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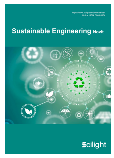

Opinion

Commemorating Academician Ouyang Pingkai: A Pioneer in Sustainable Engineering and Industrial Biotechnology †

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† In memoriam: Academician Ouyang Pingkai (1945–2023), whose pioneering spirit continues to illuminate the path toward sustainability.

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Abstract: Professor Ouyang Pingkai is a pioneering figure in the field of sustainable engineering and industrial biotechnology in China. As an esteemed academician of the Chinese Academy of Engineering and a visionary educator, Professor Ouyang's career was marked by groundbreaking contributions to industrial biotechnology, green biomass refining, and the sustainable utilization of biological resources. His research, particularly in the areas of microbial biosynthesis and enzymatic catalysis, not only advanced scientific frontiers but also drove significant industrial applications, bridging the gap between laboratory innovation and real-world production. Beyond his scientific achievements, Professor Ouyang was revered as a dedicated mentor who nurtured generations of scientists and engineers, embodying a spirit of rigorous scholarship, integrity, and innovation. Herein, this paper commemorates his major scientific accomplishments, institutional leadership, and enduring impact on green manufacturing, which will continue to shape the trajectory of biochemical engineering in China and serves as a beacon for future generations in the scientific community.

Keywords: Ouyang Pingkai; sustainable engineering; industrial biotechnology; scientific legacy

1. Introduction: A Visionary in Sustainable Engineering

Academician Ouyang Pingkai (1945–2023) was a pioneering force in China's sustainable engineering landscape. As a distinguished biochemical engineer and former president of Nanjing Tech University [1], he dedicated his career to advancing industrial biotechnology and biorefining processes that prioritize ecological sustainability. His work laid the groundwork for transforming waste biomass into valuable materials, energy, and chemicals, aligning economic growth with environmental stewardship. This article honors his legacy by exploring his scientific contributions, institutional leadership, and enduring impact on green manufacturing.

2. Scientific Contributions: Transforming Waste into Resources

Professor Ouyang's research focused on leveraging biotechnology to address resource scarcity and pollution. Key achievements include:

2.1. Valorization of Lignocellulosic Biomass

Circular Bioeconomy Model: Professor Ouyang advocated using agricultural waste (e.g., crop straws) as feedstocks for biomanufacturing. He pointed out that China produces approximately 1 billion tons of straw annually. He emphasized that utilizing this resource could generate ¥300 billion in economic value while mitigating environmental pollution.

Lignin Optimization: His team developed methods to extract and upgrade lignin from biomass, improving the viability of cellulosic ethanol production. This approach reduced production costs by 30% compared to grain-based ethanol, thereby enhancing its competitiveness against fossil fuels [2]. Specifically speaking, in biodegradable materials, lignin-modified PLA showed a 10~15 °C increase in melting point and 20% enhancement in tensile modulus, and bio-nylon 56 achieved a 70% reduction in fossil carbon content versus nylon 66. For low-carbon energy solutions, producing 1 ton of bio-based polymers saved 6 tons of crude oil and reduced 3 tons of CO_2 emissions. Technological innovations included a 40% yield increase in L-amino acids via chitin microspheres and an 80% reduction in methane emissions from organic waste conversion.

2.2. Biodegradable Materials to Combat Plastic Pollution

Professor Ouyang identified biodegradable polymers as a critical solution to "White pollution". His research on polylactic acid (PLA) modified with lignin addressed PLA's brittleness and low heat resistance while maintaining biodegradability [3].

He pioneered bio-based alternatives to petrochemical materials, such as nylon 56 synthesized from bio-based pentamethylene diamine (PDA). This innovation broke China's dependency on imported hexamethylenediamine for nylon 66, a material once monopolized by foreign corporations.

2.3. Low-Carbon Energy Solutions

He championed biomass energy as a carbon-neutral alternative, criticizing the lifecycle emissions of solar/wind technologies. By calculating that 1 ton of bio-based polymers saves 6 tons of crude oil and reduces 3 tons of CO_2 emissions, he demonstrated biomass's potential to decarbonize industries.

3. Institutional Leadership and Ecosystem Building

Professor Ouyang's impact extended beyond the laboratory to institution-building and policy advocacy:

3.1. Founding China's First Bioengineering Programs

In 1985, he established the nation's first biochemical engineering program at Nanjing Tech University, later founding the National Biochemical Engineering Research Center. These institutions became hubs for talent development in sustainable engineering.

3.2. Promoting Industry-Academia-Research Integration

As director of the Jiangsu Industrial Technology Research Institute, he bridged gaps between research and market adoption. He cautioned against an overreliance on theoretical publications, urging scientists to "innovate from problem-oriented research" [4].

He facilitated partnerships with companies like Changmao Biochemical, commercializing technologies for bio-based malic acid and fumaric acid.

3.3. Policy Advocacy for Green Manufacturing

Professor Ouyang advised national strategies, including the "Two Replacements, One Upgrade" framework:

- Industrial Feedstock Replacement: Replacing fossil resources with renewable biomass [5].
- Process Route Replacement: Adopting synthetic biology and biocatalysis over chemical synthesis.
- Upgrading Traditional Industries with biotechnology.

4. Technological Innovations and Engineering Breakthroughs

4.1. Advanced Biocatalysis Systems

His team engineered self-sufficient biocatalysts using chitin-based microspheres to co-immobilize enzymes and cofactors (e.g., pyridoxal 5′-phosphate). This improved efficiency in producing chiral compounds like L-amino acids.

They developed metal-surfactant hybrid living cells for high-activity biocatalysis, enabling sustainable synthesis of chemicals.

4.2. Sustainable Material Production

By leveraging jet loop reactors, they achieved efficient synthesis of bio-based pentamethylene diisocyanate, avoiding toxic phosgene used in traditional methods.

His work on oleic acid conversion to heptadecane via bimetallic NiPt catalysts enabled hydrocarbon production without external hydrogen, reducing energy inputs.

4.3. Waste-to-Resource Systems

Professor Ouyang designed processes to convert organic waste (e.g., kitchen waste, feces) into bio-natural gas and organic fertilizers, addressing water eutrophication and methane emissions.

5. Educational Legacy and Global Influence

5.1. Pedagogical Innovation and Curriculum Development

As a pioneering educator, Professor Ouyang played a foundational role in establishing the academic discipline of biochemical engineering in China. He authored and edited seminal textbooks, most notably the first nationally planned textbook on Bioseparation Engineering, which became the standard teaching material and helped define the core knowledge framework for the field across Chinese universities. He was instrumental in designing interdisciplinary courses that merged fundamental biology with chemical engineering principles, fostering a systems-thinking approach essential for solving complex industrial biotechnology problems

5.2. Mentorship Philosophy and Problem-Based Learning

Professor Ouyang's mentorship was characterized by a profound philosophical tenet he instilled in his students: the paramount importance of "steadfastness over mere cleverness". He emphasized rigorous diligence, perseverance, and the courage to tackle hard problems. He considered these qualities more valuable than innate talent alone. This ethos encouraged students to commit to long-term, meaningful research rather than seeking shortcuts. Furthermore, he championed problem-based learning rooted in industrial practice, routinely directing his research group to address challenges encountered in real-world production facilities, thereby bridging the gap between theoretical knowledge and practical application.

5.3. Globalizing Educational and Strategic Perspectives

Professor Ouyang also served as a formidable ambassador for Chinese engineering education and sustainable development strategy on the world stage. As an esteemed speaker at international forums such as the UN Clean Energy Forum, he effectively articulated China's strategies and advances in building a sustainable bioeconomy. His engagements were not merely technical presentations; they showcased the depth of China's engineering educational paradigm and fostered meaningful international dialogue and collaboration. He actively promoted student and scholar exchanges, attracting international students to his programs and thereby extending his educational influence globally.

6. Conclusions and Future Outlook

Collectively, Professor Ouyang had published over 300 papers, authored or translated more than 10 books, and applied for over 70 patents by 2015. Qualitatively, these outputs were instrumental in moving the Chinese bio-economy from conceptual stages to global competitiveness. Professor Ouyang's work exemplifies how biotechnology-driven engineering can reconcile industrial development with planetary health. His contributions—spanning waste valorization, biodegradable materials, and institutional reform—provide a roadmap for achieving carbon neutrality and circular economies. As he aptly stated, "Innovation must stem from real-world problems, not merely following trends". His vision continues to inspire policies and innovations aimed at building an ecologically civilized society.

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Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

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