ISSN 2523-6873

Journal of Innovative Engineering

Volume 8, Issue 22 – January – June – 2024

Journal of Innovative Engineering, Volume 8, Issue 22, January – June 2024,is a journal edited semestral by RINOE. La Raza Av. 1047 No.-Santa Ana, Cusco. Peru. Postcode: 11500, WEB: www.rinoe.org journal@rinoe.org.Editor in Chief: Miranda-Torrado,Fernando. PhD. ISSN-2523-6873. Responsible for the latest update of this number RINOE Computer Unit. Escamilla-Bouchán, Imelda. PhD. Luna Soto, Vladimir. PhD. La Raza Av. 1047 No.-Santa Ana, Cusco- Peru. Postcode: 11500 last updated June 30, 2024.

Journal of Innovative Engineering

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Knowledge Area

The works must be unpublished and refer to topics of Production systems design, product quality management, operations research, computer simulation, supply chains, quality certification, hydrometeorology and other topics related to Engineering and Technology.

Presentation of Content

In the first article we present, *Prototype of a structure with variations in the angle of inclination for photovoltaic panels* by Herrera-Romero, José Vidal, Escobedo-Trujillo, Beatris Adriana, Alaffita-Hernández, Francisco Alejandro and Morales-Salas, Lizbeth, with adscription in Universidad Veracruzana, as the next article we present, *Effectiveness of acetic acid, sodium bicarbonate and the vinegar/baking soda mixture to control the population of motita hay (Tillandsia recurvata) on the campus of the Tula-Tepejí Technological University* by Reséndiz-Vega, Marisol, García-Melo, José Alberto and Hernández-Sánchez, Eduardo, with adscription in Universidad Tecnológica de Tula Tepeji, as the next article we present, *Rectenna for energy harvesting at 2.45 GHz* by Tecuatl-Tecuatl, Marco Antonio, Torrealba-Meléndez, Richard, Tamariz-Flores, Edna Iliana and López-López, Mario, with adscription in Benemérita Universidad Autónoma de Puebla, as the last article we present, *Design and manufacture of a prototype dryer for fruits and vegetables using a convection system* by Vera-Cruz, Gustavo, Hernández-Velázquez, Lorena, Canseco-Hernández, Felipe and Flores-Benavidez, Joel, with adscription in Universidad Tecnológica de Tecamachalco.

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Content

Journal of Innovative Engineering June 2024 Vol.8 No.22 1-6
Article

Prototype of a structure with variations in the angle of inclination for photovoltaic panels

Prototipo de una estructura con variaciones en el ángulo de inclinación para paneles fotovoltaicos

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CONAHCYT classification:

Área: Engineering
Campo: Engineering
Disciplina: Mechanical Engineering
Subdisciplina: Energy

https://doi.org/10.35429/JIE.2024.22.8.1.6
History of the article:
Received: February 03, 2024
Accepted: June 30, 2024

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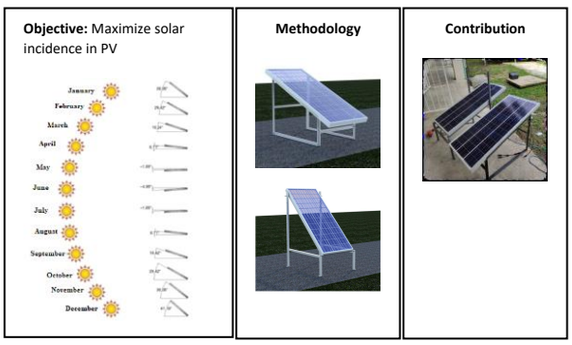
Abstract

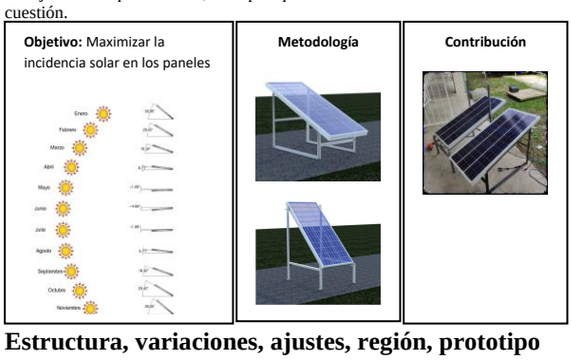
One of the most critical parameters for the capture of solar radiation is the angle of inclination of the surface and its contribution to optimization to maximize the amount of solar irradiation received. Numerous methods have been used worldwide to determine the angle of inclination. Unfortunately, many of these models are for fixed angles, which do not adapt to the sun's position during the year, resulting in the loss of essential amounts of irradiation that could be used. This work presents the methodology for developing a structure for photovoltaic (PV) panels fixed to the floor, which includes variations in the angle of inclination. The goal is to maximize the solar energy gain (energy per square meter) the panel receives over a year by making monthly tilt angle adjustments. The inclination angles are calculated for a structure, which will be placed in Coatzacoalcos, Veracruz, Mexico. The monthly angle of the prototype can have positive and negative values (tropical region); the maximum is 41.19° for December, and the minimum is - 4.95°, corresponding to June. The study can be applied to build a similar structure, with related variations in the angle of inclination, to work in any city, as long as information from the city in question is



Structure, variations, adjustments, region, prototype

Resumen

Uno de los parámetros más importantes para la captación de radiación solar es el ángulo de inclinación de la superficie, su optimización contribuye a maximizar la cantidad de irradiación solar recibida. Se han utilizado numerosos métodos para determinar el ángulo de inclinación en todo el mundo; desafortunadamente, muchos de estos modelos son para ángulos fijos, que no se adaptan a la posición del sol durante el año, lo que resulta en la pérdida de importantes cantidades de irradiación que podrían aprovecharse. En este trabajo se presenta la metodología para el desarrolló una estructura para paneles fotovoltaicos (FV), fija en el piso, que incluya variaciones en el ángulo de inclinación. El objetivo es maximizar la ganancia de energía solar (energía por metro cuadrado) que recibe el panel durante un año, al realizar los ajustes del ángulo de inclinación por mes. Se calculan los ángulos de inclinación para una estructura, que se colocará en Coatzacoalcos, Veracruz, México El ángulo mensual del prototipo puede tener valores positivos y negativos (región tropical), el máximo es 41.19°, para diciembre, y el mínimo es de -4.95°, correspondiente a junio. El estudio se puede aplicar para construir una estructura similar, con las variaciones correspondientes en el ángulo de inclinación, para que trabaje en cualquier ciudad, siempre que se utilice información de la ciudad en cuestión.



Estructura, variaciones, ajustes, región, prototipo

Citation: Herrera-Romero, José Vidal, Escobedo-Trujillo, Beatris Adriana, Alaffita-Hernández, Francisco Alejandro and Morales-Salas, Lizbeth. Prototype of a structure with variations in the angle of inclination for photovoltaic panels. Journal of Innovative Engineering. 2024. 8-22: 1-6.

Journal of Innovative Engineering June 2024 Vol.8 No.22 1-6
Article

Introduction

Solar photovoltaic energy is a renewable energy that in recent years has reduced its prices and has become equal to conventional energies such as coal and natural gas (Muñoz, 2023). Solar energy is a resource that naturally benefits countries located within the sunbelt or tropical zones. It can be converted into thermal energy via a solar collector or into electrical energy by means of a photovoltaic cell. However, despite its multiple benefits for the environment, its use is limited due to atmospheric factors and the Earth's translational and rotational movements. Solar radiation is characterized by variations throughout the day and year; therefore, to design photovoltaic systems, it is necessary to optimize the tilt angle of the panels to obtain the maximum incident irradiance (Yadav, 2013).

The amount of solar energy received on a collector depends on the latitude (Φ), day of the year (n), tilt angle (β), surface azimuth angle (ϒ), hour angle (ω) and the angle of incidence (θ) (Fig. 1)[(Yadav, 2018), (Duffie, 2013), (Makenzi, 2020)].

Box 1

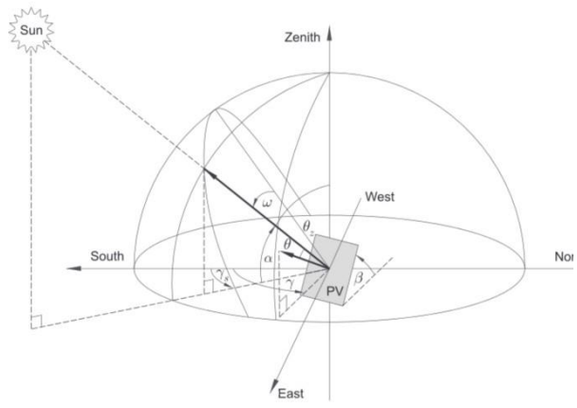


Figure 1
Variables for tilt angle calculation
Source*: (Despotovic, 2015)*

Around the world there are techniques to deduce the optimal tilt angle based on different parameters [(Alyami, 2020), (Makenzi, 2020), (Yadav., 2018)]. Among them is the work of Cruz-Hidalgo (2021), where he determines the monthly tilt angles of photovoltaic panels oriented towards the equator, located in Coatzacoalcos, Veracruz, Mexico, with a latitude of 18°8'16" (Cruz-Hidalgo, 2021).

The work consists of the design and fabrication of a prototype to mount photovoltaic solar panels, having as main function the adjustment in tilt angles for such panels, thus presenting 7 configurations for the tilt angles according to the data reported by Cruz- Hidalgo (2021), which will act throughout the year. The main function of this prototype is to maximize the solar incidence and in turn generate more electrical energy. Additionally, this structure must be manually operated every month.

This work is organized as follows: in the next section the basic concepts of solar radiation are presented, as well as the calculation process to determine the optimum tilt angle. The results section presents the design of the proposed prototype of the designed structure, which includes the calculated tilt angles and includes the construction process of the prototype structure and shows the result for a fixed inclined surface and on a surface using the designed prototype for further tests. The paper ends with a conclusion of the results.

Methodology

The angle of incidence of direct solar radiation on an inclined surface (θ) is calculated with (Duffie, 2013):

$$\begin{aligned}\cos\theta &= \text{sen}\delta\text{sen}\phi\cos\beta - \text{sen}\delta\cos\phi\text{sen}\beta\cos\gamma \\ &+ \cos\delta\cos\phi\cos\beta\cos\omega \\ &+ \cos\delta\text{sen}\phi\text{sen}\beta\cos\gamma\cos\omega \\ &+ \cos\delta\text{sen}\beta\text{sen}\gamma\text{sen}\omega\,,\end{aligned} \quad [1]$$

The optimum tilt angle of a surface can be obtained by deriving the cosine of θ with respect to the tilt angle and equals zero (d cos θ / dβ = 0) in order to find the maximum. To capture the greatest solar radiation throughout the year, the collector is oriented to the geographic south (oriented to the equator in the northern hemisphere; ϒ = 0). In addition, during the solar midday, the radiation is at its highest. Therefore, the optimum tilt angle can be calculated with the following expression:

$$\beta = \phi - \delta \quad [2]$$

Where β is the angle of inclination, Φ is the latitude of the location where the structure will be installed and δ is the declination, calculated with equation 3.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Herrera-Romero, José Vidal, Escobedo-Trujillo, Beatris Adriana, Alaffita-Hernández, Francisco Alejandro and Morales-Salas, Lizbeth. Prototype of a structure with variations in the angle of inclination for photovoltaic panels Journal of Innovative Engineering. 2024. 8-22: 1-6.
https://doi.org/10.35429/JIE.2024.22.8.1.6

$$\delta = 23.45\, sin\left(360\frac{284+n}{365}\right) \quad [3]$$

Where n is the number of days of the year (1 for January 1, up to 365 for December 31).

With Equation 2, the daily optimum angle for Coatzacoalcos, Veracruz (Φ = 18°8'16" N), for the 365 days of the year is calculated from the theoretical formulation presented. The daily tilt angles are presented in Figure 2, represented by the black trend line, identified as "daily".

Box 2

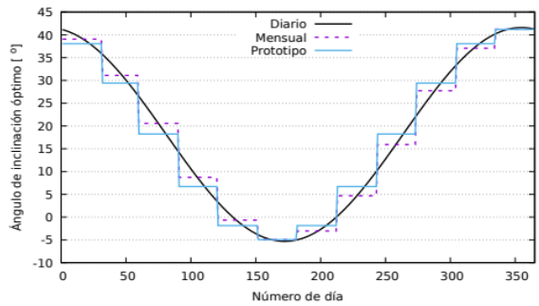


Figure 2

Plot of daily, monthly and prototype tilt angles

Box 3

Table 1

Theoretical and prototype angle of inclination values

	Monthly average angle [°] (Cruz-Hidalgo, 2021)	Monthly angle of the prototype [°]
January	39.06	38.05
February	31.10	29.42
March	20.56	18.24
April	8.72	6.71
May	-0.65	-1.85
June	-4.95	-4.95
July	-3.04	-1.85
August	4.69	6.71
September	15.92	18.24
October	27.74	29.42
November	37.05	38.05
December	41.19	41.19

From the work of Cruz-Hidalgo (2021), where he determines the average monthly tilt angles (Table 1), for a structure of photovoltaic panels oriented towards the equator, located in Coatzacoalcos, Veracruz, Mexico, (Cruz-Hidalgo, 2021), it can be seen that there are two extreme data, one for the month of June (-4.95) and the other corresponds to the month of December (41.19).

On the other hand, the months with similar values are identified, forming five groups of two months, and averaging to obtain the angle corresponding to that pair of months.

Results

From the daily tilt angles, the monthly average tilt angles are calculated (Table 1) and the graph is presented in Figure 2. The extreme values are obtained and for the rest of the values, the months with similar values are identified by pairs with the objective of averaging them, to obtain seven variations throughout the year. These values are the variations that the structure has to modify the tilt angle for PV panels (Fig. 3).

Box 4

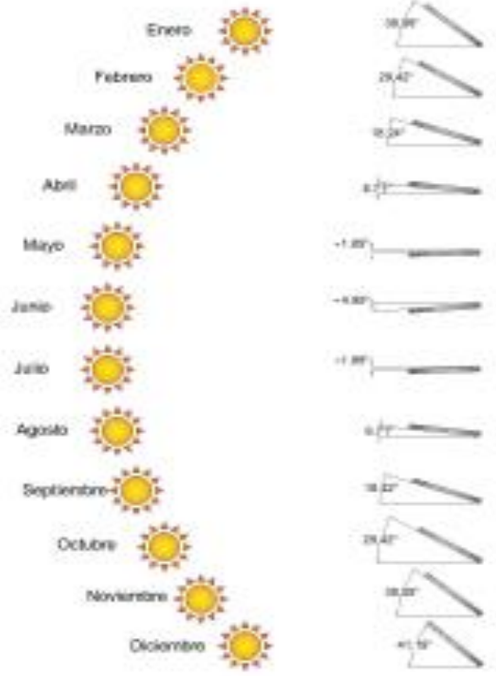


Figure 3

Graphical image of the changes in the angles per month.

The prototype structure must have 7 angles of inclination according to the previous calculations, so that the solar panel can be oriented with respect to the angle of inclination that corresponds to each month, in order to put the prototype into practice by installing a PV panel.

This structure must withstand climatic changes, such as rain, wind, sun, etc. Above all, it must guarantee an excellent assembly of the solar panel.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Journal of Innovative Engineering June 2024 Vol.8 No.22 1-6
Article

Box 5

Figure 4
Fixed structure for PV solar panel

The prototype design was created from a fixed structure, with an angle of inclination of 18° (Figure 4), where we looked for a way to create an economical and easy to build structure, thus having the final result shown in Figure 4.

Box 6

Figure 5
Variable structure for PV solar panel

For this physical project we are looking for a material that is in an intermediate price range among the variety of metals and above all that has a good resistance to climatic phenomena, so we chose to use 1 inch rectangular tubular profile (PTR) and 1 inch PTR angle. After cutting the pieces to size, the welding bead was applied using the straight pass technique. After applying the weld bead, the slag that is generated is removed, giving a final finish.

For each of the vertical tubes located at the back of the structure, which have 7 holes, these holes will be either ¼ or 6.25mm, and a ¼ x 3 in stainless steel rod is used as an axis to hold the panel frame at different angles of inclination. As shown in Figure 6.

Box 7

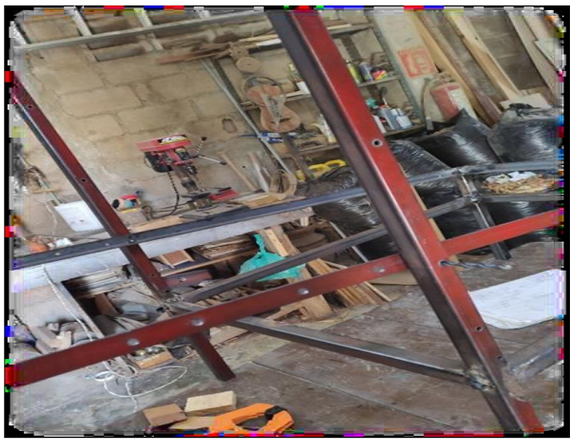


Figure 6
Fixing shafts

The frame that will hold the PV panel to the structure was made with a 1” PTR angle and the use of forge door barrels to simulate a hinge in order to be able to satisfactorily rotate or adjust the PV panel. The final result of the complete structure can be seen in figure 7.

Box 8

Figure 7
Physical structure

Installation of the photovoltaic panels. In this process, the panel-frame assembly will require stainless steel screws. To do this, four holes are drilled in the solar panel frame and the frame of the structure so that they are as parallel as possible and so that the panel can be satisfactorily fixed to the frame (Figure 8).

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Herrera-Romero, José Vidal, Escobedo-Trujillo, Beatris Adriana, Alaffita-Hernández, Francisco Alejandro and Morales-Salas, Lizbeth. Prototype of a structure with variations in the angle of inclination for photovoltaic panels Journal of Innovative Engineering. 2024. 8-22: 1-6.
https://doi.org/10.35429/JIE.2024.22.8.1.6

Box 9

Figure 8
Mounting of PV panels on structures

Conclusions

The mathematical formulation for the calculation of the optimum tilt angle is presented. The tilt angles are obtained for a structure to be placed in Coatzacoalcos, Veracruz, Mexico. The monthly angle of the prototype can have positive and negative values (tropical region), the maximum is 41.19°, for December, and the minimum is -4.95°, corresponding to June. The study can be applied to build a similar structure, with the corresponding variations in the angle of inclination, to work in any city, as long as information from the city in question is used.

As future work, it is proposed that with the construction of the structure, the measurement of experimental data be carried out, both for the fixed and the variable structure, to see the efficiency of the variable structure and to be able to quantify the percentage of gain in energy generation.

Statements

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this article.
in this article.

Authors' Contribution

The contribution of each researcher in each of the points developed in this research was defined based on:

Herrera-Romero José Vidal: Contributed to the project idea, method and research technique. He performed the data analysis and supported the construction of the prototype, in addition to writing the article.

Escobedo-Trujillo, Beatris Adriana: Contributed to the project idea, method. She performed the data analysis and reviewed the writing of the article.

Alaffita-Hernández, Francisco Alejandro: Contributed to the project idea, development of the prototype. Supported in the construction of the prototype, in addition to writing the article.

Morales-Salas, Lizbeth: Contributed to the project idea, systematized the background for the state of the art. Supported the design of the prototype. She carried out the data analysis and reviewed the writing of the article.

Data availability

Data will be made available on request.

Funding

The research did not receive any funding.

Acknowledgments

The authors are grateful for the facilities provided by the authorities of the Faculty of Engineering for the development of the prototype.

Abbreviations

PV	photovoltaic
RTP	Rectangular Tubular Profile

References

Antecedents

Alyami, F. H. (2020). Semi-seasonally optimized tilt angles for design of utility-scale photovoltaic generation station. In 2020 IEEE Texas Power and Energy Conference (TPEC) (pp. 1-5). IEEE.

Muñoz, A. (09 de octubre de 2023). ¿Qué son los costes operativos de una instalación fotovoltaica sobre cubierta?

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Yadav, A. K. (2013). Tilt angle optimization to maximize incident solar radiation: A review. Renewable and Sustainable Energy Reviews, 23, 503-513.

Yadav, A. K. (2018). Formulation of new correlations in terms of extraterrestrial radiation by optimization of tilt angle for installation of solar photovoltaic systems for maximum power generation: case study of 26 cities in India. Sādh. Sādhanā.

Basics

Despotic, M., & Nedic, V. (2015). Comparison of optimum tilt angles of solar collectors determined at yearly, seasonal and monthly levels. Energy Conversion and Management, 97, 121-131.

Duffie, J. A. (2013). Solar engineering of thermal processes. New Jersey: John Wiley & Sons.

Makenzi, M. M. (2020). Maximization of site-specific solar photovoltaic energy generation through tilt angle and sun-hours optimization. Journal of Renewable Energy.

Supports

Cruz-Hidalgo, D. H.-R.-G. (2021). Determination of optimum tilt angle of photovoltaic panels with monthly variations for Coatzacoalcos, Veracruz. 2021 IEEE International Conference on Engineering Veracruz (ICEV), 1-7.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Herrera-Romero, José Vidal, Escobedo-Trujillo, Beatris Adriana, Alaffita-Hernández, Francisco Alejandro and Morales-Salas, Lizbeth. Prototype of a structure with variations in the angle of inclination for photovoltaic panels Journal of Innovative Engineering. 2024. 8-22: 1-6.
https://doi.org/10.35429/JIE.2024.22.8.1.6

Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Effectiveness of acetic acid, sodium bicarbonate and the vinegar/baking soda mixture to control the population of motita hay (Tillandsia recurvata) on the campus of the Tula-Tepejí Technological University

Efectividad del ácido acético, bicarbonato de sodio y la mezcla entre vinagre/bicarbonato para controlar la población de heno motita (Tillandsia recurvata) en el campus de Universidad Tecnológica de Tula-Tepejí

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CONAHCYT classification:

Area: Biotechnology and Agricultural Sciences
Field: Agricultural Sciences
Discipline: Agronomy
Subdiscipline: Phytopathology

https://doi.org/10.35429/JIE.2024.22.8.7.19
History of the article:
Received: February 4, 2024
Accepted: June 27, 2024

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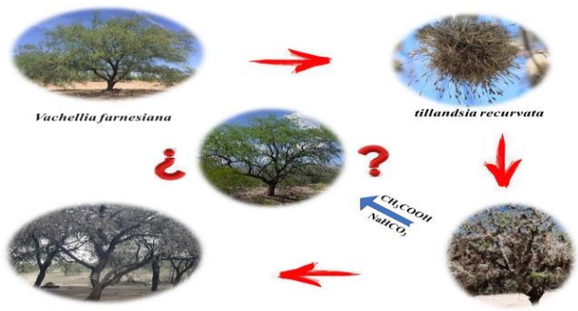
Abstract

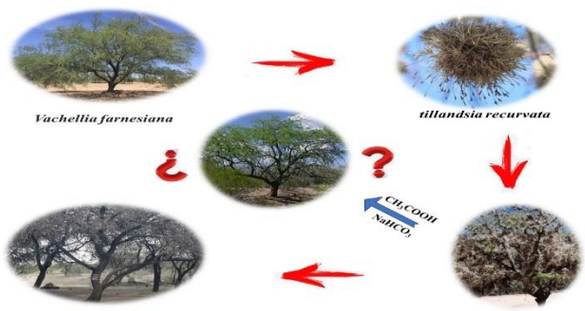
Tillandsia recurvata spreads easily in contaminated environments. At the Technological University of Tula-Tepeji, 82 plants with severe damage were identified, highlighting mesquite and huizache. Empirically, the population treats the hay on the tree with commercial vinegar, 10% baking soda and an equal mixture of both. The effectiveness of each solution was tested on the huizaches with the following findings: Baking soda (10%) and vinegar (5%) damage the trichomes of the plant, affecting the uptake of water and particles and with them nutrients as well. there is pH damage. 10% bicarbonate was more effective since the speck deteriorated, presenting a dry appearance; However, one week after completing the 9-week treatment, the hay began to recover. It is recommended to apply mechanical treatment, supported by chemicals with 10% sodium bicarbonate in times of drought.



Baking, Vinegar, Motita hay

Resumen

Tillandsia recurvata se propaga fácilmente en ambientes contaminados. En la Universidad Tecnológica de Tula-Tepeji se identificaron 82 plantas con afectación severa, destacando el mezquite y huizache. De manera empírica la población trata el heno en el árbol con vinagre comercial, bicarbonato de sodio 10% y la mezcla por igual de ambos. Se probó la efectividad de cada solución en los huizaches con los siguientes hallazgos: El bicarbonato de sodio (10%) y el vinagre (5%) dañan los tricomas de la mota afectando la captación de agua y partículas y con ellos de nutrientes así mismo existe un daño por el pH. Resultó más efectivo el bicarbonato 10% ya que la mota se deterioró, presentando un aspecto seco; sin embargo, a la semana de haber concluido el tratamiento de 9 semanas el heno inició su recuperación. Se recomienda aplicar tratamiento mecánico, apoyado del químico con bicarbonato de sodio 10% en época de sequía.



Bicarbonato, Vinagre, Heno motita

Citation: Reséndiz-Vega, Marisol, García-Melo, José Alberto and Hernández-Sánchez, Eduardo. Effectiveness of acetic acid, sodium bicarbonate and the vinegar/baking soda mixture to control the population of motita hay (Tillandsia recurvata) on the campus of the Tula-Tepejí Technological University. Journal of Innovative Engineering. 2024. 8-22: 7-19.

Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Introduction

Motite hay (Tillandsia recurvata) is one of the most familiar species to the urban population as it is very easy to find on light wires, poles and trees. This plant is not parasitic, but through years of evolution it has adapted to grow on inert surfaces and vegetation in order to reach the sunlight.

They do not feed on the host plant; however, if the host plant proliferates too much, they can limit the regrowth of trees and contribute to their weakening and can be attacked by diseases, fungi or true parasitic plants. Tillandsia recurvata, not having roots in the soil, are extremely dependent on the atmosphere for their nutrient and water needs, making them sensitive to air humidity and therefore useful for measuring response to changes in climate (Helliker B. R., and Griffiths H. 2007).

Benzing D. H. (1990,1998, 2000) and Andrade et al. (2009) have found that one of the main evolutionary responses of plants growing in epiphytic habitats is crassulacean acid metabolism (CAM), which is present in epiphytic bromeliad species. This is a photosynthetic pathway that allows plants to use water efficiently. In CAM photosynthesis, gas exchange takes place at night, when the evaporative demand of the atmosphere is low, resulting in reduced water loss through transpiration. Epiphytic bromeliads have evolved physiological structures and mechanisms (formation of tanks for water uptake, leaf succulence, leaf trichomes specialised in water and nutrient absorption, as well as CAM photosynthesis), which have allowed them to successfully adapt to environments with low amounts of water, high light densities and instability of the branches of the phorophytes (trees on which they grow) in strong winds.

In addition, motite hay secretes an allelopathic substance called hydroperoxycycloartane, which damages new shoots and inhibits the growth of new branches (Neumann, 2004), and it reproduces both sexually and asexually. Due to these biological advantages, the hay rapidly proliferates on the tree on which it lands, causing its rapid deterioration.

The Secretariat for the Environment and Natural Resources in Hidalgo (SEMARNATH), has reported the affectation in the area of the Mezquital Valley, in the municipalities of Actopan, Alfajayucan, El Arenal, Atitalaquia, Atotonilco de Tula, Chapantongo, Francisco I. Madero, Huichapan, Ixmiquilpan, Mixquiahuala, Nopala, Progreso, San Agustín Tlaxiaca. As well as in Santiago de Anaya, San Salvador, Tasquillo, Tecozautla, Tepejí del Río, Tepetitlán, Tetepango, Tezontepec de Aldama, Tlahuelilpan, Tlaxcoapan and Tula de Allende (Herrera L. and Méndez O., (2024). This problem has also been observed in the Universidad Tecnológica de Tula - Tepejí (UTTT), since it has an area of 16 hectares in which there are trees of different species, some of them were in the limits of the UTTT before its construction, others are the product of reforestation campaigns carried out by the students. Part of the objective of this work is to carry out a census to determine the quantity and variety of species, as well as to evaluate the infestation problem by knowing the percentage of trees infested by motita hay. In talks with people from the communities in the area of influence of the UTTT, they stated that they use vinegar and a solution of sodium bicarbonate, as well as a mixture of equal parts of vinegar and bicarbonate solution, so it is necessary to evaluate its effectiveness in order to propose a control method to recover the infested trees.

Theoretical Framework

Epiphytic bromeliads are one of the most threatened groups in nature, since the root system only adheres them to the host, and the nutrients and water necessary for their growth are absorbed by the leaves.

Description of Tillandsia recurvata

The following is a general outline and description of the main structures of the motite hay (see Figure 1).

Box 1

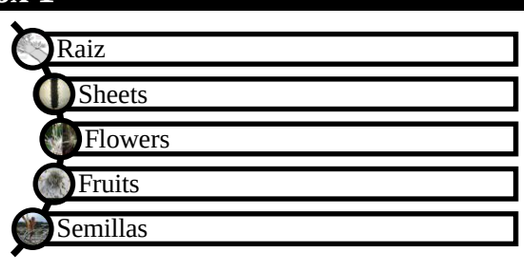


Figure 1

Structures of T. recurvata

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ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Root

Mainly used for anchorage and support of the plant. The roots do not penetrate the tissues of the phorophyte (host), only the development of a suber no more than 400 µm thick is observed, with dead cells, radially dilated and with crystalline inclusions, thin walls and wide lumen, alternating with radially compressed cells with thick walls containing substances that are observed in a dark tone, which are also found above the suber (Paez et al., 2005).

Leaves

According to Kamila (2005), this species has small structures known as trichomes which replace the roots in the function of absorbing nutrients and water. Mystic orderly, 3-17 cm long, densely pruinose-scaly with cinereous or ferruginous scales; sheaths elliptic-ovate, slender, multinervate with a broad hyaline enervate margin, with the extreme base glabrous, and otherwise densely scaly and with a ciliate margin of elongate, imbricate scales, completely concealing the caul; laminae typically recurved, sometimes only patent or even erect, linear, plump, 0. 5-2 mm in diameter, a little soft with a weak point (Matuda, 1957).

Inflorescence

Usually 1-2-flowered or sometimes up to 5-flowered, dense; floral bracts like scape bracts, but smaller, equal to or longer than sepals, but often distinctly shorter, varionervate, densely scaled. Flowers erect, subsessile. Sepals lanceolate, usually acute, 4-9 mm long, slender, with 3 or more prominent veins, up to 13 cm long, nearly 0.5 mm in diameter; scapose bracts, species somewhat scaly in an increasing proportion of specimens.

Petals narrow, pale-violet or white. Stamens deeply surpassing the pistil. Capsule slenderly cylindrical, abruptly short-pointed, up to 3 cm (Matuda, 1957).

Fruit

This is a cylindrical capsule about 5 to 25 mm long, with two or more carpels, with a variable number of cavities and dehiscence lines, abruptly ending in a short beak. It contains several seeds of a slimy consistency (Villarreal, 1994).

Seeds

The seeds, contained in capsules, open at maturity and have a high germination capacity; they are disseminated by the wind and some birds after dehiscence or natural opening of the capsules; the seeds also have trichomes, a characteristic that makes them more likely to adhere to the bark of host trees and shrubs (Crow, 2000).

Vegetative and reproductive phenology Reproduction

They reproduce in two ways. The first, and most common, is by pollination and seed production. These are not self-fertilising and the pollen has to come from another plant of the same species. The other way is the reproduction of seedlings called "tillers". New plants emerge from the mother plant, often on the stem. This usually happens after flowering. A plant can have several tillers that can be removed and developed separately or left together with the mother plant to form a colony (Paez et al., 2005).

Biological cycle

According to Arellano et al., (2007) it begins with the fertilisation of the ovules by pollen and the consequent formation of numerous seeds in the bald fruits called capsules. The numerous seeds are dispersed by wind or animals and germinate in trees, rocks or soil that meet the conditions for their development, such as light, humidity and temperature. A small percentage of the total number of seeds released germinate and give rise to seedlings. After several days of development, the species flowers, fruits and dies, thus closing its life cycle. (This method is used to keep the species in perpetuity in cultivation sites when the plant is in full flower and will soon dry up.

Effect of Tillandsia *recurvata* on the phorophyte

According to Neumann (2004), *T. recurvata* secretes an allelopathic substance called hydroperoxycycloartane through its rhizoids, which can cause bud death and foliage abscission**.** On the other hand (Reséndiz and Sánchez, 2021), point out that *T. recurvata* absorbs heavy metals found in the air as a result of environmental pollution, which could have a toxic effect on the host tree.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

According to (Páez et al., 2005), the roots do not penetrate the tissues; the presence of hay causes the plant to develop in response a scar tissue no more than 400 µm thick, with dead cells, dilated radially and with crystalline inclusions, alternating with thick-walled cells containing substances that are observed to be dark in colour, separating the hay from the tissues of the phorophyte.

Properties of Apple Cider Vinegar

The word vinegar comes etymologically from the French word "vin-aigre" meaning "sour wine" (Bourgeois & Barja, 2009). According to FAO/WHO, vinegar is a liquid fit for human consumption and is produced exclusively from suitable products containing starch or sugars or starch and sugars by double fermentation processes (Joint FAO/WHO Food Standards Programme, 1998).

In Mexico NMX-F-122-1968. Food for human use. Quality for vinegar packaged for public consumption classifies vinegar in two grades:

- Grade "A" or Vinegar from fruit juice, wines, cereals, etc.
- Grade "B" or Vinegar made from potable ethyl alcohol denatured with vinegar.

And it indicates the physicochemical properties that they must have for their commercialisation (see table 1).

Box 2

Table 1

Physicochemical properties of vinegar

Ess	Grado A		Grado B	
	Min	**Max**	**Min**	**Max**
Relative density at 15ºC	1.013	1.025	1.010	1.013
Dry extract %	1.8	4.52	0.26	0.30
Ashes %	0.25	0.45	0.03	0.05
Total acidity in acetic acid %	4	8	4	8
Fixed acidity in acetic acid %	0.06	0.41	0	0
Volatile acidity in acetic acid	3.94	7.56	4	8

Note: taken from NMX-F-122-1968

Properties of Sodium Bicarbonate Sodium

Bicarbonate is a white crystalline solid compound soluble in water, with a slight alkaline taste, with the formula NaHCO3. It can be found as a mineral in nature or can be produced artificially (IUPAQ, 2005).

Box 3

Table 2

Physicochemical properties of Sodium Bicarbonate

Physical properties	
Appearance	Blanco cristalino
Density	2173 kg/m³; 2,173 g/cm³
Masa molar	84,01 g/mol
Chemical properties	
Acidity	10.329[2] pK_a
pH (5 g NaHCO3/100 ml water)	8.0 - 8.6
Solubility in water	10,3 g/100 g de H2O

Note: Data taken from the safety data sheet (Química Básica S.A., 2006)

Box 4

Table 3

Hazard characteristics, toxicological information and first aid measures to be observed when handling sodium bicarbonate

Hazard characteristics
Weak base which is safe to handle. It is not combustible. Should not be heated in closed containers as the CO2 produced can easily break them.
Toxicological information
Oral (rat): LD50 = 7.3 g/kg. Inhalation: LC50 (rat) > 4.74 mg/l. Irritation: Skin, may cause skin irritation and hypersensitivity. Not dermatologically toxic. Irritation: Eyes, may cause irritation, chemical conjunctivitis, tearing and pain. Respiratory: May cause irritation to mucous membranes. Effects of overexposure: Although rare, the possibility of skin sensitization should be considered due to prolonged contact effects.
First aid
After skin contact: Remove contaminated clothing and wash affected skin with plenty of soap and water. If irritation persists, call a doctor. Wash with waterAfter eye contact: Rinse with plenty of water After swallowing: If large quantities have been swallowed, do not induce vomiting. Give water, if the person is conscious. Consult a doctor if discomfort persists Note to physician: Large doses may cause systemic alkalosis and expansion of extracellular fluid volume. Inhalation: Move patient to fresh air, and assist breathing if necessary.

Note: Data taken from the safety data sheet (Química Básica S.A., 2006)

Equal parts mixture of apple cider vinegar and commercial grade sodium bicarbonate. According to Gallego (2023), sodium bicarbonate is a mild base and vinegar is a weak acid. When these two compounds are combined, an acid-base neutralisation reaction takes place. This chemical reaction results in the formation of carbon dioxide (CO2), water (H2O) and sodium acetate (CH3COONa), all of which are non-toxic and safe products (see figure 2).

ISSN: 2523-6873
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Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Box 5

$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$

Figure 2

Chemical reaction between vinegar and sodium bicarbonate to obtain sodium acetate

Box 6

Table 4

Physicochemical properties of Sodium Acetate

Physico-chemical properties	
Melting point/ freezing point	Melting point/melting range: > 300 °C (> 572 °F)
Density	1.528 g/cm3
pH	8.5 - 9.9 a 246 g/l a 25 °C (77 °F)

Note: Data taken from the safety data sheet (Química Básica S.A., 2006)

Box 7

Table 5

Potential health effects, first aid, accidental release measures and storage of sodium acetate

Potential health effects
Inhalation May be harmful if inhaled. May cause respiratory tract irritation. Skin May be harmful if absorbed through the skin. May cause skin irritation. Eyes May cause eye irritation. Ingestion May be harmful if swallowed.
First aid
General recommendations Consult a physician. Show this safety data sheet to the doctor on duty. If inhaled If aspirated, move person to fresh air. If breathing has stopped, give artificial respiration. Consult a doctor. In case of skin contact Wash off with soap and plenty of water. In case of eye contact Flush thoroughly with plenty of water for at least 15 minutes and seek medical advice. If swallowed Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a doctor.
Accidental release measures
Personal precautions Wear personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Avoid breathing dust. Environmental precautions Do not allow product to enter sewage system. Methods and material for containment and cleaning up Collect and prepare for disposal without causing dust. Clean and shovel. Store in suitable closed containers for disposal.
Handling and storage
Precautions for safe handling Avoid contact with eyes and skin. Avoid formation of dust and aerosols. Adequate extraction should be provided where dust is formed. Conditions for safe storage Keep container tightly closed in a dry, well-ventilated place.

Note: *Química suastes S.A. de C.V., (2018).*

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Methodology

The approach of the study is quantitative experimental because it seeks to evaluate the effectiveness of acetic acid, sodium bicarbonate and the mixture between vinegar/bicarbonate to control the motita hay pest and propose a method to recover the infested trees.

Study area

The study area is the campus of the Technological University of Tula-Tepeji, with an extension of 16 hectares. Coordinates: 20°0′46.8″ N, 99°20′47.4″ W, located at Av. Universidad Tecnológica No. 1000, C.P. 42830, El Carmen, Tula de Allende, Hidalgo, Mexico. The municipality of Tula de Allende has maximum temperatures with values of 24 to 27.9 degrees, the average between a range of 16 to 19.9 degrees and for the minimum is 8 to 11.9 degrees.

Analysis of species present

A counting strategy was designed by dividing the university campus into areas and the surveyed trees were marked.

Assessment of infestation class

Assessment of infested trees was carried out using the 6-class assessment system (Hawksworth, 1980), described below:

1. Divide the live crown into 3 thirds.

2. Assess each third separately. Each third is given a score of 0, 1 or 2 as described below:
   - 0= No visible infestation.
   - 1= Light infestation (Half or less of the branches infected).
   - 2= Severe infestation (More than half of the branches infected).

3. Add the rating values for each third to obtain the level of infestation.

As shown in table 5 the trees were classified into 3 classes:

Ø Sample 1/Class 6 those with the highest Infestation.
Ø Sample 2/Class 4 those of medium infestation
Ø Sample 3/Class 2 those with a low infestation.

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Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Solution preparation and treatment application

Vinegar was used at commercial grade and concentration (acetic acid 5%).

Sodium bicarbonate was weighed on a Felissa analytical balance and dissolved in purified water.

Trupper sprinklers were prepared and filled with the solutions;

- Sprinklers labelled red contained 5% vinegar.
- Sprinklers labelled green contained 10% sodium bicarbonate
- Sprinklers labelled yellow contained the 5% vinegar/10% sodium bicarbonate mixture.

Trees were mechanically treated according to their infestation class (see table 5), hay was removed following the steps dictated by NOM- 011-Semarnat-1996 and:

Class 6/ pruning of heavily infested branches
Class 4/ manual removal
Class 2/ manual removal

By class and in triplicate the trees were exposed to different chemical treatments:

1. 5% acetic acid
2. Sodium bicarbonate 10%.
3. Equal parts mixture of 5% vinegar and 10% sodium bicarbonate and 10% sodium bicarbonate.
4. A group of 3 trees received only mechanical treatment.
5. One group in triplicate received only chemical treatment (sodium bicarbonate).

The exposure was carried out every 24 hr. from Monday to Friday, recording the changes that occurred during the nine weeks of observation.

Results

The following results were obtained:

Ø 62500.1 m2 of green areas are available.
Ø There are 2,882 perennial plants of high and low growth.
Ø There is an average plant load of 0.05 plants/m2.
Ø There is an average of 1 plant per 21.6 m2.

Table 6 shows the record of tall species identified in the UTTT facilities, where it can be seen that of the six species that are observed in greater numbers, only two are native to the region (mesquite and huizache).

Box 7

Table 6

Tall species identified at the UTTT campus

Species	Number
Álamo	2
Capulín	29
Casuarina	116
Cipreses	154
Encino	4
Eucalipto	20
Fresno	89
Huizache	113
Jacaranda	9
Mezquite	131
Nogal	7
Nopal	6
Palma	9
Pino	18
Pirul	22
Retama	13
Tepozán	4
Trueno	116
TOTAL	862

As shown in Figure 3, 18 species with 862 tall plants were identified in the UTTT.

Box 8

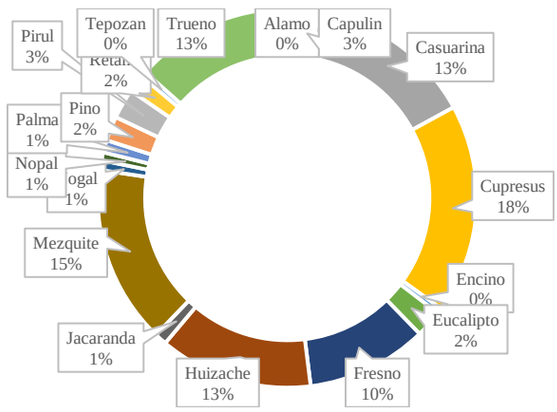

Figure 3

Tall species identified on the UTTT campus

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ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Table 7 shows the low-growing species by nature, where maguey stands out with 42% and lechuguilla 11%. Table 8 shows the low-growing species identified by phenological stage, with the greatest abundance of truenos (20%), mezquites (19%) and huizachez (29%).

Box 9

Table 7

Low-growing species by phenological stage

Species	Number	%
Agave tequilero	15	1.6
Biznaga	13	1.4
Cardón	2	0.2
Chabacano	2	0.2
Ciruelo	12	1.3
Durazno	34	3.5
Garambullo	29	3.0
Granada	49	5.1
Guayaba	70	7.3
Higo	2	0.2
Lechuguilla	109	11.4
Lima persa	8	0.8
Maguey	408	42.5
Mamilaria	17	1.8
Manzana	5	0.5
Nopal	63	6.6
Órgano	37	3.9
Palo blanco	6	0.6
Pitaya	1	0.1
Sábila	75	7.8
Vindhó	2	0.2
TOTAL	959	100.00

Box 10

Table 8

Low growth by phenological stage

Especie	Number	%
Capulín	8	0.8
Casuarina	18	1.7
Cipreses	139	13.1
Encino	10	0.9
Eucalipto	5	0.5
Fresno	27	2.5
Huizache	309	29.1
Jacaranda	7	0.7
Mezquite	209	19.7
Níspero	3	0.3
Nogal	29	2.7
Palma	25	2.4
Pino	7	0.7
Pirul	15	1.4
Retama	34	3.2
Trueno	216	20.4
TOTAL	1061	100

Evaluation of the degree of infestation of individuals Fifty-seven plants were identified as requiring severe pruning, of which 20 were huizache and 8 were mesquite, both of which are affected with motite hay (see table 9 and Figure 3).

Box 11

Table 9

Plants infested by motite hay requiring pruning

Área	No
Capulín	3
Casuarina	2
Cipreses	4
Durazno	1
Eucalipto	6
Fresno	1
Huizache	20
Maguey	1
Mezquite	8
Retama	7
Trueno	4

The cause of the need for severe pruning in the trees is due to the degree of infestation with mota hay, especially mesquites and huizaches; in the case of the maguey, it is due to having dry stalks. The percentages by species are shown in Figure 4.

Box 12

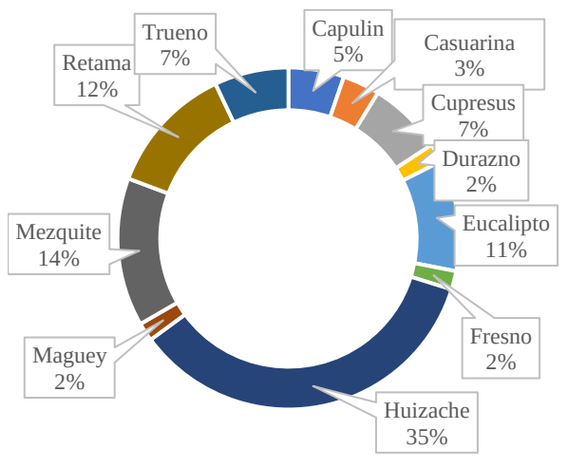

Figure 4

Plants requiring severe pruning

Eighty-two plants were identified with severe and medium motite hay damage, with mesquite standing out with 50% and huizache with 45% (see Figure 5).

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Reséndiz-Vega, Marisol, García-Melo, José Alberto and Hernández-Sánchez, Eduardo. Effectiveness of acetic acid, sodium bicarbonate and the vinegar/baking soda mixture to control the population of motita hay (Tillandsia recurvata) on the campus of the Tula-Tepejí Technological University. Journal of Innovative Engineering. 2024. 8-22: 7-19.
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Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Box 13

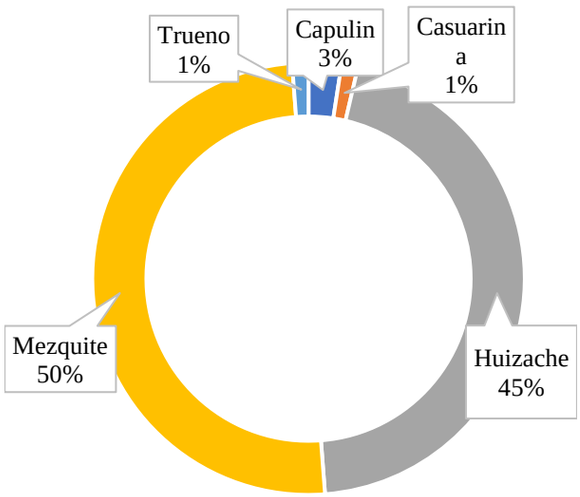

Figure 5
Plants with severe motita hay infestation

Since most of the infested trees are mesquites and huizaches, it was decided to work with huizaches because they are lower and within reach, with less risk of falling and accidents, for manual and chemical treatment.

In figure 6A. A class 6 huizache is shown according to the classification proposed by Hawksworth, 1980.

6B. Environmental Engineering students carrying out manual removal work on a class 2 huisache.

6C. Hay shoots emerging from small fragments that remain attached to the trunk and branches, observed 8 days after manual removal.

6D. Optical microscope observation of the chemically treated specks.

Figure 6 Field work: assessment of the type of infestation, mechanical removal, chemical treatment, recovery capacity of the motite hay and observation of the treated motes with the 4X and 10X optical microscope.

Box 14

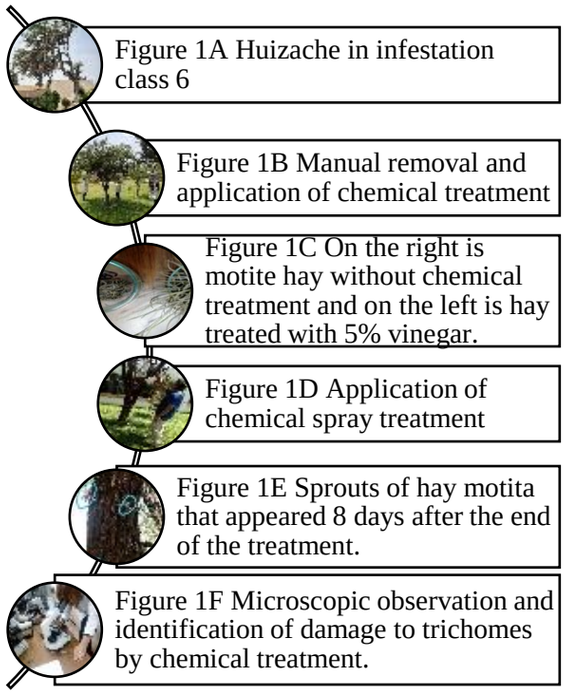

Figure 6
Field work

Table 10 shows a summary of the observations made during 9 weeks of treatment: Sample with the highest degree of infestation (Class 6): required pruning of the most affected branches, manual removal and treatment with bicarbonate gave better results when the shoots dried out.

Sample with medium infestation (Class 4): Required manual removal; in this case 10% sodium bicarbonate was more effective in controlling the new shoots. Low infestation sample (Class 2): Required manual removal and again sodium bicarbonate was more effective.

It was observed that applying only manual removal is not convenient since the motite hay recovers quickly (see figure 1E), and in a short time it infests the tree again; prolonged maintenance is required applying the chemical treatment, since as soon as the hay stops being applied it recovers.

In the case of not applying manual removal and only applying the 10% bicarbonate, it facilitates the removal of the specks, but if the hay stops being applied it recovers.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Reséndiz-Vega, Marisol, García-Melo, José Alberto and Hernández-Sánchez, Eduardo. Effectiveness of acetic acid, sodium bicarbonate and the vinegar/baking soda mixture to control the population of motita hay (Tillandsia recurvata) on the campus of the Tula-Tepejí Technological University. Journal of Innovative Engineering. 2024. 8-22: 7-19.
https://doi.org/10.35429/JIE.2024.22.8.7.19

Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Box 15

Table 10

Treatment applied to the huizaches infested with motita hay and observations made during 9 weeks of treatment Sampling of motita hay with chemical treatment and observation under the optical microscope.

	Treatment			
Sample	**Mechanic**	**Chemist**	**Remarks**	**Recommendations**
Sample 1 Class 6	Pruning of the most affected branches and manual removal of the total hay.	Vinegar 5%/24 hr	The shoots deteriorate, but if left alone they recover and proliferate..	Pruning of heavily infested branches, manual removal of less infested branches and treatment with 10% bicarbonate for at least 3 months. Do not apply chemical treatment on rainy days. Apply chemical treatment in the afternoon-evening; once sunlight decreases.
	Pruning of the most affected branches and manual removal of the total hay.	Bicarbonato 10%/ 24 hr	Increased effectiveness in the deterioration of the shoots.	
	Pruning of the most affected branches and manual removal of the total hay.	Vinagre/ Bicarbonato / 24hr	The shoots deteriorate, but if the application is discontinued, they recover and proliferate.	
	No Manual Withdrawal	Bicarbonate 10%/ 24 hr	With weeks of treatment, the specks dry out and are easier to remove.	
	Pruning of the most affected branches and manual removal of the total hay.	Untreated	The tree looks recovered, with new leaves, but the hay starts to proliferate the next day and proliferates rapidly.	
Sample 2 Class 4	Manual removal of total hay	Vinegar 5%	The shoots deteriorate, but if the application is discontinued, they recover and proliferate.	Manual removal and treatment with 10% bicarbonate for at least 3 months. Do not apply chemical treatment on rainy days. Apply chemical treatment in the afternoon-evening; once insolation decreases..
	Manual removal of total hay	Bicarbonate 10%	Increased effectiveness in the deterioration of the shoots.	
	Manual removal of total hay	Vinagre/Bicarbonato	The shoots deteriorate, but if the application is discontinued, they recover and proliferate.	
	No Manual Withdrawal	Bicarbonate 10%.	After 6 days of application, the specks dry out and are easier to remove.	
	Manual removal of total hay	Untreated	The tree looks recovered, with new leaves, but the hay starts to proliferate the next day and proliferates rapidly..	
Muestra 3/Clase 2	Manual removal of total hay	Vinegar 5%	The young shoots deteriorate, but if application is discontinued, they recover and proliferate, again reaching infestation class 2.	Manual removal & treatment with 10% bicarbonate for at least 3 months Do not apply chemical treatment on rainy days.Apply chemical treatment in the afternoon-evening; once insolation decreases..
	Manual removal of total hay	Bicarbonate 10%.	The tree recovers and the shoots dry up with the treatment.	
	Manual removal of total hay	Vinagre/Bicarbonato	The shoots deteriorate, but if the application is discontinued, they recover and proliferate.	
	No Manual Withdrawal	Bicarbonate 10%.	After 6 days of application the specks dry out and are easier to remove.	

Manual removal of total hay

Untreated

The tree looks recovered, with new leaves, but the hay starts to proliferate rapidly the next day.

When the hay was treated with 5% vinegar and 10% bicarbonate, it was observed that the hay changed colour to a darker shade and after a week of application it turned black, the change being greater in the hay treated with 10% bicarbonate.

Under the microscope (see figures 6 and 7), it was observed that the structures damaged by both vinegar and bicarbonate are the trichomes, which are small membranes in the form of very thin "nets" in which polluting particles from the atmosphere are trapped; these are the same particles that the hay uses to obtain the minerals necessary for photosynthesis. Small water droplets are also trapped in the trichomes. When these trichomes are damaged, the hay deteriorates because it is unable to trap its nutrients.

On the left side, we can see the motita hay damaged by the chemical treatment and on the right side, hay without treatment. We can see the trichomes that form membranes that trap polluting particles from the atmosphere.

Box 16

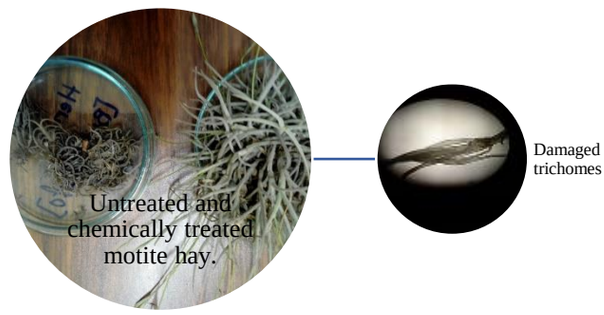

Figure 7

Motite hay with chemical treatment (sodium bicarbonate 10%). Optical microscope observation 10X

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

Box 17

Figure 8

Heno motita filament with damaged trichomes. 10X light microscope observation.

Analysis of results

It seems that the roughness and folds that exist in the bark of mesquite and huizache and the sticky gums they secrete are attributes that facilitate the fixation of *T. recurvata* seeds, which favour infestation in a higher percentage of these species; probably also as reported by Páez (2005) the articulated hairs of the seed contribute to their fixation.

The apple vinegar (acetic acid) used according to NMX-F-122-1968, is class A, a weak acid with an acid pH that acts as a desiccant agent (Lozano, 2011) and damages the membranes, which coincides with the findings since the motite hay was observed dry and with a change in colouring from dark green to a burnt appearance. Optical microscopic observation (10X objective) revealed damage to the trichomes. According to Alvarado et al., (2016), vinegar acts better on broad-leaved plants, as it exerts more desiccant action because the horizontal position of the leaves facilitates their adhesion to plant tissues, so to increase its effectiveness, an agent that favours their adhesion had to be added. As it is apple cider vinegar, it contains sugars that help it to adhere, but this was not enough in this case.

From a practical point of view, vinegar has limitations, as it is not selective and affects both the hay and the support plant, it is easily diluted in water and therefore it is not advisable to apply it after rain or on days with high relative humidity. Inappropriate, unplanned use of vinegar could upset the balance of biodiversity.

According to Arce (2001), the combination of vinegar with table salt increases the desiccant effect and soap can be added to achieve a better desiccation result.

Protective equipment is necessary for handling vinegar as it irritates the skin, the conjunctiva of the eye and can cause problems if inhaled for a prolonged period of time.

Sodium bicarbonate is a weak base with an alkaline pH, very soluble in water. By exposing the hay to the 10% solution, better results were observed, as the hay suffered greater deterioration, which was manifested by dryness and retraction of the leaves. Anaya (2006), reported that mote hay is very sensitive to pH changes, so the alkaline pH of bicarbonate affects the trichomes, also bicarbonate contains sodium which contributes to dehydrate the plant tissues, it also showed a better adherence. The 10% sodium bicarbonate was more effective in killing the hay motita. The dead motes remained attached to the phorophyte and had to be removed manually, but it was easier to remove them.

For the handling of 10% sodium bicarbonate, it is necessary to use protective equipment as it irritates the skin, the conjunctiva of the eye and can cause problems if inhaled for a prolonged period of time.

It is important to mention that both treatments are affected if applied during the rainy season, since, being water-soluble, the motes are washed away by rainwater and their effectiveness is reduced.

Better results are obtained during the dry season when, due to the low water availability, the motes are already deteriorated. The trichomes are considered to be the weak structure of the motita hay, as it is through them that the nutrients are captured, and when they are affected by chemical agents, the health of the whole mota is impacted.

The mixture of 10% sodium bicarbonate and 5% vinagra did not give good results, as it forms sodium acetate, which can be harmful if inhaled, cause irritation to the respiratory tract, be harmful if absorbed through the skin, cause irritation to the feet and eyes and can be harmful if ingested.

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Journal of Innovative Engineering June 2024 Vol.8 No.22 7-19
Article

It is necessary to find an ecologically harmless, technically feasible, economically viable, and socially acceptable control method in order to reduce the damage it is currently causing to the forest cover of arid and semi-arid zones and in particular to the mesquites and huizaches of the semi-desert in Mexico.

In recent years, acetic acid has been used in the treatment of electronic waste to recover rare earths, as well as sodium bicarbonate, which have resulted in environmentally friendly and non-polluting processes (Zhang et al., 2024, Gandam et al., 2024).

Conclusions

The texture and gum production by the branches and trunk of huizaches and mesquites favour the adherence of motite hay seeds and thus make them the most infested trees.

Motes are sensitive to desiccation, so thinning can work and give good results in controlling the mota hay population.

The dry season is the best time to apply mechanical and chemical control.

Treatment with 10% sodium bicarbonate is more effective than 5% vinegar and the combination of both.

It is recommended to combine mechanical and chemical treatment for better control:

- Class 6 infestation/branch pruning/10% sodium bicarbonate treatment.
- Infestation class 4/manual removal/ 10% sodium bicarbonate treatment
- Infestation class 2/manual removal/treatment with 10% sodium bicarbonate of soda.

Once control is stopped, the motite hay recovers in 8 days.

Declarations

Conflict of interest

The authors declare no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Reséndiz-Vega Marisol: Contributed to the project idea, research method and technique.

García-Melo Jose Alberto and Hernández-Sánchez, Eduardo: Contributed to the research method and technique.

Availability of data and materials

Material and equipment from the microbiology laboratory of the Environmental Engineering Department of the Technological University of Tula-Tepeji was used. The results obtained are available to address the problems that affect the University and different municipalities in the State and the country.

Funding

The project received financial support from the Universidad Tecnológica de Tula-Tepeji.

Acknowledgements

We thank the Universidad Tecnológica de Tula-Tepeji for allowing us to use their facilities, for the support in the purchase of reagents and consumables and the participation of students from the Environmental Engineering course.

Abbreviations

CAM	Acid Metabolism of Crassulaceae
NMX	Mexican Standard
pH	Hydrogen Potential
SEMARNAT	Ministry of Environment and Natural Resources
SEMARNATH	Ministry of Environment and Natural Resources of the State of Hidalgo
UTTT	Technological University of Tula-Tepeji

References

Antecedents

Arellano, M. J.J.; M. E. Miranda. J.; B. Z. Salazar A.; F. Hernández. M.; R. Quero. C.; L. Pérez. S.2007. Colección Manejo Campesino de Recursos Naturales, Bases para el manejo comunitario de bromelias ornamentales. Grupo Autónomo parala Investigación Ambiental A.C. México D.F. Pp.98.

ISSN: 2523-6873
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https://doi.org/10.35429/JIE.2024.22.8.7.19

Crow, W. T. (2000). Ball Moss. The Texas Agricultural Extension Service

Basics

Andrade J. L., Cervera J. C. Graham E. A. (2009). Microenvironments, water relations and productivity of CAM plants. En: De la Barrerar E., Smith W. K., Eds. Prespectives in Biophysical Plant Ecophysiology: A Tribute to Park S. Nobel, pp. 95-120. Universidad Nacional Autónoma de México. Centro de Enseñanza para Extranjeros, Centro de Investigaciones en Ecosistemas, campus Morelia, México. D. F. ISBN: 978-0-578-00421

Benzing D. H. (2000). Bromeliaceaoe: Profile of an Adaptative Radiation. Cambridge University Press. Cambridge.

Benzing D. H. (1998). Vulnerabilities of tropical forest to climate change: The significance of resident epiphytes. Climate Change 39:519-540.

Benzing D. H. (1990). Vascular Epiphytes. General Biology and Related Biota. Cambridge University Press. Nueva York.

International Union of Pure and Applied Chemistry (2005), Nomenclature of Inorganic Chemistry IUPAC recommendations, ISBN 0-85404-438-8

International Union of Pure and Applied Chemistry (IUPAQ), (2005), Nomenclature of inorganic chemistry.

Joint FAO/WHO Food Standards Programme. (1998). Fermented Fruits and Vegetables.

Matuda, E. (1957). Bromeliáceas y Aráceas del Estado de México. Impreso en talleres gráficos de la nación, México D.F. Pp. 63

Supports

Bourgeois, J., & Barja, F. (2009). The history of vinegar of its acetification systems. Arch. Sci., 147-160.

Diario Oficial de la Federación [DOF]. (1996). Norma Oficial Mexicana NOM-011-SEMARNAT-1996, que establece los procedimientos, criterios y especificaciones para realizar el aprovechamiento, transporte y almacenamiento de musgo, heno y doradilla. Gobierno Federal, México.

Dirección General de Normas (1968), NMX-F-122-1968, Alimentos para uso humano. Calidad para vinagre envasado para consumo público. Normas mexicanas. Dirección general de normas.

GALLEGO A. PICÓ M., GARCINUÑO R.; MORCILLO J., VÁZQUEZ M. (2023). *QUÍMICA BÁSICA.* Editorial UNED. ISBN 9788436267846.

Helliker B. R., Griffiths H. (2007). Toward a plant-based proxy for the isotope ratio of atmospheric water vapor. Global Change Biology 13:273-733.

Lozano F., (2011), Determinación de Acidez del Vinagre

Neumann, R. (2004). Clavel del aire (Tillandsia *recurvata*) y su control. Trabajo presentado en el XIII Congreso Latinoamericano de Malezas 17,18 y 19 de Septiembre de 1997. Buenos Aries Argentina Boletín Técnico N.º 17. Buenos Aires, Argentina, p. 22.

Química Básica S. A. (5 de mayo de 2006) Hoja de seguridad del bicarbonato de sodio.

Química Suastes S.A. de C.V. (2018), Hoja de datos de Seguridad.

Differences

Hawksworth, F.G. 1980. Memoria, primer simposio nacional sobre parasitología Forestal, Uruapan Michoacán. pp. 239-251

Kamila, P.G. (2005). Clavel del aire, una planta que afecta a árboles y arbustos, métodos de control. Argentina.

Discussions

Alvarado Aguayo A., Carrera Maridueña M. y Yance Carvajal G., (2016): "Estudio del impacto en el control natural de malezas a partir del vinagre", Revista Caribeña de Ciencias Sociales (diciembre 2016).

ANAYA C.; 2006; El Clavel del Aire. Turf Grass Management, 38.

Arce, G. (2001). *Evaluación técnica del vinagre para el manejo de malezas*. Honduras, Zamorano: Escuela Agrícola Panamericana.

ISSN: 2523-6873
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Reséndiz-Vega, Marisol, García-Melo, José Alberto and Hernández-Sánchez, Eduardo. Effectiveness of acetic acid, sodium bicarbonate and the vinegar/baking soda mixture to control the population of motita hay (Tillandsia recurvata) on the campus of the Tula-Tepejí Technological University. Journal of Innovative Engineering. 2024. 8-22: 7-19.
https://doi.org/10.35429/JIE.2024.22.8.7.19

Gandam, PK, Chinta, ML, Gandham, AP, Pabbathi, NPP, Velidandi, A., Prabhu, AA y Baadhe, RR (2024). Optimización multiobjetivo integrada del pretratamiento con bicarbonato de sodio para la porción anatómica externa de la mazorca de maíz utilizando un diseño compuesto central, redes neuronales artificiales y algoritmos metaheurísticos. Cultivos y productos industriales, 207, 117717

Herrera L. y Méndez O., (2024). ¿Qué es el heno "motita", la plaga que está matando árboles en Hidalgo?

Páez-Gerardo L.E. 2005. Biología de Tillandsia *recurvata* L. (Bromeliaceae) y su importancia en aplicaciones prácticas y ecológicas. Tesis de Licenciatura, Facultad de Estudios Superiores Iztacala. Universidad Nacional Autónoma de México. Tlalnepantla, Edo. de México. 82 pp.

Páez L., Aguilar., T., Terrazas, M. Huidobro S. y Aguirre, E. (2005). Cambios anatómicos en la corteza de Parkinsonia praecox (Ruiz y Pavon) Hawkins causados por la epifita Tillandsia *recurvata* L. (Bromeliaceae). Boletín de la Sociedad Botánica de México. 077, pp. 59-64.

RESÉNDIZ-VEGA, Marisol & SÁNCHEZ-TRUJILLO, Gabriela. Environmental function and control of henomotita (Tillandsia *recurvata*) in the atmospheric basin of Tula de Allende Hidalgo. Journal of Environmental Sciences and Natural Resources. 2021. 7-19:19-30

Zhang, Y., Chen, J., Zhang, H., Gong, S., Xiao, Y. y Huang, L. (2024). Reducir la pérdida de tierras raras mediante la adición de ácido acético en el proceso de eliminación de aluminio de la solución de lixiviación de tierras raras. Revista de Producción Más Limpia , 435 , 140537

ISSN: 2523-6873
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https://doi.org/10.35429/JIE.2024.22.8.7.19

Journal of Innovative Engineering June 2024 Vol.8 No.22 20-26
Article

Rectenna for energy harvesting at 2.45 GHz

Rectena para el cosechamiento de energía a una frecuencia de 2.45GHz

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CONAHCYT classification:
Area: Physics-Mathematics and Earth Sciences
Field: Physics
Discipline: Electromagnetism
Subdiscipline: Antennas

https://doi.org/10.35429/JIE.2024.22.8.20.26
History of the article:
Received: February 11, 2024
Accepted: June 23, 2024

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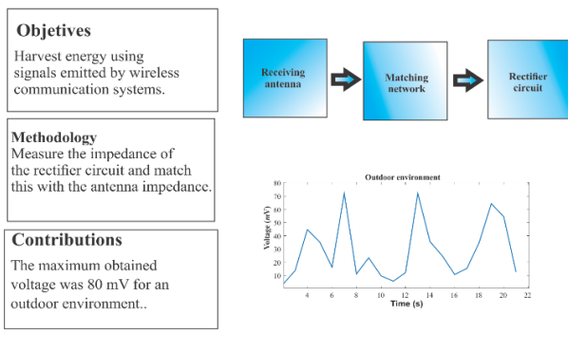
Abstract

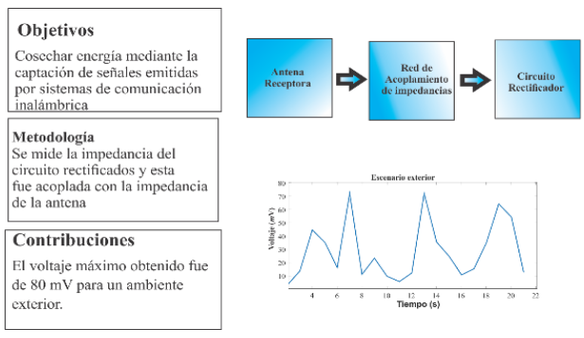
This paper presents the design and implementation of a rectenna for energy harvesting at a frequency of 2.45 GHz. The stages that conform to the rectenna are described. We emphasized that the impedance match is essential to achieve adequate rectena performance. Regarding this, the input impedance of the rectifier was measured experimentally to design the match network. On the other hand, the antenna that makes up the rectenna is a microstrip patch antenna. The present rectenna was evaluated in three environments where the maximum voltage was 80 mV for an outdoor environment.



Rectenna, Microwaves, RF Harvesting

Resumen

El presente articulo presenta el diseño e implantación de una rectena para cosechamiento de energía a una frecuencia de 2.45 GHz. Se describen las etapas que conforman a la rectena. Se hace énfasis que la etapa de acoplamiento de impedancias es importante para lograr un desempeño correcto de la rectena. Respecto a eso se midio la impedancia de entrada del rectificador de manera experimental para diseñar la red de acoplamiento. Por otro lado la antena que conforma la rectena es una antena de parche de microcinta. La presente rectena fue evaluada en tres ambientes donde se consiguió cosechar un voltaje máximo de 80 mV para un ambiente en exterior.



Rectena, Microondas, Cosechamiento

Citation: Tecuatl-Tecuatl, Marco Antonio, Torrealba-Meléndez, Richard, Tamariz-Flores, Edna Iliana and López-López, Mario. Rectenna for energy harvesting at 2.45 GHz. Journal of Innovative Engineering. 2024. 8-22: 20-26.

Journal of Innovative Engineering June 2024 Vol.8 No.22 20-26
Article

Introduction

Nowadays, wireless communications have significantly impacted human life. These communications have promoted the development of concepts and technologies such as 5G [1], the Internet of Things (IoT) [2], smart cities [3], and Industry 4.0 [4]. All these concepts and technologies are composed of several wireless nodes and base stations that use antennas to emit information in the form of radiation waves. The waves are radiated by the antenna in all directions in most cases.

Furthermore, the waves do not travel directly toward the receiver; the waves are reflected and refracted in buildings, trees, vehicles, and the ground when the wave propagates across the wireless channel. These reflections and refractions produce a multipath of the transmitted wave [5]. These mean that free radiated energy can be exploited to feed small electronic devices such as sensors and actuators or charge small batteries. One way to catch and exploit this free energy is by using rectennas. The rectennas are capable of receiving radiated waves and converting these into direct current signals. Research and development regarding rectennas have been done in the last decade [6]-[8]. The proposed rectennas have been designed for different operation frequencies like ISM bands or mobile communications bands [9]. This paper presents a rectenna for harvesting energy at 2.4 GHz using an L circuit for the match impedance. Besides this, rectenna uses a two-stage voltage multiplier.

Finally, the performance of the proposed rectenna was evaluated in indoor and outdoor scenarios. The collected maximum voltage for the proposed rectenna is 80 mV. This paper is organized as follows: first, we present rectenna elements. Next, we describe and design each element. Finally, we present the performance of the rectenna in three environments.

1. Rectennas

Rectennas are devices capable of catching radiated waves and converting them into direct current signals. Their architecture consists of three parts: an antenna for a specific frequency, an impedance-matching network that matches the impedances between the antenna, and the rectifier circuit, which is the final part of the rectenna. Figure 1 shows the general architecture of rectennas.

Box 1

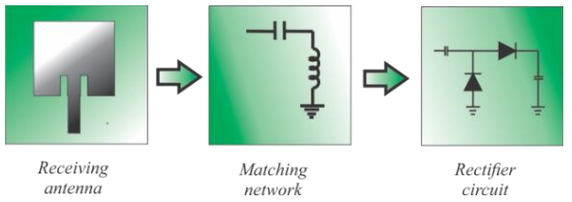


Figure 1
The general architecture of a rectenna

In some research, the authors emphasize the importance of the impedance match between the antenna and the rectifier circuit [10]-[16]. In this paper, the proposed rectenna, the impedance matching network, is an L circuit conformed by one capacitor and one inductor. With impedance matching, we can ensure that the rectifier circuit receives the maximum power of the receiving antenna. The rectifier circuit is responsible for converting the waves into direct current signals. The rectifier circuit for this rectenna is formed in two stages based on the Dickson rectifier. Finally, we used a microstrip patch antenna to complete the rectenna in this paper.

2. Rectifier Circuit design

The rectifier circuit is a crucial component in a rectenna. The rectifier circuit also works as a multiplier circuit.

This circuit is conformed by semiconductor devices such as transistors and diodes.

Different configurations of rectifiers and multipliers. Two configurations are the most used. One is the Cockcroft-Walton multiplier [17], formed by two capacitors and two diodes, and the other is the Dickson multiplier [18], which improves the Cockcroft-Walton multiplier. Figure 2 shows the configuration of the Dickson multiplier with two stages.

This circuit operates as follows: Diode D_1 charges the capacitor C_1 when the input voltage has its negative cycle. Moreover, capacitor C_2 is charged through diode D_2 in the following positive semi-cycle; the voltage in C_2 is the sum of the voltage in C_1 and the source voltage (V_{in}).

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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Journal of Innovative Engineering June 2024 Vol.8 No.22 20-26
Article

In the following negative semi-cycle, diode D_3 charges the capacitor C_3; the voltage in C3 is the sum of the voltage in C_1, C_2, and the source voltage (V_{in}). Finally, for the next positive semi-cycle, D_4 charges capacitor C_4 with the voltage in C_3 and the source voltage (V_{in}). The direct current (DC) output voltage of the Dickson multiplier is described in the following equation:

$$V_{DC} = 2N(V_{in} - V_t) \quad (1)$$

Box 2

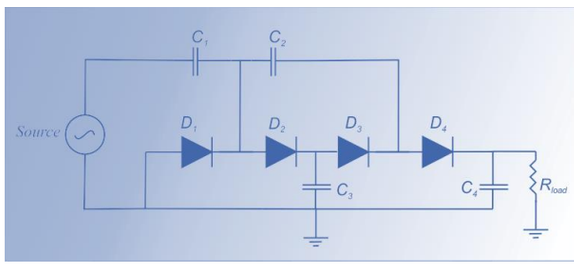

Figure 2

Configuration of the Dickson multiplier with two stages

N is the number of states of the multiplier, and V_t is the conduction voltage of the diodes. Figure 3 shows the proposed layout for the Dickson multiplier of two stages.

Box 3

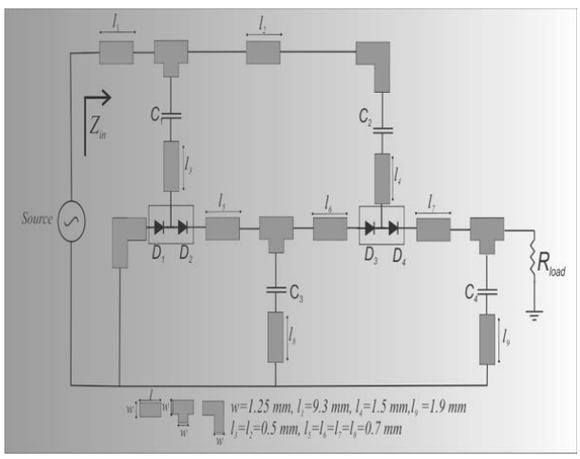

Figure 3

Layout of the proposed rectifier circuit

For the design, we employ Shockley diodes. Shockley diode is one of the most employed diodes in harvesting energy systems. In this design, we use the commercial diode BAS 70-04, which has a maximum operating frequency of 15 GHz.

Regarding the capacitors, we employ capacitors of 30 pF and a load resistance of 50 Ohms. In this design, we use Rogers 4003c as a substrate to implement the multiplier, with a permittivity of 3.5 and a thickness of 0.55 mm. For the layout, 50 Ohms microstrip lines were considered to interconnect the diodes and capacitors; the width (w) of the lines is 1.25mm. The impedance of the source was considered 50 Ohms. The layout of the multiplier was fabricated using a lithography process; then, the devices were soldered, and finally, an SMA connector was added. Figure 4 shows the fabricated circuit and the measurement of its input impedance, which is measured by connecting the multiplier to a vector network analyzer (VNA).

Box 4

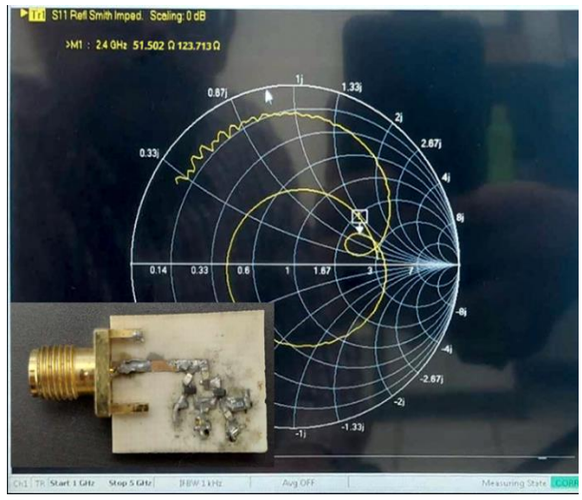

Figure 4

Measured Input impedance for the rectifier circuit

The measured impedance of the multiplayer at 2.4 GHz is $Z_{in} = 51.5 + j123.73\ Ohms$, as shown in Figure 4. This impedance is used to design the match L network described in the next section.

3. Impedance Matching Network

The multiplier impedance must be matched to the antenna impedance of Z_0 =50 Ohms. The proposed rectenna uses an L network to match the impedances between the multiplier and the antenna. The L network consists of two reactive elements, as shown in Figure 5.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Tecuatl-Tecuatl, Marco Antonio, Torrealba-Meléndez, Richard, Tamariz-Flores, Edna Iliana and López-López, Mario. Rectenna for energy harvesting at 2.45 GHz. Journal of Innovative Engineering. 2024. 8-22: 20-26.
https://doi.org/10.35429/JIE.2024.22.8.20.26

Journal of Innovative Engineering June 2024 Vol.8 No.22 20-26
Article

Box 5

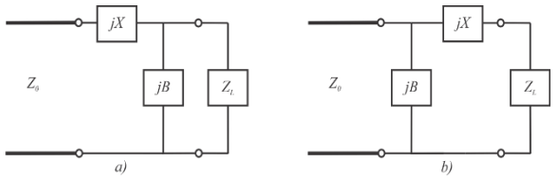

Figure 5

a) L network for $\Re(Z_L) > Z_0$. b) L network for $\Re(Z_L) < Z_0$.

These reactive elements could be capacitors or inductors. From the model presented in Figure 5, we appreciated that the impedance of the L network must be equal to Z_0. This condition is related to the following equation

$$Z_0 = jX + \frac{1}{jB+1/(R_L+jX_L)} \quad (2)$$

In this case $Z_0 = 50\ Ohms$ and $Z_L = 51.5 + j123.73\ Ohms$, in this case, the real part of Z_L is bigger than Z_0, we can obtain B and X with the following equations [19]:

$$B = \frac{X_L \pm \sqrt{R_L/Z_0}\sqrt{R_L^2+X_L^2-Z_0R_L}}{R_L^2+X_L^2} \quad (3)$$

$$X = \frac{1}{B} + \frac{X_L Z_0}{R_L} - \frac{Z_0}{BR_L} \quad (4)$$

The calculated values are $B = 0.694\ Simens$ ans $X = 2.44\ Ohms$. Next, we transform B in a capacitor and X in an inductor at f=2.4 GHz using the following equations [19]:

$$C = \frac{B}{2\pi f Z_0} \quad (5)$$

$$L = \frac{XZ_0}{2\pi f} \quad (6)$$

Substituting the values of B, X, Z_0, and f in equations 5 and 6, we obtain that C=0.92 pf and L=8.13nH. This L network is connected to the rectifier's input. Figure 6 shows the simulated reflection coefficients of the rectifier with and without the L-match network. The simulated reflection coefficient of the rectifier with the L network presents a level under -10dB in a frequency range of 2.2 to 2.55 GHz. At the frequency of 2.45 GHz, the value of the reflection coefficient is -25dB, and this shows that the L match network is matching the impedance of the rectifier with Z_0.

Box 6

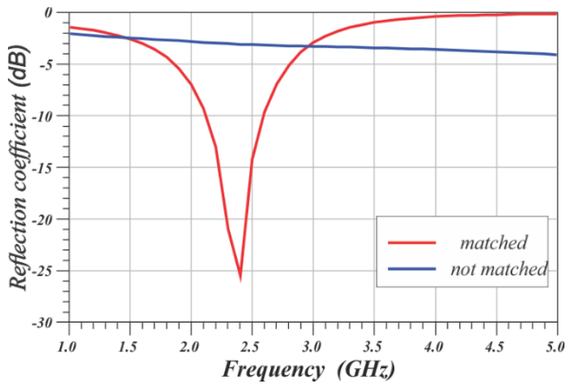

Figure 6

The simulated reflection coefficients of the rectifier with and without the L network

The designed L-match network was implemented and added to the rectifier circuit in the same PCB. The reflection coefficient of the rectifier circuit with the L network was measured using a VNA. Figure 7 shows the comparison between the simulated and measured reflection coefficients.

The measured reflection coefficient is in concordance with the simulated. The minimum peak of the reflection coefficient was shifted to 2.36 GHz. However, the reflection coefficient at 2.45 GHz is under -10 dB. With these results, the integration of the antenna with an impedance of 50 Ohms can be possible.

Box 7

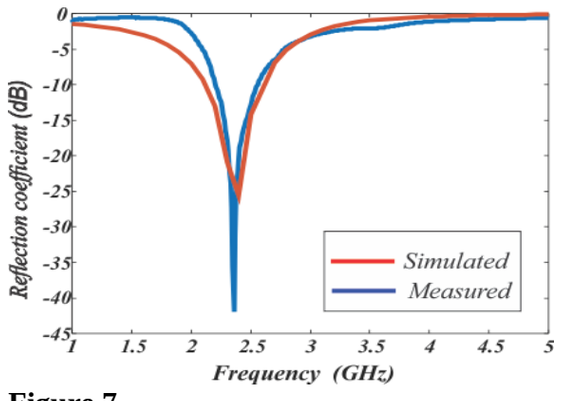

Figure 7

Simulated and measured reflection coefficient for the rectifier circuit with L match network

4. Microstrip patch antenna

The proposed rectenna employs a microstrip patch antenna. This antenna was designed on the same substrate as the rectifier circuit and at 2.45 GHz.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Tecuatl-Tecuatl, Marco Antonio, Torrealba-Meléndez, Richard, Tamariz-Flores, Edna Iliana and López-López, Mario. Rectenna for energy harvesting at 2.45 GHz. Journal of Innovative Engineering. 2024. 8-22: 20-26.
https://doi.org/10.35429/JIE.2024.22.8.20.26

Journal of Innovative Engineering June 2024 Vol.8 No.22 20-26
Article

The antenna design was performed according to the methodology described in [20]. Figure 8 shows the geometry and dimensions of the microstrip path antenna.

Box 8

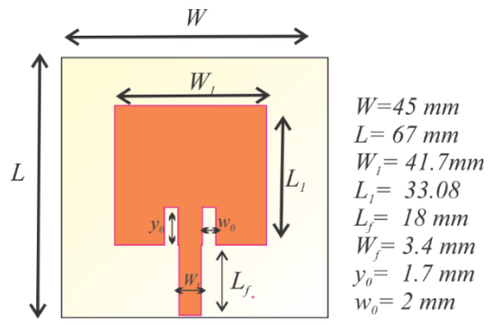

Figure 8
The geometry of the microstrip patch antenna

The antenna was characterized by simulation and measurement of its reflection coefficient. The simulation was performed in HFSS, and the measurement was connecting the antenna to a VNA. The comparison between the simulated and measured reflection coefficient is shown in Figure 9. The reflection coefficients simulated and measured are in concordance; in both, the reflection coefficient is under -10dB for the frequency of 2.45 GHz. The measured reflection coefficient has a minimum peak of -19.5 dB at 2.45 GHz. This result makes this antenna suitable for connecting to the rectifier circuit.

Box 9

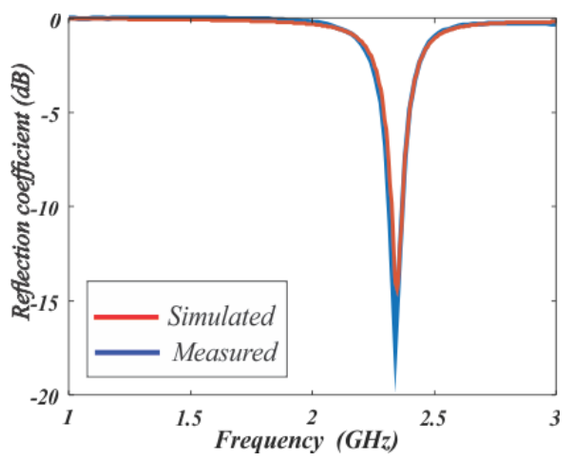

Figure 9
Simulated and measured reflection coefficient of the microstrip patch antenna.

5. Evaluation of the rectenna

As shown in Figure 10, the antenna and the rectifier circuit with the L-match network were connected using a through adaptor.

Box 10

Figure 10
Photography of the proposed rectenna

The voltage recollected by the rectenna was measured using a voltmeter in the load resistance of the rectifier. The rectenna was evaluated in three proposed environments. Figure 11 shows the collected voltage for the three environments.

First, we considered an outdoor environment where the rectenna was placed at 5 m of a WiFi access point working at 2.45GHz; the rectenna's collected voltage is shown in Figure 11a, and Figure 11 shows a window of time of 22 s where the voltage measured was performed. In this first environment, the maximum peak of collected voltage was 72 mV.

The second environment was indoors, where no WiFi access points were placed. In this case, the peak voltage was 50 mV, as is shown in Figure 11b. Finally, the third case was also in an indoor environment with WiFi access points at a 5m distance from the rectenna. The maximum peak of voltage in this environment was 80 mV, and the collected voltage in this case is shown in Figure 11c.

Conclusions

In this paper, we describe designing a rectenna for harvesting energy and highlight the importance of designing an optimal match network to achieve a suitable rectenna performance.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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https://doi.org/10.35429/JIE.2024.22.8.20.26

Concerning the collected voltage, we appreciate that the best results can be obtained when the transmitter is close to the rectenna, in this case, when the WiFi access points are in the environment.

Finally, these rectennas can be helpful devices to obtain energy and feed low-consumption circuits for sensing or IoT applications.

Box 11

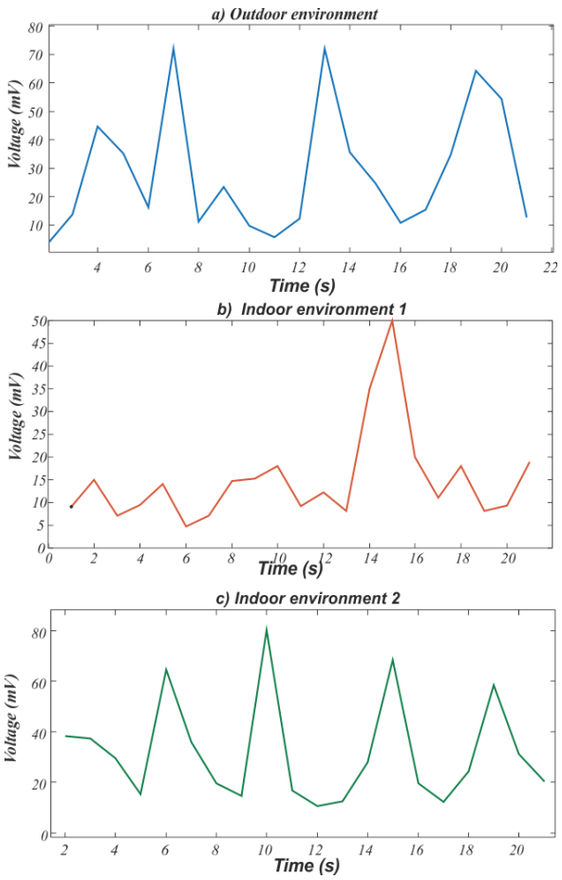

Figure 11

Collected voltage for the rectenna in three environments. a) Outdoor environment, b) indoor environment 1, and c) indoor environment 1

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Tecuatl-Tecuatl, Marco Antonio: Contributed to the project idea, research method, and measurements.

Torrealba-Meléndez, Richard: Contributed to the project idea and research method measurements and writing and editing.

Tamariz-Flores, Edna Iliana: Contributed to the project idea and research method, as well as writing, reviewing, and editing.

López-López, Mario: Contributed to the project idea and research method, as well as writing, reviewing, and editing.

Availability of data and materials

The datasets used or analyzed during the current study are available from the corresponding author.

Funding

This research received no external funding.

Acknowledgments

The authors thank the Laboratory of characterization system based on microwave of the BUAP.

Abbreviations

IoT- Internet of Things

References

Antecedents

Torrealba-Meléndez, R., Tamariz-Flores, E. I., and López-López, (2023) M. Sistemas de comunicaciones electrónicas de quinta generación (5G), SPINOR, BUAP, 13(39).

Laghari, A. A., Wu, K., Laghari, R. A., Ali, M., & Khan, A. A. (2021). A review and state of art of Internet of Things (IoT). Archives of Computational Methods in Engineering, 1-19.

Javed, A. R., Ahmed, W., Pandya, S., Maddikunta, P. K. R., Alazab, M., & Gadekallu, T. R. (2023). A survey of explainable artificial intelligence for smart cities. Electronics, 12(4), 1020.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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https://doi.org/10.35429/JIE.2024.22.8.20.26

Soori, M., Arezoo, B., & Dastres, R. (2023). Internet of things for smart factories in industry 4.0, a review. Internet of Things and Cyber-Physical Systems.

Lee, J., Park, J. J., Kim, K. W., Kwon, H. K., & Kim, M. D. (2023, March). Sub-THz outdoor urban measurements and multipath propagation characteristics. In 2023 17th European Conference on Antennas and Propagation (EuCAP) (pp. 1-4). IEEE.

Support

Prashad, L., Mohanta, H. C., & Mohamed, H. G. (2023). A compact circular rectenna for RF-energy harvesting at ISM band. Micromachines, 14(4), 825.

Aboualalaa, M., Mansour, I., & Pokharel, R. K. (2023). Energy harvesting rectenna using high-gain triple-band antenna for powering internet-of-things (IoT) devices in a smart office. IEEE Transactions on Instrumentation and Measurement, 72, 1-12.

Olaimat, M. M., Nayyeri, V., & Ramahi, O. M. (2023). Simulation and optimization of rectenna systems. Scientific Reports, 13(1), 17107.

Differences

Abdullah, M. H., Marzuki, A., & Mustaffa, M. T. (2023). Design of Dual ISM bands low power rectenna for indoor wireless power transfer application. International Journal of Electrical and Electronic Engineering & Telecommunications, 12(1), 60-70.

Mulkanuri, Y., Kurimineni, J., Mekala, P. C. S., Reddy, B. S., Das, J., & Deshpande, R. (2024, February). Wireless Energy Harvesting with Rectenna Technology for Wi-Fi Band. In 2024 IEEE Wireless Antenna and Microwave Symposium (WAMS) (pp. 1-4). IEEE.

Surender, D., Halimi, A., Khan, T., Talukdar, F. A., & Antar, Y. M. (2023). A triple band rectenna for RF energy harvesting in smart city applications. International Journal of Electronics, 110(5), 789-803.

Support

Maher, R., Allam, A., Kanaya, H., & Abdelrahman, A. B. (2024). Dualband rectenna for RF energy harvesting using metamaterial reflect array and novel matching technique. AEUInternational Journal of Electronics and Communications, 173, 155020.

Chen, Z., Song, C., Zhang, J., Zheng, X., Volskiy, V., Chu, P., & Vandenbosch, G. A. (2023). Wearable rectenna with integrated miniaturized feeding slot and rectifier structure. IEEE Transactions on Antennas and Propagation, 71(5), 3868-3881.

Singh, N., Khan, T., Kumar, S., Kanaujia, B. K., Choi, H. C., Kim, K. W., & Kishk, A. A. (2024). Ultra-thin flexible rectenna integrated with power management unit for wireless power harvester/charging of smartwatch/wristband. Scientific Reports, 14(1), 7447.

Sharma, P., Singh, A. K., Naresh, B., Verma, R. K., Singh, V. K., & Pandey, M. K. (2024). Design and optimization of broadband CPW rectenna for RF energy harvesting. International Journal of Electronics, 1-19.

Khodaei, M., Boutayeb, H., & Talbi, L. (2024, March). A High Efficiency and Ultra-Wideband Rectenna For RF Energy Harvesting Application. In 2024 18th European Conference on Antennas and Propagation (EuCAP) (pp. 01-04). IEEE.

Ali, E. M., Yahaya, N. Z., Saraereh, O. A., Assaf, A. H. A., Alqasem, B. H., Iqbal, S., ... & Patel, A. V. (2021). Power conversion using analytical model of Cockcroft–Walton voltage multiplier rectenna. Electronics, 10(8), 881.

Nakashima, D., Kino, Y., & Eguchi, K. (2023). Design of a bipolar Dickson voltage multiplier suitable for low output voltage conditions to provide efficient food processing. Energy Reports, 9, 207-213.

Basics

Pozar, D. M. (2011). Microwave engineering. John Wiley & Sons.

Balanis, C. A. (2016). Antenna theory: analysis and design. John Wiley & Sons.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Tecuatl-Tecuatl, Marco Antonio, Torrealba-Meléndez, Richard, Tamariz-Flores, Edna Iliana and López-López, Mario. Rectenna for energy harvesting at 2.45 GHz. Journal of Innovative Engineering. 2024. 8-22: 20-26.
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Journal of Innovative Engineering June 2024 Vol.8 No.22 27-31
Article

Design and manufacture of a prototype dryer for fruits and vegetables using a convection system

Diseño y fabricación de un prototipo secador para frutas y hortalizas por sistema de convección

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CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: System engineer
Subdiscipline: Control

https://doi.org/10.35429/JIE.2024.22.8.27.31
History of the article:
Received: February 09, 2024
Accepted: June 28, 2024

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Abstract

The scarcity of funds for acquiring industrial-type equipment and devices for laboratory practices at technological universities is a recurring issue. This financial constraint is particularly evident in the educational program of engineering in Biofood Processes at the Technological University of Tecamachalco, where the absence of drying equipment for water reduction practices in fruits and vegetables is a pressing concern. To address this, we have developed a prototype of a convection dryer. The Mechatronics engineering research group has been at the forefront of developing this innovative prototype. Our team has harnessed the power of a PID control system, integrating a microcontroller, a potentiometer for temperature programming, and an-LED screen for real-time monitoring. This state-of-the-art design is a testament to our commitment to advancing laboratory equipment. If the temperature is reduced, the installed electrical resistances will be activated. If the upper limit of the programmed temperature is exceeded, an air extractor placed in the upper part of the prototype will be activated to reduce it as necessary.After rigorous testing, we conducted three water reduction tests on apples with the guidance of food engineering experts. The apples were subjected to a temperature of 60 °C for approximately two hours, a condition necessary to prevent any deterioration. In all three tests, we successfully reduced the water activity from 70% to 12%, a crucial step for preservation. With the successful completion of the tests, the prototype was transitioned to the Food Engineering laboratory, ready for practical use. This significant advancement in our ability to carry out laboratory practices offers a promising solution to the lack of industrial-type equipment in our educational program. We are optimistic about the potential impact of this prototype and look forward to seeing it in action.

Convection Dryer, Prototype, System Control PID

Resumen

La escasez de fondos para la adquisición de equipos y dispositivos de tipo industrial para prácticas de laboratorio en las universidades tecnológicas es un tema recurrente. Esta restricción financiera es particularmente evidente en el programa educativo de ingeniería en Procesos Bioalimentarios de la Universidad Tecnológica de Tecamachalco, donde la ausencia de equipos de secado para prácticas de reducción de agua en frutas y verduras es una preocupación apremiante. Para solucionar este problema, hemos desarrollado un prototipo de secador por convección. El grupo de investigación en ingeniería Mecatrónica ha estado al frente del desarrollo de este innovador prototipo. Nuestro equipo ha aprovechado el poder de un sistema de control PID, integrando un microcontrolador, un potenciómetro para programación de temperatura y una pantalla LED para monitoreo en tiempo real. Este diseño de última generación es un testimonio de nuestro compromiso con el avance de los equipos de laboratorio. Si se reduce la temperatura se activarán las resistencias eléctricas instaladas. Si se supera el límite superior de temperatura programada, se activará un extractor de aire colocado en la parte superior del prototipo para reducirla según sea necesario. Después de pruebas rigurosas, realizamos tres pruebas de reducción de agua en manzanas con la guía de expertos en ingeniería alimentaria. Las manzanas fueron sometidas a una temperatura de 60 °C durante aproximadamente dos horas, condición necesaria para evitar cualquier deterioro. En las tres pruebas, redujimos con éxito la actividad del agua del 70% al 12%, un paso crucial para la preservación. Una vez completadas con éxito las pruebas, el prototipo fue trasladado al laboratorio de Ingeniería de Alimentos, listo para su uso práctico. Este avance significativo en nuestra capacidad para realizar prácticas de laboratorio ofrece una solución prometedora a la falta de equipos de tipo industrial en nuestro programa educativo. Somos optimistas sobre el impacto potencial de este prototipo y esperamos verlo en acción.

Secador por convección, Prototipo, Sistema de control PID

Citation: Vera-Cruz, Gustavo, Hernández-Velázquez, Lorena, Canseco-Hernández, Felipe and Flores-Benavidez, Joel. Design and manufacture of a prototype dryer for fruits and vegetables using a convection system. Journal of Innovative Engineering. 2024. 8-22: 27-31.

Journal of Innovative Engineering June 2024 Vol.8 No.22 27-31
Article

Introduction

The use of industrial equipment in the Educational Program of Engineering in Biofood Processes belonging to the Technological University of Tecamachalco is of utmost importance for learners to carry out practices that allow them to develop their knowledge regarding food processes, which is why, In conjunction with the research group of the Mechatronics Engineering career, the design and manufacture of a prototype of a convection dryer for fruits and vegetables will be carried out since this career has industrial equipment. However, more is needed to carry out this process. It is necessary to expand students' knowledge.

The convection drying process is a conventional method. This process reduces the water activity in fruits and vegetables. The cost of this equipment is high, making its acquisition complicated. The convection dryer is equipment that reduces food's water activity to increase the products' shelf life or facilitate their transportation. Drying is a unitary operation of heat transfer to evaporate a liquid found in the solid and diffusion of mass of the liquid from the solid phase to the gas phase. That is why, with joint work between specialty areas such as the Food Engineering and Mechatronics career, this prototype was designed and manufactured.

The research group of the Mechatronics engineering educational program seeks to develop, based on knowledge of PID control and design of mechanical elements, the manufacture of laboratory equipment for student practices.

Objective of the project

General

Our project entails the innovative design and manufacture of a prototype dryer, a significant advancement in the field of Biofood Process Engineering. This dryer utilizes a convection system, a novel approach that promises enhanced efficiency and effectiveness.

Particular

The heart of our prototype is the PID Control system, meticulously designed to emit precise signals for temperature control. This system plays a crucial role in reducing water activity in fruits and vegetables, ensuring optimal product quality.

Description

To reduce water activity in fruits and vegetables, the PID Control was designed. A potentiometer, a type of variable resistor, was used in this design. The temperature at which the prototype will work is programmed, which will be displayed and monitored on a 2.4-inch OLED screen.

Once the temperature is programmed, a resistance will be activated to reach the desired temperature inside the prototype. If the programmed range is exceeded, an air extractor will be activated to maintain it. If it is reduced, the resistance will be activated again to continue with the temperature process.

To achieve the above, the appropriate electronic components were sought, and a PCB card was designed to better connect the electronic components. Electrical components of a range of durability were also selected since working with high temperatures reduces their useful life.

The microcontroller selected for the prototype is the Atmega 328P. It is placed on a small PCB card with the necessary programming functions, such as temperature sensing, control signal generation, and user interface management, to carry out the process. Another critical element is the “J” type thermocouple, used in industrial processes to sense temperature changes.

The PID Control, together with the type J thermocouple, will maintain the appropriate temperature in the prototype to reduce water activity. The main elements used to develop our Project are shown below in Figure 1.

Box 1

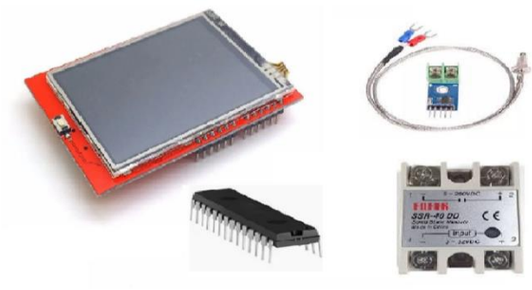

Figure 1
Oled screen, Thermocouple “J”, Microcontroller and solid-state relay

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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https://doi.org/10.35429/JIE.2024.22.8.27.31

Journal of Innovative Engineering June 2024 Vol.8 No.22 27-31
Article

A simplified connection diagram of the electronic control elements is shown in figure 2**.**

Box 2

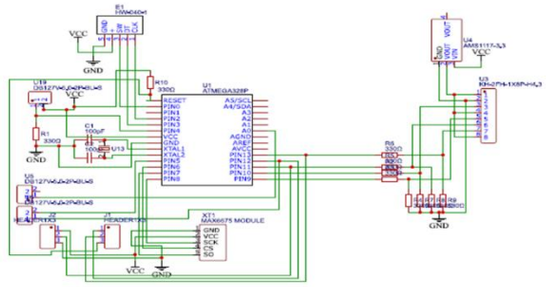

Figure 2
Electronic control connection diagram

The final physical assembly of the basic components for the convection drying prototype is shown in Figure 3.

Box 3

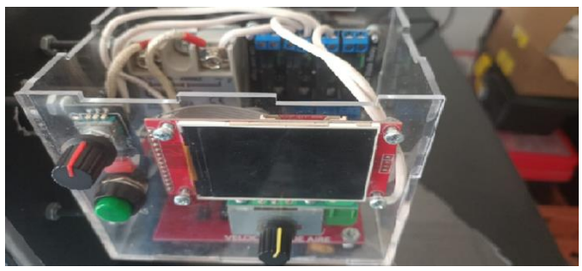

Figure 3
Final assembled device showing all the elements used

The microcontroller card, a testament to our efficient design, was programmed using the Arduino IDE. It is worth mentioning that a PCB card was designed to extend the useful life of the components, further enhancing its efficiency. The device's operation is straightforward. It's programmed to the working temperature of the fruit or vegetable, and the PID control system maintains this temperature. If it decreases, an internal resistance is activated, and if it increases, a top-mounted extractor is triggered until it stabilizes. The real value of our device lies in its monitoring feature, which allows for easy verification of the process on the OLED screen.

Theoretical fundament

PID control

An essential part of achieving temperature control is having used a type “J” thermocouple that is reliable for these purposes.

This thermocouple in connection with a PID Type Control (Proportional, Integral and Derivative Control), whose block diagram will have the following structure as shown in Figure 4.

Box 4

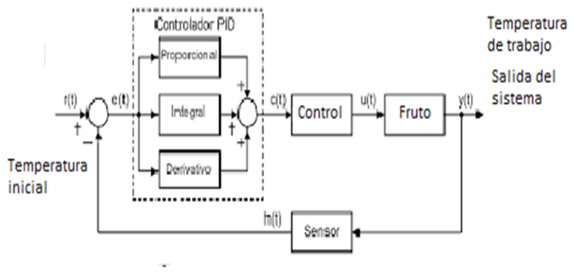

Figure 4
PID temperature control structure

In this scheme, it is observed that the Controller will act to obtain the desired working temperature according to the type of fruit or vegetable for which the water activity needs to be reduced.

Project development

Until the writing of this report, physical functional tests of the electronic components had been carried out to verify the functionality of the PID Control in the prototype.

The following figures show the physical test of the prototype's operation on an apple.

Box 5

Figure 5
Water activity reduction test for an apple

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Vera-Cruz, Gustavo, Hernández-Velázquez, Lorena, Canseco-Hernández, Felipe and Flores-Benavidez, Joel. Design and manufacture of a prototype dryer for fruits and vegetables using a convection system. Journal of Innovative Engineering. 2024. 8-22: 27-31
https://doi.org/10.35429/JIE.2024.22.8.27.31

Journal of Innovative Engineering June 2024 Vol.8 No.22 27-31
Article

Box 6

Figure 6
Temperature and working time programming

Box 7

Figure 7
Completion of the water activity reduction process indicated on the Oled screen.

Box 8

Figure 8
Verification of the apple at the end of the process.

The procedure for reducing water activity in the apple was based on the following: Apple slices were cut with an area of 3.0 cm x 2.5 cm +/—0.2 mm and a thickness of 0.2 mm.

The drying was carried out in duplicate, evaluating the functionality of the equipment at a Temperature of 50°C at a speed of the results were treated by statistical analysis of the measure of central tendency and graphed.

At the end of the process, the reduction in water activity in the block was verified, obtaining the following results, which are shown in the following table.

Box 9

Table 1
Percentage of moisture removed

Time (min)	% of moisture removed
0	0
30	35
60	60
90	80
120	82
150	82

Box 10

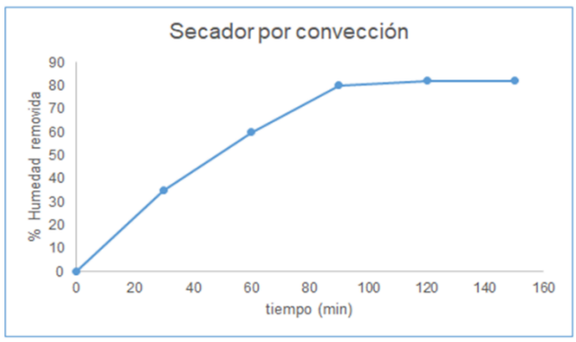

Figure 10
Percentage of humidity reduced in graph

Conclusions

In talks held with teachers of the educational program of the Biofood Processes career, it was commented that the design and manufacturing of prototypes such as the one presented in this article are of utmost importance since, with equipment of this type, students will be able to carry out their practical work. The laboratory is satisfactory, with the certainty that its functionality and results are similar to those of some industrial equipment.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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Based on the above, the research group of the Mechatronics program, together with the teachers of the Biofood Processes program, reached an agreement to continue collaborating to continue the design and manufacture of other equipment necessary to carry out practices—laboratory in this career. We also conclude that we consider our device to be economical since it has a cost of about $4000.00, which from our point of view, is quite affordable for an application for use in laboratories.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Authors' Contribution

The contribution of each researcher in each of the points developed in this research, was defined based on:

Vera-Cruz, Gustavo: contributed to the idea of the design and construction of the prototype, as well as supporting the writing of the article.

Hernández-Velázquez, Lorena: carried out the tests and evaluation of the drying curve for the characterization of apple drying, as well as supporting the writing of the article.

Canseco-Hernández, Felipe: I carried out the PID control, as well as supporting the writing of the article.

Flores-Benavides, Joel: Contributed to the technological innovations of the prototype, as well as supporting the writing of the article.

Availability of data and materials

All the materials used in the manufacture of the dryer prototype were financed by the Mechatronics engineering research group, as well as the drying tests with the apple.

Funding

This research only received funding, only the payment for this article

Abbreviations

IDE	Integrated Development Environment
FIG	Figure
MIN	Minutes
OLED	Organic Light Emitting Diode
PCB	Printed circuit board
PID	Proportional, integral and derivative

References

Basics

Gallego Yanza, C. J. (2006). Diseño de un horno por convección forzada para la deshidratación de frutas y hortalizas.

Paul G. Hewitt, Física Conceptual, 9ª Edición, 2002.

Malvino, Principios de Electrónica, 7ª Edición., Mc. Graw Hill.

Enrique Palacios, Arduino: Desarrollo de Proyectos, 3ª. Edición, Editorial Alfaomega, 2009.

Supports

Barraza Járegui, G., Rojas Padilla, C., & Moscol Orozco, R. (2013). Cinética de secado de rodajas de manzana (Pirus malus L.) variedad Pachacamac osmodeshidratas. Tecnología y Desarrollo (Trujillo), 11(1), 23-32.

Omar Enrique Barra, Microcontrolador Pic con Programacion PBP, 1ª Edición, Edit. Alfaomega, 2011.

William Bolton, Mecatrónica Sistemas de Control Electrónico en la Ingeniería, 5ª Edición, Alfaomega, 2019.

Differences

Ariza, O., Casallas, I., & Fajardo, A. (2024). Innovador secador solar para la conservación sostenible del gel de aloe vera en Colombia. Sostenibilidad. 16 (8), 3392.

ISSN: 2523-6873
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ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

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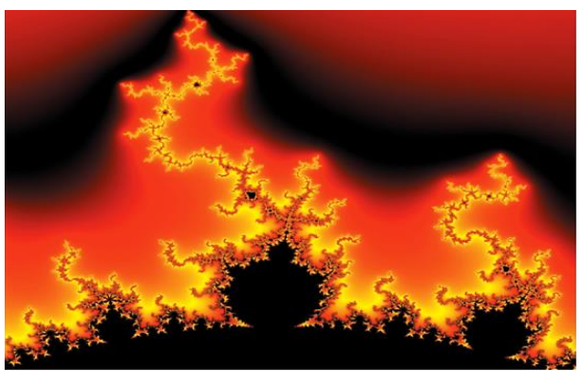

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