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Conversion of Ocean-based Chitin Biomass into Acetic Acid

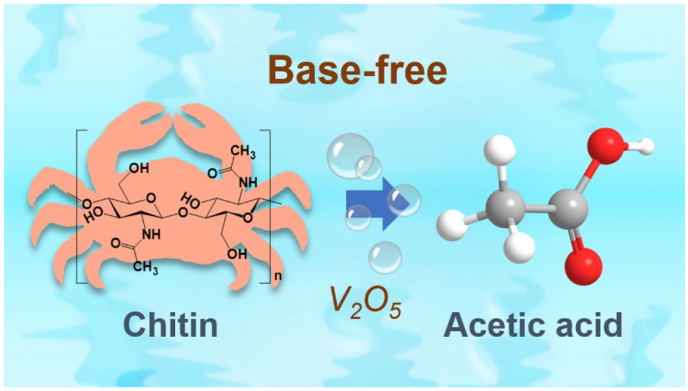
AUTHORS
Xi CHEN / SHANGHAI JIAO TONG UNIVERSITY, 800 DONGCHUAN ROAD, SHANGHAI

PURPOSE OF THE ABSTRACT

To mitigate the society's reliance on nonrenewable fossil resources and the associated environmental problems such as global warming, biomass resources have been intensively studied as sustainable and abundant alternatives to produce chemicals, fuels and materials. The ?Shell Biorefinery? concept to utilize chitin biomass as a resource for chemical production has been proposed in 2015 and advanced rapidly in recent years.[1] A variety of organonitrogen and organooxygen chemicals were obtained from the ocean-based chitin biomass, showing the viability and huge prospects.[2] The natural structure of chitin boasts an acetamido side chain, enabling it an ideal platform to synthesize organonitrogen compounds as well as acetic acid. Acetic acid is a valuable commodity chemical with broad applications in textiles, medicines, agricultures, pharmaceuticals, cosmetics, etc. It is also adopted in a great number of chemical reactions as a precursor, acidity regulator, solvent, etc. The global market for acetic acid was estimated to be 9.3 billion USD in 2020 and predicted to incline in the forthcoming years.

However, the current production method of acetic acid in industry was nonrenewable based on fossil fuels. Lignocellulosic biomass valorization to produce acetic acid has been attempted, but the transformation was difficult and usually resulted in relatively low yield (a typical range of 10-20%). Chitin conversion into acetic acid was first demonstrated in 2016 by Jin and Yan's group, obtaining acetic acid with a high yield of 38.1% in 2 M NaOH solution with copper oxide catalyst under pressurized O2 gas at 300 °C.[3] A noncatalytic approach was also reported dissolving chitin in a KOH/urea system at freezing temperatures and then heating at 200-320 °C to produce acetic acid in 31.0% after 12 h. Chitin is superior to lignocellulosic biomass because the simple hydrolysis of the acetamido side chain could readily lead to a considerable amount of acetic acid production. To eventually realize a green, low-carbon and sustainable society, biomass transformations with milder conditions or less usage of corrosive reagents are highly desirable. We first developed a base-free catalytic route to convert chitin polymer into acetic acid using V2O5 catalyst.[4] The product in its acidic form could be readily separated by simple and mature technologies such as solvent extraction, etc. The highest AA yields of 33.4% and 30.0% were obtained from NAG and BM chitin at 220 °C under 0.5 MPa O2 gas in water after a short reaction time of 2-3 h. The homogeneous V2O5 species was the catalytically active component, which played multiple roles to promote the hydrolysis of chitin polymer chains, the deacetylation, and the oxidation. The solid residues after reaction were characterized by XRD and FTIR showing the unchanged chitin backbones while gradually destructing crystallinity as the reaction proceeded. Following this, a facile, efficient and mild protocol was also established to convert chitin monomer into various organic acids at near room temperature and 0.5 MPa O2 gas.[5] Acetic acid was obtained in 23.4% yield under such mild conditions. Compared to the conventional methods at high temperatures and/or pressures, the established approach requires minimal energy inputs, inexpensive equipment with reduced carbon emission, capital costs, and safety risks.

FIGURES



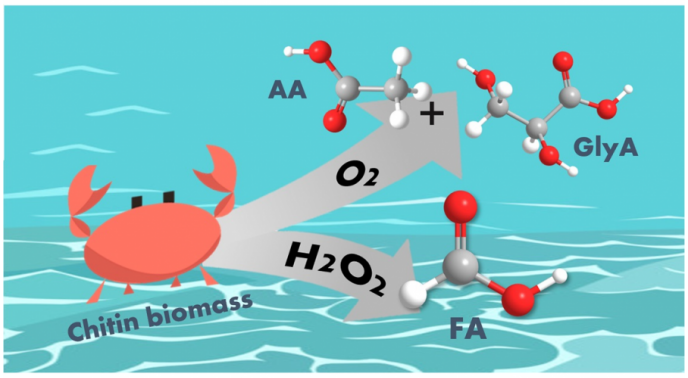


FIGURE 1

Figure 1

Base-free conversion of chitin into acetic acid

FIGURE 2

Figure 2

Conversion of chitin monomer at near room temperature to organic acids

KEYWORDS

biomass conversion | chitin | acetic acid | catalysis

BIBLIOGRAPHY

[1] N. Yan, X. Chen, Nature, 2015, 524, 155-157.

[2] X. Chen, S. Song, H. Li, G. Gozaydin, N. Yan, Acc. Chem. Res., 2021, 54, 1711-1722.

[3] X. Gao, X. Chen, J. Zhang, W. Guo, F. Jin, N. Yan, ACS Sustain. Chem Eng., 2016, 4, 3912-3920.

[4] M. Qi, X. Chen, H. Zhong, J. Wu, F. Jin, ACS Sustain. Chem. Eng., 2020, 8, 18661-18670.

[5] J. Wu, M. Qi, G. Gozaydin, N. Yan, Y. Gao, X. Chen, Ind. Eng. Chem. Res., 2021, 60, 3239-3248.