Efficient Oxidation of Alcohols and Synthesis of Sustainable and Renewable, Environmentally Friendly Compounds with Microreactors in Continuous Flow Chemistry

Nida Ambreen[1,2]*, Thomas Wirth[2]

[1]Department of Chemistry, Abdul Wali Khan University, Mardan, Pakistan.

[2]School of Chemistry, Cardiff University, Wales, United Kingdom.

*E-mail: nidaambreen@awkum.edu.pk

ABSTRACT

The growing demand for sustainable and green chemical processes has accelerated the shift from conventional batch methods to continuous flow systems. In this study, we demonstrate the efficient oxidation of alcohols using microreactor-based continuous flow chemistry. Microreactors offer superior heat and mass transfer, precise control over reaction parameters, and reduced waste generation, making them ideal for green synthesis. A range of primary and secondary alcohols was oxidized to their corresponding aldehydes and ketones using environmentally benign oxidants under mild conditions. The process was optimized for catalyst loading, temperature, and flow rate to achieve maximum yield and selectivity. Compared to traditional batch reactions, the microreactor system showed enhanced reaction efficiency, reduced reaction time, and improved safety. The developed method contributes significantly toward the synthesis of renewable and environmentally friendly compounds, aligning with the principles of green chemistry and sustainable industrial production. This work underscores the potential of microreactor technology as a transformative tool for eco-efficient chemical manufacturing.

The abstract is required to provide a description of the content to be discussed during the presentation. The description must be structured under the following sub-headings

Keywords: Microreactor, Carbohydrate, 5-HMF, Chiral Pool, Eco-Efficient.

INTRODUCTION

The Development of efficient flow reactor system for molecular transformation is an important area in organic synthesis. Flow chemistry, also known as continuous-flow chemistry or microreactor technology, is an advanced chemical synthesis technique in which chemical reactions occur in a continuously flowing stream rather than in traditional batch reactors. In this process, reactants are pumped through narrow channels or microreactors, where they mix and react under precisely controlled conditions of temperature, pressure, and reaction time. The introduction of more general platforms to perform reactions under continuous flow rather than in batch mode has led to improvements regarding safety and sustainability. Microreactor technology can be beneficial over classical approaches in a variety of chemical reactions. Many reactions can benefit from the properties of microreactors. Enhanced mass- and heat transfer and short diffusion distances can lead to better yields within shorter reaction times. Reactions in microreactors can benefit from the physical properties of such devices: short diffusion distances, enhanced mass- and heat transfer owing to a very large surface-to-volume ratio, and regular flow profiles can lead to improved yields, shortened reaction times, and better selectivities [1-4].

OBJECTIVES

The primary objectives of this research are focused on developing sustainable and innovative methodologies in organic synthesis. The development of novel transformations aims to expand the toolbox of synthetic chemistry by discovering new reaction pathways that improve efficiency and selectivity. A key aspect of this

work involves the use of subcritical water as a green solvent, which serves as an environmentally friendly alternative to traditional organic solvents due to its low toxicity, renewability, and ability to promote various organic reactions under mild conditions.

METHODOLOGY

Benzyl alcohol was chosen as a substrate in order to examine the efficiency of the reaction and the microreactor flow system. In a batch reaction, the mixture of benzyl alcohol (**1a**) and (diacetoxyiodo) benzene (**2**) did not show any reaction after stirring for 12 h in dichloromethane at 35 °C. The addition of a catalytic amount TEMPO to the reaction mixture led to a rapid conversion to benzaldehyde (**3a**). For initial investigations of a flow system, a simple setup consisting of two syringes driven by a syringe pump, a T-connector and a tubing reactor (PTFE tubing, length: 4 m, internal diameter: 0.75 mm) was used forthe oxidation of benzyl alcohol to benzaldehyde. The tubing reactor was inserted in a water bath at constant temperature as shown in Figure **1**.

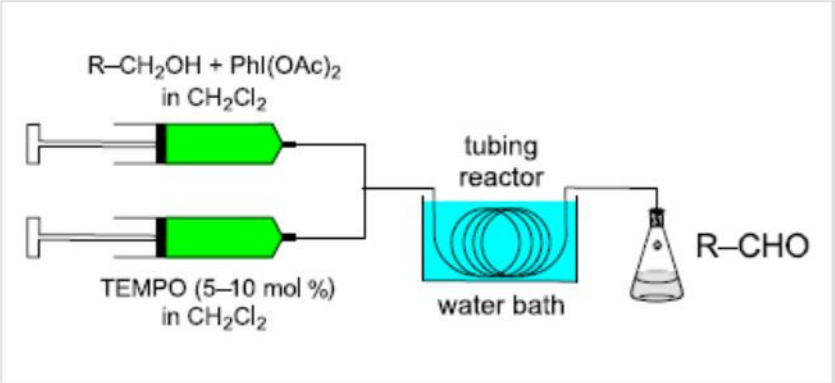
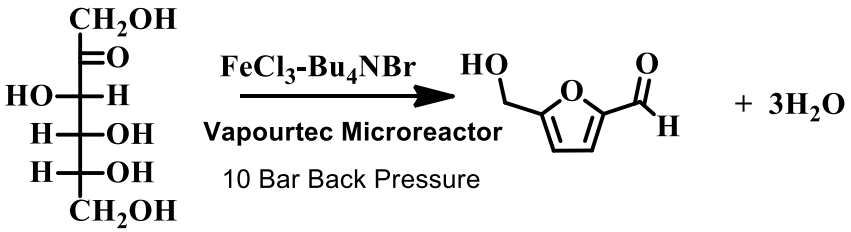


Figure 1: Flow setup for alcohol oxidations.

Some other reaction with glucose was also carried out using mircroreactor technique as per the following scheme.



KEY FINDINGS

It has been found that the utilization of carbohydrates as starting materials, taking advantage of their natural abundance, enantiomeric purity, and cost-effectiveness. These carbohydrate-based substrates provide a renewable and chiral pool for the synthesis of valuable organic compounds, aligning the research with the principles of green and sustainable chemistry.

CONCLUSION

In conclusion a highly efficient and selective continuous flow for the oxidation of different alcohol was developed. Apart from short reaction time high conversion and excellent selectivities were obtained. These feature with low toxicity of the reagent made the process attractive compared to the batch reactions.The

Glucose conversion to 5-HMF using THF: H_2O reaction showed the good results with minimum reaction time. The economical and benign oxidation is broadly applicable to a wide range of alcohol.

REFERENCES

1. Zhang, Lu, and Jun Yue. "Packed bed microreactors for sustainable chemistry and process development." Chemistry 7.2 (2025): 29.
2. Hessel, Volker, et al. "Sustainability of flow chemistry and microreaction technology." Green Chemistry (2024).
3. Hessel Ramírez-Coronel, Andrés Alexis, et al. "A green chemistry approach for oxidation of alcohols using novel bioactive cobalt composite immobilized on polysulfone fibrous network nanoparticles as a catalyst." Frontiers in Chemistry 10 (2022): 1015515.
4. Ma, Yun, et al. "Thermal decay of TEMPO in acidic media via an N-oxoammonium salt intermediate." Organic & biomolecular chemistry 9.15 (2011): 5573-5578.