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Microwave assisted green synthesis of thiazolidin-4-one derivatives: A perspective on potent antiviral and antimicrobial activities

Neha Sainia, Archana Sharmaa, Vijay Kumar Thakurb, Charalampos Makatsorisc, Anshu Dandiad, Madhulika Bhagate, Rajiv Kumar Tonkf, Prabodh Chander Sharmaa,†

a Institute of Pharmaceutical Sciences, Kurukshetra University, Kurukshetra, 136119, India
b Biorefining and Advanced Materials Research Centre, Scotland’s Rural College (SRUC), Kings Buildings, Edinburgh, EH9 3JG, UK
c Department of Engineering, Faculty of Natural & Mathematical Sciences, King’s College London, United Kingdom
d Centre of Advanced Studies, Department of Chemistry, University of Rajasthan, Jaipur, 302015, India
e School of Biotechnology, University of Jammu, Jammu, 180006, India
f Department of Pharmaceutical Chemistry, School of Pharmaceutical Sciences, Delhi Pharmaceutical Sciences and Research University, New Delhi-110017, India

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ABSTRACT

Thiazolidin-4-one has been known as a powerful moiety present in various approved medications. Thiazolidin-4-ones are amongst the most effective and actively explored fields of current antimicrobial and antiviral chemotherapy that portray broad spectrum and potent activity. The wide range of medicinal properties of thiazolidin-4-one related drugs encourages the medicinal chemists to synthesize a significant variety of new medicinal substances. Microwave induced organic reactions earned substantial coverages in recent years due to many advantages such as ease of work, cost-effectiveness, short reaction time and excellent yield. Microwave radiations provide a substitute for traditional heating by incorporating energy to the reactions. The usage of microwave irradiation has contributed to the emergence of innovative ideas in chemistry, as energy absorption and propagation in microwave irradiation is entirely dissimilar to the traditional heating method. In synthetic chemistry, microwave heating is a rapidly growing area of research. This review cover organic synthesis of thiazolidin-4-one analogues via the use of microwave irradiation as an effective technique and the antiviral and antimicrobial action of thiazolidin-4-one based compounds.

Introduction

Microwave-assisted organic synthesis is an emerging technology having immense potential for industrial processes because it significantly decreases the time of reaction, utilizes a secure heating source, helps to expand the yield of the reaction, enhances the “atom economy” by increasing chemical yield and selectivity of product, can be used for solvent-free reactions. The word microwave applies to alternating current signals having frequencies amid 0.3–300 GHz. Microwaves are high-energy electromagnetic waves from crest to crest varying from 1 mm to 1 m [1]. Microwave-assisted organic synthesis of various heterocyclic moieties is an effective and environment-friendly synthetic approach and becoming an effective tool of green chemistry method [2]. In recent decades a wide array of researchers working on microwave-assisted organic synthesis [3]. The mechanism of heat transfer via conventional and microwave heating is reflected in Fig. 1:

Microwave irradiation is an effective form of heating depends on the capacity of analogues to translate electromagnetic energy into heat [6]. Microwave technology applies for not only the production or conversion of a simple fragment but also for the cluster of the bioactive fragments. Therefore, the fundamental underlying principle behind heating in microwave ovens is based on the contact of polar bodies of the substance with the electromagnetic waves of particular frequency. The production of heating by electromagnetic irradiation may occurs either through collision or through conduction and occasionally both. Microwave heating method reduces the reaction time from days to hours, hours to minutes efficiently and also useful in process chemistry for the production of fine chemicals [4]. Few

* Corresponding author. Department of Pharmaceutical Chemistry, School of Pharmaceutical Sciences, Delhi Pharmaceutical Sciences and Research University, New Delhi-110017, India.
E-mail address: sharma.prabodh@rediffmail.com (P.C. Sharma).

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benefits and applications of microwave-assisted organic synthesis are depicted in Fig. 2:

Thiazolidin-4-one analogues represent a significant class of heterocyclic compounds for their possible medicinal applications [7]. These are among the molecules that biochemist and medicinal chemist have studied most thoroughly [8]. Thiazolidin-4-one ring structure has a range of effective therapies comprising antibacterial, antiviral, anticancer, anti-tubercular, anti-fungal, anticonvulsant, cardiovascular effects, hypnotic activity, anti-histaminic activity etc. [9]. Literature survey indicated that in most of methods for the synthesis of thiazolidin-4-one analogues high boiling hydrocarbons like benzene or toluene with regular removal of water, desiccants such as sodium sulfate and ZnCl2, molecular sieves and stoichiometric quantity of DCC is necessary in solution-phase reactions. The synthesis of thiazolidin-4-one analogues is significantly improving via usage of microwave irradiation [10]. Infectious viral diseases are one of the most dangerous ones and their transmission can be minimized if the rate of the reaction can be raised, it provide uniform and specific heat to the reaction mixture and also increasing the reproducibility of the reaction.
treatment remains a significant problem owing to the proliferation of drug-resistant varieties, leading to the accelerated mutability of the virus [11]. Microbial infections are a frequent concern in hospitals and healthcare environments around the world and have become a growing issue in public. Indeed, the discovery and production of novel antimicrobial mediators and different actions is still a big task for the scientific area [12].

Microwave-assisted synthesis of thiazolidin-4-one derivatives

Microwave-assisted organic synthesis is already acquired significance in synthetic organic chemistry in a time of just a decade [13]. In organic synthesis, the usage of microwave irradiation has become ever more prevalent in medicinal and educational areas since it is a novel assisting skill for discovery and expansion of medicines [14]. Fig. 3 depicts different representative microwave-assisted organic synthesis examples:

Anti-infective activity

Microbial infections are the foremost cause of mortality around the world. A vast variety of antimicrobial drugs is currently accessible in the market but still, there is an imperative necessity to design and develop innovative and potent anti-infective agents due to continuous progress of resistance. From literature study, we concluded that Thiazolidin-4-one analogues prepared via microwave irradiation method are found to be innovative inhibitors of several microbial enzymes and blockers of the pathogenic mechanism of microbial agents.

Antiviral activity

Viruses are the major cause of diseases and death from last few decades. Based on the current situation the emergence of coronavirus originated in Wuhan, China in December 2019 spreading globally and becomes the topic of debate among the researchers. Coronavirus are the enveloped form of RNA viruses widespread in humans, birds and other mammals. Various researchers and pharmaceutical firms are focusing on the development of vaccines and drugs to combat this deadly virus.

Göktaş et al., (2012), developed an innovative sequence of N-(1-thia-4-azaspiro[4.5]decan-4-yl)carboxamide analogues via microwave-assisted synthesis and investigated in MDCK cell cultures toward influenza B virus and influenza A (H1N1 and H3N2) for their antiviral activity. The analogues structures were recognized via elemental as well as spectral examination. Results indicated that analogue 1 (for structural representation see Fig. 4) exhibited noteworthy antiviral activity toward influenza A/H3N2 virus having an EC50 value of 1.4 μM [20].

Chen et al., (2009), explored a new class of thiazolidin-4-ones via a microwave-assisted one-pot protocol and assessed against HIV-1 reverse transcriptase for their antiviral activity. Most of the analogues displayed good antiviral activity but analogue 2 and 3 (structures of the analogues are mentioned in Fig. 4) demonstrated potent antiviral activity via inhibition of “HIV-1 reverse transcriptase with an IC50 value of 0.26 μM and 0.23 μM, respectively” [21].

Sriram et al., (2005), have identified an innovative sequence of 2,3-diaryl-1,3-thiazolidin-4-ones via microwave-induced synthesis and examined for their anti-YFV activity. Among all the synthesized analogues, analogue 4 (structure refer Fig. 4) displayed promising anti-YFV activity having an EC50 value of 6.9 μM [22].

Antimicrobial activity

Microbes are the microscopic living creatures present all around us and are small particles that cannot be seen by naked eyes. Due to increased advent of microbial diseases, microbes pose resistance toward antimicrobial agents and becomes a significant concern in the scientific world. Hence, the production of modern, effective and special antimicrobial agents is perhaps is the most critical means of overcoming increased microbial resistance.

Beniwal et al., (2019), introduced an innovative sequence of Thiazolidin-4-one substituted pyrazoles using MW irradiation method and recognized based on Rf values, melting point series, 1H NMR, MS, mass spectral information and elemental investigation. Amongst them, two analogues 5 and 6 (structures are shown in Fig. 5) revealed noteworthy
antimicrobial activity toward all the verified bacterial and fungal strains with MIC value of 1.71–2.13 μM/ml. The antibacterial activity analysis demonstrated that analogues comprising electron-withdrawing groups were measured to be most effective in comparison to the analogues comprising electron releasing groups [3].

Aouali et al. (2016), explored a novel sequence of 3-(5-alkyl-2-phenyl-2H-1,2,4-triazol-3-yl)thiazolidin-4-ones using MW irradiation method and tested for their antimicrobial activity. Most of the analogues demonstrated noteworthy activities. Among all the tested analogues, analogue 7 (structurally represented in Fig. 5) demonstrated notable activity toward Gram positive, gram negative bacteria (zone of inhibition = 11–23 mm, MIC = 0.021–2.75 mg/ml) and pathogenic fungal strains having little MIC values (MIC = 0.172–1.375 mg/ml) [12].

Desai et al. (2012), presented an innovative sequence of 2-((1-(4-(4-arylidene-2-methyl-5-oxo-4,5-dihydro-1H-imidazole-1-yl)phenyl)ethyldiene)hydrazono)thiazolidin-4-ones via MW irradiation method and examined towards Escherichia coli, Staphylococcus aureus, Staphylococcus pyogenes, Aspergillus niger, Pseudomonas aeruginosa, Aspergillus clavatus and Candida albicans via serial broth dilution method for their antimicrobial activity. All the manufactured analogues were recognized through 1H NMR, IR, 13C NMR and mass spectra. The outcomes of the

Fig. 4. Thiazolidin-4-one comprising analogues with antiviral activity.

Fig. 5. Thiazolidin-4-one comprising analogues with antimicrobial activity.
study indicated that analogues 8, 9, 10 and 11 (structural representation is depicted in Fig. 5) displayed promising antimicrobial activity (MIC = 25–50 μg/ml toward bacterial strains and 25–100 μg/ml toward fungal strains) [23].

Sekhar et al. (2010), under solvent-free environment on silica as solid support developed a novel class of 3-(2-methylquinolin-3-yl)-2-(substitutedphenyl)thiazolidin-4-ones via microwave irradiation and screened for antifungal and antimicrobial properties. All the synthesized analogues were characterized by infrared spectroscopy, elemental microanalysis, 1H NMR, and mass spectroscopy. The consequences of the biological activities discovered that the analogues 12, 13, 14 and 15 (structures are displayed in Fig. 5) (zone of inhibition = 10–30 mm) demonstrated exceptional antibacterial activities while 13 and 15 (zone of inhibition = 15–30 mm) revealed virtuous antifungal activity [24].

Upadhyay et al. (2010), have identified a new class of N-[(4-oxo-2-substituted aryl-1, 3-thiazolidine)-acetamidyl]-5-nitroindazoles via both conventional as well as microwave method and examined toward bacterial and fungal strains for their antimicrobial activity. The structures of these analogues were predicted by 1H NMR, IR, FAB-mass spectra, 13C NMR as well as microanalytical records. Analogue 16 and 17 (structures are indicated in Fig. 5) displayed effective antibacterial action (MIC = 11 and 10 μg/ml) toward E. coli and antifungal activity (MIC = 9 and 8 μg/ml) toward Fusarium oxysporum [2].

Conclusion

The current review includes the synthesis of thiazolidin-4-one analogues via microwave irradiation method and their antiviral and antimicrobial potential. The thiazolidin-4-one framework was regularly provided in the article. The information given in this manuscript can be descriptive examples of microwave heating based reactions have been assist in the management of microbial resistance and even addressing the appropriate antiviral and antimicrobial therapy required for the treatment of diverse deadly viral and microbial infectious diseases. Several descriptive examples of microwave heating based reactions have been provided in the article. The information given in this manuscript can be deemed useful to maximize the antiviral and antimicrobial ability for more research on thiazolidin-4-one nucleus. Due to immensely powerful antiviral and antimicrobial potential the thiazolidin-4-one scaffold gained the interest of chemists, microbiologist, pharmacologist and other researchers to design and develop novel and effective anti-infective agents.

Future prospects

Due to the increased incidence of viral and microbial infections, the researchers require to develop or produce novel antiviral and antimicrobial drugs [25]. To fulfil this purpose the scientific communities focusing toward the synthesis of thiazolidin-4-one containing compounds via microwave irradiation or other green chemistry methods because of their huge antiviral and antimicrobial potential. From literature study, we concluded that the future of medicinal chemistry focuses on the invention of suitable synthesis methods by implementing green chemistry protocols to provide a clear guiding force for the potential production of thiazolidin-4-one containing compounds.

Declaration of Competing Interest

The authors declare no conflict of interest. The authors alone are responsible for the content and writing of the paper.

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Abbreviations

| Symbol | Name            | Unit            |
|--------|-----------------|-----------------|
| GHz    | Gigahertz       |                 |
| Mm     | Millimeter      |                 |
| M      | Meter           |                 |
| MW     | Microwave       |                 |
| W      | Watt            |                 |
| RF     | Retention factor|                 |
| IR     | Infrared        |                 |
| HNM     | Proton-nuclear magnetic resonance |                 |
| EC50   | Half maximal effective concentration |                 |
| IC50   | Half maximal inhibitory concentration |                 |
| μM     | Micromolar      |                 |
| YFV    | Yellow fever virus |               |
| MIC    | Minimum inhibitory concentration |                 |
| μM/ml  | Micromol per milliliter |             |
| mg/ml  | Milligram per milliliter |             |
| μg/ml  | Microgram per milliliter |             |
| FAB    | Fast atom bombardment |            |
| HIV    | Human immunodeficiency virus |         |
| MDCK   | Madian-darby canine kidney |              |

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