONES OBTAINED
FROM REACTION OF 5-FORMYL-8-HYDROXYQUINOLINE WITH P-SUBSTITUTED
ACETOPHENONES

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RESUMO

Chalconas (cetonas α,β -insaturadas) contendo radicais aromáticos ou heterocíclicos são altamente reativas, permitindo a síntese de novos compostos orgânicos. Neste estudo, as constantes de dissociação (pKa) de sete calconas derivadas de 8-hidroxiquinolina foram determinadas e a influência na dissociação de substituintes no grupo (-CH₃, -OCH₃, -N(CH₃)₂, -Cl, -Br, e -NO₂) foi analisado. Os valores de pKa são importantes porque determinam o pH ao qual os ligantes são totalmente desprotonados - quando mostram suas propriedades quelantes máximas - e determinam as interações dos ligantes em diferentes valores de pH. Os pKa de chalconas foram calculados por espectroscopia ultravioleta visível em uma mistura de água-etanol (1: 1) usando a equação de Henderson-Hasselbach. Foi demonstrado que o fragmento 8-hidroxiquinolico tem um grande efeito doador de elétrons no sistema π das chalconas. A introdução de substituintes (R) no fragmento fenílico das chalconas afetou levemente a dissociação do grupo hidroxila e a protonação do nitrogênio no fragmento hidroxiquinolina. Os substituintes aceitadores (Cl, Br, NO₂) aumentaram a polaridade de OH⁻ e sua acidez. A protonação de nitrogênio diminuiu as propriedades doadoras de elétrons desse fragmento, e a desprotonação do hidroxila causou o efeito oposto. A introdução de substituintes no fragmento fenílico afetou levemente a dissociação do grupo hidroxila e a protonação do nitrogênio.

Palavras-chave: cetonas α,β -insaturadas, chalconas, 8-hidroxiquinolina, constantes de dissociação

ABSTRACT

Chalcones (α,β -unsaturated ketones) containing aromatic or heterocyclic radicals are highly reactive, allowing the synthesis of novel organic compounds. In this study, the dissociation constants (pKa) of seven chalcones derived from 8-hydroxyquinoline were determined and the influence on dissociation of substituents in the phenyl group (-CH₃, -OCH₃, -N(CH₃)₂, -Cl, -Br, and -NO₂) was analysed. pKa values are important because they determine the pH at which ligands are fully deprotonated -when they show their maximum chelating properties- and determine the ligands interactions at different pH values. The chalcones' pKa's were calculated by visible ultraviolet spectroscopy in a water-ethanol (1:1) mixture using the Henderson-Hasselbach equation. It was shown that the 8-hydroxyquinolinic fragment has a large electron donor effect on the π system of the chalcones. The introduction of substituents (R) in the phenyl fragment of the chalcones slightly affected the dissociation of the hydroxyl group and the protonation of the nitrogen in the hydroxyquinoline fragment. The acceptor substituents (Cl, Br, NO₂) increased the polarity of OH⁻ and its acidity. Nitrogen protonation decreased electron donor properties of this fragment, and deprotonation of the hydroxyl caused the opposite effect. Substituents introduction in the phenyl fragment slightly affected hydroxyl group dissociation and nitrogen protonation.

Keywords: α,β -unsaturated ketones, chalcones, 8-hydroxyquinoline, dissociation constants

INTRODUCTION

Chalcones containing aromatic or heterocyclic radicals have attracted the attention of researchers mainly due to their high reactivity, which allows the synthesis of new organic compounds (Khalil *et al.*, 1988; Kovtun *et al.*, 2003; Kovtun *et al.*, 2004). These chalcones can be prepared from 8-hydroxyquinoline (Figure 1), which transfers them its chelating properties:

Figure 1. Structure of 8-hydroxyquinoline

The atoms responsible for its chelating properties are the oxygen and nitrogen, with which it forms complexes, oxyquinolinates, with many elements. 8-Hydroxyquinoline, as a weak base in acid medium, is strongly protonated and found in cationic form, while the concentration of the anionic form is low. However, many metals react, even in an acid medium, with 8-hydroxyquinoline substituting the hydroxyl hydrogen, forming a coordinated bond with the nitrogen producing a stable five-member cyclic chelate (Figure 2) (Vinogradov and Elinson, 1979):

Figure 2. Metal complexes (Me) with 8-hydroxyquinoline (left), quinoline (centre) or α -naphthol (right).

These complexes are more stable than those of quinoline or α -naphthol. This shows that the stability of oxyquinolinates is determined by both groups ($-N =$ or $R-OH$), which form a cyclic chelate (Vinogradov and Elinson, 1979).

8-hydroxyquinoline is one of the most used organic reagents in analytical chemistry and its interaction with more than half of the elements of the periodic table, metals and non-metals, has been studied (Daneshfar *et al.*, 2012; Ahmed *et al.*, 1998). 8-hydroxyquinoline was proposed as an analytical reagent (Hahn, 1926; Hahn *et al.*, 1927; Berg, 1927a, 1927b). Modified silica gel was used to anchor 8-hydroxyquinoline using 5-

formyl-8-hydroxyquinoline as reagent; the modified silica was applied to the preconcentration of metals and its determination by flame atomic absorption spectrometry (Goswami *et al.*, 2003).

8-hydroxyquinoline and its derivatives arise interest for their coordination capacity and their use as metal ion chelators and are precursors for obtaining metallochromic dyes that change their hue depending on the bound metal or pH and can be used as indicators for complexometric or acid-base titrations. The so-called merocyanine dyes and their complexes with transition metal ions have been obtained from 5-formyl-8-hydroxyquinoline (Kovtun *et al.*, 2003; Kovtun *et al.*, 2004). At the same time, the conjugation of the hydroxyquinoline fragment and the highly reactive enonic fragment in chalcones opens up a broad perspective for the synthesis of new organic compounds with expedited chelating properties (Khalil *et al.*, 1988; Kovtun *et al.*, 2003; Kovtun *et al.*, 2004).

Complexometry still arise attention in the scientific community and numerous metals continue to be determined using various chelators (Dapporto *et al.*, 2000; Ambrosi *et al.*, 2007; Ambrosi *et al.*, 2009). Although many derivatives have been used as chelators in different types of titration, there are no known applications of these chalcones as chelators for any type of titration. Metal titrations by complexometry traditionally use ethylenediaminetetraacetic acid (EDTA) when the metal concentrations are 0.001 M or greater; these titrations have the advantage that EDTA has a low environmental impact, is economical, easy to handle and stable. In addition, complexation reactions with EDTA are rapid, stoichiometric and quantitative, and their formation constants are generally high, which produces sharp titration curves. However, EDTA is not selective because titrations determine the total concentration of all the metals and usually cannot titrate solutions with a concentration of less than 0.001 M. In addition, most indicators are unstable, they bind irreversibly with some metals, so they must be back titrated (Skoog *et al.*, 2014) and have unclear colour changes. For these reasons, new chelators for complexometric titrations are always welcome in analytical chemistry. Other applications of these chelators are masking and preconcentration, extracting metals from a large aqueous phase volume to a smaller organic phase volume and oxidation-reduction reactions that produce coloured

compounds that can be determined spectrophotometrically (Worsfold *et al.*, 2013).

1.1 Determination of dissociation constants

The most convenient method to determine dissociation constants is potentiometric titration (Albert, 2012). The spectrophotometric method is useful for poorly soluble substances, as well as for working with very small or very large pH values, where the use of glass electrodes is useless. This method can be used only when the substance absorbs light outside the absorption maxima of its ionic forms (Bates and Vijh, 1973). In general, the absorption spectra of acids or organic bases depend on the solution pH because the spectra of the ionic forms differ from those of the neutral ones. When a base B is dissolved in an acidic medium, AH, the following equilibrium is established:

The degree of transition from B to BH⁺ depends on the solution's pH and on the acid-base strengths of B and AH. The quantitative characteristic of the base strength is the basicity constant, that is, the equilibrium constant of the ionization reaction of the base, which measures its ability to accept a proton. Ionization is a process of equilibrium administered by the law of mass action; it is possible to characterize this process by means of the dissociation constant of BH⁺, the conjugate acid of base B (Alexandrov, 1981):

$$K_a = \frac{a_{\text{H}^+} a_{\text{B}}}{a_{\text{BH}^+}} \quad (\text{Equation 2})$$

Where a is the activity of the species. Equation 2 yields the Henderson-Hasselbach equation:

$$pK_a = pH - \log \frac{a_{\text{B}}}{a_{\text{BH}^+}} \quad (\text{Equation 3})$$

To find the ratio of the activities of the base and the conjugate acid, the spectrophotometric method is used, provided that the absorption of the base differs from that of the conjugate acid. At any wavelength the absorbance of the solution is the sum of the

absorbances of the species present:

$$A = \varepsilon_{\text{B}} C_{\text{B}} l + \varepsilon_{\text{BH}^+} C_{\text{BH}^+} l \quad (\text{Equation 4})$$

Where ε is the molar absorptivity; C the molar concentration and l the thickness of the solution layer or size of the absorption cell. According to Equation 4, the ratio of the concentration of the base and the conjugate acid can be described by:

$$\frac{C_{\text{B}}}{C_{\text{BH}^+}} = \frac{A_{\text{A}^-} - A}{A - A_{\text{HA}}} \quad (\text{Equation 5})$$

For diluted solutions, the ratio of the activities is equal to the ratio of the molar concentrations; replacing (5) in (3) we obtain:

$$pK_a = pH + \log \frac{A_{\text{A}^-} - A}{A - A_{\text{HA}}} \quad (\text{Equation 6})$$

Equation 6 is valid for any wavelength except for those that correspond to the isosbestic point of the system and is the main equation for all the spectrophotometric pKa determinations. For pKa calculation, the molar absorptivities of the base and the conjugated acid at a random wavelength are required, and the absorbance, concentration and pH, at the same wavelength (Bernstein and Kaminsky, 1986).

The absorbance depends on this pH only in a narrow range where the concentrations of both forms are comparable to each other, around pH values similar to the pKa. This limits the pH changes where changes in absorption can be observed, depending on the sensitivity of the instrument. The determination of pKa using Equation 6 is carried out in several stages. The spectra of the molecule and the ionic species must be obtained at the analytical wavelength. Normally, it is the wavelength in which the absorption difference of the two species, neutral and ionic, is maximum; for example, the maximum absorption of only one of the forms, either neutral or ionic. Sometimes, a series of wavelengths is used to improve accuracy; more often, one is used where $\varepsilon_{\text{B}} > \varepsilon_{\text{BH}^+}$ and another where $\varepsilon_{\text{B}} < \varepsilon_{\text{BH}^+}$. With the selected wavelengths, the values ε_{B} and $\varepsilon_{\text{BH}^+}$ are determined (Bernstein and Kaminsky, 1986).

To determine pK_a accurately, it is necessary to prepare a series of buffered solutions with a certain pH value. The absorption spectra are obtained at the same temperature of pH measurement. The calculated values of pK_a in the series should be discarded if their variation exceeds ± 0.06 . The equilibrium constants of a reaction depend on the temperature, so it must be kept constant in the laboratory. The constants calculated in this way are not thermodynamic values, pK_a^T . To obtain thermodynamic constants the ionic strength of the solution, I , must be taken into account. At 20 °C, the correction is obtained with the following equation (Bernstein and Kaminsky, 1986):

$$pK_a = pK_a^T \pm \frac{0.5\sqrt{I}}{1 + 1.6\sqrt{I}} \quad (\text{Equation 7})$$

Where the negative sign is for acids, and the positive for bases.

The spectrophotometric method for the determination of the acid-base equilibrium is easy if ϵ_B and ϵ_{BH^+} , at any wavelength, are significantly different and there are no environmental effects, that is, if there are no shifts of absorption bands and changes in ϵ_B and ϵ_{BH^+} not related to protonation. If these conditions are not met, special pK_a measurement techniques are required (Bernstein and Kaminsky, 1986).

The present work investigates the acid-base equilibria of chalcone derivatives obtained from 5-formyl-8-hydroxyquinoline, with scarce references in the literature, limited to our studies (Marrugo-González *et al.*, 2012, 2015, 2016).

MATERIALS AND METHODS

The methodology for the synthesis of chalcone **4a-g** derivatives (Figure 3) has been reported, as well as the physicochemical, antifungal and NMR, UV-vis and IR spectra of these substances (Marrugo-González *et al.*, 2012). A summary of the synthesis and the IUPAC name for **4a** are presented in electronic supplementary information.

2.1 Spectrophotometric titration

The dissociation constants were measured in a water-ethanol mixture (1:1). pH was controlled with a glass electrode. Solutions of the organic

ligands (chalcones **4a-g**, about 10^{-5} M) were prepared adding sulfuric acid or NaOH to obtain the neutral, protonic and anionic species. The absorption spectra were taken at each pH.

Figure 3. Synthesis of chalcones **4a-g**. R = -CH₃, -OCH₃, -N(CH₃)₂, -Cl, -Br, and -NO₂ for compounds **4a**, **4b**, **4c**, **4d**, **4e**, **4f** and **4g**, respectively (Marrugo-González *et al.*, 2012).

2.2 Calculation of dissociation constants

Dissociation constants were calculated with the software TITR (A.O. Doroshenko, Institute of Chemistry, National University of Karazin, Ukraine), specially designed for these purposes. TITR implements the Fletcher-Powell algorithm by the nonlinear least squares method with the minimization of the sum of the squares of the deviations between experimental and calculated absorbances. For the analysis, 20-25 wavelengths were selected. Then, the software calculates the values of the constants simultaneously to 20-30 "sectors" of each series of spectra with an iterative method (Bernstein and Kaminsky, 1986) using Equation 6. The basis of the calculation is the selection of the sigmoidal curve, calculated according to Equation 6, which best matches the curve obtained with the experimental points. The degree of concordance of the curves is determined by the correlation coefficient between the experimental data and the theoretical curve that, after the iterations, should yield 0.990-0.999. Input files were typed by hand.

From Equation 6 we find equations 9 and 10 that yield the values of the dissociation constants:

$$A_{HA^-} = A + (A - A_{H_2A}) \cdot 10^{(pK_{a1} - pH)} + (A - A_{A^{2-}}) \cdot 10^{(pH - pK_{a2})} \quad (\text{Equation 8})$$

$$pK_{a1} = -\log \left[\frac{A_{H_2A} - A}{(A - A_{A^{2-}}) \cdot 10^{(pH - pK_{a2})} + A - A_{HA^-}} \right] + pH \quad (\text{Equation 9})$$

$$pK_{a2} = -\log \left[\frac{(A - A_{HA^-}) \cdot 10^{(pH - pK_{a1})} + A - A_{H_2A}}{(A_{A^{2-}} - A) \cdot 10^{(pH - pK_{a1})}} \right] + pH \quad (\text{Equation 10})$$

Where A_{H_2A} , A_{HA^-} y $A_{A^{2-}}$, are the absorbances of the solutions if there were only H_2A , HA^- and A^{2-} (for example, $A_{H_2A} = \varepsilon_{H_2A} C_0 l$) and A is the total solution absorbance at each of the pH values of the experiment (from 1 to 7),

$$A = l \sum_{i=1}^m \varepsilon_i C_i \quad (\text{Bernstein and Kaminsky, 1986}).$$

Standard deviations and confidence intervals were determined for the constants according to the student's t criterion with $p = 95\%$. The constants were weighted averaged for each of the wavelengths as statistical weights.

2.3 Materials, instruments and reagents

Merck and MolLabs reagents, analytical grade ($\geq 98\%$) were used. For absorptiometric titrations, a S2100 UV⁺ Cole Parmer spectrophotometer and an Orion 940 potentiometer with a glass electrode for pH measurements were used. The potentiometer was calibrated with aqueous buffer solutions (pH 4.01, 6.86, 9.18, 12.45).

RESULTS AND DISCUSSION

Table S1 (electronic supplementary information) shows the boiling temperature, formula, percentage of nitrogen and spectral properties of chalcones **4a-g** and the reaction yield of their synthesis. The structure of chalcones **4a-g** is given in the Experimental section.

Molecules **4a-g** possess at least two acid-base centres: the nitrogen atom, capable of accepting a hydrogen ion, as well as the

hydroxyl, capable of dissociating. Compound **4d** also contains a dimethylamino substituent on the phenyl fragment, capable of protonation. By increasing the acidity of solutions of **4a-g**, the proton is bound to the nitrogen and the intensity of the band corresponding to the neutral form of **4a-g** decreases (~ 390 nm, Figures 4 and 5, and Table 1) due to the reduction of the charge transfer from the nitrogen to the conjugated system.

Figure 4. Chalcone **4e** absorption spectra at pH values from 1 to 7

Figure 5. Absorption spectrum of chalcone **4d** by increasing the acidity of the solution from pH 1-7 (indicated by the arrows).

The dissociation constants of chalcones **4a-4d** are in a narrow range of values, 3.1 ± 0.1 (Table 1). This is a further confirmation that the phenyl and hydroxyquinolinic fragments are cross-conjugated (Figure 6) and hardly affect each other. In other words, the introduction of electron donor or acceptor substituents in the phenyl fragment has little effect on the electron availability of the heteroatoms and, therefore, has little effect on the dissociation constants. Only important differences are observed for chalcone **4d**, with the dimethylamino substituent, one of the

strongest electron donors. The dimethylamino group weakens the acceptor properties of the carbonyl, affecting the charge distribution in the hydroxyquinoline fragment, which is reflected in its pKa values of 3.50 and 9.83, the most basic of the series. The nitro-substituted chalcone, **4g**, also departs from the behaviour of this series due to its strongly electron-accepting character that reduces the charge in the carbonyl group, and attracts the electron density of hydroxyquinoline increasing acidity; this is reflected in its pKa values of 2.64 and 8.5, the most acidic in the series (Table 1).

For **4d**, the shape of the spectra changes mainly by the introduction of the additional proton-acceptor centre of the dimethylamino group. This provides an additional equilibrium, seen in a third pKa (4.0 ± 0.1 , Table 1).

In a conjugated system, the dimethylamino group strengthens the charge transfer and produces a bathochromic shift in the absorption band at long wavelength. In the case of cross-conjugation in **4d**, this influence manifests in a band change of about 1500 cm^{-1} compared with other compounds of this series (Table 1, from 25520 to 24120 cm^{-1} with respect to **4a**). Apparently, for this same reason, no significant spectral changes are recorded when **4d** is protonated (Figure 5). In addition, due to the acceptor property of the carbonyl group, the basicity of the dimethylamino group ($\text{pK}_{\text{a}2}$ 4.0, **4d**, Table 1) decreases compared to dimethylaniline (Figure 6), pK_{a} 4.4 (Alexandrov, 1981).

The influence of the R substituents (Figure 4) on the dissociation of the hydroxyl group is only somewhat significant. The introduction of acceptor substituents (Cl, **4e**; Br, **4f**; and NO_2 , **4g**) increases the polarity of the hydroxyl group, which decreases $\text{pK}_{\text{a}2}$ from 9.26 (**4a**) to 9.1 (**4f**), 9.0 (**4e**) and 8.5 (**4g**). At the same time the electron donor dimethylamino group reduces the mobility of the hydroxyl group protons and increases $\text{pK}_{\text{a}2}$ from 9.26 (**4a**) to 9.36 (**4b**), 9.5 (**4c**) and 9.8 (**4d**) (Table 1).

Table 1. Spectral characteristics and acid-base properties of chalcones **4a-g**

№	R	Species	Absorption		
			λ , nm	$\epsilon \times 10$	pK_{a}
4a	H	Neutral	389	2140	
		Cation	392	1106	3.13 ± 0.05
		Anion	484	3450	9.26 ± 0.07
4b	CH_3	Neutral	384	2360	
		Cation	393	1170	3.18 ± 0.05
		Anion	484	2904	9.36 ± 0.08
4c	OCH_3	Neutral	383	1700	
		Cation	393	1040	3.14 ± 0.02
		Anion	482	2530	9.5 ± 0.1
4d	$\text{N}(\text{CH}_3)_2$	Neutral	414	3391	
		Cation1	415	2340	3.5 ± 0.1
		Cation2	-	-	4.0 ± 0.1
		Anion	481	3160	9.83 ± 0.02
4e	Cl	Neutral	389	2200	
		Cation	393	1380	3.3 ± 0.1
		Anion	495	3840	9.0 ± 0.1
4f	Br	Neutral	390	1280	
		Cation	387	920	3.2 ± 0.1
		Anion	491	1190	9.1 ± 0.1
4g	NO_2	Neutral	400	1860	
		Cation	429	1050	2.6 ± 0.1
		Anion	492	2620	8.5 ± 0.1

Figure S1 (Supplementary information) shows the graph of α values, made with Curtipot, (Gutz, 2018), which indicates the distribution of species of **4d** and **4a** according to pH. The graphs for **4b**, **4c**, **4e**, **4f** and **4g** are similar to **4a**

but with a slight difference in the position of the lines intersections, which indicate when the pH values are equal to the chalcone's pK_a .

Figure 6. Comparison of chalcone 4d with dimethylaniline and cross-conjugation in chalcones **4a-g**.

CONCLUSIONS

The dissociation constants of chalcones **4a-g** were calculated and changes in the wavelengths and intensity of the bands demonstrated that the 8-hydroxyquinoline fragment has an electron donor effect on the π system of the whole molecule. The most important basic centre of **4a-g** was the nitrogen atom of the hydroxyquinoline fragment. Its protonation destroyed the intramolecular hydrogen bridge formed with the hydroxyl group and was reflected only slightly in the electronic distribution of the molecule. On the other hand, deprotonation, accompanied by phenolate formation, caused an increase in electronic properties (the bathochromic effect in the absorption spectra of the anionic forms was greater than 100 nm).

The introduction of substituents (R) in the phenyl fragment slightly affected the dissociation of the hydroxyl group and the protonation of the nitrogen. Acceptor substituents (Cl, Br, NO_2) increased the polarity of the hydroxyl group, which increased the acidity of the hydroxyl proton. Among the electron donor groups, dimethylamino was the one that most decreased the acidity of the hydroxyl proton. These studies are important for the development of new chelating materials. Future studies will aim to

introduce new substituent groups to these chalcones.

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SUPPLEMENTARY MATERIAL

Distribution of species of **4a** and **4d** according to pH values; physicochemical properties of **4a-g** and reaction yields; synthesis of **4a**.

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Supplementary material

Figure S1. Distribution of species of **4a** (top) and **4d** (bottom) according to pH values (Gutz, 2017). The dotted lines indicate when $\text{pH} = \text{pKa}$. R' : dimethylamino fragment in **4d**; R : **4a**, **4b**, **4c**, **4f**, **4g** or **4d** minus the dimethylamino fragment.

Table S1. Physicochemical properties of chalcones **4a-g** and reaction yields (Marrugo *et al.*, 2012).

Species	R	Boil. Temp. °C ⁽¹⁾	% Yield/ hour ⁽²⁾	Formula	%N Experimental/ %N theoretical	v, cm ⁻¹	
						C=O	O-H
4a	H	165	70/8	C ₁₈ H ₁₃ NO ₂	5.09/5.12	1656	3304
4b	CH ₃	162-5	28/7	C ₁₉ H ₁₅ NO ₂	4.84/4.97	1656	3175
4c	OCH ₃	155-7	70/8	C ₁₉ H ₁₅ NO ₃	4.59/4.63	1652	3188
4d	N(CH ₃) ₂	210	23/15	C ₂₀ H ₁₈ N ₂ O ₂	8.80/8.72	1644	3312
4e	Cl	170-2	70/4	C ₁₈ H ₁₂ ClNO ₂	4.52/4.58	1652	3288
4f	Br	186	70/10	C ₁₈ H ₁₂ BrNO ₂	3.95/3.49	1652	3288
4g	NO ₂	205-7	20/22	C ₁₈ H ₁₂ N ₂ O ₄	8.75/8.83	1652	3250

⁽¹⁾ Boiling temperature. ⁽²⁾ Yield after crystallization from ethanol / Reaction time in hours

Synthesis of 3-(8-hydroxyquinolin-5-yl)-1-phenylprop-2-en-1-one (**4a**)

To a solution of (**2**) (0.016 moles) in hot concentrated hydrochloric acid (50 ml) acetophenone (**3**) was added (0.033 moles); the solution was stirred for 8 hours and the precipitate, as hydrochloride, was washed with ether, neutralized with 0.1 mol/L aqueous sodium acetate, and recrystallized from ethanol. Chalcones **4a-g** were obtained by exchanging acetophenone for the corresponding reagent. The reactions were monitored by thin layer chromatography. The chromatograms were developed on Silufol UV-254 plates using acetic acid as diluent. The plates were developed with ultraviolet light or iodine. The structure of the molecules was clarified with UV-VIS, IR and NMR spectroscopy and their purity was demonstrated by measuring their physicochemical parameters and by gas chromatography coupled with mass spectrometry (Marrugo *et al.*, 2012).