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Optimization of Ultrasonic-Assisted Claisen–Schmidt Condensation in Chalcone Synthesis and Its Antioxidant Evaluation

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Abstract: Chalcone (1,3-diphenyl-2-propen-1-one), an important precursor of flavonoids, has attracted considerable interest because of its broad biological potential. This study evaluated the ultrasonic-assisted Claisen–Schmidt condensation of equimolar acetophenone and benzaldehyde (0.04 mol each) using sodium hydroxide as the catalyst. The effects of reaction temperature (30, 40, and 50 °C) and sonication time (10, 20, and 30 min) on product yield were investigated with a 20 kHz ultrasonic bath. The synthesized products were characterized by thin-layer chromatography, melting point determination, FT-IR, UV–Vis, LC–MS/MS, and NMR analyses. Sonication time exerted a greater influence on yield than temperature, with the highest crude yield (91.00%) obtained at 30 °C after 30 min. Spectroscopic analyses confirmed chalcone as the major product; however, the elevated melting point (186.1–186.7 °C), together with TLC and LC–MS/MS results, indicated the presence of co-eluting impurities, suggesting incomplete product purity. Antioxidant activity measured by the DPPH assay produced IC_{50} values ranging from 75.93 to 191.39 µg/mL, with the strongest activity observed under the optimum synthesis condition (30 °C, 30 min), compared with 5.97 µg/mL for ascorbic acid. Considering the weak intrinsic radical-scavenging activity of pure chalcone, the observed antioxidant effect is likely attributable to co-produced impurities rather than chalcone itself. Ultrasonic-assisted synthesis substantially reduced reaction time while achieving a high crude yield. However, further optimization of purification is required to obtain pure chalcone and improve the overall sustainability of the process as a green synthetic approach.

Introduction

Chalcone (1,3-diphenyl-2-propen-1-one) is a flavonoid precursor widely distributed in plants as a secondary metabolite and has attracted considerable attention owing to its diverse biological activities (1). Structurally, chalcone comprises two aromatic rings connected by an α,β-unsaturated carbonyl system, a feature that underlies both its chemical reactivity and its pharmacological properties. Chalcone and its derivatives have been reported to exhibit antioxidant, anti-inflammatory, antidiabetic, antimicrobial, and anticancer activities, positioning them as promising scaffolds for pharmaceutical and nutraceutical development (2, 3).

Several synthetic routes are available for chalcone preparation, including Claisen–Schmidt condensation, Friedel–Crafts acylation, and transition-metal-catalyzed cross-coupling reactions such as Suzuki, Hiyama, and Stille coupling. Among these, Claisen–Schmidt condensation remains the most widely employed method owing to its operational simplicity, mild reaction conditions, and high selectivity. This approach proceeds via a base- or acid-catalyzed aldol condensation between an aromatic aldehyde and an aromatic ketone, typically benzaldehyde and acetophenone (1, 4).

Previous studies have reported the synthesis of chalcone from acetophenone and benzaldehyde in ethanol under conventional magnetic stirring, achieving a yield of 83.39% after 3 h (8), and a yield of 84.98% after 1 h in the presence of NaOH (5). Ultrasonic-assisted synthesis has more recently emerged as a green chemistry alternative capable of enhancing reaction rates and improving yields. Ultrasonication generates acoustic cavitation, producing localized regions of elevated temperature and pressure that intensify molecular collisions and mass transfer between reactants, thereby accelerating the reaction (5, 6). This technique has been applied successfully to the synthesis of chalcone derivatives and related heterocycles, including dimethylaminochalcones and pyrazoline derivatives, affording high conversions within markedly shorter

reaction times of 10–30 min (5, 6).

Although ultrasonication has been shown to reduce reaction time and improve chalcone yield, previous studies have largely focused on yield optimization while overlooking the combined effects of reaction temperature and irradiation time on product purity. In addition, the influence of ultrasonically induced by-products on subsequent bioactivity evaluation remains poorly understood. Acoustic cavitation may promote competing base-catalyzed reactions, including Cannizzaro disproportionation, acetophenone self-aldol condensation, and over-condensation, potentially affecting product purity without introducing new functional groups. Therefore, this study systematically optimizes reaction temperature and irradiation time for ultrasonic-assisted Claisen–Schmidt condensation, characterizes the synthesized chalcone using complementary analytical techniques (TLC, melting point, FT-IR, UV–Vis, LC–MS/MS, and NMR), and evaluates whether the observed antioxidant activity is attributable to chalcone rather than co-formed by-products.

Based on these considerations, this study aimed to optimize the ultrasonic-assisted Claisen–Schmidt condensation of chalcone by varying reaction temperature and time to identify the conditions affording the optimal yield. The synthesized products were further evaluated for antioxidant activity using the DPPH radical-scavenging method, with ascorbic acid as a reference standard. The findings are expected to provide a time-efficient synthetic approach for chalcone preparation and to contribute a more critical framework for interpreting the biological activity of chalcone obtained by ultrasonic methods.

Methodology

Materials and Instrumentation

The materials used in this study, all of analytical grade, comprised benzaldehyde, acetophenone, sodium hydroxide (NaOH), 96% ethanol, methanol, distilled water, silica gel GF254 plates (Merck), and 2,2-diphenyl-1-picrylhydrazyl (DPPH).

The following instruments were employed: an ultrasonic bath (GT Sonic, 20 kHz), a thin-layer chromatography densitometer (Camag TLC Scanner 3), a UV–Vis spectrophotometer (Shimadzu UV-1900), an FT-IR spectrophotometer (Shimadzu FT-IR 8400S), a liquid chromatography-tandem mass spectrometer (Waters Xevo G2-S QTOF), a nuclear magnetic resonance spectrometer (Bruker Avance Neo, 500 MHz), and a melting-point apparatus (Electrothermal).

Procedures Synthesis of Chalcone

Chalcone was synthesized from acetophenone and benzaldehyde used in equimolar amounts (0.04 mol each, corresponding to 4.5 mL acetophenone and 4 mL benzaldehyde), together with 1.6 g of sodium hydroxide as base catalyst. The reagents were combined in a beaker, which was placed centrally within the tank of the ultrasonic bath (GT Sonic, 20 kHz) with its outer wall immersed in and in direct contact with the circulating bath water, and the mixture was subjected to ultrasonic irradiation at 20 kHz for 10, 20, or 30 min. Vessel position relative to the transducers was kept the same for all nine reaction conditions but was not itself varied as an experimental factor; because cavitation intensity is known to depend on this positioning, it is acknowledged as a parameter that should be reported and controlled more systematically in future work. The reaction temperature (30, 40, or 50 °C) was set and maintained using the ultrasonic bath's built-in digital heater and temperature controller, with the displayed bath-water temperature taken as the reference value for each condition; as this reflects the temperature of the circulating bath water rather than a direct, continuous measurement inside the reaction vessel, transient, localized elevation of the internal solution temperature caused by acoustic cavitation cannot be excluded and is acknowledged as a limitation of the temperature-control protocol used here. This gave nine combinations of reaction conditions (**Table 1**). Upon completion of the reaction, the mixture was washed with distilled water until neutral pH, filtered under vacuum through a Büchner funnel, and cooled in a refrigerator for 24 h to promote solidification. The resulting solid was oven-dried for 3 h, ground into a fine powder, and recrystallized from ethanol to obtain the purified product used for yield determination and further characterization.

Synthesis yield was calculated as the ratio of the practical (actual) mass of purified product to the theoretical mass expected from complete conversion of the limiting reagent, multiplied by 100%, as seen in **Equation 1**.

Because acetophenone and benzaldehyde were used in equimolar amounts (0.04 mol each), the theoretical mass was calculated from the molar mass of chalcone (208.25 g/mol), giving a theoretical yield of 8.326 g for each reaction condition.

Reaction progress was monitored by TLC on silica gel GF_{254} plates using ethyl acetate–n-hexane (1: 3, v/v) as the mobile phase over a development distance of 8 cm. Sample solutions (10 mg of synthesized product dissolved in 1 mL of 96% ethanol) were applied as 10 µL spots using a capillary tube. Spots were visualized under a UV254 lamp, and retardation factor (Rf) values were compared with that of the acetophenone reference standard, followed by densitometric analysis (Camag TLC Scanner 3) (7, 8).

Characterization of the Synthesized Compound

Before spectroscopic characterization, the synthesized product was examined for its physical appearance, including color, odor, and solid-state characteristics. Although organoleptic assessment is primarily applied in food analysis, it also serves as a simple preliminary tool in organic synthesis to indicate product identity, as deviations from the expected color or odor may reflect the presence of impurities or side products before instrumental confirmation. The melting point was then determined using the capillary-tube method by packing approximately 5 mm of powdered sample into a capillary

$$\% \text{ Yield} = \left(\frac{\text{Practical mass}}{\text{Theoretical mass}} \right) \times 100\% \quad \textbf{(Eq. 1)}$$

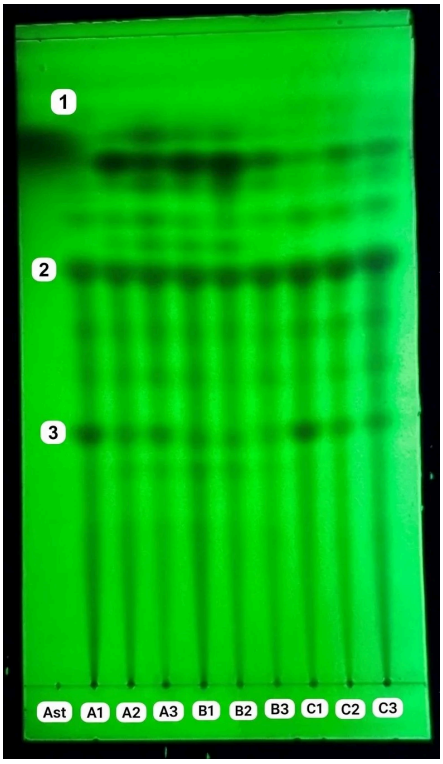


Figure 1. TLC plate showing spots of the synthesized compounds under a UV254 lamp. Note: Ast = acetophenone standard; spot 1 = acetophenone residue; spot 2 = chalcone; spot 3 = by-product.

tube and measuring it with a melting-point apparatus. Functional group analysis was subsequently performed by FT-IR spectroscopy using an attenuated total reflectance (ATR) accessory. Approximately 1 mg of sample was analyzed directly over the spectral range of 4000–600 cm^{-1}.

For UV–Vis analysis, the synthesized compound (5 mg) was dissolved in 5 mL of methanol, and 1.0 mL of this solution was further diluted to 10.0 mL with methanol. The absorption spectrum was recorded over the ultraviolet (200–400 nm) and visible (350–800 nm) ranges, and the maximum absorption wavelength (λmax) was determined and compared with literature values for chalcone.

LC–MS/MS analysis was performed using an ultra-performance liquid chromatography system fitted with a C18 HSS column (1.8 µm, 2.1 × 100 mm) maintained at 50 °C (25 °C ambient), with a mobile phase of water containing 5 mM ammonium formate (A) and acetonitrile containing 0.05% formic acid (B) at a flow rate of 0.2 mL/min over a 23 min run. Samples (5 µL, pre-filtered through a 0.2 µm syringe filter) were analyzed in positive-mode electrospray ionization (ESI+) over a mass range of 50–1200 m/z, with a source temperature of 100 °C.

For NMR analysis, the synthesized compound was dissolved in deuterated methanol (CD_3OD) and analyzed by ^1H- and ^{13}C-NMR spectroscopy at 500 MHz to determine its structure; chemical shifts were referenced to the residual solvent signals of CD_3OD (δH 3.31 ppm, δC 49.0 ppm).

Antioxidant Activity Assay (DPPH)

Antioxidant activity was evaluated using the DPPH free-radical scavenging assay. Prior to sample analysis, the wavelength of maximum absorbance of the DPPH blank was determined by scanning over 400–800 nm, and the operating time (the incubation period required for the DPPH–antioxidant reaction to reach a stable absorbance) was determined by monitoring absorbance at 5 min intervals over 60 min; a stable absorbance was reached at 40 min, and this incubation time was subsequently used for all sample and control measurements.

Ascorbic acid (vitamin C) was used as the positive control. A stock solution (5.0 mg in 5.0 mL methanol; 1000 ppm) was diluted with methanol and combined with 1.0 mL of DPPH stock solution to obtain final concentrations of 1, 2, 3, 4, and 5 ppm.

For the test samples, a stock solution of each synthesized chalcone product (5.0 mg in 5.0 mL methanol; 1000 ppm) was similarly prepared and diluted to final concentrations of 10, 30, 50, 70, and 90 ppm. All solutions (blank, positive control, and test samples) were prepared and measured in triplicate. After the 40 min operating time, absorbance was measured using a UV–Vis spectrophotometer at the determined wavelength of maximum absorbance, and the percentage of DPPH radical scavenging was calculated using **Equation 2**.

The half-maximal inhibitory concentration (IC50) for each sample and for the ascorbic acid control was

$$\% \text{ Inhibition} = \left(\frac{A_{blank} - A_{sample}}{A_{blank}} \right) \times 100\% \quad \textbf{(Eq. 2)}$$

Table 1. Results of chalcone synthesis optimization.

Temperature (°C)	Time (min)	Sample code	Rf 1	Rf 2	Rf 3	Yield after recrystallization (%)
30	10	A1	0.39	0.64	0.84	85.37
30	20	A2	0.39	0.64	0.84	87.82
30	30	A3	0.39	0.64	0.84	91.00
40	10	B1	0.38	0.63	0.83	67.13
40	20	B2	0.38	0.63	0.83	84.16
40	30	B3	0.38	0.63	0.82	90.31
50	10	C1	0.38	0.63	0.82	89.18
50	20	C2	0.39	0.64	0.83	85.17
50	30	C3	0.39	0.64	0.83	86.25
Note: Rf 1, Rf 2, and Rf 3 correspond to residual acetophenone, chalcone (major product), and by-product.						

determined by linear regression of the percentage inhibition against concentration.

Results and Discussion

Optimization of Chalcone Synthesis

Chalcone was synthesized via base-catalyzed Claisen–Schmidt condensation of acetophenone and benzaldehyde under ultrasonic irradiation. Ultrasonication accelerates the reaction by generating acoustic cavitation, which produces localized regions of elevated temperature and pressure that enhance molecular collisions and mass transfer between reactants, allowing the reaction to proceed efficiently within a substantially shorter time than conventional stirring methods (11).

Reaction optimization was carried out by varying the temperature (30, 40, and 50 °C) and irradiation time (10, 20, and 30 min); the results are summarized in **Table 1**.

Overall, ultrasonication enhanced the efficiency of chalcone synthesis by reducing reaction time and improving product yield compared with conventional stirring. At 30 °C, the yield increased progressively with irradiation time, reaching a maximum of 91.00% after 30 min. A similar trend was observed at 40 °C, where the yield increased markedly with prolonged irradiation, indicating more efficient reaction progression. In contrast, the yield at 50 °C exhibited a non-monotonic pattern, suggesting that elevated temperature may promote competing side reactions or partial product degradation, thereby offsetting the beneficial effects of extended ultrasonication. Thin-layer chromatography under UV254 revealed multiple spots under all reaction conditions, indicating the presence of residual starting materials and minor by-products in addition to chalcone. Consequently, recrystallization with ethanol was performed before further characterization, although complete purification was not achieved. The optimal synthesis condition was identified as 30 °C for 30 min, affording the highest yield (91.00%), and the resulting product was selected for comprehensive spectroscopic characterization.

Characterization of Chalcone

The product obtained under the optimum reaction condition (30 °C, 30 min) was a pale-yellow solid with a characteristic aromatic odor, consistent with previous reports for chalcone. However, its melting point (186.1–186.7 °C) was markedly higher than the reported value for unsubstituted chalcone (55–57 °C) and was comparable to those observed for substituted chalcone derivatives. Similar melting points (186.0–187.9 °C) were obtained under all reaction conditions, suggesting that this discrepancy was systematic rather than experimental. These findings are inconsistent with the TLC and LC–MS/MS results, which indicated the presence of residual impurities that would typically broaden and depress the melting point. Collectively, the data suggest that the major recrystallized product may not be unsubstituted chalcone or that co-crystallization phenomena occurred during ethanol recrystallization. Consequently, the melting-point

Table 2. Melting point of the synthesized product across reaction conditions.

Temperature (°C)	Time (min)	Melting point of recrystallized product (°C)	Literature melting point of chalcone (°C)
30	10	186.0–186.5	
30	20	186.2–186.6	
30	30	186.1–186.7	
40	10	186.1–187.1	
40	20	186.5–187.8	55–57 (12)
40	30	186.6–187.9	
50	10	186.2–187.0	
50	20	186.5–187.8	
50	30	186.3–187.5	

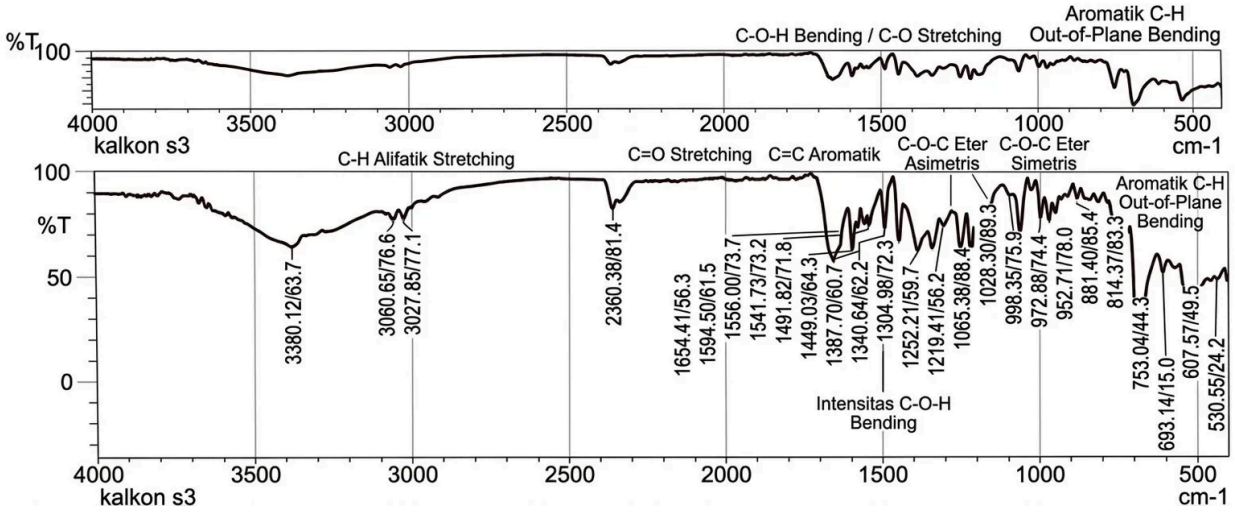


Figure 2. FT-IR spectrum of the synthesized chalcone. Note: upper trace: reference; lower trace: synthesized product.

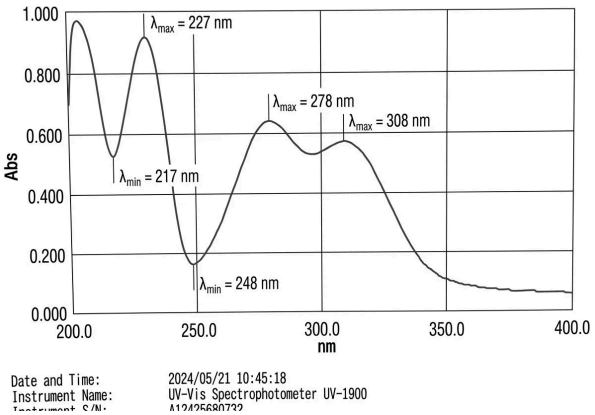


Figure 3. UV–Vis absorption spectrum of the synthesized compound in methanol.

data alone cannot confirm product identity, and further structural characterization is required. Functional groups were subsequently identified by FT-IR spectroscopy (**Figure 2**).

The FT-IR spectrum displayed absorption bands at 3060.65 and 3027.85 cm^{-1} (aromatic C–H stretching), 1654.41 cm^{-1} (conjugated C=O stretching of the α,β-unsaturated ketone), 1594.50–1491.82 cm^{-1} (aromatic C=C stretching), and bands between 972.68 and 753.04 cm^{-1} (out-of-plane =C–H bending of the trans-alkene), consistent with the expected chalcone framework.

The UV–Vis spectrum of the synthesized compound (**Figure 3**) showed absorption maxima at 230 and 280 nm (peak I) and 320 nm (peak II), all of which fall within the reported wavelength range for chalcone (13). The absorption at 280 nm was closest to the theoretical maximum wavelength reported for chalcone (281 nm), supporting the identification of the synthesized compound.

LC–MS/MS analysis further supported the formation of chalcone as the major component of the dominant chromatographic peak. The full chromatogram (**Figure 4**) showed the most intense peak at a retention time of 13.10 min, together with numerous additional peaks at other retention times (e. g. , 11.25, 12.09–12.97, 12.66–12.73, 13.59–14.99, and 16.00–16.48 min), indicating that the crude product was a mixture of several co-eluting compounds rather than a single pure substance.

The mass spectrum recorded at the dominant peak (13.10 min, **Figure 5**) showed a base peak at m/z 209.10, matching the theoretical $[M+H]^+$ of chalcone (calculated 208.25 g/mol; PubChem reference 209.096 m/z), together with signals at m/z 210.10 and 211.10 and additional signals at m/z 103.05, 131.05, and 191.09. According to library matching performed with the instrument software, all of these ions were assigned to the isotopic and fragmentation pattern of the chalcone molecular ion itself (**Table 3**) rather than to independent co-eluting compounds. This confirms the presence of chalcone-consistent ions in the dominant peak at 13.10 min but, taken alone, does not indicate the presence of impurities. Evidence for by-products instead comes from the additional chromatographic peaks at other retention times noted above (**Figure 4**), which point to co-eluting compounds distinct from the chalcone peak, consistent

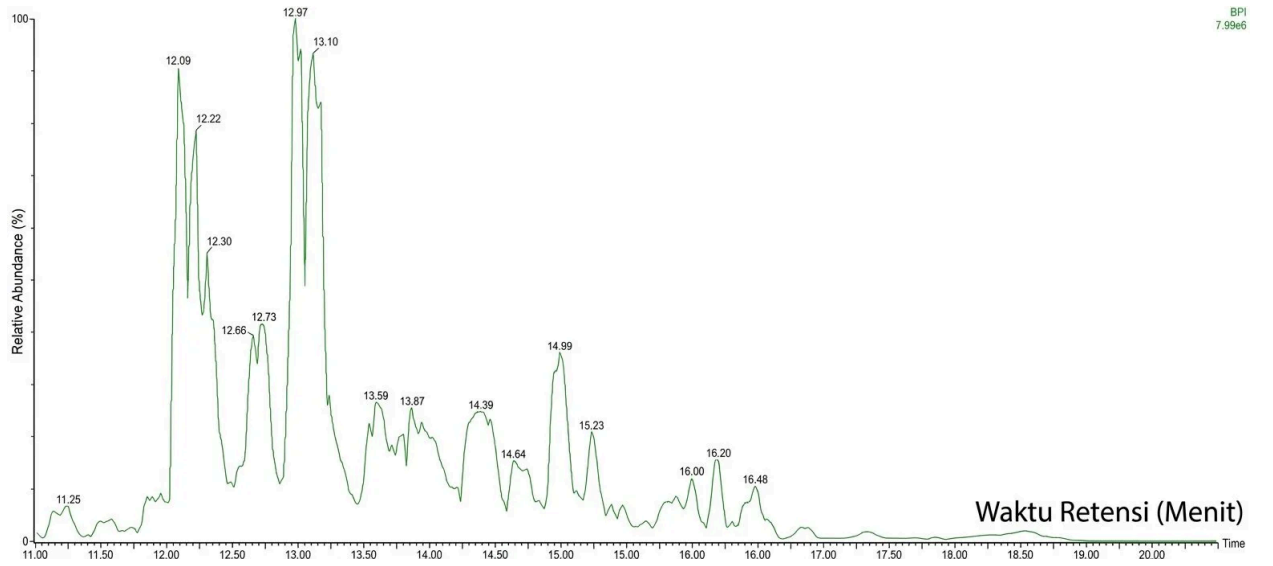


Figure 4. LC–MS/MS chromatogram of the synthesized compound.

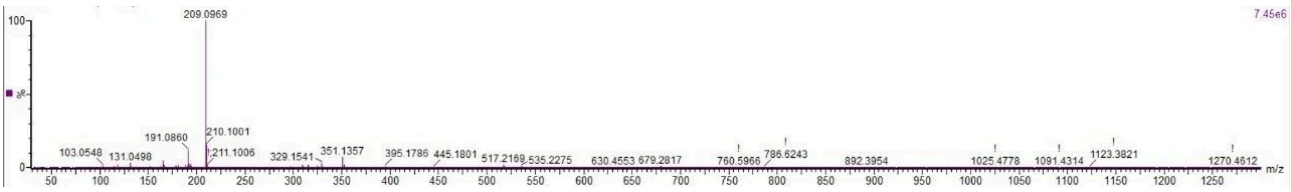


Figure 5. LC–MS/MS mass spectrum at the dominant peak (retention time 13.10 min).

Table 3. Ions identified at retention time 13.10 min (library-matched to chalcone).

Retention time (min)	m/z	Assignment (instrument library)
13.10	103.0548	Fragment/isotope pattern of chalcone molecular ion
13.10	131.0498	Fragment/isotope pattern of chalcone molecular ion
13.10	191.0860	Fragment/isotope pattern of chalcone molecular ion
13.10	209.0969	[M+H]+ molecular ion of chalcone
13.10	210.1001	[M+1] isotopologue
13.10	211.1006	[M+2] isotopologue

with the multiple TLC spots and the additional NMR signals discussed below. Notably, the base-peak chromatogram shows peaks at 12.09–12.97 min of intensity comparable to the target peak at 13.10 min, indicating that the by-product content of the recrystallized solid was substantial rather than a trace-level contaminant. Because synthesis yield in this study (up to 91.00%) was calculated gravimetrically from the total mass of recrystallized solid without correction for this co-eluting material, the reported yields should be understood as yields of total recrystallized solid rather than of pure chalcone; if a substantial fraction of this mass corresponds to by-products and unreacted starting material, as the LC–MS/MS and TLC data suggest, the true yield of chalcone itself is likely lower than the values reported in **Table 1**.

NMR spectroscopy further indicated that the synthesized product was not chemically pure. The experimental ^{1}H-NMR spectrum contained the expected aromatic and vinylic proton signals of chalcone, together with additional peaks (2–7 ppm) attributable to residual starting materials, aldol intermediates, or retained solvent. Likewise, the ^{13}C-NMR spectrum displayed extra signals in

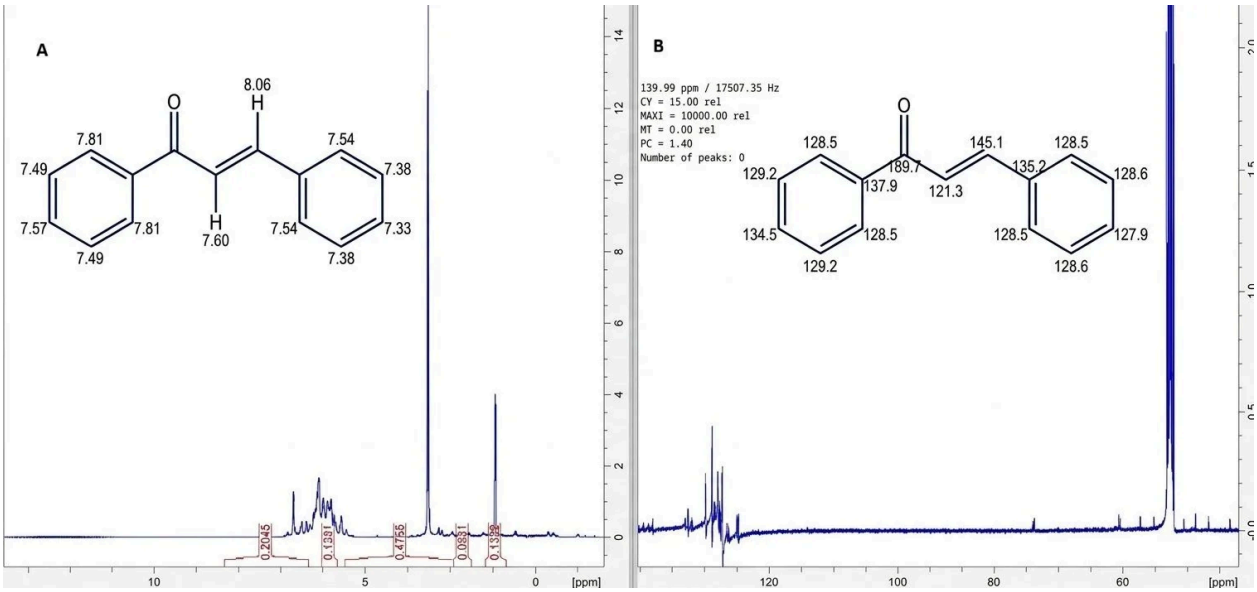


Figure 6. (A) ^{1}H-NMR and (B) ^{13}C-NMR spectra of the synthesized product, with predicted chemical shifts for pure chalcone shown on the structure.

Table 4. DPPH radical-scavenging activity (IC50) of the synthesized product across reaction conditions and of the ascorbic acid reference standard.

Sample	Temperature (°C)	Time (min)	IC50 (µg/mL)	Category*
A1	30	10	80.90	Strong
A2	30	20	80.18	Strong
A3	30	30	75.93	Strong
B1	40	10	127.08	Moderate
B2	40	20	124.53	Moderate
B3	40	30	121.04	Moderate
C1	50	10	191.39	Weak
C2	50	20	174.02	Weak
C3	50	30	170.00	Weak
Ascorbic acid (positive control)	-	-	5.97	Very strong

Note: *Category based on the commonly used IC50 scale for DPPH radical-scavenging activity: < 50 µg/mL = very strong, 50–100 µg/mL = strong, 100–150 µg/mL = moderate, 150–200 µg/mL = weak, > 200 µg/mL = very weak.

the 40–60 ppm region, consistent with aliphatic carbons not present in the chalcone structure. These findings, together with the FT-IR, UV–Vis, LC–MS/MS, and melting-point results, demonstrate that although chalcone-related structural features were detected, the isolated recrystallized product remained a mixture. Therefore, product identity cannot be confirmed solely by the current spectroscopic evidence, and additional structural characterization is required.

Antioxidant Activity

Antioxidant activity was evaluated for the products obtained under all nine reaction conditions, as well as for ascorbic acid as a positive control, using the DPPH radical-scavenging assay. IC_{50} values, determined by linear regression of percentage inhibition against concentration, are summarized in **Table 4**.

Two clear trends emerged from **Table 4**. First, at a fixed temperature, IC_{50} decreased slightly (i.e., antioxidant activity increased) with increasing irradiation time. Second, and more markedly, IC_{50} increased substantially with increasing reaction temperature: the 30 °C group fell within the "strong" category (75.93–80.90 µg/mL), the 40 °C group fell within the "moderate" category (121.04–127.08 µg/mL), and the 50 °C group fell within the "weak" category (170.00–191.39 µg/mL). Because synthesis yield was comparable, or even higher, at 40–50 °C than at 30 °C for the longest irradiation time (**Table 1**), this decline in antioxidant activity with increasing temperature cannot be explained simply by a lower proportion of chalcone in the product; it more plausibly reflects a temperature-dependent shift in the profile or amount of by-products formed, some of which may be more effective hydrogen-atom donors to DPPH than others.

The lowest IC_{50} value (75.93 µg/mL) was obtained at the optimum reaction condition (30 °C, 30 min), which also produced the highest synthesis yield, indicating relatively strong antioxidant activity. Nevertheless, the activity remained markedly lower than that of ascorbic acid (IC_{50} = 5.97 µg/mL), with the synthesized products exhibiting approximately 13–32 times lower radical-scavenging potency. These results should be interpreted cautiously because unsubstituted chalcone is generally recognized to possess weak intrinsic antioxidant activity due to the absence of a readily donated hydrogen atom. Consistent with this, previous studies have reported weak antioxidant activity for chalcone and related derivatives. Moreover, the NMR spectra indicated the presence of residual starting materials and/or aldol intermediates, which may contain hydrogen-donating hydroxyl groups capable of contributing to DPPH radical scavenging. Therefore, the observed antioxidant activity is likely attributable, at least in part, to co-formed by-products rather than chalcone itself. Consequently, the reported IC_{50} values represent the antioxidant activity of the semi-purified reaction mixtures rather than pure chalcone. Further studies using chromatographically purified chalcone are required to accurately determine its intrinsic antioxidant activity.

Conclusion

Ultrasonic-assisted Claisen–Schmidt condensation significantly reduced reaction time and achieved the highest crude yield (91.00%) at 30 °C for 30 min compared with conventional stirring. Although FT-IR, UV–Vis, and LC–MS/MS analyses indicated the presence of chalcone, the melting point, TLC, LC–MS/MS, and NMR results collectively suggested that the recrystallized product remained a mixture, preventing definitive confirmation of chalcone as the major component. Antioxidant activity varied from 75.93 to 191.39 µg/mL (IC_{50}), substantially weaker than ascorbic acid (5.97 µg/mL), and was likely influenced by co-formed by-products rather than pure chalcone. Therefore, additional purification and comprehensive structural characterization are required to establish product identity and accurately evaluate its intrinsic antioxidant activity. Although ultrasonication effectively accelerated the synthesis, further optimization of purification is necessary before the method can be considered an efficient and sustainable green chemistry approach.

Declaration

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During the preparation of this manuscript, the authors used ChatGPT-4 solely as an assistant for language editing, grammar correction, and improving readability. No data, figures, or original research concepts were generated using artificial intelligence. The authors thoroughly reviewed and edited all AI-assisted text, take full responsibility for the contents of the published article, and approved the final manuscript prior to submission.

Conflict of Interest

The authors declare no conflicting interest.

Data Availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

Not available.

Funding Information

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Additional Information

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