Automated Flow Control System–

Real-time Mass-Flow Balance System

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MICRO HARVEST

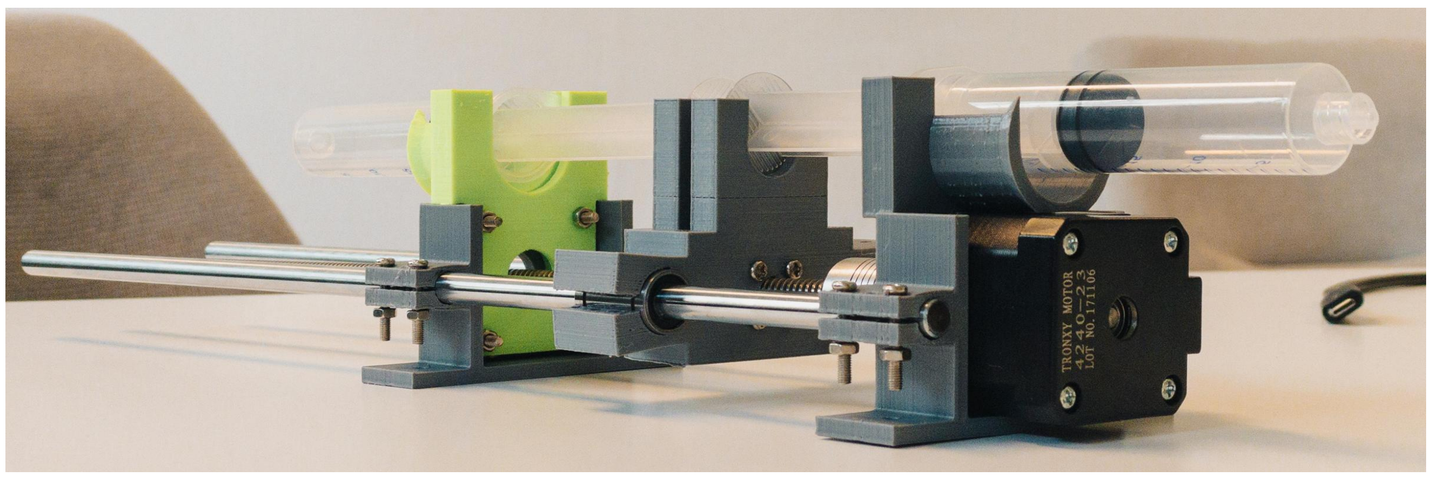
FISHING FOR EXPERIENCE

ABSTRACT

This project focuses on the development of an automated flow control system for nutrient feeding in lab-scale fermentation processes. The system replaces continuous manual operation with syringe pumps driven by stepper motors and coordinated through a 3D-printer controller. Flow regulation is achieved without traditional sensors, instead relying on calibrated motor step counts and a conversion factor. Sterility is maintained through the use of sterile syringes, autoclavable tubing, and check valves. The current prototype demonstrates reliable single-motor control, precise start/stop functionality, and accurate flow adjustment. This framework establishes a foundation for future work on multi-pump integration, advanced calibration strategies, and extended laboratory validation under real fermentation conditions.

INTRODUCTION

Manual nutrient feeding in fermentation experiments is labor-intensive, prone to error, and unsuitable for long or continuous processes. Precise flow control within ±1–5% is essential for microbial growth and product yield, yet conventional flow sensors often lack accuracy and are incompatible with sterilization requirements. Automated pumping systems using syringe pumps and stepper motors controlled by a 3D-printer controller provide a reliable alternative. Such systems remove the need for flow sensors, reduce manual workload, and maintain sterilization compatibility, thereby improving reproducibility and efficiency in fermentation experiments.



RESEARCH PROBLEM

Lab Scale Bioreactors require fine control of their contents, what components are added, and what is taken out. The unique process used by Micro- Harvest, requires specific controls not catered to commercially.

METHODS

HARDWARE

Syringe pump with autoclavable tubing + check valves

3D-printer controller (supports up to 4 motors, I used here)

Accuracy and reproducibility recorded

SOFTWARE

Step-based flow calculation with conversion factor

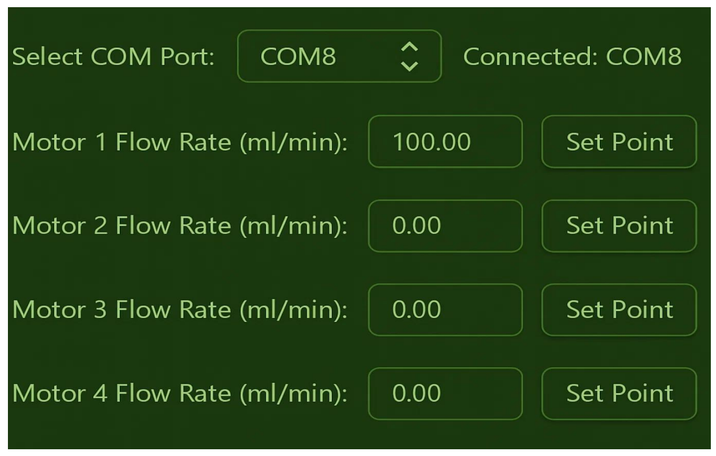
TESTING

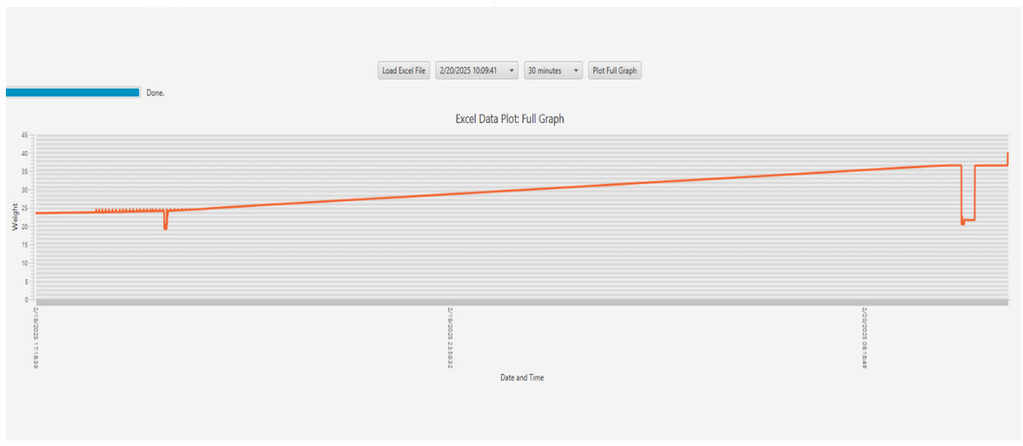
Single-pump assembly

Flow measured at different motor speeds

Accuracy and reproducibility recorded

empty weight	full weight	difference				
163,7	1147,3	983,6				
162,8	1116,1	953,3				
162,8	1112,9	950,1				
162,8	1113,6	950,8				
162,9	1083,1	920,2				
162,9	1065,1	902,2				
163,3	1107,3	944				
163,3	1094,3	931				
162,7	1070,7	908				
162,8	1077,7	914,9				
		Average:	Max:	Min:	Max%:	Min%:
		935,81	983,6	902,2	5,106805869	3,591541018





RESULTS & DISCUSSION

- Prototype syringe pump with tubing and check valves successfully assembled; motor control and emergency stop fully functional.
- Conversion factor implemented, enabling precise and reproducible flow calibration.
- Demonstrated reliable, controllable, and repeatable operation, with ongoing tests focused on accuracy and long-term stability.
- Approach achieves high-precision flow regulation without sensors, though sterility, durability, and scalability remain key challenges.
- Compared with peristaltic pumps: offers greater precision but less suited for continuous flow applications.
- Future work: multi-motor integration, extended lab validation, sterility assurance, and scaling design for industrial use.