

















ORIGINAL

Design and implementation of a low-cost orbital shaker for laboratories

Diseño e implementación de un agitador orbital a bajo costo para laboratorios

Ernesto Díaz-Roncero¹  , Ángel David Hernández-Amasifuen²  , William Joel Marín-Rodríguez^{1,3}  , Daniel Andrade Girón¹  , José Luis Ausejo-Sánchez^{1,3}  , Algemiro Julio Muñoz-Vilela¹  , Abrahán Cesar Neri-Ayala^{1,3}  

¹Universidad Nacional José Faustino Sánchez Carrión. Lima. Huacho, Perú.

²Universidad Nacional Agraria La Molina, Programa Doctoral en Ciencias e Ingeniería Biológicas, Lima, Perú.

³Universidad Tecnológica del Perú. Lima, Perú.

Cite as: Díaz-Roncero E, Hernández-Amasifuen Ángel D, Marín-Rodríguez WJ, Andrade Girón D, Ausejo-Sánchez JL, Muñoz-Vilela AJ, Neri-Ayala AC. Diseño e implementación de un agitador orbital a bajo costo para laboratorios. Salud, Ciencia y Tecnología. 2023;3:397. <https://doi.org/10.56294/saludcyt2023397>

Submitted: 02-04-2023

Revised: 19-04-2023

Accepted: 27-05-2023

Published: 28-05-2023

Editor: Lic. Mabel Cecilia Bonardi 

ABSTRACT

Orbital shakers are of great importance in plant culture laboratories, however, the high cost of this equipment often makes it impossible for researchers to acquire them. Therefore, the objective of the study was to design and implement a low-cost orbital shaker for plant culture laboratories. The type of research was applied and experimental. As results, the 3D printed design of the support structure was obtained, as well as the control system based on an ATmega328P microcontroller. The range of the revolutions per minute of the orbital shaker was between 0 and 350rpm. It is concluded that the orbital shaker meets the objective set out in this research, obtaining an implementation cost of USD 153,50 US dollars.

Keywords: Orbital Shaker; Atmega328p Microcontroller; 3D Printing.

RESUMEN

Los agitadores orbitales son de gran importancia en los laboratorios de cultivo vegetal, sin embargo, el costo elevado de estos equipos muchas veces imposibilita que los investigadores los puedan adquirir. Por lo tanto, el objetivo del estudio fue diseñar e implementar un agitador orbital a bajo costo para laboratorios de cultivo vegetal. El tipo de investigación fue aplicado y experimental. Como resultados se obtuvo el diseño impreso en 3D de la estructura de soporte, así como el sistema de control basado en un microcontrolador ATmega328P. El rango de las revoluciones por minuto del agitador orbital estuvo comprendido entre 0 y 350rpm. Se concluye que el agitador orbital cumple con el objetivo planteado en la presente investigación, obteniendo un costo de implementación de USD 153,50 dólares americanos.

Palabras clave: Agitador Orbital; Microcontrolador Atmega328p; Impresión 3D.

INTRODUCTION

In laboratories, orbital shakers are used for the homogenous mixing of liquids or for the cultivation of moving samples. Orbital shakers generally come in small tabletop sizes, where it shakes at laboratory temperatures. These shakers operate in a comparable way, but they keep the product in a closed and incubated environment while it is being stirred.⁽¹⁾ A specific application of the orbital shaker is to stir cultures that grow in flasks in constant orbital motion which will provide controlled growth of cultures within the inner environment of the flasks. The gentle, circular, and uniform agitation at a controlled speed is important for maintaining a similar

growth rate among batches of culture in different containers. Orbital shakers have been used in various areas where stirring is necessary, ranging from medicine to agriculture. The mechanism of the orbital shakers consists of a motor coupled to a platform. The orbit is attached to the motor and as the motor rotates in a circular motion, the orbit shakes the content of the container. The entire platform of an orbital shaker travels in a circular orbit.^(2,3)

It would be difficult to imagine modern laboratories without stirring equipment with temperature control, as they are essential to facilitate the reaction between different substances and the growth of biological cultures that would not naturally occur due to the particular conditions necessary for their development. For example, some microorganisms have minimum, maximum, or optimal growth depending on their temperature, and without proper stirring, they would not be able to absorb the oxygen necessary for their development.⁽⁴⁾

The use of oxygen by microorganisms is only possible when it is dissolved in the medium, which underscores the importance of employing stirrers in analyses involving aerobic microorganisms. Moreover, under certain conditions, stirring is necessary for microbial fermentation, which is composed of three phases: liquid-solid reactions, gas-solid, and gas-liquid reactions.⁽⁴⁾

Currently, there are several companies in the industry dedicated to the manufacturing of laboratory equipment, including electromechanical shakers with orbital movement, which can have temperature control or not. These devices have similar specifications, but prices may vary depending on the company and the functionalities of the equipment. On average, the cost of these devices is more than 1000 US dollars.^(4,5)

Therefore, the objective of this research was to design and implement a low-cost orbital shaker for laboratories.

METHODS

An applied and experimental study was developed, focusing on the design and implementation of the orbital shaker device, whose reliability will be based on the tests carried out. The following stages were employed to carry out its implementation: 3D printing of the support structure, design of the electronic system, programming of the Arduino UNO board, tests of the orbital shaker at different revolutions, and final assembly of the device.

The bibliography used focuses on experimental research, using sources from scientific databases with digital access, university libraries, and scientific journals that address the challenges, tasks, and proposals raised by researchers for the design of an orbital shaker.

RESULTS

3D Printed Structure

For the development of the orbital shaker's structure, the 3D printing technique was employed using a Creality Ender 3 Pro printer, as seen in figure 1, it was then assembled and secured using screws.



Figure 1. 3D printed virtual stirrer structure

Electronic System

Inside, its electronic system was set up (figure 2), composed of an Arduino UNO board, a 12VDC NEMA stepper motor, a DRV8825 driver, a 5k potentiometer, a 100uf capacitor, and a 16x2 LCD screen.

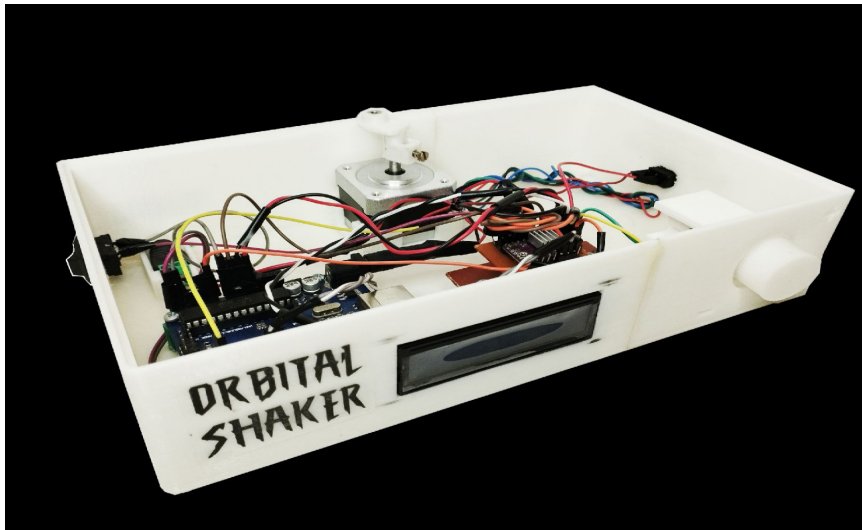


Figure 2. Internal electronic system of the orbital shaker

Programming the ATmega328P Microcontroller

The Arduino UNO board, based on an Atmel ATmega328P microcontroller, was tasked with acquiring the analog signal from the potentiometer through its AN0 peripheral input. It then proceeds to scale the signal with a 10-bit resolution for later use through the `#include <AccelStepper.h>` library. To calculate the revolutions, the scaling command `stepperMotorSpeed = map(potValue, 0, 1023, 0, 1000)`; and the $RPM = (30 * \text{stepperMotorSpeed}) / 100$ formula were used. Finally, it sends the information to the DRV8825, which controls the 12VDC NEMA motor using the `stepper.setSpeed(stepperMotorSpeed)` command.

Operation of the Orbital Shaker

To start the orbital shaker, first, its power supply must be connected at the back, which consists of a 12VDC 1.5A charger. Then the LCD screen lights up, showing a welcome message for a few seconds before indicating the RPM (revolutions per minute) setting that needs to be assigned. To do this, there is a knob on the front right (figure 3). After selecting the speed, the motor power is activated with the left side switch (figure 4), and to start the rotational movement, the right side switch (figure 4) must be activated. The orbital shaker will continue to move indefinitely until the user or researcher decides to stop it by changing the movement switch mode. At this point, the user can choose to vary the speed and start the movement again or deactivate the NEMA motor power and turn off the equipment.



Figure 3. Orbital shaker RPM adjustment mode

Range of revolutions per minute (RPM)

The revolutions per minute are related to the resolution of the analog signal, the RPM range is from 0 to 350rpm (figure 5).



Figure 4. Orbital shaker side views

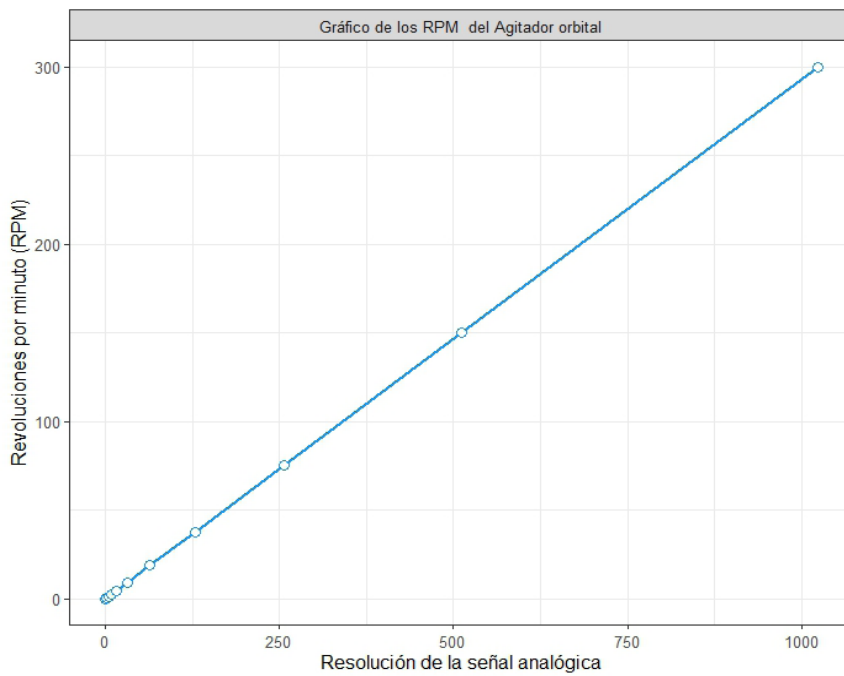


Figura 5. Range Of Revolutions Per Minute (RPM)

Budget

Table 1. Orbital shaker budget		
Costs	Quantity	Price
3D Printing	1	60,00
12V stepper motor NEMA 17 34mm	1	23,00
Pololu DRV8825 driver	1	5,00
Arduino Micro Pro, with swords	1	10,00
Rocker Switch	1	0,50
DC female adapter	1	0,50
10K potentiometer	1	1,00
I2C	1	3,50
LCD 16X2	1	4,00
Charger 12V 2A	1	8,00

Swords	3	1,50
Freight	3	20,00
Pololu DRV8825 driver	1	6,50
Arduino UNO	1	10,00
Total Cost		USD 153,50

DISCUSSION

The results demonstrate that the developed device fulfills the functionality that an orbital shaker should have. In this sense, we agree with Arboleda⁽²⁾, who mentions that after the evaluation performed, it was concluded that the low-cost orbital shaker was adequate and viable. However, during the investigation, it was found that a low-cost direct current motor could supply and regulate the sophisticated orbital shaking movement.

In another sense, Panizo⁽⁴⁾ mentions that after reviewing the speed control and the prototype's motor and implementing the necessary recommendations, it was concluded that if a motor is selected whose current consumption does not exceed 2 amperes and is capable of reaching a speed of 400 RPM or more at its nominal torque, a speed for the prototype will be achieved within the desired range of 40 to 400 RPM. In the case of Espinoza's research⁽⁶⁾, the working range of the Modular Orbital Shaker is 20 to 120 (RPM) due to the needs provided by the Vegetable Cultures Laboratory; in our research, the range obtained for the orbital shaker was 0 to 300 RPM.

The ability to control the shaking speed is crucial during the conduct of tests, and the use of a stepper motor allows precise and straightforward operation.⁽⁷⁾ Control of the motor's pulses is possible thanks to a proportional controller, which increases precision in speed regulation.⁽⁸⁾

The budget for our virtual shaker was USD 153,50, being a low-cost amount compared to the equipment that exists on the market. In this sense, we agree with Loza⁽⁸⁾ who states that economic profitability is a key factor in the construction of our prototype, especially compared to international market prices. With a cost lower by around 50 %, our alternative offers an opportunity to promote the innovation and manufacture of these devices in our country, which could reduce import rates for highly used laboratory equipment. Also, our prototype has optimal quality for teaching and uses the university's multidisciplinary technical knowledge and resources.⁽⁸⁾ Similarly, Mohini⁽³⁾ mentions that the entire manufactured system is cost-effective and capable of immediately responding to any type of changes. Thus, the system successfully provides the necessary functions required in various microbiology laboratories and pharmaceutical labs at a very affordable price.

CONCLUSIONS

We were able to design and implement a low-cost orbital shaker device for vegetable culture laboratories. The technological proposal allows for a working speed between 0 to 300 rpm; it is important to note that the movement only starts at 80 rpm, at which point the stepper motor breaks the moment of inertia. An open-loop control system was designed using the ATmega328P microcontroller, which allows the acquisition of the analog signal coming from a 5K Ω potentiometer (knob). For motor control, a DRV8825 device was used, which receives information from the ATmega328P microcontroller and establishes the revolutions of the stepper motor. It is recommended to use two separate power sources, one for the electronic system and another for the nema motor, to avoid voltage and current drop conflicts in the microcontroller when starting the movement. The device cost USD 153,50. Finally, it can be concluded that the low-cost orbital shaker device was implemented and will significantly contribute to the research carried out in vegetable culture laboratories.

REFERENCES

1. Oostrom, RD Van. Design of an orbital shaker for future laboratory use. 2023. <http://essay.utwente.nl/94328/>
2. Arboleda E. Design, construction, and evaluation of transformer-based orbital shaker for coffee micropropagation. *Journal of Mechatronics, Electrical Power, and Vehicular Technology*. 2022; 13(2), 147-156. <https://doi.org/10.14203/j.mev.2022.v13.147-156>
3. Mohini A. Microcontroller based orbital motion shaker, 2015 International Conference on Intelligent Informatics and Biomedical Sciences (ICIIBMS), Okinawa, Japan, 2015, pp. 115-120. <https://doi.org/10.1109/ICIIBMS.2015.7439504>
4. Panizo D. Revisión de un prototipo de agitador electromecánico con movimiento orbital y diseño de sus

mejoras. Pontificie Universidad Católica del Perú. Lima, Perú. 2011. <http://hdl.handle.net/20.500.12404/812>

5. Nedbal J, Gao L, Suhling K. Bottom-illuminated orbital shaker for microalgae cultivation. *HardwareX*. 2020; 8:e00143. <https://doi.org/10.1016/j.ohx.2020.e00143>.

6. Espinosa FI, Trávez GL. Diseño y construcción de un agitador orbital modular de doble bandeja para el laboratorio de cultivo de tejidos vegetales de la carrera de Ingeniería en Biotecnología. Universidad de las Fuerzas Armadas. Sangolquí, Ecuador. 2016. <http://repositorio.espe.edu.ec/handle/21000/11730>

7. Cisnero-Piñeiro AL, Delgado MCF, Mendoza JAR. Tendencias de la producción científica en el área Industrial and Manufacturing Engineering en Scopus entre 2017 y 2021. *Data & Metadata* 2022;1:6. <https://doi.org/10.56294/dm20226>.

8. Loza Matovelle D, Torres M, Ruilova M, Albán L, Velasco R, Segura L, Dabirian R. Diseño y Construcción del Prototipo de Código Abierto de una Incubadora con Agitación Orbital. *Rev. Politéc.* 2023;36(3):51.

FINANCING

Research carried out with the researchers' own resources.

CONFLICT OF INTEREST

There are no conflicts of interest.

AUTHORSHIP CONTRIBUTION:

Conceptualization: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen.

Data curation: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez

Formal Analysis: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez

Acquisition of funds: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez, José Luis Ausejo Sánchez, Algemirol Julio Muñoz Vilela, Abrahán Cesar Neri-Ayala

Research: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez

Methodology: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez, José Luis Ausejo Sánchez, Algemirol Julio Muñoz Vilela, Abrahán Cesar Neri-Ayala

Project management: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez

Resources: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez, José Luis Ausejo Sánchez, Algemirol Julio Muñoz Vilela, Abrahán Cesar Neri-Ayala

Software: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen

Supervision: William Joel Marín Rodríguez

Validation: José Luis Ausejo Sánchez, Algemirol Julio Muñoz Vilela, Abrahán Cesar Neri-Ayala

Visualization: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez, José Luis Ausejo Sánchez, Algemirol Julio Muñoz Vilela, Abrahán Cesar Neri-Ayala

Writing - original draft: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez

Writing - proofreading and editing: Ernesto Díaz Ronceros, Ángel David Hernández-Amasifuen, William Joel Marín Rodríguez