Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Enhancing Sustainable Agriculture through Heat Recovery from Light Fixtures in Indoor Vertical Farming Systems

Hassan Sarailoo[1], Thabet Belamri [1], Lesley Campbell [2], Habiba Bougherara[1*]
[1] Department of Mechanical & Industrial Engineering, Toronto Metropolitan University, Toronto, Canada
[2] Department of Chemistry and Biology, Toronto Metropolitan University, Toronto, ON, Canada
* habiba.bougherara@torontomu.ca

Abstract

Indoor vertical farming (IVF) presents a sustainable alternative to traditional agriculture by facilitating year-round crop cultivation in controlled settings, particularly in regions where prolonged cold climates limit conventional farming practices. This method not only ensures consistent yields but also optimizes space through vertical stacking and precise management of environmental parameters such as light and temperature. IVF reduces water usage and the need for pesticides and herbicides through its closed-loop system, making it a more sustainable and environmentally friendly farming option.

Despite its numerous advantages, IVF's energy consumption remains a significant hurdle due to its reliance on LED grow lights and energy-intensive HVAC systems for climate regulation. These systems are essential for maintaining optimal growing conditions but contribute to high operational costs and a larger carbon footprint. To address this issue, our study introduces an air exhaust system designed to capture and repurpose heat generated by lighting and plant respiration. This heat, which would otherwise be wasted, can be redirected to heat up the fresh cold air, reducing the HVAC system's workload during colder periods. By integrating this heat recovery mechanism, we aim to lower energy consumption and operational costs while maintaining the ideal growing environment for crops.

We will employ Computational Fluid Dynamics (CFD) simulations to analyze temperature distributions within the exhaust air duct, assessing the base design's heat recovery efficiency. These simulations will provide insights into airflow patterns, temperature distributions, and potential areas for optimization. To validate the numerical model, we plan to conduct experimental measurements, including air velocity and temperature at multiple points within the system, as well as heatsink surface temperatures. Once the base model is validated, we will explore various return duct configurations to enhance thermal recycling efficiency. These configurations will be designed to maximize heat recovery while ensuring proper air circulation within the cultivation area, preventing hotspots or uneven temperature distributions that could negatively impact plant growth.

The outcomes of this research are anticipated to reduce the carbon footprint of indoor agriculture, particularly in cold-weather countries like Canada. By improving energy efficiency, IVF can become a more viable and eco-friendly solution, contributing to local food production and reducing reliance on imported produce. This advancement has the potential to reduce reliance on imported produce, enhance food security, and strengthen supply chain resilience in Canadian communities, ultimately contributing to the broader goal of achieving environmental sustainability while addressing the growing demand for food in a changing climate.