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DESIGN AND FABRICATION OF A PROTOTYPE FLUIDIZED BED DRYER FOR SPECIES

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Abstract: This project shows the development of a fluidized bed dryer prototype design for the Tecamachalco Technological University laboratories. The fluidized bed dryer prototype was built with a manageable and disassembled size. To dry 5 g quantities and evaluate times, temperature and drying speed with a low cost of electricity consumption. The drying technologies are evaluated for given time, temperature, humidity and speed of drying species, whose objective is to design and build a fluidized bed dryer to dry 5 g of a wet sample, applying the reuse of materials (Circular Economy) to reduce the construction cost. We start with the methodological scheme applied for the design, engineering analysis of each part of the equipment, construction and functional test of fluidized bed equipment in laboratory scale. As a result, the equipment will operate between temperatures of 50°C to 70°C, adjustable speeds between 4 to 11 m /s, drying time 4 hours, consumption of 1.7 kW/h, allowing homogeneous drying of the product. The dryer is automated by means of arduinos that send digital signals to LCD screens and also control the resistors by means of thermostats that perform automatic temperature control and air flow control, in order to handle different speeds.
Keywords: fluidized bed; energy; dryer; laboratory equipment.

INTRODUCTION

Drying is one of the most widely used unit operations. According to INEGI data, approximately 28.4% of the final energy consumed in the industry is used for product drying. In the biofood processes program it is usual to dry products in an oven or thermobalance, however, there are no fluidized bed drying prototypes that can be used by students. In this context, together with the research group of the Mechatronics Engineering program, the idea of building a prototype dryer that makes possible the drying of different leaf species was conceived.

In addition to the fact that the biofood processing area only has a rack dryer, another limitation of this dryer is the long drying times and the difficulty to regulate the drying temperatures. Based on the above, the construction of a fluidized bed dryer is proposed. The low efficiency of the system, which consists of hot air turbines, is compounded by the fact that the current system does not have a system for measuring drying parameters. To solve this problem, we propose the construction of a prototype that simulates the characteristics of the dryers currently in operation, with significant improvements and with the ability to measure the parameters associated with the drying process for educational purposes.

CONTEXT AND JUSTIFICATION OF THE STUDY

Drying is a fundamental operation for the stabilization of biological products. It is also a common operation in food processes and because of this there is a wide variety of drying equipment. The design and development of a fluidized bed dryer prototype for the biofood processes laboratory, whose purpose is to enable students' learning with a concept and design project activity, where students must solve a technical problem through the development of a prototype.

OBJECTIVE OF THE PROJECT

GENERAL:

Design and fabrication of a prototype fluidized bed dryer for drying leafy species.

PARTICULAR:

Design automation using a smart card that emits a signal to control the temperature.

The objective of this work is the design and construction of a fluidized bed dryer prototype. Mechatronics engineering starts the project by incorporating simulation and design planning tools. By means of a study, the equipment needed to control the prototype parameters during its operation is defined. It is proposed to calculate the mass transfer in lollipop sheets and the costs of the system.

METHODOLOGY

1) The applied, convenience, single-design, monocausal, single-causal research model was selected.

2) Bibliographic research. The research process begins with the approach to the operation of a fluidized bed stove, then it will be necessary to carry out the task of searching and retrieving information on the subject.

3) Design, development and performance test of the prototype bed.

THEORETICAL FUNDAMENTALS OF FLUIDIZED BED DRYING

Drying is an industrial operation that refers to the removal of moisture (liquids) in solid products, which brings as physical consequences a decrease in volume, modifications in their electrical and mechanical properties, as well as a change in the vapor pressure of some materials.

Fluidized bed drying is a method that uses a gas as a heat transfer fluid which, in the case of this proposal, is air. This gas, by projecting an adequate velocity of the air passing through the bed of particles, avoiding moments of inadequate flow, will cause the particles not to agglomerate creating spaces through which the gas flows, generating a bed of particles in suspension with behavior similar to a liquid. The air passes through the particles reaching the interior of the particle and dragging the water as it passes through the surface of the particle and eliminating the humidity, obtaining the dry solid. The fluidized bed studied consists of a drying vessel, a fan, a mechanical agitator and an electrical resistance. To control the temperature, the amount of air and the drying time, an automation system with a smart card is required.

FLUIDIZED BED OPERATING PRINCIPLES

In a fluidized bed, the particulate solid is entrained by the air or other gas in such a way that the whole acquires the behaviors of the fluid. For this situation to occur, a minimum velocity of the entrainment fluid is required, the magnitude of which depends on the size and shape of the particles that make up the bed. Thus, by intensifying the flow, the fluidized bed regime is reached, obtaining a perfect mixture of particles, with low resistance to mass and energy transfer, as well as total control of temperature, uniform presence of gas exposure of the feed, low particle fall speed and no particle segregation by size and density.

DESIGN AND CONSTRUCTION OF THE PROTOTYPE

Table 1 shows the global configuration of our prototype, composed of two independent systems according to their operation: the loading system, which is in charge of supplying the raw material (lollipop leaf) to our fluidized bed dryer called dryer. It has attached to its lower part a motor and a helical screw that simulates the effect of particle transport.

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SELECTION OF MATERIALS AND COMPONENTS

Materials
Thermocouple 8000w
4000w dimmers
Power Supply 12v at 40Amps
Brushless motor, with controller
Led screen (Lcd)
Arduino
Cables (22 caliber)
Screws 3.3mm
Blender cup
Relays 5v
Swich

List of components and materials to be used.

Regarding the dryer body, 3-D printing with recycled pet material was used, considering the size of the drying chamber to strategically place the location of sensors, connect pipes and support the electrical panel.

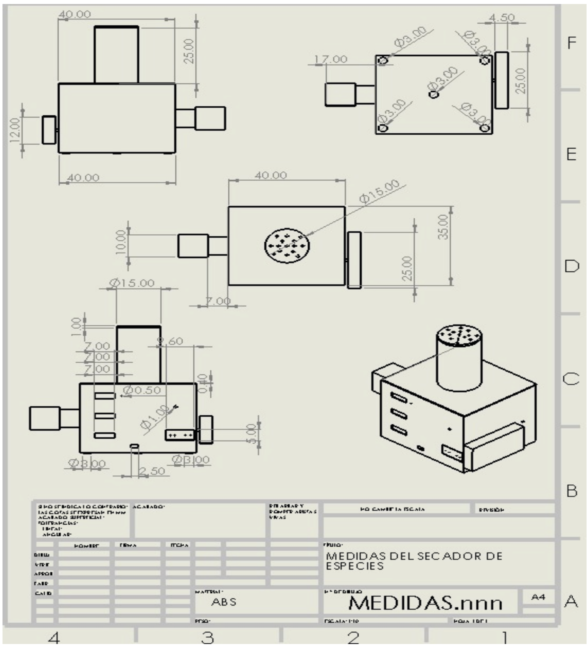


Figure 1. Dimensional drawing of the dryer (exploded view).

DRYER INSTRUMENTATION AND CONTROL

The experimental prototype has two Arduino boards that collected four variables: air flow, ambient temperature, air temperature and material temperature. Similarly, a smart card programmed reference values to be followed for air and material temperature. To adjust it, the sensors used were calibrated. In addition, the measurements and readings were taken using university laboratory equipment.

TEMPERATURE AND HUMIDITY SENSORS

Sensors are devices that transform physical variables (temperature, humidity, pressure, etc.) into electrical signals, allowing microcontrollers to read and process the data of the variables we are monitoring. The information captured by the sensor is processed in real time and allows us to acquire data at a specific rate (sampling time). In addition, one or several sensors connected to a data acquisition board allow us to monitor more than one variable at a time, important factors when working with a convective drying system to know how the process is performing.

Automatic control system

According to the objectives of the research study, the prototype fluidized bed dryer will be equipped with a controller to monitor the fluidized bed outlet temperature through a PT100 sensor. The outlet temperature through the air collector will be in the range of 50 to 60 °C, by means of a PT100 sensor. From the indicated temperatures, it will be possible to visualize the recordings in numerical values on a graphical interface. In order to avoid damage to the panel due to high temperature, a temperature limit switch will be installed.

TIME-TEMPERATURE MEASURING EQUIPMENT FOR AIR AND SOLID MATERIAL

Use of "J" type thermocouples (accuracy: ±0.6 °C), for taking time and temperature data between the drying air.

The machine works through a brushless motor that goes inside the equipment, which will serve to be able to throw it towards the resistances that are approximately at 150 °C, this will make the air heat up and go up through the drying chamber, where the species are.

CHARACTERISTICS OF THE PROTOTYPE MACHINE

Thermocouple 8000 W

It is a temperature sensor that measures the temperature of an object by means of the electrical potential difference between two dissimilar metals. It has a measuring capacity of up to 8000 W. It is an important component in temperature control systems, such as in ovens, stoves and welding machines.

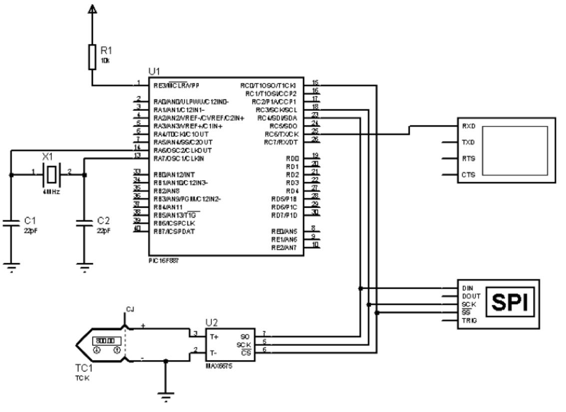


Figure 2. Diagram of electronic control connections

A simplified connection diagram of the control electronics shown in Figure 2.

Dimmer 800W

It is a device used to control the light intensity or power of an electrical circuit. It has a dimming capacity of up to 800 W. It is used in a variety of applications, such as lighting, household appliances and industrial machines.

Resistors

They are electrical components used to generate heat. They are manufactured in a variety of shapes and sizes, and can have different power ratings. They are used in a variety of applications, such as ovens, stoves and welding machines.

LCD Displays

These are digital displays that use light-emitting diodes (LEDs) to display information. They are high brightness and have low power consumption. They are used in a variety of applications, such as watches, computers and industrial equipment.

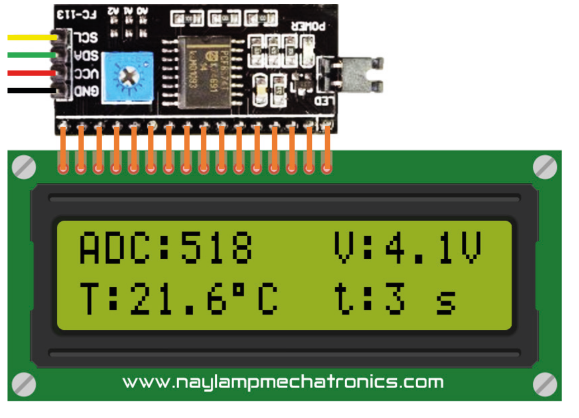


Figure 3. LSD display, Thermocouple "J", Microcontroller and solid state relay.

Arduino

It is a free and open source hardware platform used to create electronic projects. It is easy to use and has a wide variety of resources available. It is used in a variety of applications, such as robotics, home automation and machine learning projects.

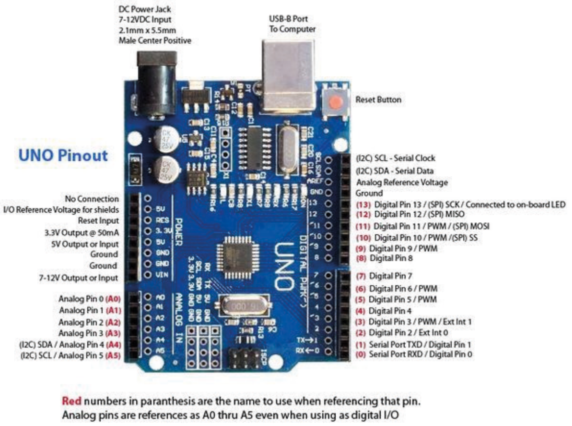


Figure 4. Arduino UNO controller board

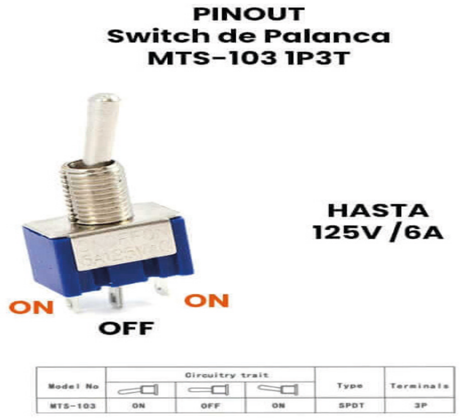


Figure 6. Switch

Relay

An electromechanical device used to control the flow of electric current. It consists of an electromagnet that activates a mechanical switch. It is used in a variety of applications, such as in alarm systems, household appliances and industrial machines.

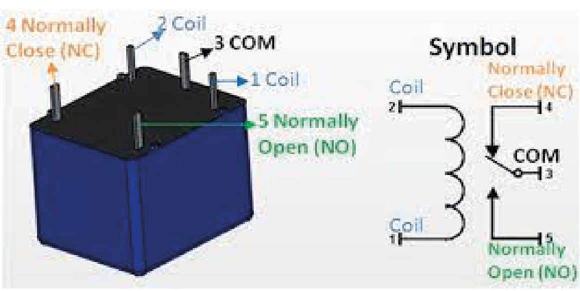


Figure 5. Relay

Switch

A mechanical device used to connect or disconnect an electrical circuit. They are manufactured in a variety of shapes and sizes, and can have different types of contacts. They are used in a variety of applications, such as in household appliances, industrial machines and safety equipment.

Brushless motor with 20 A controller

It is an electric motor that does not require brushes for its operation. It is more efficient and durable than brushed motors. The 20 A controller allows to control the speed and torque of the motor.

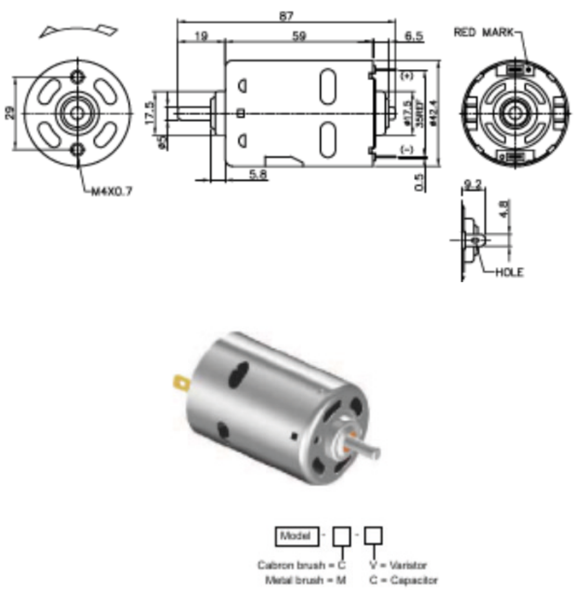


Figure 7. Brushless motor.

12 V TO 40 A POWER SUPPLY

It is a power supply that provides a voltage of 12 V and a current of up to 40 A. It is used to power a variety of electronic devices, such as computers, routers and audio equipment.

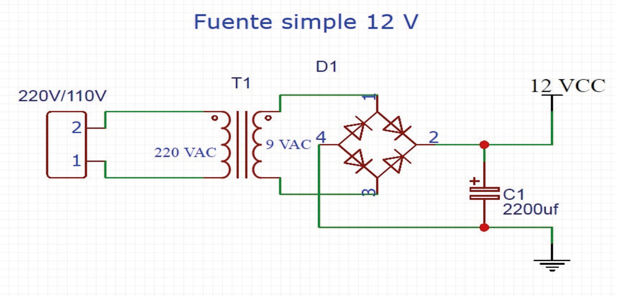


Figure 8. Single source 12 V

Equipment structure and drying chamber

Made of ABS, a type of thermoplastic that is characterized by its high impact resistance.

W12 Modules

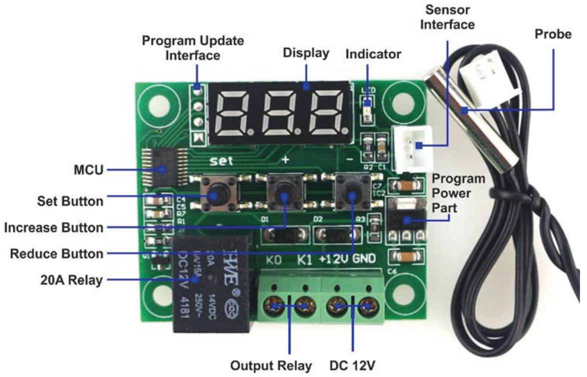


Figure 9. Module W12

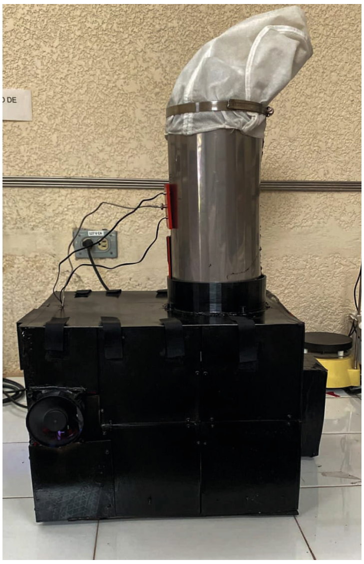


Figure 10. Dryer prototype

PROJECT DEVELOPMENT

At the time of writing this report, physical functional tests of the electronic components have been performed to verify the functionality of the prototype.

TIME AND TEMPERATURE ANALYSIS IN THE DRYING PROCESS

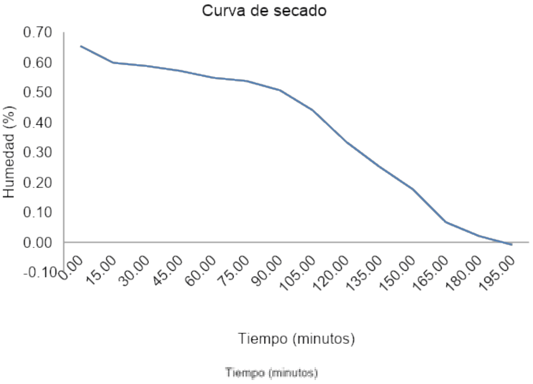
The selected material was subjected to a cleaning and screening process. In the drying process, both the air temperature adjustment and the time required for the process are present.

Figure 11 Dried pirul leaves in thermo scale

% Humidity (thermobalance)=65.32

Xs= 100 - 65.32

Xs= 34.60



Tiempo (Min)	Peso inicial (g)	SS	Agua	Humedad (%)
0.00	5.018	1.74	3.28	62.32
Tiempo (min)	Peso final (g)	SS	Agua	Humedad (%)
195.00	1.726	1.74	-0.01	-0. 83

Figure 12. Drying curve of pirul leaves.

Taking an average according to the tests performed, after approximately 120 minutes of the system working at 50°C, it decreased by 1.5°C, which indicates reliability in its use.

Interpretation of results

The results obtained show that the equipment fulfills the function of reducing the amount of water present in the lollipop leaf at the working temperature of 50°C. With the current fluidized bed drying efficiency of 120 min and a final humidity of 1%. During the drying of the lollipop, there were failures, one of which is the fluidization of the air inside the system (drying chamber), since the air dispersion is deviated in the corners of the chamber, and not in the central zone.

This behavior can be explained by the fact that the treated particles do not overcome the adhesion forces between them, such as electrostatic, cohesion or Van der Waals forces, which keep them together as single units, which may influence the amount of effective fluid flow through and consequently the overall transmission coefficient, since it depends on the dimensioning variables.

RESULTS AND DISCUSSION

The main motivation for the development of this prototype was the need to transmit the concepts and fundamental aspects of the operation of conventional dryers, as well as the work done to reduce energy consumption in them. The average initial time is 120 minutes, in order to obtain significant results. From these values, it was found an average drying time in relation to the initial humidity of 65% and 1% of final humidity, with a constant air flow during 2 hours. Therefore, considering the power of the drying oven versus the power of the fluidized bed dryer with respect to the time used, the test cost in a conventional oven is 45% higher.

PRACTICAL AND THEORETICAL IMPLICATIONS

For the development of drying technology, it is necessary to make a study of temperature, humidity, as well as to apply energy balances to determine the input and output parameters in order to achieve efficient drying. At the experimental level, it is necessary to calculate the energy balance by applying the energy equations in the bed. The particle size distribution will impact both the predominant mechanisms of the drying phenomenon and the efficiency of the process, which in turn also makes it necessary to measure them, since they have a determining influence on the design and selection of the drying equipment.

CONCLUSIONS AND RECOMMENDATIONS

Considering the current difficulties of universities to acquire drying equipment that complies with all current regulations, especially in rural areas, and the possibility offered by this prototype to be built with different diameters, increasing its drying capacity and homogenizing the material, it is recommended to improve the prototype in order to provide the user with equipment that facilitates the drying process in the laboratory to evaluate the properties and behavior of agro-industrial materials.

In the analysis of the drying process of the pirul leaf, clear and evident results are presented on the drying process from the point of view of time, temperature and energy cost, and it is determined that it is the most efficient process to eliminate water.

REFERENCES

Barducci, G., Sireni G., Lucchini F., and Marseglia C. (2006). Design and characteristics of a solar dryer adapted for use in different regions of Tunisia. Solar Energy. 80. 348-360.

Bhargava, A.; Kulkarni, A. A. (2013). Energy and exergetic analysis of fluidized-bed drying process of solids. International Journal of Energy Research. 37 (10): 1263–1279.

Cheresorm, S., Guthrie, K. M., Chaurand J. (2003). Moisture diffusivity data in food products: Literature Sources, Data, and Assessment. Drying Technology 21 (10) 1793-1844.

Costa, A. B., Tonetto, G., Brezolin, L. S., Wieth, C. H., Silva-Portela, V., Stadtke Jr., A., & Correa, J. A. (September 01, 2012). Cement hydration humidity cell for use in scanning electron microscopy. Microscopy and Microanalysis, 18(4), 797-802.

Crank, J. (1975). The mathematics of diffusion. 2nd ed., Oxford University Press, New York.

Desai, D., et al., European Convention on Products and Applications for Passive Cooling. 2011: Crete, Greece.

Giambusso, M., Squire, J. P., Chang Díaz, F. R., Corrigan, A., & Hardy, T. (2020). 120kw rf power processing unit in-vacuum testing for a vasimr® system. In ASCEND 2020 (p. 4020). [HTML]

Giambusso, M., Squire, J. P., Díaz, F. R. C., Corrigan, A. M., & Hardy, T. Development and Testing of a 120 kW RF Power Processing Unit for the VASIMR® System. adastrarocket.com

Martinović, Ž, Dadić, M., Matas, I., & Grgec Bermanec, L. (2024). A 10 µH Inductance Standard in PCB Technology with Enhanced Protection against Magnetic Fields. Electronics. mdpi.com

Park, J., Hong, H. G., Kwon, T. Y., & Lee, J. K. (2020). Flexible hybrid approach for a 3D integrated physics package of chip-scale atomic clocks. IEEE Sensors Journal. [HTML]

Plumed, E., Acero, J., Lope, I., & Burdío, J. M. (2020). Design methodology of high performance domestic induction heating systems under worktop. IET Power Electronics. wiley.com

Plumed, E., Lope, I., & Acero…, J. (2022). Domestic induction heating system with standard primary inductor for reduced-size and high distance cookware. IEEE Transactions on …. unizar.es

Plumed, E., Lope, I., & Acero, J. (2020). Induction heating adaptation of a different-sized load with matching secondary inductor to achieve uniform heating and enhance vertical displacement. IEEE Transactions on Power Electronics, 36(6), 6929-6942. [HTML]

Song, P., Shi, Z., Wu, Q., Yang, Y., Zhang, L., Wu, B., ... & Qu, T. (2020). General design of a 300-Kvar HTS synchronous condenser prototype. IEEE Transactions on Applied Superconductivity, 30(4), 1-5. [HTML]

Teissier, P. (2020). Modern Heating Technologies. In Between Making And Knowing: Tools In The History Of Materials Research (pp. 257-272). hal.science

Zhao, X., Hu, J., Ravi, L., Dong, D., & Burgos, R. (2021, October). Planar common-mode EMI filter design and optimization in a 100-kW SiC-based generator-rectifier system for high-altitude operation. In 2021 IEEE Energy Conversion Congress and Exposition (ECCE) (pp. 3555-3562). IEEE. [HTML]