NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE | Nanyang Environment and Water Research Institute

FULL-SCALE MICROBIAL SYNTHESIS OF HIGH-VALUE SINGLE-CELL PROTEIN FROM WASTEWATER FOR AQUACULTURE

Abstract

This project aims to valorize clean organic waste streams into single cell protein (SCP) for human consumption and other high-value applications. The approach involves optimizing the nutritional quality of SCP through the formulation of diverse waste-derived feedstocks (e.g., food waste, food processing wastewater, and rejected food and beverage products) and the use of microbial consortia, including bacteria and microalgae, under tailored growth conditions and micronutrient supplementation. At the technological level, the project will develop a pilot-scale, membrane-based biotechnology for bacterial SCP production, alongside a modular bioreactor system for microalgal SCP cultivation, both designed for practical deployment in local farming contexts. The ultimate objective is to produce high-quality microbial protein through an efficient and cost-effective system that integrates upstream cultivation with effective separation and downstream processing. The working hypotheses are that: (1) the proposed biological platform will establish a sustainable and economically viable process for SCP production; (2) it will demonstrate flexibility in handling multiple feedstocks and generating a range of products for multipurpose applications; and (3) it can be advanced to demonstration-scale implementation by the conclusion of the project.

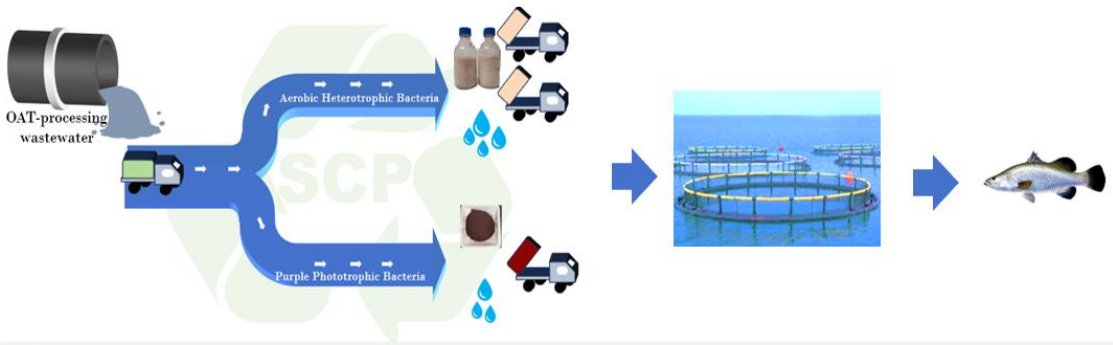
General methodologies:

(1) To achieve sustainability and cost-effectiveness, the platform will integrate multiple biological processes for full waste valorization. Waste streams will first undergo anaerobic digestion (AD), producing a liquid flow of small organic molecules and a gaseous flow of biogas. The liquid will be used by purple phototrophic bacteria (PPB) or heterotrophic bacteria (HB), while CO_2 from the gas stream will be utilized by microalgae. Membrane modules will be applied to enhance gas utilization, biomass yield, and energy efficiency.

(2) To handle diverse and fluctuating waste streams, regulating strategies will be adopted to stabilize influent quality. Feedstocks such as soya milk, oat milk, soft drinks, and CIP wastewater will be tested to ensure system robustness. The process will generate multiple types of biomass, with both bacteria (50–80% protein) and microalgae (60–70% protein) serving as sources of SCP, alongside valuable co-products like lipids, vitamins, and enzymes. These can be used individually or combined for animal feed and human supplements.

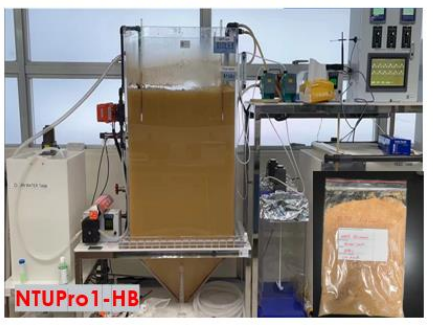
(3) Customized membranes will also address scale-up challenges such as low gas transfer rates, biomass loss, and energy-intensive separation. Finally, the project will leverage and upgrade existing Yeo Hiap Seng (YHS) facilities for full-scale deployment, reducing capital and time costs.

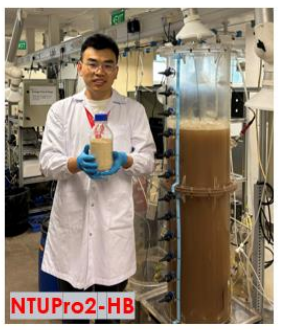
AQUACULTURE FEED SINGLE CELL PROTEIN



Raw materials → Processes → SCP → Aquaculture → Products

To optimize the nutritional quality of single cell protein (SCP) aiming for human consumption and other valuable products by formulating various clean organic waste streams and microbial consortium (Hetetrophic bacteria (HB) and purple phototrophic bacteria (PPB)) with optimal conditions; To produce high quality microbial protein employing a cost-effective production system






PI Prof Zhou Yan


Co-I Dr Jianbo Liu


Co-I Dr Hui Xu


Co-I Dr Lei Li

- Please refer to NTUPro1 (Jianbo Liu), NTUPro2 (Hui Xu), and NTUPro3 (Lei Li)
- Email：zhouyan@ntu.edu.sg; Jianbo.liu@ntu.edu.sg；hui.xu@ntu.edu.sg; lei.li@ntu.edu.sg

A GREEN PATHWAY FROM WASTE TO FOOD

- SCP yields are 0.3-0.5g/g $COD_{Removed}$ in HB system and 0.6-0.7g/g $COD_{Removed}$ in PPB system, 30-50% replacement of conventional fish meal
- The protein content in SCP is 30-48% in HB biomass and 50-70% in PPB biomass
- The carbon-to-nitrogen ratio in the influent regulates intracellular storages
- Energy-efficient systems coupled with membranes and edible reagents
- Potential to control fish pathogens.