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I CONGRESSO BRASILEIRO DE BIOTECNOLOGIA INDUSTRIAL
XXIV SINAFERM ** XV SHEB ** XV ENZITEC FLORIANÓPOLIS ** 2024
Creating connections between biotechnology and industrial sustainability
August 25 to 28, 2024
Costão do Santinho Resort, Florianópolis, SC, Brazil
BIOPROCESS ENGINEERING

DEVELOPMENT OF AN AFFORDABLE AND AUTOMATED BIOREACTOR FOR MICROALGAL CULTIVATION

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ABSTRACT

Microalgae cultivation holds significant promise for the sustainable production of various bioproducts. Key parameters for predicting their growth include pH, light intensity, temperature, and initial biomass concentration. However, traditional equipment for these measurements is often very expensive. This study aims to solve this problem by developing a low-cost bioreactor system integrated with Arduino-based automation for cultivating *Chlorella vulgaris*, focusing on constructing an affordable continuous flow turbidimeter. This automated bioreactor represents a significant advancement, offering a sustainable and economical solution for cultivating microalgae across different genera, and ensuring savings of over 96% in sensor acquisition costs compared to traditional equipment typically used.

Keywords: Arduino. Low-cost sensor. *Chlorella vulgaris*. Microalgae.

1 INTRODUCTION

Integrating robotics and artificial intelligence in the early stages of microalgae cultivation enhances automation, monitoring, and data management, resulting in more precise process control and ultimately increasing cultivation efficiency and optimization[1]. For microalgae cultivation, controlling environmental factors and carbon sources is crucial for productivity. Factors such as light, temperature, carbon dioxide, and pH play essential roles in their growth, multiplication, and chemical composition[2].

In biotechnological processes, traditional sensors are essential for monitoring, but their high costs for procurement and maintenance constitute a challenge. A promising alternative is Arduino-based sensors, which offers a low-cost solution applicable to nearly all biotechnological processes[3]. Recent developments have seen Arduino applied in microalgae cultivation for monitoring cell growth and refining biotechnological processes[4]. However, there is a gap in its use in biotechnological processes with *Chlorella*. Therefore, the objective of this work is to build a low-cost bioreactor and apply it to the cultivation of *Chlorella vulgaris*.

2 MATERIAL & METHODS

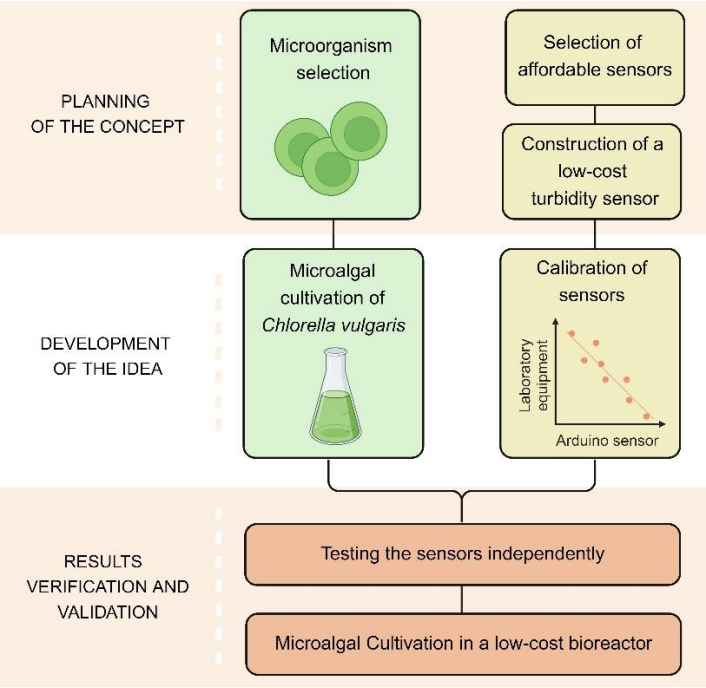

Figure 1 Development Process.

3 RESULTS & DISCUSSION

To monitor microalgal growth, the LGZD turbidity sensor was tested. It includes an infrared emitter and receiver encased in plastic, allowing immersion in the liquid. Calibrated against a traditional spectrophotometer at 600 nm, it showed excellent correlation (R^2 = 0.9514). However, when applied to the cultivation of *Chlorella vulgaris* in a 1L flask, it proved unsuitable. Direct contact with the liquid damaged its electrical components and generated inconsistent data (Figure 2a).

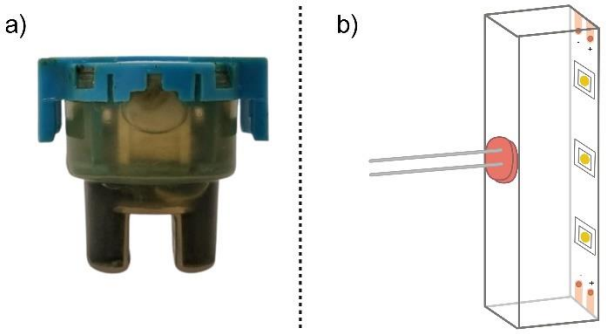

Figure 2 Turbidity sensor. a) Corrupted LGZD turbidimeter. b) Assembled turbidity sensor.

To address this issue, a bioreactor with a continuous turbidity measurement system was constructed in a 2L flask. A small peristaltic pump was used to promote the fluid circulation from the bottom to the top of the flask. In this circuit, the liquid flow and its turbidity were continuously measured. In addition, the flask cap includes temperature and pH sensors - immersed in the liquid -, a CO_2 concentration sensor, a pump for introducing air, and a hose with a filter for air outlet. The sensors chosen for the system assembly are listed in Table 1.

Table 1 Comparison between the costs of low-cost sensors and traditional laboratory equipment.

Parameter	Low-Cost Sensor	Price (R$)	Similar Commercial Equipment	Price (R$)	Reference
pH	PH4502C	188.39	pHmeter Kasvi	2,487.29	[5]
Temperature	DS18B20	14.73	Temperature datalogger RC-4	199.90	[6]
Light intensity	BHI1750-FVI	19.46	Radiometer Radalert-100	10,773.00	[7]
CO_2 concentration	CO_2 concentration	379.05	CO277	2,787.00	[8]
Air pump	SC3704PM	28.41	Aerator pump	73.63	[9]
Flow rate	YF-S401	42.66	LCD K24	310.09	[10]
Peristaltic pump	CPK-DC-S08	66.41	Intlab OFA	199.90	[11]
Turbidimeter	LDR 5mm	1.14	Spectrophotometer Kasvi	4,740.21	[5]
	Cool white LED strip	17.98			
	Cuvette	0.63			

A new turbidity sensor was constructed, similar to a spectrophotometer, with emitting and receiving light sources. For continuous measurement of cell concentration in the medium, a plastic cuvette with cuts at the edges was used, where connectors were glued with resin. On the smooth sides of the cuvette, cool white LEDs were fixed on one side and an LDR photoresistor on the other (Figure 2b). The system was covered to avoid external light interference.

All sensors were calibrated, ensuring excellent linear correlations with traditional laboratory equipment, as shown in Table 2, proving their applicability in the system.

Table 2 Calibration of low-cost sensors.

Sensor	R^2	Range analyzed	Unit	Calibration instruments
pH	0.9846	2.39 – 10.54	-	pHmeter
Temperature	0.9999	14.5 – 75.0	°C	Mercury Thermometer
Light intensity	0.9869	0.0 – 105.6	PPFD	Radiometer
CO_2 concentration	0.9833	1.2 – 94.3	%	O_2/CO_2 gas analyzer
Air pump	0.9906	3.8 – 31.0	$mL.s^{-1}$	Water column
Flux	0.9849	0.23 – 0.49	$L.min^{-1}$	Volume measurement over time
Turbidimeter	0.9951	0.014 – 1.272	OD_{650nm}	Spectrophotometer

After validating the constructed bioreactor, it was observed that the total cost for building the operating system was R$ 758.86, which represents only 3% of the cost required for traditional equipment (Table 1) and highlights the prominent financial advantage.

The project was funded with a total investment of R$ 1,758.02 (Table 3).

Table 3 Construction costs for the bioreactor.

Item	Price (R$)
Low-cost sensors	758.86
Flask	676.43
Arduino kit (board + protoboard + jumpers + energy source)	200.00
Aquarium hose	10.99
Syringe filter	3.72
Real Time Clock	9.41
LCD display	29.93
Sd card reader	8.88
SD card	59.80
TOTAL	**1,758.02**

This illustrates that the developed system not only offers good cost-effectiveness compared to traditional methods of measuring biotechnological parameters, but it also significantly reduces the researcher's workload. This allows researchers to focus more on data analysis and the research itself, with less time-consuming and repetitive work involved.

It is important to note that this system does not completely replace commercial laboratory equipment, once these are essential for the correct calibration of the constructed system.

4 CONCLUSION

The construction of the low-cost bioreactor significantly improved the monitoring and automation of *Chlorella vulgaris* cultivation, guaranteeing precise and effective data collection, while also reducing financial investment and manual workload for researchers. Finally, this study presented promising results by indicating the potential of low-cost sensors associated with Arduino-based automation in the cultivation of *Chlorella vulgaris* and in a wide possible range of other biotechnological processes.

REFERENCES

[1] SHITANAKA, T., FUJIOKA, H., KHAN, M., KAUR, M., DU, Z. Y., KHANAL, S. K. 2024. Recent advances in microalgal production, harvesting, prediction, optimization, and control strategies. *In*: Bioresour. Technol. (Vol. 391). Elsevier Ltd. doi: 10.1016/j.biortech.2023.129924.

[2] VITOVA, M., BISOVA, K., KAWANO, S., ZACHLEDER, V. 2015. Accumulation of energy reserves in algae: From cell cycles to biotechnological applications. *In*: Biotechnol. Adv. Nov 1;33(6 Pt 2):1204-18. doi: 10.1016/j.biotechadv.2015.04.012.

[3] MONK, S. 2013. Programação com Arduino: Começando com sketches. *In*: Bookman, Porto Alegre. ISBN: 978-85-8260-027-6.

[4] WANG, K., KHOO, K. S., LEONG, H. Y., NAGARAJAN, D., CHEW, K. W., TING, H. Y., SELVARAJOO, A., CHANG, J. S., SHOW, P. L. 2022. How does the Internet of Things (IoT) help in microalgae biorefinery?. *In*: Biotechnol. Adv.; 54:107819. doi: 10.1016/j.biotechadv.2021.107819. PMID: 34454007.

[5] Prolab. Available in: https://www.lojaprolab.com.br/. Acessed in: 05/03/2024.

[6] Elitech Brasil. Available in: https://www.elitechbrasil.com.br/. Acessed in: 05/03/2024.

[7] Instrutherm. Available in: https://www.instrutherm.com.br/. Acessed in: 10/06/2024.

[8] Lader Química. Available in: https://www. laderquimica.com.br/. Acessed in: 10/06/2024.

[9] Cerveja da casa. Available in: https://www.cervejadacasa.com/. Acessed in: 10/06/2024.

[10] Grandado. Available in: https://www.bra.grandado.com/. Acessed in: 10/06/2024.

[11] O.F.A. Available in: https://www.ofaambiental.com.br/. Acessed in: 10/06/2024.

[12] Instrutherm. Available in: https://www.instrutherm.com.br/. Acessed in: 10/06/2024.

ACKNOWLEDGEMENTS

This study was financially supported by Fundação de Amparo à Pesquisa e Inovação do Estado de Santa Catarina – FAPESC (Project number 2023TR000275) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES (Finance Code 001). The authors also thank LABSIN/LABMASSA – Mass Transfer Laboratory, LAFIC – Phycology Laboratory and the Federal University of Santa Catarina – UFSC for the infrastructure provided. Bastos thanks PROSPECMAR (440472/2022-9) and CNPq for the financial support (381216/2023-3).