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Journal Renewable Energy

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The works must be unpublished and refer to topics of Solar energy and its applications, renewable energies and climate change, environmental impact, hydroelectric plants, renewable energies, energy geothermal power in the world and other topics related to Engineering and Technology.

Presentation of the content

In the first article we present, *Solar drying study of mango (Mangifera indica) and determination of glucose content in dehydrated samples* by CASTILLO-TÉLLEZ, Margarita, CASTILLO-TÉLLEZ, Beatriz, HERNÁNDEZ-CRUZ, Luz María and MEJÍA-PÉREZ, Gerardo Alberto, with adscription in the Universidad Autónoma de Campeche and the Universidad de Guadalajara, in the next article we present, *Synthesis and characterization of Zinc Oxide thin films deposited by Spray Pyrolysis technique for possible applications in solar cells* by VÁZQUEZ-VALERDI, Diana Elizabeth, LUNA-LÓPEZ, José Alberto, ABUNDIZ-CISNEROS, Noemí and JUAREZ-DÍAZ, Gabriel, with adscription in the Benemérita Universidad Autónoma de Puebla and the Universidad Nacional Autónoma de México, in the next article we present, *Mechanical characterization of spent- coffee-grounds briquettes* by CHAMARRAVÍ-GUERRA, Oscar & MORENO-ARIAS, Claudio Alberto, with adscription in the Fundación Universidad de América, in the last article we present, *Measurement of degradation of solar panels induced by damp heat* by SALAZAR-PERALTA, Araceli, PICHARDO-SALAZAR, José Alfredo, PICHARDO-SALAZAR, Ulises and CHÁVEZ, Rosa Hilda, with adscription in the Tecnológico de Estudios Superiores de Jocotitlán, Centro de Bachillerato Tecnológico Industrial y de Servicios No. 161, Centro de Estudios Tecnológicos Industrial y de Servicios No. 23. And the Instituto Nacional de Investigaciones Nucleares.

Content

Article

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Solar drying study of mango (*Mangifera indica*) and determination of glucose content in dehydrated samples

Estudio del secado solar de mango (*Mangifera indica*) y determinación del contenido de glucosa en muestras deshidratadas

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Abstract

Today, the food industry processes are increasing both the costs and the consumption of energy through fossil fuels. The dehydration process to preserve food is increasingly used worldwide to safeguard both its organoleptic and nutritional properties, so it is essential to use renewable energies to replace conventional technologies. Mexico is a great producer and exporter of different mango varieties, with excellent culinary quality and nutritional properties. In the present work, direct cabinet-type solar dryers were used, and drying times between 420 and 540 min were obtained in fresh samples with 74.5% and 7.5% of initial and final humidity, respectively. Compared to its new mango content, glucose decreased in the dry samples.

Glucose, Moisture Content, Drying Rate

Resumen

Los procesos de la industria alimentaria en la actualidad están incrementando tanto los costos como el consumo de energéticos mediante combustibles fósiles. El proceso de deshidratado para conservar alimentos es cada vez más utilizado en todo el mundo para conservar las propiedades tanto organolépticas como nutrimentales de estos, por lo que es imprescindible utilizar energías renovables para sustituir las tecnologías convencionales. México es un gran productor y exportador de diferentes variedades de mango, con una gran calidad culinaria y propiedades nutrimentales. En el presente trabajo se utilizaron secadores solares directos tipo gabinete, se obtuvieron tiempos de secado entre 420 y 540 min, en muestras frescas con 74.5% y 7.5% de humedad inicial y final, respectivamente. Se encontró que la glucosa disminuyó en las muestras secas, en comparación con su contenido en mango fresco.

Glucosa, Contenido de humedad, Velocidad de secado

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1. Introduction

The mango is a tropical tree species, of permanent vegetation, which can reach 10 to 40 m in height. The fruit is succulent, fleshy, kidney-shaped or oval, greenish, yellowish, reddish, very sweet and enclosing a large stone or cavozo, flattened, surrounded by a woody cover. It is consumed in fresh fruit as well as in juices, ice creams, candies, jams and preserves. Industrially it is processed into pulp, pickles and frozen products. Mango is considered a highly healthy fruit; its high water content (86.1%) is a pleasant way to hydrate (SADER, 2017). Mango production in the country today has the ideal conditions to supply the growing external demand. In 2019, a new maximum in exports of the fruit was observed: 450 thousand 524 tons (Secretaría de Agricultura, 2020).

Mango is also an important source of dietary fiber; apart from its high content of fructose, sucrose and glucose, it is characterized by having a high content of vitamins and minerals (such as ascorbic acid, thiamine, riboflavin, niacin and β-carotene). In particular, almost all varieties are a rich source of ascorbic acid and carotenoids that, together with its phenolic compounds, make a specific synergy in the total antioxidant capacity of each variety. 100 grams of mango pulp is enough to cover 146, 69 and 45% of the recommended daily intake of ascorbic acid in Mexicans aged 4-8, 9-18 and 19-50 years respectively.

Apart from its high fructose, sucrose and glucose content, this pulp is recognized for being a source of uronic acid heteropolysaccharides and neutral sugars (pectins) for the food industry where citrus pectins are commonly used (Wall-Medrano et al., 2015).

Mexico stands out for the production of 9 kinds of mango, Ataulfo, Tommy Atkins, Haden, Kent, Keitt, Manila, Manzanillo Núñez, Irwin and Diplomático. The first five varieties are destined for the international market. In the State of Campeche, the varieties that stand out are Manila, Ataulfo and Tommy Atkins. The average yield in the state's mango-growing regions fluctuates between 12 and 13 tons ha-1. Around 300 direct and indirect jobs and 450 eventual jobs are generated between the field and the industry (Postgraduados & Campeche, 2014).

The Tommy Atkins species has a slightly sweet flavor, firm texture, juicy flesh and low fiber content. Its size is medium to large, it is oval and elongated in shape. The dark red color covers much of the fruit, but is accompanied by green, orange and yellow. Harvest time is from the end of February to August, it is produced in Michoacán, Jalisco, Colima, Guerrero, Nayarit, Sinaloa and Campeche. The size ranges from 12 cm to 14.5 cm, with a width of 10 cm to 13 cm and a weight of 450 gr to 700 gr. It is also consumed in its original form, but it stands out as an accompaniment to main entrees and grills (LEGISCOMEX, 2014).

There are two important varieties in the state, Tommy Atkins and Manila. Mango is a priority product at the state and national level (Campeche Government, 2012).

The agricultural harvest is usually greater than the immediate consumption of the populations, which causes significant waste, in addition to shortages in the post-harvest periods. Therefore, a reduction in post-harvest losses of food products will bring a considerable positive effect on the countries' economy.

Solar drying of food supports the improvement of product color, flavor and shelf life by reducing the risk of microorganism growth and preventing insect infection and contamination by toxic materials (Devan et al., 2020).

Currently, there is a great diversity of solar dryer designs, which in many cases have the purpose of studying the properties of dehydrated agricultural products and specifically tropical fruits (Iglesias Díaz et al., 2017).

Studies have been found in the literature mainly related to mango drying using indirect dryers with forced convection (Wang et al., 2018), indirect by adding solar collectors (Dissa et al., 2009) mathematical modeling (Koua et al., 2009), tunnel type with natural convection (Koua et al., 2009) and greenhouse dryers (Mugododo & Workneh, 2021).

In the present work, the drying of Tommy Atkins mango was experimentally studied using direct cabinet-type solar dryers, with and without forced convection, mathematical modeling was performed and studies of glucose levels in the dehydrated samples were carried out.

2. Experimental Study

The study was carried out in the city of San Francisco de Campeche, Campeche, Mexico, located at the geographical coordinates: between parallels 17°49' and 20°51' north latitude and meridians 89°06' and 92°27' west longitude. The climate of the State of Campeche is warm sub-humid.

An experimental study was carried out on the drying of Tommy Atkins mangoes using cabinet-type solar dryers, evaluating two modes of operation: with natural convection and with forced convection. The glucose parameter in the dried samples was analyzed in order to evaluate the conservation of this parameter once the mangoes were dehydrated using solar energy.

2.1 Experimental setup

Direct cabinet-type solar dryer. A direct solar dryer made of acrylic, with a treatment surface of 0.5 m^2, was used. The chamber contains a solar radiation absorbing tray where the product is placed. It has perforations on the sides, bottom and rear, to allow the circulation and extraction of hot humid air.

The front surface has a 20° slope to take advantage of the incident solar radiation and to allow condensation and water runoff. It can operate in natural or forced convection, by means of a fan placed at the rear, with a power of 20 W, and allows a maximum air speed of 2 m/s^{-1}. Figure 1 shows the solar dryer in operation.

Figure 1 Cabinet type direct solar dryer
Source: Photo by author

2.2 Materials and Methods

2.2.1 Materials

Tomy Atkyns mango variety, purchased in the Municipal Market of Campeche, Mexico, was used for the experiment. Sliced samples were used as samples, taking care of their homogeneity in terms of ripeness, size, unit weight and thickness. Samples weighed between 20 and 22 g, with an average fresh moisture content of 80%.

2.2.2 Methods

In this work, two similar drying chambers were used for natural convection and forced convection drying. In each dryer, the interior temperature, weight and size of the samples, as well as solar irradiance, relative humidity and air temperature were recorded.

Mango weight measurements were taken every 30 minutes using a high-precision scale from 9 a.m. to 4 p.m.

The humidity of the different samples was carried out using a moisture analyzer Ohaus model MB45 halogen type, with an accuracy of 1mg ± 0.01% in a temperature range of 50 to 200 °C.

Climatic conditions. During the testing period, climatological parameters were recorded at the UAC Faculty of Engineering weather station. The characteristics (manufacturer's data) are as shown in Table 1.

Variable	Description	Model	Maximum error
Global radiation	Pyranometer brand LICOR	LI-200R	Azimut: < ± 1% over 360o at 45o elevation.
Relative humidity	NRG Systems	RH-5X	± 3%
Ambient temperature	NRG Systems	110S	± 1.1°C
Wind direction	NRG Systems	Series #200P	± 3º
Anemometer	Windsensor	P2546C-OPR	± 0.3 m/s

Table 1 Characteristics of weather station measuring equipment
Source: Author with manufacturer's data

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For the glucose tests, a Thermo Scientific spectrophotometer was used, with a deviation of <0.002 A/hr.

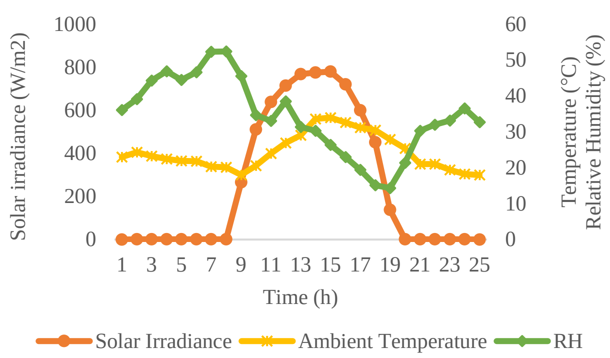
Likewise, for greater precision, a Thermo Scientific automatic pipette was used, with a precision of 0.01 µL. To dilute the portions of mangoes, they were placed in a solution of different densities of sulfuric acid mixed with water.

The portions of dried mangoes were cut into 5 mm squares and 3 different solutions were obtained in order to obtain a larger solution for evaluation.

3. Experimental results and discussion.

3.1 Climatological parameters.

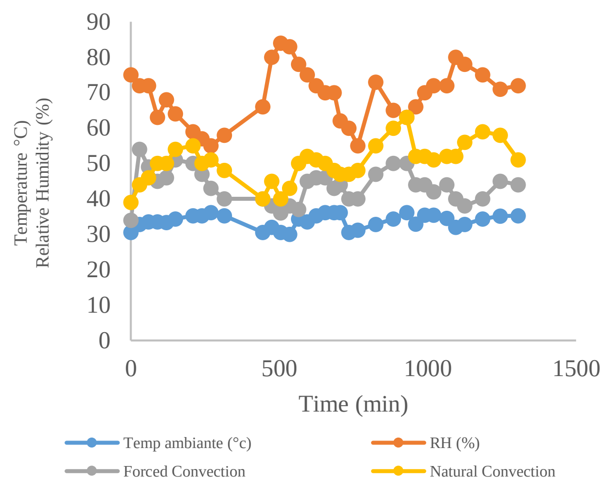
The experimental study was carried out in the Solar Drying Laboratory of the Faculty of Engineering of the Autonomous University of Campeche. Figure 1 shows the evolution of the climatological parameters, taking a test day as a reference.



Graphic 1 Solar irradiance, ambient temperature and relative humidity during the sunniest day of the test period
Source: Author with data from weather station

As can be seen, the maximum global irradiance reached was 780 W/m^2. The ambient temperature values were between 30.0 °C and 33.3C. On the other hand, the average value of relative humidity during the peak hours of solar irradiation was 30%.

Graph 2 shows a comparison of the ambient temperature, relative humidity and temperatures in the drying chambers, both with natural convection (NC) and forced convection (FC).

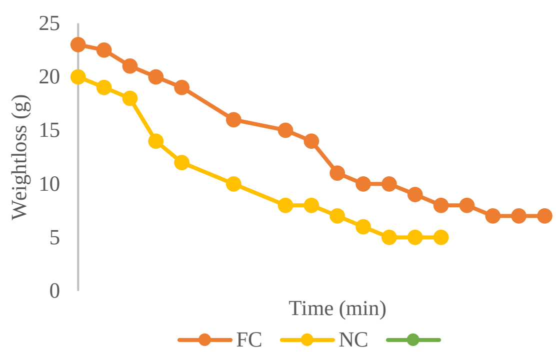


Graphic 2 Ambient temperature, relative humidity and temperatures in the drying chambers (natural convection and forced convection)
Source: Author, with data from meteorological station

The previous graph shows that the maximum temperature obtained with the natural convection dryer was 65°C, while the forced convection dryer obtained 52°C, with an ambient temperature of 36°C maximum and a relative humidity of 63°C.

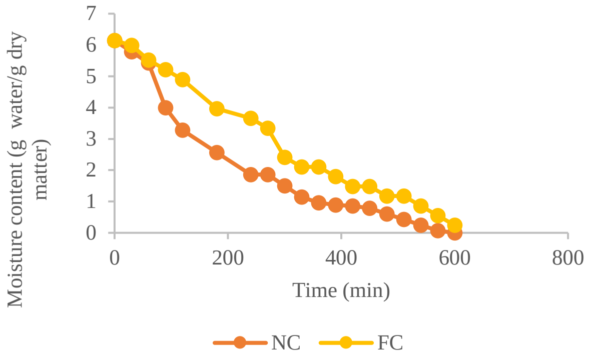
3.2 Drying kinetics

Graphic 3 presents the experimental results of mango dehydration in the direct dryers with forced convection and natural convection. The initial weights of the samples were 20 g (CN) and 23 g (CF). The drying kinetics in both cases follow the same trend.



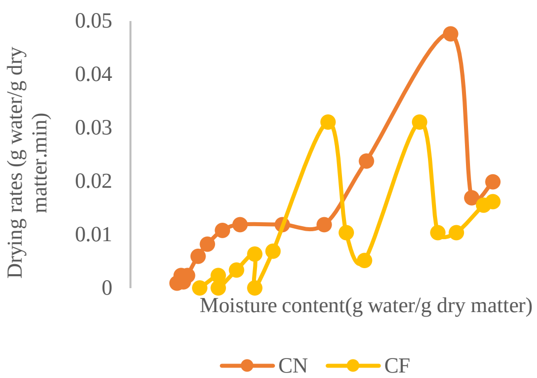
Graphic 3 Weight loss of samples in direct solar dryers
Source: Author with data from measuring equipment

Graphic 4 shows the moisture content (dry basis) as a function of drying time for both samples.



Graphic 4 Moisture content as a function of drying time
Source: Author with data from measuring equipment

As can be seen, the drying kinetics is faster with natural convection than with forced convection; the drying time in the first case was 420 min, while in the second case it was 540 min. Graphic 5 shows the drying rate as a function of moisture content in the dehydrated samples.



Graphic 5 Drying rate as a function of moisture content
Source: Author with experimental data

It can be observed in graph 6 that the highest drying rates in the dried samples with natural convection and with forced convection are found at points 5.4 and 4.9 g of water/g of dry matter, respectively.

It is also very noticeable that the highest drying rate was presented in the samples with natural convection, this was reflected in all the tests performed.

It is important to note that despite the fact that the sunniest day was selected, we obtained cloudiness during the test day, this can be seen in the oscillations of the climatic parameters throughout the day (Figure 3), and we see these temperature changes reflected in graph 6:

The drying speed varies more in the dryer with forced convection while in the dryer with natural convection it is more stable, this is due to the fact that because of the extraction of the interior air by the action of the fan, the dryer does not retain the temperatures that are reached during periods of high ambient temperature, however, in the second case, the dryer reaches higher temperatures and during periods of cloudiness, it maintains high temperatures for a longer time, by accumulation of heat in the drying chamber, the temperature is lost, but more slowly.

The initial percentage of humidity was practically the same in both cases; however, the final humidity was in a range between 8.9% and 6.06% in all samples, with an average of 7.48%. The average moisture reduction was set at 72.52%.

3.3 Glucose content in dry samples

The objective of these tests was to observe and quantify the loss of properties of the dried fruits, in this case, the dried mango samples. As mentioned in the Methodology section, the dried mango samples obtained in the two drying methods were diluted in order to perform the glucose content analyses. Once the mango was diluted, it was prepared to perform the respective tests in the spectrophotometer and for this purpose, 5 solutions of 5 different densities of sulfuric acid and distilled water were prepared.

The diluted mango was poured into each of these 5 solutions in a test tube and labeled, obtaining 5 tubes per type of mango (dry samples in natural convection and forced convection), plus a stock solution of 30% sulfuric acid solution and 70% water that served as a reference to calibrate the spectrophotometer between each measurement.

These tests were performed in duplicate in order to have two values at the end to make an average. The aim was to have values as close as possible to reality. Figure 7 shows the solutions obtained.

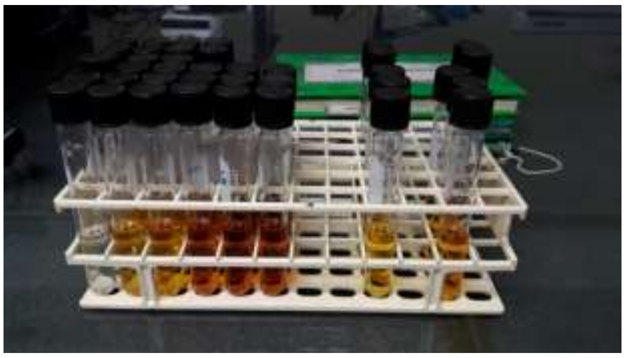
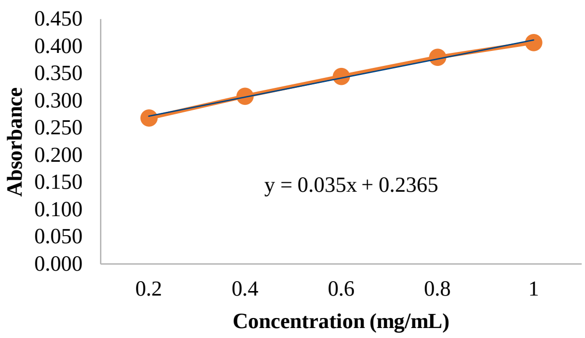


Figure 2 Samples of dehydrated mangoes obtained in solar dryers, for analysis of glucose content
Source: Photo by Author

Graphic 6 shows the absorbances obtained as a function of concentration.



Graphic 6 Absorbance for each solution as a function of concentration
Source: Author with data from measuring equipment

Table 2 shows the glucose concentrations obtained in the samples of mangoes dehydrated with solar dryers.

	FC sample (forced convection)	NC sample (natural convection)
Concentration x (in mg/ml)	**0.64**	**0.59**

Table 2 Glucose concentrations obtained in the dry samples.
Source: Author with experimental data

According to the results shown in Table 2, "x" represents the concentration and means that the mango sample in forced convection contains 63.7% and the mango sample in natural convection 59.4% glucose, without rounding the final values obtained. According to previous studies, Glucose represents 82.5 % of the total neutral sugars in fresh mango (Cardenas-Coronel et al., 2012), thus decreasing the glucose content in the dried hand, although not significantly.

4. Conclusions

The drying kinetics of mango was determined in a direct solar dryer operating by two different modes of operation: natural convection and forced convection

The fresh ripe mango samples weighed between 20 g and 22 g, with an average initial moisture content of 80%. The drying kinetics was faster with natural convection than with forced convection, drying times were 420 min and 540 min, respectively.

In both cases, the average final moisture content was 7.48%. The average moisture reduction was 72.52%.

These results for the dried mangoes are similar to the moisture percentages found commercially in national markets.

Regarding the glucose study, the results of the present study indicate that the content of this parameter decreased in both solar drying modes, compared to the content in fresh mangoes. This result is important in the case of health problems in people such as diabetes, since it is less likely to affect health when consuming dried mangoes than fresh mangoes.

In addition to the above, it is important to emphasize that solar drying supports the reduction of environmental pollutants and the use of conventional energy, contributing to the care of the environment.

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Synthesis and characterization of Zinc Oxide thin films deposited by Spray Pyrolysis technique for possible applications in solar cells

Síntesis y caracterización de películas delgadas de Óxido de Zinc depositadas por la técnica de Spray Pirolisis para su posible aplicación en celdas solares

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Abstract

In the present study, the synthesis and characterization of ZnO thin films deposited at 300, 350 and 400°C using the Ultrasonic Spray Pyrolysis technique, as a possible candidate for electron transport layer (ETL) in solar cells is reported. X-ray diffraction (XRD) analysis revealed that the films have a hexagonal wurtzite phase with a preferential orientation (101) with good polycrystallinity. The mean crystallites size based on the Debye-Scherrer model was calculated, indicating that the size of the crystals decreases as the deposition temperature increases. The optical characterization of the material showed a high transmittance in the visible region (85-99%) with which the optical band gap (3.06-3.29 eV) was determined. The thickness, surface roughness and optical constants (n and k) were determined by Spectroscopic Ellipsometry using the Gaussian oscillator model. Hall Effect revealed a low resistivity of 1-4 Ω cm and a high mobility of charge carriers (304 cm^2/Vs) in the films. Due to all these properties, ZnO is considered an ideal material for optoelectronic applications, as well as a material with potential to be used as ETL in solar cells.

ZnO, Spray Pyrolysis, Solar cell

Resumen

En el presente estudio, se reporta la síntesis y caracterización de películas delgadas de ZnO depositadas a 300, 350 y 400°C mediante la técnica de Spray Pirolisis Ultrasónico, como posible candidato de capa transportadora de electrones (ETL) en celdas solares. El análisis de difracción de rayos X (XRD) reveló que las películas tienen una fase hexagonal wurtzita con una orientación preferencial (101) con una buena policristalinidad. Se calculó el tamaño medio de los cristalitos en base al modelo de Debye-Scherrer, indicando que el tamaño de los cristales disminuye a medida que aumenta la temperatura de depósito. La caracterización óptica del material mostró una alta transmitancia en la región visible (85-99%) con lo cual se determinó la banda prohibida óptica (3.06-3.29 eV). El espesor, la rugosidad de la superficie y las constantes ópticas (n y k) se determinaron mediante Elipsometría Espectroscópica utilizando el modelo de oscilador Gaussiano. Efecto Hall reveló una baja resistividad de 1-4 Ωcm y una alta movilidad de portadores de carga (304 cm^2/Vs) en las películas. Por todas estas propiedades, el ZnO se considera un material idóneo para aplicaciones optoelectrónicas, así como un material con potencial para utilizarse como ETL en celdas solares.

ZnO, Spray Pirolisis, Celda solar

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1. Introduction

Zinc oxide is a transparent n-type semiconductor with a direct band gap of ~3.37 eV and an exciton energy of 60 meV at room temperature [1, 2] due to its unique physical characteristics, it is considered a material with excellent optical and electrical properties, further it is non-toxic and inexpensive due to its abundance in the nature [3, 4]. Others positive properties include high electrochemical and thermal stability [4, 5]. For all these properties, the ZnO has generated special interest between the researchers for its use in optoelectronic devices.

The main crystalline structures that ZnO presents are the hexagonal wurtzite and zincblende [6, 7, 8]. ZnO films have been obtained by various techniques such as sputtering [9, 10], electron beam evaporation [11], spin coating, chemical vapor deposition, sol-gel [8] and ultrasonic spray pyrolysis (USP). [6, 12]. In the present study, the ZnO thin films have been deposited by SPU technique due to its low cost, simplicity (no high vacuum requirement, deposition shorts times), versatility and deposition uniformity [6].

The objective of this work is synthesized and characterized ZnO thin films deposited by Ultrasonic Spray Pyrolysis technique as possible candidate for electron transport layer (ETL), integral part in solar cell, which offers the electron contact selectivity and mitigates recombination phenomena for enhanced device performance by its relatively high electron mobility, environmental stability, and transmissivity in the visible region [8, 13, 14].

There are many studies using ZnO in solar cells, such as ZnO nanowires, ZnO nanorods, ZnO nanoparticles and ZnO films, [14, 15, 16] that help improve device performance. Nevertheless, in these studies, the complexity of the methods, the high temperature sintering process, the sophisticated, time-consuming processing used for the obtained of the ETL are the disadvantage principal.

For all this reason, we considered that the ZnO thin films obtained by SPU technique have a big potential to be used as ETL in solar cells.

2. Description of the method

The ZnO was synthesized at a deposited temperature (Td) of 300, 350 and 400°C by the Ultrasonic Spray Pyrolysis technique. The thin films were deposited on glass and n-type silicon substrates, orientation (1 0 0), with a resistivity of 1-10 Ω cm.

The precursor solution was obtained using a molarity of 0.2 M of zinc acetate dihydrate [$Zn(CH_3COO)_2 \cdot 2H_2O$] ≥98% dissolved in 50 ml methanol. The flow rate of solution was of 0.5 ml/min. The nozzle to substrate distance was 15 cm and diameter of nozzle was 2 cm. The deposition time was of 10 minutes for all samples.

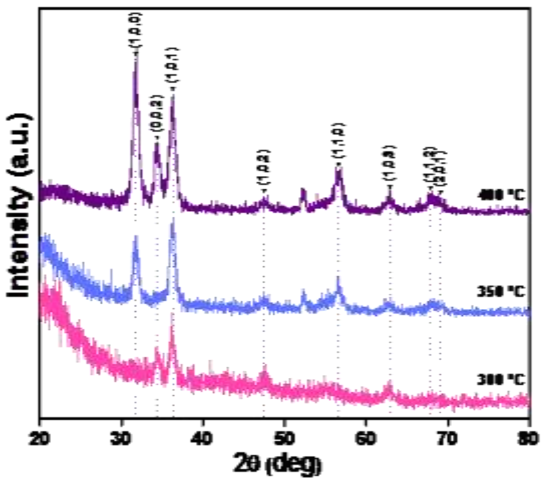
The structural properties were investigated by X-ray Diffraction (XRD), a Diffractometer Bruker model D8 Discover equipped with ray X tube of Cu Kα radiation (λ=1.54059 Å), operated to 40 kV and 40 mA was used. The XRD patterns of ZnO thin films were recorded at grazing incidence measurements with an angle θ-2θ of 1°

The optical properties were investigated by UV-Vis Spectroscopy, a Spectrophotometer Perkin Elmer 330, speed 120nm/min was used. Spectroscopic ellipsometry (SE), J.A. Woollam, M-2000DI. The ellipsometric parameter (amplitude Ψ and phase Δ) were acquired using an incidence angle of ~70 in a 193-1690nm spectral range.

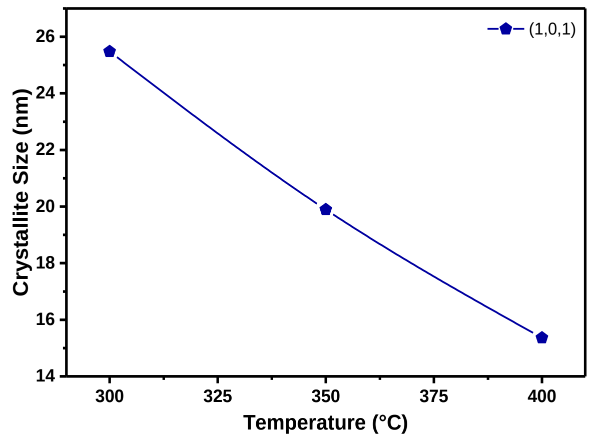
The electrical properties were obtained by Hall Effect Measurement System, HMS-5000 at room temperature with a Magnetic Flux density of 0.5T.

3. Results

Graph 1 show the XRD patterns of ZnO thin films obtained at 300, 350 and 400°C. According to the peak positions matched in the (00-036-1451) PDF database the ZnO films have a hexagonal wurtzite structure with a preferential orientation (101). As the films were processed at different temperatures (300, 350, 400°C) the intensity of the XRD peaks were increased.



Graph 1 XRD patterns of ZnO thin films obtained at 300, 350 and 400°C



Graph 2 Crystallite size by Scherrer equation of ZnO thin films obtained at 300, 350 and 400°C

The observed XRD profile allow calculating the average crystallite size from peak (101). The X-ray diffraction peak broadening acquired in a diffractometer is due to the instrumental and the physical factors (as the crystallite size). The breadth that depends solely on the physical factors is extracted by subtracting the instrumental broadening factor from the experimental line profile according to [17]:

$$\beta = B\left(1 - \frac{b^2}{B^2}\right) \text{ (rad)} \qquad (1)$$

2θ is the diffraction angle. B and b are the breadths of the peak from the XRD pattern at the same position of the experimental and reference sample respectively. The average diameter of the crystallites was calculated using Scherrer equation:

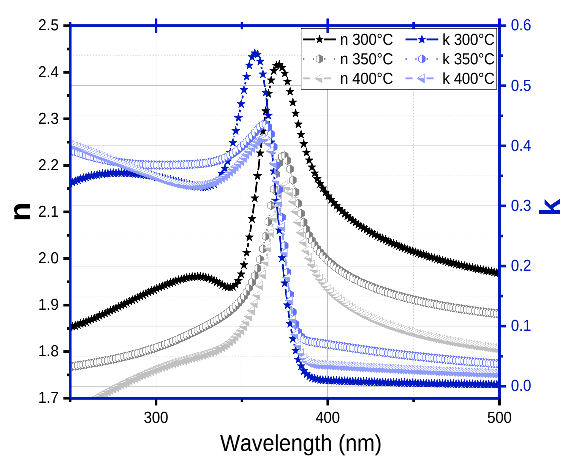
$$L = \frac{D\lambda}{\beta cos\theta} \qquad (2)$$

where θ is the Bragg angle, λ is the X-ray wavelength (CuKa radiation) = 1.54056 Å, L is the crystal size, and D is the shape factor which is approximately the unity.

Graph 2 shows crystallite size by Scherrer equation of ZnO thin films obtained at 300, 350 and 400°C. The size of the obtained crystallites decreases as the temperature increases; however, the number of crystallites increases as indicated by the change in the intensity of the peaks.

ZnO thin films were characterized by Spectroscopic Ellipsometry (SE), which is a frequently used optical characterization method for materials and nanoscale systems. It is based on measuring the change in the polarization state of a linearly polarized beam of light reflected from the sample surface. The ellipsometry spectra obtained from the Ψ and Δ parameters are fitted with an appropriate optical model for nanostructure thin film, and thus, rich information including surface roughness, film thickness, and optical constants of the nanomaterial are revealed [18].

Graph 3 show the complex refractive index (n and k) of ZnO thin films deposited at 300, 350 and 400°C. To obtain the optical properties the Gaussian oscillator model was used by the Complete EASE software.



Graph 3 Complex Refractive index (n and k) of ZnO thin films obtained at 300, 350 and 400°C

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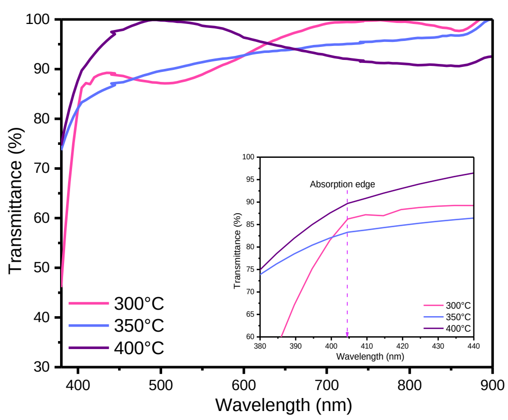
Table 1 show the thickness, surface roughness, complex refractive index (n and k) of the ZnO samples deposited at 300, 350 and 400°C.

Td (°C)	Thickness (nm)	Roughness (nm)	n@370 nm	k@360 nm
300	205±2.05	29.28±1.12	2.4	0.54
350	128.81±0.80	28.33±0.230	2.2	0.43
400	121.23±1.59	12.01±1.98	2.11	0.41

Table 1 Values of thickness, surface roughness, complex refractive index (n and k) of ZnO samples deposited at 300, 350 and 400 °C

The thicknesses and roughness of the films decrease as the temperature increases even though the deposition time was constant. All the films showed a refractive index (n) greater than 2 in λ equal to 370nm (see table 1 and graph 3). Both, n and k increase towards lower energies, however for wavelengths greater than 370 nm these parameters tend to decrease, observing this behavior for all films. These changes in the optical properties can be associated with variations in the crystal structure and superficial morphology of the ZnO films [19, 20].

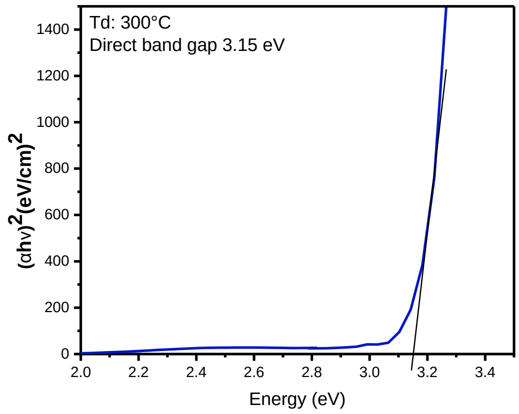
Graph 4 show the Transmittance spectra of the ZnO thin films. The optical characterization of the material showed a high transmittance in the visible region (85-99%). The figure inset in the graph 4 shows the absorption edge (404nm) of the samples.



Graph 4 Transmittance spectrum of ZnO thin films obtained at 300, 350 and 400°C. Inset absorption edge

Graph 5 shows the band gap calculated by means of transmittance spectrum and the relationship known as Tauc plot [21], considered a direct transition. The band gap (Eg) obtained was of 3.15 eV for the sample deposited at 300°C, which has a shift towards lower energies.

For the case of the samples deposited at 350°C the Eg was of 3.06 eV and for the sample deposited at 400°C was of 3.29 eV.



Graph 5 $(\alpha h\nu)^2$ versus energy (hv). Example to obtain the Eg approximated value by using the relationship known as Tauc plot of ZnO thin film deposited at 300 °C

The electrical properties of the ZnO thin films were obtained by Hall Effect measurement system, which revealed a low resistivity of 1-4 Ω cm for all samples and a relativity high electron mobility of charge carriers of 304 cm^2/Vs in the films.

4. Analysis

From XRD analysis, which revealed that the ZnO thin films have a hexagonal wurtzite phase with a preferential orientation (101) and that the mean crystallites size decreases of 25nm to 15mn as the deposition temperature increases of 300 to 400°C, it is confirmed that the polycrystallinity of the films increases with the increases of the deposition temperature.

Also, it is observed that the film deposited at 400°C has other preferential orientation (100) with a FWHM like peak corresponding to the orientation (101), indicating two possible orientations, which results very interesting in its electrical properties. It could be confirmed in a work to future by an electrical characterization more complete and its conduction mechanisms (current-voltage curves in condition of darkness).

Thicknesses and surface roughness of the films decrease of 200 to 120 nm and of 29 to 12 nm, respectively, as the temperature increases, which are related with the crystallite and grain size.

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These results confirm that the thickness of the films can be controlled through the deposit temperature, which is important aspect for the use of the material as ETL [14], since it has been reported that at a lower thickness, there is a mitigated recombination phenomena for enhanced device performance [22, 23].

From optical characterization, the samples showed a high transmittance in the visible region (85-99%), which is optimal for the application as ETL. In relation with the change in the value of the band gap, it could be modulated with the change of the deposition temperature.

The electrical measurements, which revealed a low resistivity of 1-4 Ω cm and a relativity high electron mobility of charge carriers of 304 cm2/Vs in all the films. This is an expected results due to the material nature.

Due to all these properties, ZnO thin films are considered a material with a big potential for to be used as ETL in solar cells.

5. Conclusions

In conclusion, highly transparent ZnO thin films were successfully prepared by the Ultrasonic Spray Pyrolysis technique on glass and n-type silicon substrates at 300, 350 and 400 °C, using solution of zinc acetate dihydrate. The X-ray diffraction analysis showed that films are polycrystalline nature with hexagonal wurtzite phase (preferential orientation (101)), in addition, the crystallites size is estimated of 25 to 15 nm. Optical measurements show that the films possess high transmittance over 85 % in the visible region and sharp absorption edge near 400 nm. The film has a direct band gap with an optical value of 3.06 to 3.29 eV which is close to the previously reported value (3.37 eV). Electrical results revealed a low resistivity of 1-4 Ω cm and a relativity high electron mobility of charge carriers of 304 cm2/Vs in all the films.

The properties of the ZnO thin film can be controlled through the deposit temperature, which allowed found the best characteristics for obtained the electron transport layer as integral part of the solar cell.

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Article
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Mechanical characterization of spent- coffee-grounds briquettes

Caracterización Mecánica de Briquetas de Borra de Café

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Abstract

This article provides an overview of the manufacture of briquettes by mixing spent coffee grounds (SCG) and recycled newsprint (RNP), with some established compositions. Hollow cylindrical briquettes were used as samples for mechanical characterization for the research project "Characterization of type 2 biomass briquettes as solid fuel alternative to firewood and coal in kitchens, restaurants and small businesses, based on the Colombian Technical Standard 2060" carried out at the University of America in Bogotá, Colombia. Initially, the process of design and construction of a Peterson type press for the manufacture of briquettes was carried out. A universal testing machine was used for the mechanical compression tests. The shatter resistance was evaluated by launching the samples in free-fall from a height of 1 m several times until they got broken. Finally, and the abrasion resistance was measured using a ball-mill adapted to the proposed briquette size. All these tests were carried out to identify which of the proposed briquettes compositions has suitable mechanical properties to keep the shape, size and density in the actual processes of transport, handling and storage.

Briquettes, Spent coffee ground, Solid biomass, Solid biofuels

Resumen

Este artículo ofrece una visión general de la fabricación de briquetas mediante la mezcla de borra de café y papel de periódico reciclado, con algunas composiciones establecidas. Se utilizaron briquetas cilíndricas huecas, como muestras para la caracterización mecánica para el proyecto de investigación "Caracterización de briquetas de biomasa tipo 2 como combustible sólido, alternativo a la leña y al carbón vegetal en cocinas, restaurantes y pequeños negocios, con base en la Norma Técnica Colombiana 2060" realizado en la Universidad de América en Bogotá, Colombia. Inicialmente se realizó el proceso de diseño y construcción de una prensa tipo Peterson para la fabricación de briquetas. Para el ensayo de compresión mecánica se utilizó una máquina universal de ensayos, mientras que la resistencia al impacto se realizó sometiendo las muestras en caída libre desde una altura de 1 m varias veces hasta que se fragmentaban. Por último, resistencia a la abrasión se midió utilizando un molino de bolas adaptado al tamaño de briqueta propuesto.Todas estas pruebas se llevaron a cabo para identificar cuál de las composiciones propuestas de briquetas, tiene propiedades óptimas mecánicas para conservar su forma, el tamaño y densidad en procesos reales de transporte, manejo y almacenamiento.

Briquetas, Borra de café, Biomasa sólida, Biocombustibles sólidos

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Introduction

Fossil fuels cause greenhouse gases and global warming. In developing countries, mainly in Africa and Asia, the only available energy source for people is the wood obtained from forests and jungles. [1]. Colombia undergoes this problem in several rural areas, mainly in Amazonian region [2]. Besides deforestation, its combustion produces respiratory pathologies such as asthma, emphysema and chronic obstructive pulmonary disease (Nijhuis 2017) [3]. These pathologies bring similar consequences to those produced by tobacco consumption [4]. Therefore, it is necessary for rural communities to look for clean, inexhaustible, and highly competitive renewable energies such as biofuels.

In this project, briquette production from spent coffee grounds (SCG) mixed with renewable newsprint (RNP) as a binder is studied as an alternative to firewood and coal, due to availability of these feedstocks, and ease to elaboration.

The physical-chemical and mechanical properties of briquettes guarantee adequate performance as fuel. Also, they offer optimal integrity and appearance in transport, storage, and distribution. To a large extent, these features are obtained through an adequate pressing process. For these reasons, several experiences needed to be evaluated before constructing the machine.

The briquetting press is a device that produces samples in the form of briquettes (usually as a cylindrical block) to evaluate their mechanical and physicochemical properties such as compression strength, shatter and abrasive resistance, heating value, combustion gases, among others. These devices are made to compress briquettes from raw material that generally has a high moisture content. Therefore, this water must be drained while compressing.

Design variables and operation conditions were identified to evaluate the mechanisms and size the machine, applying characterization of materials and manufacturing process concepts. The main objective is to characterize mechanically briquettes of SCG and RNP in order to have an approximation to actual condition of transport, handling and store were their integrity and shape must be guaranteed.

1. Experimental Methodology

1.1 Design and construction of a Peterson type briquetting press

Following steps were carried out to design and build the briquette press:

- Review of similar projects that entail different models of briquetting machines assembled for diverse materials. Once the review was completed, the most practical, cheap, and easy-to-build device was chosen to adjust it to project requirements, adapting it, or improving some of its mechanisms.
- Determination of necessary parameters of briquettes: basic physical-chemical characteristics of the material to be briquetted (coffee residue and newsprint binder), compression force, size, weight, and shape of the briquette, among others.
- Draft of the previous press design.
- Detailed sketches of the components and parts of the machine.
- Acquisition of materials of the structure or body.
- Acquisition of cylinders to obtain the diameter and dimensions of the briquettes.
- Calculations of the compression system to be applied by the press.
- Design of the drainage system, separation, and extraction of briquettes.
- General drawings of the machine and detailed plans of its parts with the calculated measurements.
- Final assembly of its components and mechanisms, as shown in figure 1.

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Figure 1 Briquetting machine
Source: Own Elaboration

Table 1 shows all the specifications of the briquetting machine.

Briquette Machine Features	
Denomination	**Value**
Maximal compaction force (kgf/cm²) – (kN/m²)	69.299 – 6796
Dimensions (mm)	22 x 10 x 95
Weight (kg)	9.87
Nominal production (briquettes/test)	3
Average product density (g/cm3)	0.36
Briquetting process performance	Manual and intermittent
Dimensions of hollow cylinder briquette	Diameter = 64.4 mm, thickness = 21.34 mm, and average height = 49 mm

Table 1 Briquetting machine specifications
Source: Own Elaboration

1.2 Manufacture of briquettes

1.2.1 Mixture preparation

Initially magazine, bond and newspaper, were tested as a binder for SCG after several tests. It was determined the magazine is difficult to cut and shred, besides, to be less soluble in water. Between bond paper and newspaper, the second was chosen since the briquettes made with this binder became more compact. Therefore, it was left as the only binder to make the different SCG-compositions

To evaluate the mechanical properties, SCG-RNP compositions of 50-50, 70-30 and 80-20 by weight were elaborated. The preparation of the mixture was made by dissolving manually, 1 kg of RNP cut into fine pieces in 4 liters of water. Then it was left to soak for 24 hours (Figure 2).

The next day, the soaked paper was weighed for manual mixing with the SCG in compositions SCG-RNP as follows.

Composition 50-50: 0.5 kg of SCG, 0.50 kg of RNP

Composition 70-30: 0.70 kg of SCG, 0.30 kg of RNP

Composition 80-20: 0.80 kg of SCG, 0.20 kg of RNP

Figure 2 Preparation of mixture
Source: Own Elaboration

Once the mixtures were made, they were compacted in the Peterson-type briquetting press.

1.2.2 Compaction of mixture

Briquettes use experiences in countries such as Spain, Ukraine, Russia, and the United Kingdom, were analyzed. In rural areas, the lack of conventional heating is supplied with chimneys and biomass-based boilers. These systems employ biofuels from different biomass such as sawdust, shavings, branches, stems, shells, grains, among others, to produce briquettes or pellets.

In the case of briquettes, Peterson presses are used. These machines are composed of a metallic sheets and wood frame, a hydraulic jack, a drainage system, and a press-molding device. The manually operated hydraulic jack puts the mixture under pressure of 6.796 MPa. The average dimensions obtained for the selected compositions are shown in figures 3 and 4, together with table 2.

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Figure 3 SCG-RNP briquettes dimensions
Source: Own Elaboration

Figure 4 Batch of briquettes made to be tested
Source: Own Elaboration

Composition	Height (mm)	Thickness (mm)	Diameter (mm)
50:50	48.70	22.48	64.08
70:30	49.75	22.05	64.55
80:20	50.23	22.33	64.65

Table 2 Average dimensions for different SCG.RNP compositions
Source: Own Elaboration

1.2.3 Drying process

Briquettes made in the Peterson press are exposed directly to sunlight to ensure suitable moisture removal and to give them compaction properties.

1.3 Mechanical characterization of briquettes

1.3.1 Compression strength test

The compression test for briquettes was applied on the SHIMATZU E-50 Universal Testing Machine for eight samples of each composition as shown in figure 5.

Figure 5 Compression strength test in universal testing machine
Source: Own Elaboration

1.3.2 Shatter resistance test

Bhavsar´s work showed, the briquettes shatter resistance was evaluated, dropping them in free fall from a height of 1 m as shown in figure 6 [5]. This essay was also recommended by Law and Asamoah respectively[6] [7]. Repetitions were made until the briquette got completely broken in pieces. The initial weight of the entire briquette and the weight of the largest piece were measured and compared to obtain this index with the equation 1.

$$\%shatter\ resistance = \left(1 - \frac{w_1 - w_2}{w_1}\right) \times 100 \quad (1)$$

Where w_1 corresponds to the weight of the complete briquette before impact and w_2 is the weight of the biggest piece after impact.

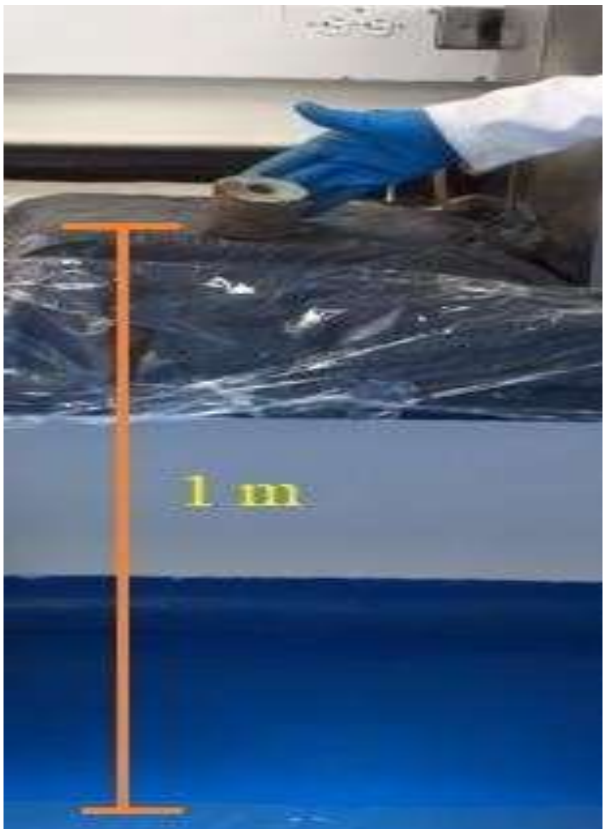


Figure 6 Shatter resistance test
Source: Own Elaboration

1.3.3 Abrasive resistance

According to the stipulations of the EN 15210-2 standard, six samples of briquettes of each composition were subjected to a rotating drum of 20 cm in diameter, 30 cm in length, for 5 minutes by rotating it at 25 rpm. [8]. The Armfield CEN-MKII-11 didactic ball mill was selected and adapted to the size of the manufactured briquettes as shown in figure 7.

Figure 7 Armfield CEN-MKII-11 didactic ball mill
Source: Own Elaboration

Instead of placing a flat dividing plate on the drum, a sheet of sandpaper 100 was placed on the inner walls to provide the abrasive medium. The weight of each briquette was measured before and after the test with a precision electronic balance. The abrasion resistance was determined using the final mass in percent after rotation as an indicator, employing the equation 2.

$$\%abrasive\ resistance = \left(1 - \frac{w_1 - w_2}{w_1}\right) \quad (2)$$

Where w_1 and w_2, correspond to the weight of the briquette before and after rotation in the drum respectively.

2. Results and discussion

The values obtained from the mechanical tests were compared and analysed, with stipulated parameters in the Colombian Technical Standard NTC 2060 and other standards, together with the experiences of different authors who carried out similar tests [9]

2.1 Compression strength tests

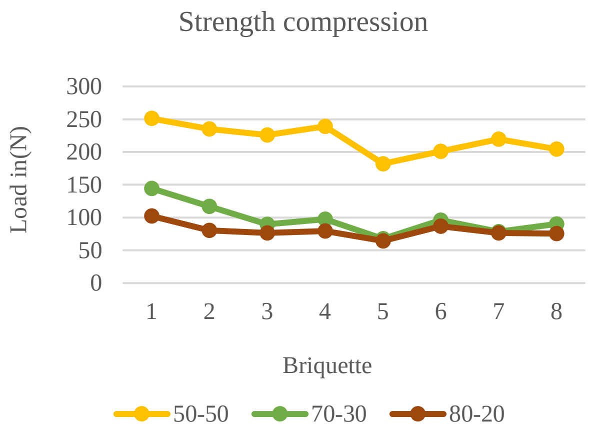
Figure 8 shows the state of the briquette after the compression test.

Figure 8 Final appearance of briquette after compression test
Source: Own Elaboration

For all the compositions, there was a characteristic deformation in the radial direction. But, as the percentage of RNP binder in the mix decreased, a greater detachment of material took place. Table 3 show the results of this test for the tested briquettes and graphic 1 shows the disposition and trend of the data obtained.

Briquette Composition	Average load (N)	Standard deviation
50:50	219,78165	22,7965282
70:30	97,683925	23,8226605
80:20	80,269138	10,9332847

Table 3 Strength Compression in (N) for briquettes SCG-RNP
Source: Own Elaboration



Graphic 1 Graphic behaviour of Strength Compression of Briquettes SCG-RNP
Source: Own Elaboration

According to the NTC 2060 standard, the strength compression for biomass briquettes weighing more than 40 g should not be less than 588.23 N or 60 kgf. In the present project, the samples had weights between 48 and 61 g. The 50:50 composition samples showed better crush resistance when loaded on the universal testing machine [9]. On average, they supported a load of 219.78 N, alike the values of 97.683 and 80.27 (N) registered by those of 70:30 and 80:20 respectively. The values obtained do not fulfil this requirement, but in similar studies carried out on batches of briquettes with different binders, it is evident that they do not reach this value either. The study carried out by Cubero et obtained average fault load values 538.93 N [10]. Balseca´s work registered an average failure load of 237.74 N [11]. Lisowskis´ test calculated the resistance to crushing stress for SCG pellets at 1.75 MPa, compared to the 68.148 kPa obtained in the present project for the 50-50 composition. However, the value of this last reference would be below that established by this standard [12]. These values are lower than those stated in Standard NTC 2060, because it takes coal as a pattern. According to the graphic 1, a marked difference is evident in terms of compressive strength based on the amount of RNP contained. Therefore, it proves that this binder has a notable impact on the increase in resistance to this load condition.

Although the minimum compression or crushing load was under standard requirement, these briquettes would support many briquettes established in table 4 based on their weight and the load held.

Composition	Maximum load on top (N)	Briquettes stacked on top
50:50	219.780	443
70:30	97.683	153
80:20	80.270	137

Table 4 Number of Briquettes help on top
Source: Own Elaboration

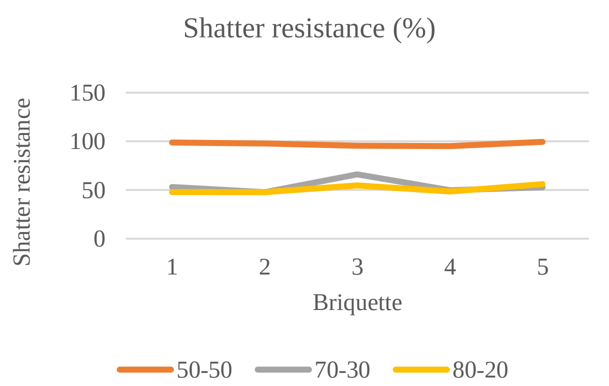
2.2 Shatter resistance tests

Table 5 show the results of this test for the evaluated briquettes and graphic 2 shows the disposition and trend of the data obtained.

Note that the number of launches is not the same for each composition, because that is when the total disintegration of the briquette occurs.

Briquette Composition	Average values (%)	Standard deviation	Number of launches in the free fall
50:50	97,347	1,93143794	20
70:30	53,909	7,12501966	7
80:20	51,069	4,04252242	4

Table 5 Shatter resistance in (%) for SCG-RNP briquettes
Source: Own Elaboration



Graphic 2 Graphic behaviour of shatter resistance of briquettes SCG-RNP
Source: Own Elaboration

The newspaper as a binder improves the compaction of the mixture and prevents the briquettes from collapsing when thrown in free-fall. In the experiment, at a large amount of paper, more launches are needed to fragment the briquette.

By decreasing its proportion, the briquette becomes more brittle. Bargazan, suggest as suitable values for this indicator those greater than 56% [13]. Law´s test found that coffee grounds develop high impact resistance when agglomerated with rice husk [6]. Approximately 96% was this indicator, while when mixed in different proportions with sugar cane bagasse, this was of almost 100% [6]. Brunerova´s study, found that this indicator improves in SCG briquettes agglomerated with wood shavings or sawdust, but does not give a suitable response to compression [14].

Regarding this indicator (20 launches in the free- fall), the 50:50 composition will guarantee the physical integrity of the briquettes if they undergo an unforeseen fall.

The variation in the graph of the compositions 70:30 and 80:20, refers to the fact that in some briquettes a kind of cracking was initially observed on them.

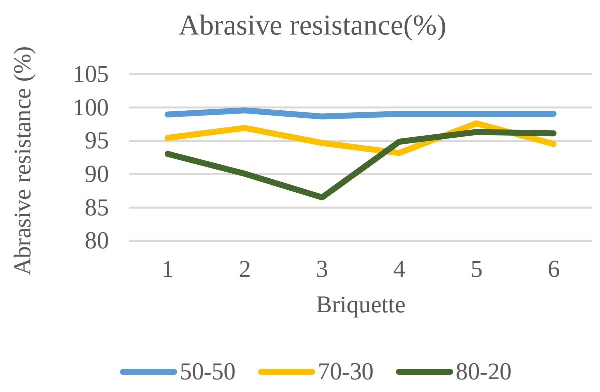
2.3 Abrasive resistance tests

Table 6 shows the results obtained in the abrasion test and graphic 3 shows the disposition and trend of the data obtained. According to requirements of NTC 2060, this test must be applied to a batch of 100 briquettes in a rotating drum with a diameter of 1.0 m. The reference for this test was the Standard EN 15210-2 [8] [6].

A smaller number of samples are allowed to be subjected to rotation and to evaluate the detachment of material. A sheet of sandpaper 100 was placed on the walls of the drum, rather than a flat barrier inside the drum. In this study 5 tests were performed with each composition. [8].

Briquette Composition	Average values (%)	Standard deviation
50:50	99,0436833	0,29385645
70:30	95,4105000	1,65221905
80:20	92,8270833	3,86789073

Table 6 Abrasive resistance in (%) for SCG-RNP briquettes
Source: Own Elaboration



Graphic 3 Graphic behaviour of abrasive resistance of briquettes SCG-RNP
Source: Own Elaboration

The test showed the newspaper maintains the physical integrity of the briquettes, detaching less than 2% of material after undergoing the rotation of the drum, the impact between them and the contact with the sandpaper wall. Law carried out the abrasion test or also called durability, for the briquettes of rice husk and mud, obtaining values between 96% and 100%. This resistance increased as the amount of SCG was added. The combination of cane bagasse and SCG remained very close to 100% regardless of composition [6]. Brunerova´s study evidenced the abrasion resistance is high in briquettes whose composition consists of 100% sawdust or sawdust - erased in 50-50 or 75-25.

On the other hand, this study verified that the resistance of wood chip briquettes had a low resistance to abrasion (below 50%). [14]. The results of this test obtained in the present study suggest that the combination of SCG with RNP makes the briquette highly resistant to abrasion. In practical applications these briquettes would not present significant material detachment, when colliding with each other as would happen in transportation. Their integrity, presentation and performance in the combustion process would not be affected.

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Conclusions

The machine can work with different granulated or powdered products, like those already studied in this article, as it offers a wide range of compacting forces. In the whole design process, it was used the highest number of easily available materials and standardized screws. The production of briquettes based on biofuels aids the creation of articles that substitute wood and hydrocarbons and encourages research for clean and renewable energy sources.

Despite not having reached the compressive strength limit, the briquettes showed high axial load support values. In practice these briquettes can support a considerable quantity of briquettes stacked on top of each other. This result ensures that they will not be disintegrate when arranged in boxes.

Briquettes, whose composition was 50-50, showed a high resistance to impact. They required several launches to show material detachment which was less than two percent. This composition would guarantee that in the event of accidental falls such as those that can occur in loading and transport processes, its integrity or shape will not be affected. As the binder content gets reduced, they become more brittle.

The 50-50 composition showed good abrasion resistance when rotated against sandpaper covered walls. Detached material was less than two percent, unlike compositions with less binder. In practice, this behavior showed the fact that the contact between briquettes or the friction between them would not produce material losses when packed in boxes. It is not necessary to put cardboard or separation divisions inside, which would save costs for this concept.

These mechanical tests showed that RNP, contributes significantly to improve mechanical properties of briquettes based on coffee grounds. In addition to being a readily available material.

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Measurement of degradation of solar panels induced by damp heat

Medición de la degradación de paneles solares inducida por calor húmedo

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Abstract

Currently the generation of electricity is carried out, mainly, from the combustion of fossil fuels; which contributes to the emission of pollutants such as SOx, NOx, CO, PM10, PM2.5 and volatile organic compounds (VOC) that affect air quality. Solar energy is an alternative for the generation of clean energy through the use of solar panels, which convert the energy they receive from sunlight into electrical energy for human use. It is cheaper and more viable, since the sun is readily available. Solar panels are built from an element called silicon, which is involved in the process of creating electrical energy. The objective of this study was to characterize the resistance to degradation of solar panels exposed to the damp heat test using the IEC 61646 Standard. The results obtained contribute to the quality assurance of the solar panel manufacturing process, which is of vital importance. and knowledge of their useful life.

Solar Panel, Degradation, Assurance Manufacturing

Resumen

Actualmente la generación de electricidad se lleva a cabo, principalmente, a partir de la combustión de energéticos fósiles; lo cual contribuye a la emisión de contaminantes tales como SOx, NOx, CO, PM10, PM2.5 y compuestos orgánicos volátiles (COV) que afectan la calidad del aire. la energía solar es una alternativa para la generación de energía limpia por medio del uso de paneles solares, los cuales convierten la energía que reciben de la luz del sol en energía eléctrica para el uso humano. Es más barata y viable, ya que el sol es fácilmente disponible. Los paneles solares se construyen a partir de un elemento llamado silicio, el cual interviene en el proceso de creación de energía eléctrica. El objetivo de este estudio fue caracterizar la resistencia a la degradación de paneles solares expuestos a la prueba de calor húmedo mediante la Norma IEC 61646. Los resultados obtenidos contribuyen al aseguramiento de calidad del proceso de fabricación de paneles solares, lo cual es de vital importancia para un buen funcionamiento y conocimiento de la vida útil de los mismos.

Panel Solar, Degradación, Fabricación de garantía

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1. Introduction

The growing demand for electricity that occurs today leads to the development of new and better technologies that allow the proper management of work for energy conversion [I, II]. Alternative technologies give the opportunity to contribute to sustainability for technological development, knowledge and growth of impact on the treatment of different components that together with other technologies allow to have more of them and also substitutes that can be replaced and / or used. to have a higher energy charge [III, IV]. Energy is present in everything that surrounds us, all bodies have the ability to produce a unit of measurement such as work, the amount of energy is measured by the work that bodies are capable of doing, which can be in motion (kinetic energy) or static (potential energy), energy sources allow greater access and lower cost over the use of electricity that is currently consumed, the use of different types of energy allow access to great technologies and sources of information, such as solar energy which generates electricity from photovoltaic solar panels.

Solar energy is one of the main sources of energy, since it is found worldwide and is accessible to all people, most of the heat generated on earth corresponds to the sun, energy that can be used through a panel solar for the generation of electrical energy to a lesser or greater extent, through photovoltaic cells.

Photovoltaic solar energy consists of a solar panel that stores the greatest amount of energy produced by the sun and extracted from the environment during the day, to later convert it into photovoltaic energy that allows the distribution of electricity in the place that is required, thus obtaining a considerable differential savings from what tends to be paid in light/electricity as it is commercially distributed.

The need to reduce the defects that may occur in the production of photovoltaic modules leads to new studies to improve their quality and useful life, for some defects there are methods that allow detecting and correcting problems during the process, which can be poor welding, broken cells or defects in the raw material, but there are problems that can only be seen with the passage of time and the deterioration of the module [V, VI, VII, VIII].

The Degradation is a natural and inexorable phenomenon that becomes an adverse factor for any photovoltaic installation, since it causes changes and a reduction in the useful life of any material [IX, X, XI]. In the case of photovoltaic modules, it causes a decrease in their useful life and, therefore, decreases the economic benefits expected from the installation, increasing the expected return time of the investment and introducing a component of uncertainty in the establishment of the guarantee period, all of which are fundamental factors so that photovoltaic technology can compete on an equal footing with other types of alternative energy [XII].

The objective of this study was to determine the resistance to degradation of solar panels exposed to the damp heat test by means of the IEC 61646 Standard, since the panels are subject to different types of climate when operating in the external environment, for which have been designed.

The study of the degradation induced by damp heat inside the climatic chamber will be able to give an overview of the final power of a solar panel at the end of a period of 25 years. This study was organized into 6 sections. Section 1 deals with the introduction. In section 2 the Methodology, in section 3 the analysis of results, in section 4 the Acknowledgment. in section 5 the conclusions of this study, and in section 6 the references consulted.

2. Development of the Methodology

In this test, the module was subjected to 85ºC±2ºC and 85%±5% relative humidity for 1000 hours. It is the most aggressive test for the photovoltaic module.

The severity of this study, tests the lamination and sealing process carried out on the module manufacturing. With this test, defects such as delamination, as well as corrosion and loss of power due to moisture ingress, can be determined. Even if no delamination or corrosion defects were detected, the module may have been stressed, which is revealed by the adhesion test.

The study was carried out in the following manner in accordance with the IEC 61646 standard with the following provisions:

The determination of the capacity of the module to withstand the effects of long-term moisture penetration was made as follows:

1. Solar Panels power was measured before damp heat test. Table 1.

2. Without previous conditioning, 5 Panels were placed inside the climatic chamber, with the following test conditions: 85ºC±2ºC and 85%±5% relative humidity for 1000 hours.

3. After the damp heat test, the power of the panels was measured to determine the percentage of degradation. Table 1

4. After Damp Heat Test, adhesion test was performed. Table 2.

3. Results

1. As can be seen in table 1. Adhesion values are within specification after the moist heat test, they ranged from 25 to 40N/cm, Graph 1.

2. Power tested before Damp Heat test was 252 to 259 Watt.

3. After the Damp Heat test, the Solar Panels presented a power between 249 to 255 Watt. Table 2, Graph 2.

4. As can be seen, the power loss of the Solar Panels after the Damp Heat test was less than 2%, ranging from 0.79 to 1.9, which indicates that its useful life will be at least 25 years.

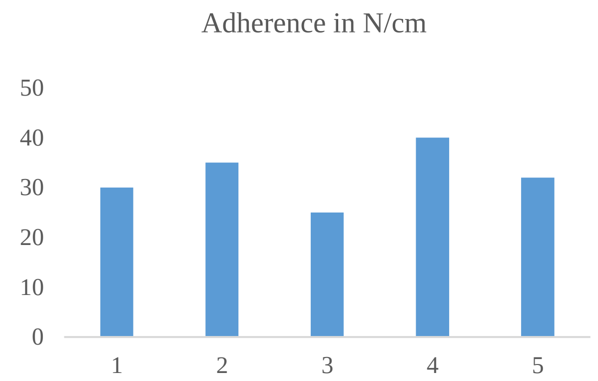
5. After the test no optical defects were found, only a yellowing of the contact plugs. Fig.1.

Module	Adherence in N/cm
1	30
2	35
3	25
4	40
5	32

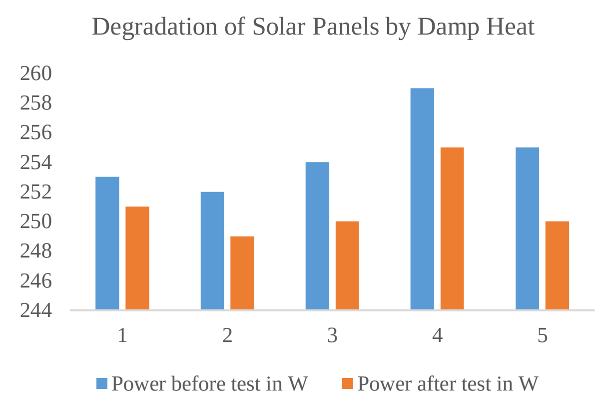
Table 1 Results of Adherence After the Damp Heat Test

Module	Power before Damp Heat Test in Watt	Power after Damp Heat Test in Watt	% Power loss
1	253	251	0.79
2	252	249	1.2
3	254	250	1.6
4	259	255	1.5
5	255	250	1.9

Table 2 Power Results before and after Damp Heat Test



Graph 1 Adherence after Damp Heat test



Graph 2 Power before and after Damp Heat test

Figure 1 Plugs after Damp Heat Test

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To all the collaborators for their support to carry out this work.

5. Conclusions

Degradation is a natural phenomenon that affects any material, in the case of photovoltaic modules the degradation phenomena can be: delamination, discoloration, oxidation, corrosion, rupture, etc. whose origin are various environmental factors such as: temperature, ultraviolet radiation, humidity, dust, pollution, depending on the geographical area where the photovoltaic solar panel is installed.

In this test, the change of the materials that make up the module in extreme conditions and the power of the modules were investigated, which directly impacts their performance and safety.

Apart from a yellowing in the sockets, no other optical defects were found. With this study it is concluded that the useful life of the module will be at least 25 years.

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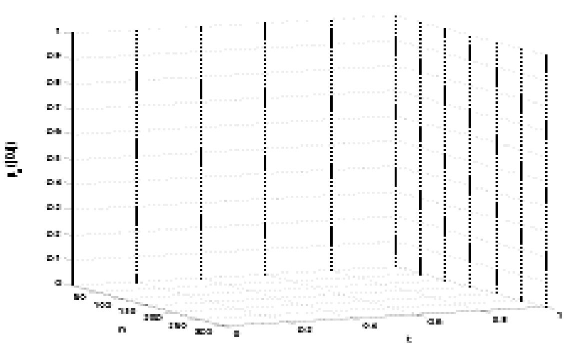

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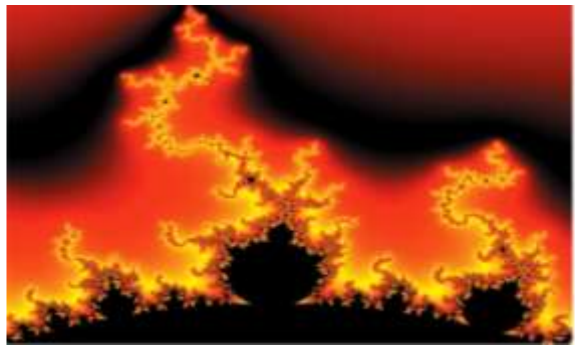

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