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Automated greenhouse with forced air circulation for vertical drying of Fibroin plates

Mayra Campista Corteletti[a*], Pablo Prata de Almeida[b], Gerlane de Souza Pereira da Costa[b], Ewerton Lyrio Nascimento[c]

[a] Multivix Serra - Ensino, Pesquisa e Extensão Ltda, Brasil
[b] Escola Superior São Francisco de Assis, Brasil
[c] Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo, Brasil
[*] Autor correspondente (mayra.ccorteletti@gmail.com)

INFO

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ABSTRACT

In processing applied to drying samples that require a parameter with greater specificity, the internal temperature control and the homogenization of the equipment chamber is fundamental in reducing the risks of modifications to active principles, which makes greenhouses with forced air circulation widely used and viable for such applications. The present project aims to the elaboration and construction of greenhouse with forced air circulation through of easily accessible materials, with automation by Arduino, being developed for vertical drying of Fibroin plates. In addition to conducting specific tests and statistical applications for validation of the same. Characterized in an experimental study, with material selection and appropriate equipments, elaboration and construction of the system in an economically viable way with standardized and controlled operation. In view of the aspects observed, achieved the development of a prototype of the equipment, verifying its functionality within the objectified parameters. Featuring a good alternative in the performance of the drying process of fibroin plates with good control of the estimated factors.

RESUMO

Palavras-chaves
dispositivo
automatização
estufa
fibroína

Estufa automatizada com circulação forçada de ar para secagem vertical de placas de Fibroína.
Em processamentos aplicados a secagem de amostras que exigem um parâmetro com maior especificidade, o controle da temperatura interna e a homogeneização da câmara do equipamento é fundamental na redução de riscos de modificações aos princípios ativos, o que torna as Estufas com circulação forçada de ar amplamente utilizadas e viáveis para tais aplicações. O presente projeto tem como objetivo a elaboração e a construção de estufa com circulação forçada de ar a partir de materiais de fácil acesso, com automatização por Arduino, sendo desenvolvida para secagem vertical de placas de Fibroína. Além da realização de testes específicos e aplicações estatísticas para validação. Caracterizando em um estudo experimental, com seleção de materiais e equipamentos apropriados, elaboração e construção do sistema de forma economicamente viável com funcionamento padronizado e controlado. Tendo em vista os aspectos observados, alcançou-se o desenvolvimento de um protótipo do equipamento, constatando sua funcionalidade dentro dos parâmetros objetivados. Apresentando uma boa alternativa na atuação do processo de secagem das placas de Fibroína com um bom controle dos fatores estimados.

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INTRODUCTION

Greenhouses with forced air circulation are widely used in procedures with greater internal temperature control and homogenization of the camera. Generally applied in the drying of plant samples allowing the reduction of risks of modifications to the active principles during processing.

By functional standard, the structure of greenhouses are basically constituted by a stainless steel camera with shelves, internal access door with silicone sealing and a set control system, what for the most part is composed of resistance, thermostat, engine for forced air circulation, temperature sensor and electronic controller.

Therefore, the main objective of the project is the development of greenhouse with forced air circulation for vertical drying of Fibroin plates obtained from silkworm cocoons (Bombyx mori), constructed with easy obtaining and low cost materials, being automated by means of the ATmega 2560 microcontroller, contained in arduino Mega 2560 board, with programming developed in the software Arduino Integrated Development Environment (IDE).

Arduino is the most popular tool in the development of IoT products from open source hardware and software, becoming the main one in the segment in the world. Widely used by hundreds of thousands of people, from the students to large corporations in the application of intelligent systems (Banzi, 2010; Monk, 2017).

Specifically the Arduino Mega 2560 has interesting capabilities for applications in more elaborate projects. Based on the 8 bit ATmega2560 microcontroller, possessing 256 KB of Flash memory with 8 KB addition to bootloader, , 8 KB of RAM and 4 KB of EEPROM, with 16 MIPS operating at 16 MHz. Having 16 analog inputs, 54 digital pins, in which 15 with PWM feature, 4 serial communication ports, having yet SPI and I2C communication, in addition to 6 external interrupt pins (MONK, 2017).

The Fibroin plates to be dried in the greenhouse, are obtained through a series of processes in an elaborate equipment and sampled in a previous study. In which, among the steps, constitutes the process of removing Sericin, rinse for removal of waste from the process and formation of the plates.

The silk thread of Bombyx mori is formed by two protein monofilaments, called brins, wet in a Sericina cover. Brins are filaments of Fibroin consisting of bundles of nanofibrils, arranged side by side to the fiber shaft, and are believed to interact with each other strongly (Altman et al., 2003; Hakimi et al., 2007).

Bombyx mori Fibroin is composed mainly of glycine (43%), alanine (30%) and serine (12%), formed by two polypeptide chains: a short one with approximately 26 kDa, and a long one with approximately 390 kDa, present in a 1:1 ratio, united by disulfide bond (Macintosh et al., 2008; Zhou, 2000).

Currently, several studies explore their potential in biomedical applications aiming develop substitutes for various tissues of the human body. Featuring numerous desirable features for application in tissue engineering due to its biocompatibility, low immunogenicity, limited bacterial adhesion and tunable biodegradability. With FDA approval, The silk is one of the best natural biopolymers for dressings (Ma, 2004).

In this way, aimed at such applications, becomes essential the edification of a system with high processing capacity and control of process parameters ensuring standardization of samples according to the specified settings.

MATERIALS AND METHODS

Experimental study focused on the elaboration and development greenhouse with forced circulation of automated by means of an Arduino Mega 2560 microcontroller board, programmed through the software Arduino Integrated Development Environment (IDE) translated into CC++ programming language accordance with the established parameters, monitored by means of temperature and humidity sensor, determining the activation of the heating system and air circulation according to temperature requirements and processing time selected by means of push-buttons.

Initially, focused on the elaboration of three-dimensional projective drawings with markers and geometric orientations specific to the system, directing your assembly order and structural distributions. Using an electronic design automation tool, through Fritzing software is elaborated the schematic diagram of connection of the system components and the squeamatic for production of the printed circuit board of the control panel.

For building the greenhouse in an economically viable way and in a way that would make it possible to evaluate its aspects of functionality and applications, focused on the search for easily accessible materials and compatible properties for its construction, for example: plywood, external power supplies, 12V cooler, push-buttons, electrical sockets and connectors, wires of several millimeters, crystal hoses siliconized and spiral flexible conduits.

With the proper materials selected the materialization of the greenhouse was achieved,

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carrying out its construction from a rectangular three-dimensional structure of plywood coated internally with layers of aluminum foil. On its front extremity, an aluminum door with glass has been installed for access and better viewing during the procedure with the aid of a light attached to the background.

The heating system, has been installed in the lower and upper part of the box a 127V electrical resistance bar with 800W of power. The airflow circulation system was carried out with the installation of a 12V fan with seven blade propeller coupled, centrally installed to the bottom of the structure.

The vertical drying of fibroin plates is carried out by means of a grid with horizontal bars, allowing coupling with an attachment system of individual bars with specific spacing hooks for attaching the plates, ensuring greater ease in handling the samples, increasing your internal capacity and facilitating air circulation inside the box.

The reading of the temperature and internal humidity of the greenhouse is evaluated by means of a centrally installed AM2302 DHT22 model sensor. With humidity measurement range of 0 the 100% with accuracy of +- 2% and with temperature measurement range between 233.15 K the 353.15 K with accuracy of +- 0.50 in an average response time of 2 seconds.

For system validation, statistical analyses is performed with Minitab 19 software, using time series studies to look for patterns and observe the behavior of temperature and humidity data over time, in addition to determining the mean time required for internal stabilization of the factors. Through control charts, will be determined whether the process is stable and under statistical control, allowing detect the presence of special causes or unexpected variations that affect the process. Through the construction of histograms, will be examined the way and dispersion of the data using bars to show the frequency of each range. Contour plot will be elaborated to examine the relationship between a response variable (Humidity) and two predictor variables (Time and Temperature), allowing to correlate both through discrete contours of the predicted response variable.

The data collection and sample size, is carried out according to the recommendations of the software itself for each type of analysis, also taking into account, characteristics of the process. Therefor, focused on evaluating the process characteristics of the greenhouse operating in its maximum temperature setting set for the drying process, providing indicative values to calibration adjustments and functional capacity assessment.

RESULTS AND DISCUSSION

Following the proposed planning, the functionality of the greenhouse with forced air circulation was verified according to the objective. The Figure 1, demonstrates the built greenhouse and its control and monitoring panel. However, they are attached to another structure belonging to an external equipment under development.

Figure 1 - Developed greenhouse and control panel and monitoring

Through Fritzing software, It's been designed the schematic diagram of connection of the system components (Figure 2) and the squeamatic of the printed circuit board of the control panel.

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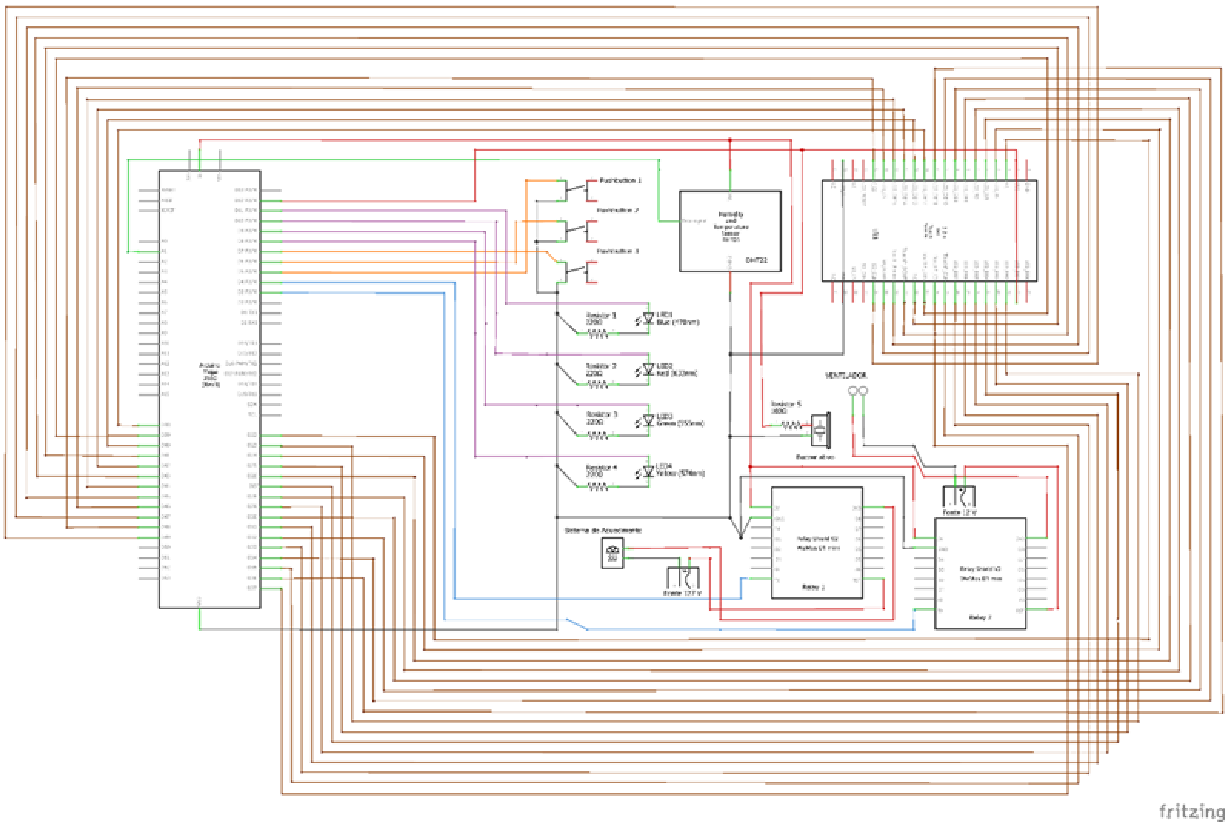

Figure 2 - Schematic diagram of connection of system components

The printed circuit board is designed in a simple face with 0.8 mm diameter drilling and 0.3 mm of thickness of the ring, which was made through the squematic (Figure 3 A) laser printed on a sheet of high glossy photo paper 180 gm^2, transferred to a copper clad board by heat. Subsequently, using an iron perchlorate solution in concentration of 42 %, the copper clad board was submerged for 1800 seconds for copper corrosion. Drilling was carried out with a specific diameter drill and with the aid of an aluminum sponge the printed drawing has been removed, leaving so only the projected copper tracks.

The top surface of the printed circuit board (Figure 3 B) was printed on a sheet of adhesive paper and fixed aligned with rails and holes about the copper clad board, allowing better orientation for attaching electronic components.

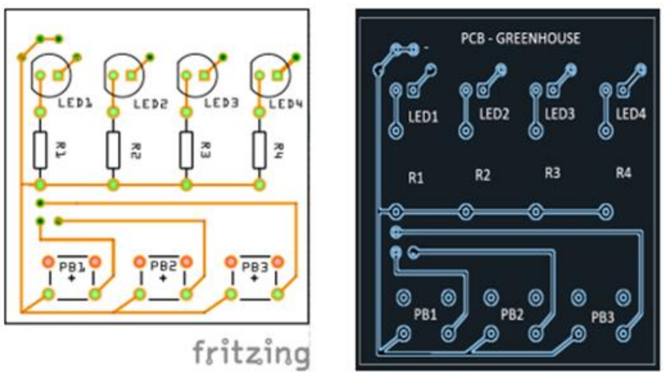

Figure 3 - (A) Squeamatic printed circuit board, bottom surface (B) printed circuit board, top surface

It was elaborated a control panel for settings and processing monitoring, consisting basically of three push-buttons connected in IMPUT PULLUP mode on digital doors of the Arduino Mega 2560 and on its GND. Being a push-button for setting processing time, other for maximum internal temperature setting and finally the system actuating.

For indication, a set of LEDs was installed connecting their anode type terminals to digital doors of the Arduino Mega 2560 and the catodo type terminals connected to resistors of 220 ohms connecting on your GND, in which the blue LED

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indicates the activation of the heating system, red LED indicating that the equipment is not in running mode, Green LED indicating that the equipment is in running mode and yellow LED indicating that the procedure has been completed. It is also possible to monitor the situation of the equipment through the display of vital information on a TFT 3.2" ILI9341 LCD Display with resolution of 240×320 pixels with direct coupling on the microcontroller.

The installation of the AM2302 DHT22 sensor consisted of connecting your VCC terminal connected to the 5 V of the Arduino Mega 2560 and another terminal connected to the GND. Being the data transition accomplished by a connection between the DATA terminal with an analog port.

The activation of the heating system is carried out by means of a rele module with output voltage of 250 VAC and 30 A, connected to the 5 V, GND and digital pin of the Arduino Mega 2560. In your common terminal (Represented only for illustration in the squematic as RST port) has been connected to the VCC from a 127 V external power supply, In followed coming out a cable of the normally open terminal (Represented only for illustration in the squematic as 3V3 port) linking directly to the VCC of electrical resistance. The GND terminal of electrical resistance is connected directly to the GND of the external power supply.

While in the second module rele with output voltage from 30 VDC to 10 A or 250 VAC to 10 A, is installed the airflow system, in which the VCC terminal of the 12 V fan is connected to the normally open terminal (Represented only for illustration in the squematic as 3V3 port) of the rele. In your common terminal (Represented only for illustration in the squematic as RST port) has been connected to the VCC from an external 12 V power supply. The GND terminal of fan is connected directly to the GND of the external power supply.

The programming developed allows the selection of the processing time of the greenhouse, also displaying a timer for monitoring the remaining time for finalization, with indicative audible alarm triggering. Allowing the definition of maximum operating temperature with staggered addition of 2 ranging from 303.15 to 323.15 K (Temperature range established for the process), in which the current internal temperature and humidity is displayed with an update rate of 2 seconds. In this way, with the parameters set the microcontroller takes control of operation through the control of the reles connecting and unplugging the air circulation systems and heating so that it always remains under the defined conditions.

All procedure record can be tracked on the Serial monitor of the Arduino Integrated Development Environment software, in which fundamental data on the executing of programming is presented, recording the time of initiation and completion of the procedure, temperature, internal humidity of the greenhouse, activation and shutdown of the reles throughout the process, thus enabling, the providing of data for statistical analysis of the process, interpretation of procedure and assessment for equipment calibration.

The equipment designed has a safety system in case of error during the process. In the event of failure to transfer data from the temperature and humidity sensor, the system immediately registers informing the interval of events of the error, in addition to pausing the activation of the reles, thus preventing the internal temperature from exceeding the selected temperature, returning its operation after data return. If the transmission fails, representative figures is displayed on the display, in addition to the activation of all indicative LEDs and audible alarm activation.

The data collection for statistical control, consisted of evaluating the operation of the equipment over a time period of 4800 seconds. During the process, the data was recorded on the serial monitor Arduino Integrated Development Environment software at an average interval of 2 seconds (DHT22 sensor response time). Subsequently, copied to a TXT file, imported into Excel for organization and table generation.

For time series analysis, the initial period of 3600 seconds of the process was isolated, to determine the objective parameters. Due to the registration of the DHT22 sensor not occurring in an exact time interval, a total sample of 1680 registered data was generated, which were divided into subgroups of 15 data and calculated your average, simulating a record every 30 seconds, generating a final sample with 112 record averages. The same process, was applied for data generation used in control charts, histogram and contour plot, however, using the final 3600 seconds period of the process, for verification of stability and suitability of the same.

The average data was calculated, due to the fact that the record happens in a relatively short interval, which generates data with small variances from each other during the 30:00 seconds period, thus enabling better fit of the sample size to be worked and plotted in the graphs.

The Figure 4 shows the time series charts generated for temperature and humidity. In which, on the left side is plotted the total set of samples. While on the right side the samples were plotted from the starting point of stabilization, enabling an magnification of the distribution visualization over the analyzed time.

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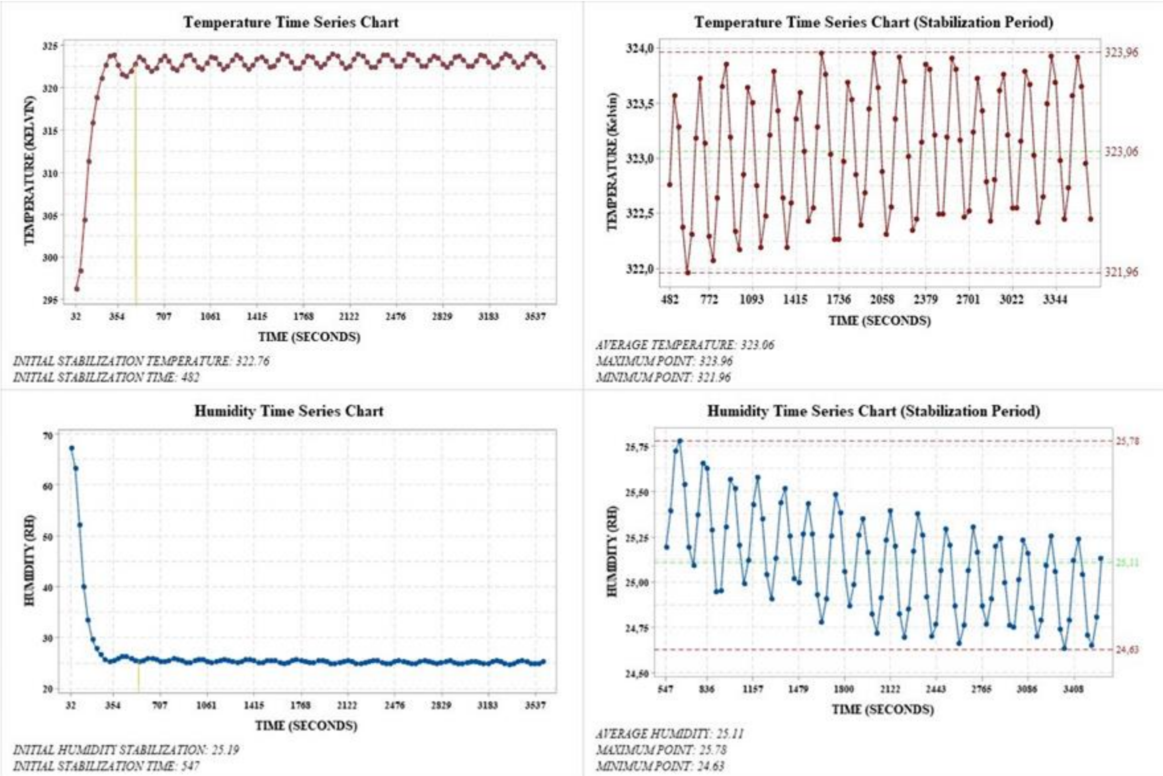

Figure 4 - Temperature and humidity time series chart

The determination of the stabilisation point was performed by observing the value closest to the overall mean of the samples in the final process period, taking into account the graphic behavior, being selected from the oscillation wave higher relative to the target value at the beginning of the process.

It was observed that the initial temperature stabilization period was 482 seconds (08:03 minutes) so that inside the camera reached an average temperature of 322.76 k. While humidity stabilized from 547 seconds (09:12 minutes) reaching an average range of 25.19 RH.

Analyzing the time series chart plotted from the stabilization period, it is possible to observe that over the evaluated time, the temperature is distributed around the average of 323.06 K, with a maximum point of 323.96 K and a minimum of 321.96 K. However, observing the distribution process over time, it was verified that only two points presented average temperature below 322.15 K, occurred in the initial waves of the stabilization period.

With this, it turns out that the process in its initial period after stabilisation, disregarding the two initial peaks below, has an average oscillation of temperature distributed within a limitation range of +- 0.90 compared to the target value of 323.15 K, more precisely a deviation of 0.81 above and 1.00 below the target value.

Analyzing the time series chart plotted from the humidity stabilization period, it is possible to observe that over the estimated time, the same is distributed around the average of 25.11 RH, with a maximum point of 25.78 RH and a minimum of 24.63 RH. When the distribution process over time is observed, it can be seen that the same presents peaks of higher values initially with a tendency to distribute around the average in a smaller interval as the processing time increases until a certain period, can be compared with the average moisture value in the final period to determine the mean range of the process. Therefore, it turns out that in its initial period the process has an average oscillation of humidity distributed within the limitation range of +_ 1.15 RH.

With samples from the final processing period, I-AM control charts were generated, allowing to monitor the average and variation of the process for temperature and humidity factors. To check for special causes in the process, type 1 tests were applied, evaluating a point greater than three standard deviations from the center line; type 2, evaluating nine consecutive points on the same side of the center line; type 7, evaluating fifteen consecutive points within a standard deviation of the center line on both sides.

The Figure 5, the left shows the charts I-AM (Inidividual; Amplitude). While the right is generated the histogram to examine how data is dispersed using bars to show the frequency of each range.

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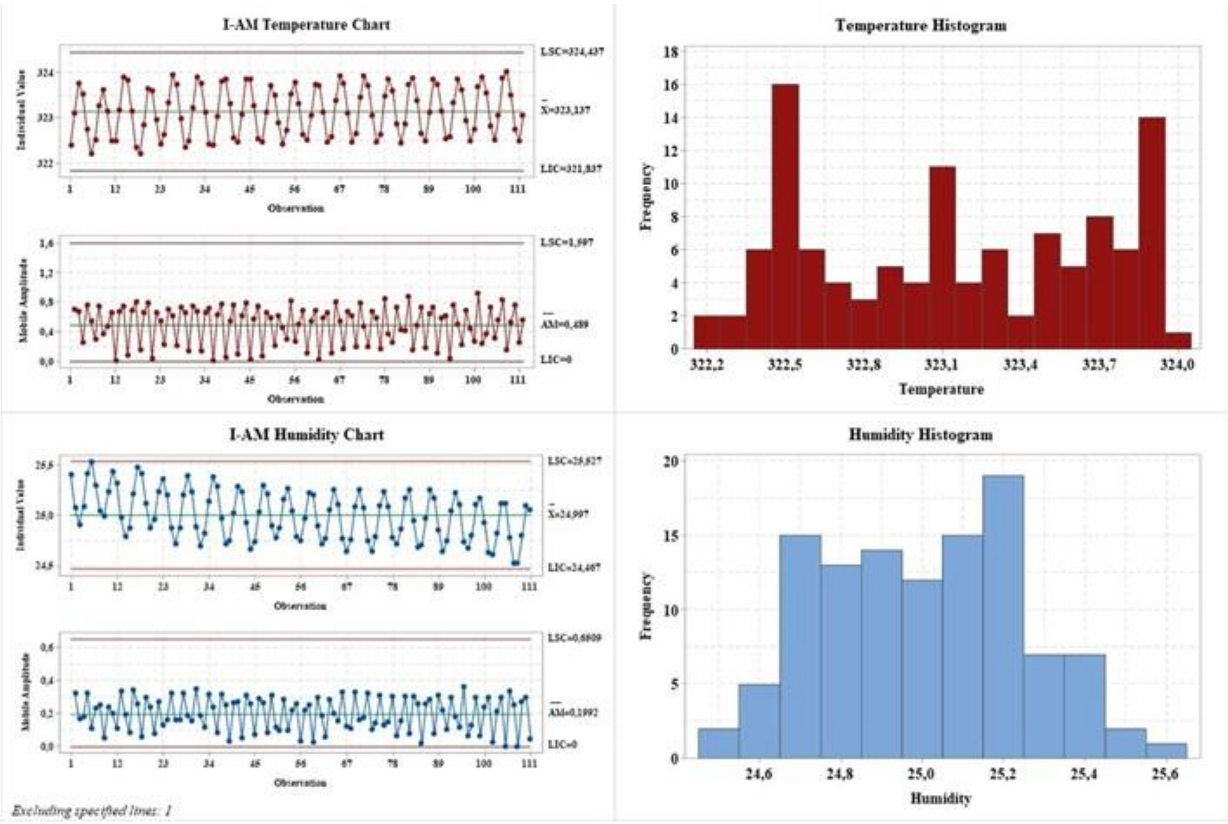

Figure 5 - Charts I-AM and histogram referring to temperature and humidity

Examining the temperature charts, it is observed that the mobile amplitude chart shows that the variation of the process is under statistical control, concluding that the control limits of chart I are accurate. The individual value chart shows that the process operated with an average estimate of 323.14 K. The limits of control, are fixed at a distance of 3 standard deviations above and below the center line, showing the amount of variation that is expected from the individual samples. Ranging from among upper control limit of 324.44 K and a lower control limit of 321.84 K . Being possible to verify that the process is under statistical control.

Through the histogram, it is possible to observe a higher frequency at the ends in relation to the target value, specifically at temperatures with a range of 322.40 to 322.50 K and 323.70 to 328.80 K, what can be justified, due to the operation of the programme, since it assesses the need or not to actuating the heating system, interpreting data at calibrated intervals for the process when the temperature is below or above the objectified value, but remaining within the estimated range.

Evaluating the humidity charts, it is observed that the mobile amplitude chart shows that the variation of the process is under control, indicating that the control limits of chart I are accurate. However, on the individual value chart the point 1 presented a value greater than three standard deviations above the center line, indicating is under special cause, probably explained by the fact that it is in the initial phase of the stabilization process. Therefore, after the identification of the cause, its value was omitted so as not to influence the estimates of the process parameters and it was possible to verify that humidity follows a process under control in line with the temperature. Presenting an approximate average of 25.00 HR, with upper control limit of 25.53 RH and lower limit of 24.47 RH. The histogram allows us to observe that the process presented higher frequency of distribution in the range between 25.15 and 25.25 RH and with considerable distribution around the process average.

Through the contour plot of humidity versus temperature; final phase time (Figure 6), it was found that it tends to present lower humidity ranges between 25.00 and 24.60 RH with temperature around 323.15 K. Being than temperatures below 322.35 K the humidity values tend to present themselves greater than 25.40 HR. Maintaining a good distribution over the final processing period.

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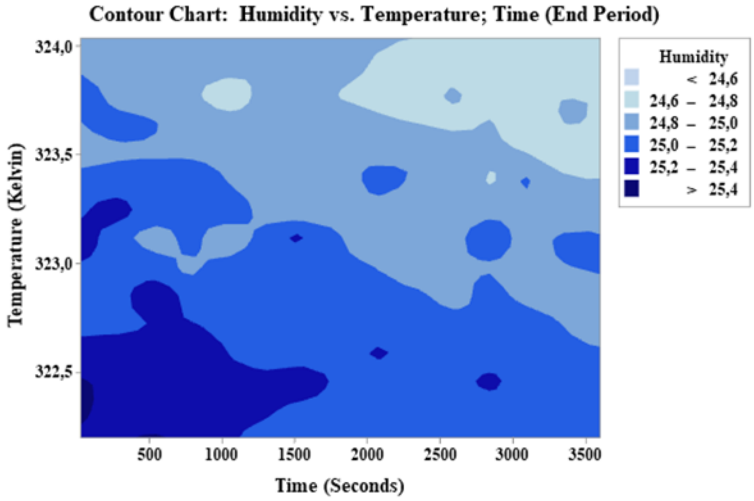

Figure 6 - Contour Plot for humidity response in initial processing period

CONCLUSION

In view of the established objectives, through the study, the structural projection was carried out and operational programming with control limits within the range determined specifically for the process. In which carried out the construction of the greenhouse with forced air circulation for vertical drying of Fibroin plates, automated by means of the ATmega 2560 microcontroller, contained in arduino Mega 2560 board. Developing a prototype in an economically viable way and with functionalities within the objective pattern. Evaluated by means of specific statistical tests.

Through the applied tests, it was found that the process kept under control throughout the operating period of the equipment at its maximum power, operating at a general average after stabilization at a temperature of 323.10 K with a variation of +-01.00 around the target value. While humidity remained in the mean range of 25.05 RH acting in line with temperature variation. Both factors, for stabilization inside the camera require an average time of 8:57 minutes (514 seconds), starting from a average initial temperature of 296.16 K and humidity of 67.36 RH.

In this way, the elaborated equipment presents a good alternative in the performance of the drying process of fibroin plates with good control of the parameters determined. Allowing a higher number of samples inside the camera and enabling better ambient circulation, ensuring the stability and distribution of the process. However, internal homogeneity studies of the camera are needed to determine the overall distribution capacity.

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