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Journal of Systematic Innovation

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Scientific Objectives

Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines of electromagnetism, electrical distribution, sources innovation in electrical, engineering signal, amplification electrical, motor design science, materials in electrical power, plants management and distribution of electrical energies.

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The works must be unpublished and refer to topics of electromagnetism, electrical distribution, sources innovation in electrical, engineering signal, amplification electrical, motor design science, materials in electrical power, plants management and distribution of electrical energies and other topics related to Engineering and Technology.

Presentation of the content

In the first article we present, *Standardization of a furniture manufacturing process*, by ACOSTA-GONZÁLEZ, Yanid, DELGADO-GÓMEZ, Gilberto, GUTIÉRREZ-ARENAS, Héctor Javier and OLIVO-CAPUCHINO, Karla Susana, with adscription in the Universidad Tecnológica de Aguascalientes, in the next article we present, *Dynamics of a plastic aging chamber with PI temperature control*, by MEDINA-MARTÍNEZ, Sergio Iván, JUÁREZ-TOLEDO, Carlos, MARTÍNEZ-CARRILLO, Irma and FLORES-VÁZQUEZ, Ana Lilia, with adscription in the Universidad Autónoma del Estado de México, in the next article we present, *Saponification index determines the efficiency in the transesterification process in the production of biodiesel,* by TORRES-RIVERO, Ligia, CORONEL-GIRON, Marco, ALCOCER-TORRES, Beatriz L. and BEN-YUSEFF-BRANTS, Sheriff, with adscription in the TECNM/Campus Instituto Tecnológico de Cancún, in the next article we present, *Classification and counting system for bacteria in microbiological culture media using image processing*, by GUTIÉRREZ-LEÓN, Diana Guadalupe, SERRANO-RAMÍREZ, Tomás, GRANADOS-ALEJO, Vignaud and DE LOS SANTOS-LARA, Pedro Jorge, with adscription in the Universidad Politécnica de Guanajuato.

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Standardization of a furniture manufacturing process

Estandarización de un proceso de fabricación de muebles

ACOSTA-GONZÁLEZ, Yanid†*, DELGADO-GÓMEZ, Gilberto, GUTIÉRREZ-ARENAS, Héctor Javier and OLIVO-CAPUCHINO, Karla Susana

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Abstract

The company where the project was carried out is Muebles Quiché, located at Av. José María Chávez 1317 interior D. The project was carried out in the "Unique Designs" process, to optimize workstations, through the implementation of methodologies and solutions for the company. Through the study of times and movements, each of the operations that make up the process were analyzed, as well as identifying the operator's movements and subsequently generating a proposal that improves the efficiency of the line. The manufacturing process has evolved empirically, the first area of opportunity was to put order in the process and based on the observation of the operation, and the continuous improvement methodology (Prioritization matrix, Pareto diagram, Kaizen newspaper among others), starting with the clarification the path of operations, also gave order to the materials, and to the standardization of operations; These activities generated savings in costs, distances, times.

Kaizen, 5´s, Unnecessary movements, spaghetti diagram,

Resumen

La empresa donde se realizó el proyecto fue Muebles Quiché, ubicada en Av. José María Chávez 1317 interior D. El proyecto fue realizado en el proceso llamado "Diseños Únicos", para optimizar las estaciones de trabajo, mediante la implementación de metodologías y soluciones para la empresa. Mediante el estudio de tiempos y movimientos se analizaron cada una de las operaciones que compone el proceso, así como identificar los movimientos del operador y posteriormente generar una propuesta que mejore la eficiencia de la línea. El proceso de fabricación, ha evolucionado de manera empírica, se encontró como primera área de oportunidad poner orden al proceso y con base a la observación de la operación y a la metodología de mejora continua (Matriz de priorización, diagrama de Pareto, periódico Kaizen entre otros), iniciando con clarificar el recorrido de las operaciones, además se dio orden a los materiales, y a la estandarización de operaciones; estas actividades generaron ahorros en los costos, distancias, tiempos.

Kaizen, 5´s, Movimientos innecesarios, diagrama, espagueti

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Introduction

Companies are currently facing a strong competence that requires the identification of opportunities in the outputs of their processes and changes in the way they operate, delivery time and costs (Hernández-Pitalua, Sánchez-Gómez, & Hernández Orduña, 2020), That is why organizations are beginning to apply lean manufacturing tools to improve their processes and be more competitives.

One of the tools used in production processes is continuous improvement (Kaizen), it is a tool that is part of the Lean Manufacturing methodology, it allows to have results such as reduction of waste and delays in each of the processes (Martínez Saavedra & Arboleada Zuñiga, 2021).

In 2017, Alvarado Ramírez & Pumisacho Álvaro conducted an evaluation of practices on continuous improvement in large and medium-sized companies, related to manufacturing and services in the Metropolitan District of Quito (DMQ), which required the involvement of directors, managers and workers in continuous improvement, solving problems to meet the organizational objectives of the company. The use of techniques has had an essential part of the business administration system where it is applied and which is to keep and improve the standards that are in place.

The spaghetti tool allows to observe the physical routes and to identify unproductive times and unnecessary movements, in order to satisfy the customer's requirement (L. Bermudez, 2009).

According to Campos Quispe, & Robles Poemape, (2020), they used the spaghetti diagram tool, within the warehouses, in order to indicate the quantity and the allocate of the products into the warehouse, since they did not have control, thus generating delays in the operations.

Regarding the time and movement study, it is used to determine the standard time of the operations of a process, the objective is to reduce costs and resources, eliminate unnecessary movements (Tejada-Díaz, Gisbert-Soler, & Pérez-Molina, 2017).

Angulo Noel & Carretero Landauro (2021), their project objective was to identify improvements that can be implemented in the warehouse area to reduce operating costs, supported by the time and motion analysis, the Deming cycle (PDCA). Also, the identification and characterization of waste from the process (Mudas) in the transportation and process, unnecessary movements and waiting times.

Particularly a fundamental tool of the Lean Manufacturing methodology, the 5's, which means: Selection, Order, Cleanliness, Standardization and Discipline (Chilón Aguilar, Esquivel Paredes, & Estela Tamay, 2017).

The company where the project was carried out is Quiché furniture, located in the State of Aguascalientes, Mexico, in order to cover the demand of customers established in Jalisco and San Luis Potosí; the location is advantageous due to the competitive cost of product transfer, even in small volumes (Martínez González, 2019).

The goal in this company was to optimize the most profitable product process, throw the times and movements methodology; standardization and continuous improvement.

The work contents: Analysis of the original situation of the process, identification of opportunity areas in order to optimize operations for contributing to the reduction of idle times (Martínez Saavedra & Arboleada Zuñiga, 2021), and the establishment of a standard in order to keep the improvements.

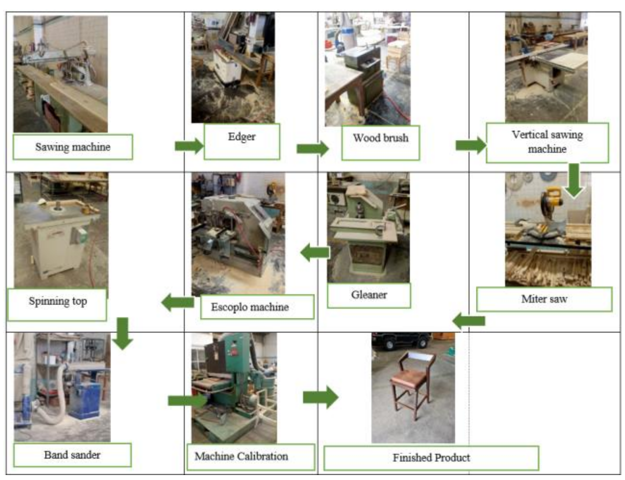

Figure 1 Standard model process
Source: Own elaboration with information from the company Muebles Quiché

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Unique Design model elaboration process

The Unique Design model, is the product, defined for analysis of its processes steps: Cutting, Sanding, pre-assembly and fixed.

No.	Descripción	Operation	Inspection	Transport	Delay	Tiempo (Sec)	Observations
1	Bring wood to the cutter			➡		15	
2	To cut wood	●				15	
3	Transfer to brush			➡			
4	Transfer of cutter wood to sander			➡		8	
5	Wood sanding	●				30	
6	Chop the wood into sections	●				30	
7	Moving wood			➡		10	
8	Remove the excess left by the cutter	●				45	
9	Moving the wood			➡		6	
10	Smooth wood	●				60	
11	Transfer the raw material			➡		8	
12	The wood is cut crosswise	●				60	
13	Transfer the raw material			➡		8	
14	The parts coupling is done (male)	●				75	
15	Transfer the raw material to turning			➡		6	
16	Parts coupling is performed (female)	●				12	
17	Transfer the raw material			➡		3	
18	The wood is leveled	●				12	
19	Transfer the raw material to contouring machine			➡		6	
20	The contour is made to the piece of wood	●				30	
21	The wood is sanded	●				30	
22	Transfer the raw material to the assembly area			➡		3	
23	Assemble	●				60	
24	Transfer the raw material to the warehouse			➡		20	

Figure 2 Flow diagram of a standard chair model (Design Area)
Source: Own elaboration with information from the company Muebles Quiché

The first operation passes the wood to the cutting area, then it goes to Sanding where an edging machine is used, and a calibrating machine that helps correct irregularities, so that all its sides are the same size and thickness; when the wood is ready, it is sent to the process where the vertical sawing machine, band saw, miter saw, tenoning machine and spinning top are located.

These machines shape the wood and make the corresponding holes for the assembly; when the wood is ready it is moved to the assembly area where different materials are used, in this case pneumatic guns are used, one for staples and another for nails, these use air compressors, industrial glue is also used to join the pieces with the nails or staples; once the final product is ready it is sent to the finished product storage area (Figure 1).

The model with the highest demand is called Unique Design, identifying areas of opportunity (Figure 2), which are described below.

After having made a referenced analysis on the manufacture of the Unique Design, and considering process sheets or operation standards, the information was organized in a prioritization matrix, taking as reference the "7 wastes" of lean manufacturing practices, as can be seen in Figure 3 (prioritization matrix) the one with the highest relevance was the unnecessary movement and lost time.

3 point ◎ 2 points ○ 1 point △

Problems	Importancy	Prioridad	Department policies	Impact	Dificulty	Sum
	Ponderation					
Unecesary movements	◎	◎	◎	◎	○	13
Product in process inventory	○	○	◎	△	△	9
Machinery inventory	○	△	○	△	△	7
Lost time	◎	◎	○	◎	○	13
No signalization	○	△	△	△	○	7

Figure 3 Problem prioritization matrix
Source: Own elaboration with information from the company Muebles Quiché

Problem Statement

The main problem detected in the operator performs was, unnecessary movements, affecting whit this, costs and timely deliver of customer orders.

General objective

Currently there is a capacity of 44 chairs per day, so it is wanted to increase by 20%, with the improvement proposal.

Justification

The Unique Design model represents 10% of total production, however, it is a product that presents a high profit margin for the company. By intervening in this project, the company incorporates production management techniques that could be replicated in other models of higher production volume.

Development

The "Muebles Quiché" company has 11 workstations with a different cycle time, due to the range of designs they have.

The manufacture of a chair consists of six parts: Seat, shipowner, chair lap, hind legs, front and back legs.

Seat

For the elaboration of the seat, unnecessary journeys were identified with a total time of 2.64 minutes (Table 1).

In the study of movements, it can be observed that there is no standard, due the operator goes slower depending on the weight of the raw material that he transfers (Figure 4).

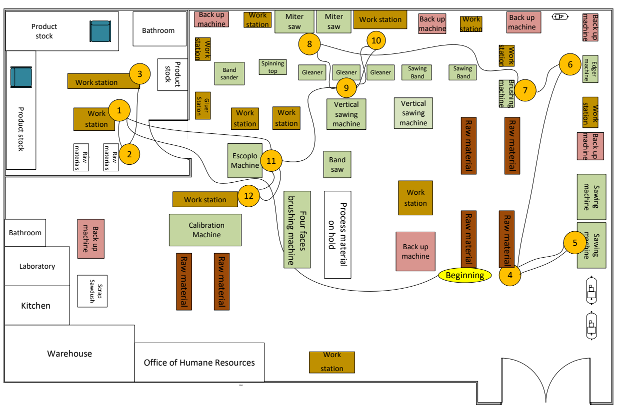

Figure 4 Spaghetti Diagram for Seat Assembly
Source: Own elaboration with information from the company Muebles Quiché

Point	Distance (Meter)	Time (sec)
Beginnig-1	30	35
1-2	1.20	2
2-3	3.20	4
3-4	36	24
4-5	2.80	8
5-4	2.80	8
4-6	12	18
6-7	10	8
7-8	20	14
8-9	3.80	7
9-10	3.30	2
10-9	3.30	3
9-11	4.70	5
11-12	7.5	6
12-11	7.5	6
11-1	13.5	9
Total of the operation	161.6	158.95 sec
		2.64 min

Table 1 Data concentration (Distance and time) of the Seat assembly
Source: Own elaboration with information from the company Muebles Quiché

Shipowner

For the owner's elaboration, unnecessary routes were identified with a total time of 2.98 minutes (Table 2 and 5), it can be observed that out of 18 movements only two are not irregular, due to the transferred load carried by the operator.

Point	Distance (Meter)	Time (sec)
1-2	6.20	6
2-3	7.80	9
3-4	20	21
4-5	2.80	6
5-4	2.80	6
4-6	12	10
6-7	10	6
7-8	5	4
8-9	7	9
9-8	7	11
8-1	5	6
1-10	3.80	7
10-1	3.80	7
1-2	3.20	5
2-3	12.70	24
3-11	10	11
11-1	10	12
1-12	10	12
Total of the operation	139	178.93 sec
		2.98 min

Table 2 Concentrated data (Distance and time) of the Shipowner's product.
Source: Own elaboration with information from the company Muebles Quiché

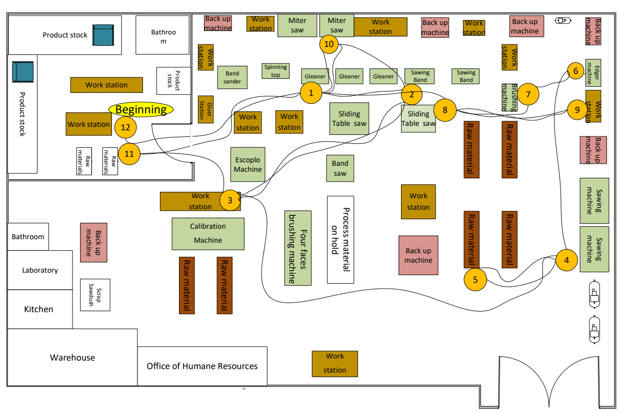

Figure 5 Spaghetti Diagram for Assembling the Lap
Source: Own elaboration with information from the company Muebles Quiché

Chair lap

For the elaboration of the lap, the incensorial paths were identified with a total time of 2.12 minutes; the longest time was 36 seconds which is at the beginning (Table 3 and Figure 6).

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Point	Distance (Meter)	Time (sec)
1- Beginning	38	36
Beginning - 2	36	34
2-3	12	15
3-4	6	9
4-5	7.5	7
5-6	3	3
6-5	3	4
5-7	1.20	1
7- Beginning	13.5	16
Total operation	120	127.23 sec.
		2.12 min.

Table 3 Data Concentration (Distance and Time) of the Lap Assembly
Source: Own elaboration with information from the company Muebles Quiché

In elaboration of the lap assembly, the first operation is located in the warehouse area, and in the process area are located machines out of operation; therefore it will be an area of opportunity for improvement the plant distribution (Figure 6).

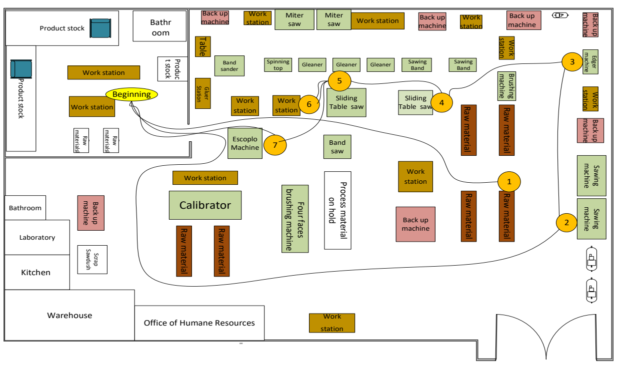

Figure 6 Spaghetti Diagram for Assembling the Lap
Source: Own elaboration with information from the company Muebles Quiché

Chair back

Elaboration of the backrest, the total journeys requires a whole time of 1.74 minutes (Table 4 and Figure 7).

Point	Distance (meter)	Time (sec)
1-2	38	28
2-3	2.80	2
3-4	12	17
4-5	1.20	5
5-6	7.25	9
6-7	6	5
7-8	20	14
8-9	3.80	6
9-10	1.20	2
10-11	1.15	1
11-12	14	11
12-1	2.37	2
Total operation	109.77	104.88 seg
		1.74 min

Table 4 Data Concentration (Distance and Time) of Backup Arming
Source: Own elaboration with information from the company Muebles Quiché

In operations one and twelve, they also use the tables as a work area and see the possibility of improving their distribution (Figure 7).

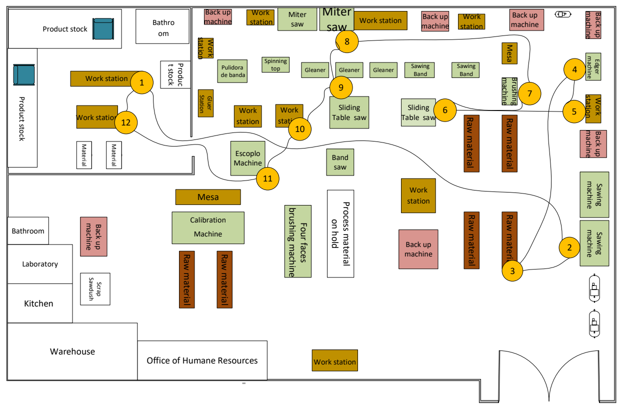

Figure 7 Spaghetti diagram for backrest assembly
Source: Own elaboration with information from the company Muebles Quiché

Hind legs

For the elaboration of the hind legs, the routes with a total time of 1.76 minutes were identified, in which it was identified that there are three long distances, the first with a route of 36mts., the other of 15 and the third of 14.8mts., it can be observed that the times vary due to the number of pieces that the operator loads from one work area to another, for this reason, sometimes the route is long or slow (Table 5 and Figure 8).

Point	Distance (Meter)	Time (sec)
Beginning-1	2.37	2
1-Beginning	2.37	2
Beginning-2	36	24
2-3	2.80	3
3-4	12	16
4-2	14.8	21
2-5	15	12
5-6	5	4
6-7	7.5	7
7-8	3.30	5
8-1	11	10
Total of the operation	112.14	105.65 Sec
		1.76 min

Table 5 Data concentration (Distance and time) of the assembly of the hind legs
Source: Own elaboration with information from the company Muebles Quiché

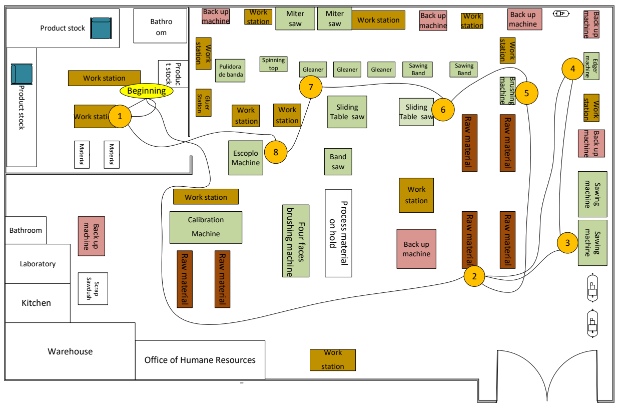

Figure 8 Spaghetti diagram for the assembly of the hind legs
Source: Own elaboration with information from the company Muebles Quiché

Front legs

For the elaboration of the lap, the incensorial movements were identified with a total time of 1.52 minutes. The first movement is the longest at 36 meters, with a time of 25 seconds (Table 6 and Figure 9).

Point	Distance (Meter)	Time (sec)
1-2	36	25
2-3	2.80	5
3-4	12	11
4-3	12	10
3-5	2.80	8
5-6	12	10
6-7	10	8
7-8	3.30	5
8-1	11	10
Total of the operation	101	91.64 seg. 1.52 min.

Table 6 Data concentration (Distance and time) of the front leg assembly
Source: Own elaboration with information from the company Muebles Quiché

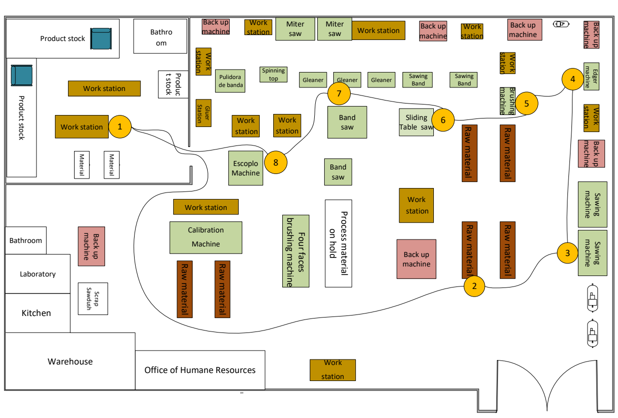

Figure 9 Spaghetti diagram for front leg assembly
Source: Own elaboration with information from the company Muebles Quiché

It can be concluded that with the spaghetti diagrams of each of these parts, the times and their respective distances are obtained as a result with a total of 12.76 minutes, since it is only performed by a single operator (Table 7).

Chair part	Distance (Meter)	Time (minutes)
Seat	161	2.64
Shipowner	139	2.98
Chair lap	120	2.12
Chair back	110	1.74
Front legs	101	1.52
Hind legs	112	1.76
Total of the operation	743	12.76 minutes

Table 7 Result of the movements of each part of the product
Source: Own elaboration with information from the company Muebles Quiché

Methodology

To achieve the main objective of increasing the production capacity of the chairs, the following Lean manufacturing management tools were used: Observation of the operation, process mapping, prioritization matrix, spaghetti diagram and the 5's methodology.

(1) Selecting, which involves separating what is necessary and identifying what is not useful in the work areas; (2) ordering, which consists of organizing everything in its place, so that it is easy to locate it considering labels, place to store, depending on the product; (3) cleaning, involves cleaning the work area before and after the shift (4) standardize, means to apply the first three "S" permanently, with the support of some photographs, statistics, procedures; (5) discipline, in this last one visits are made to the areas to verify compliance with the standardization that was proposed (Chilón Aguilar, Esquivel Paredes, & Estela Tamay, 2017).

At the beginning of this document, the company lacks a production management culture, because that, this project and some tools were implemented to generate better work practices such as: Cleaning, standardization, Kaizen. In order to adapt this work culture, the worker must be involved in training, starting with the training of the 5's and locking generate a mentality about the benefits that can be reached.

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Results

The following diagram shows the route that the operator will take to make the six parts of the chair, obtaining a distance of 55.32 meters, consuming 0.95 minutes. It was decided to place the workstation in this location since it is located in a centralized place in the plant, with the purpose of obtaining that the operator has the machines closer and thus be able to reduce unnecessary movements (Table 8 and Figure 10)

Point	Distance (Meter)	Time (sec)
1-2	3.48	4
2-3	2.60	2
3-4	14.40	12
4-5	3.30	3
5-6	6.45	7
6-7	3.57	4
7-8	3.35	4
8-9	5.55	6
9-10	2.50	2
10-1	10.12	13
Total of the operation	55.32 meter	57 sec. 0.95 min.

Table 8 Improvement Spaghetti diagram improvement
Source: Own elaboration with information from the company Muebles Quiché

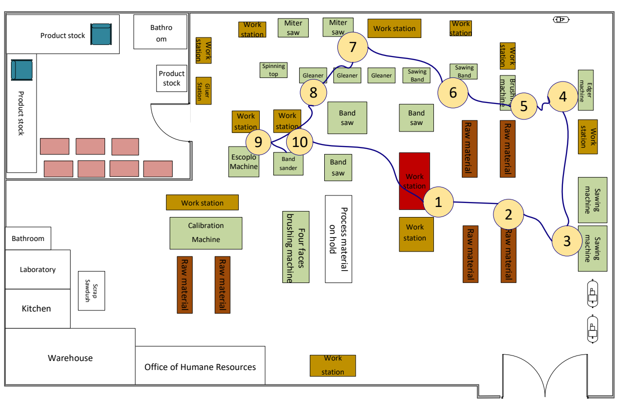
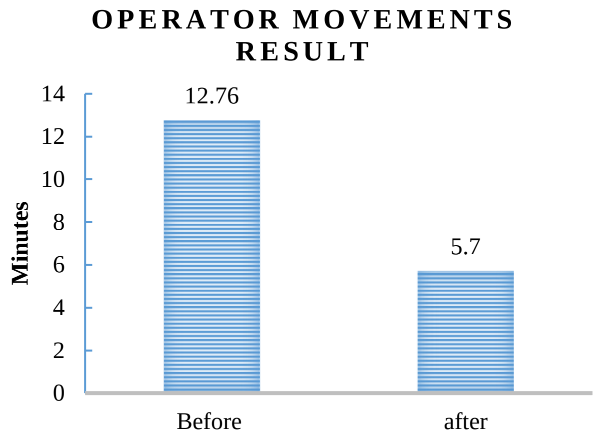
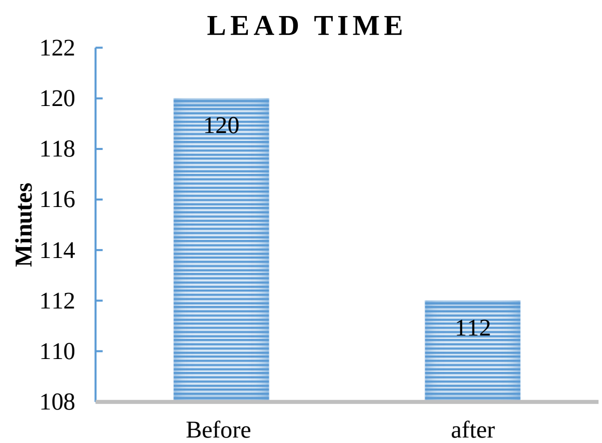


Figure 10 Spaghetti diagram improvement
Source: Own elaboration with information from the company Muebles Quiché

The total time of transfers before the intervention was 12.76 min., after the changes made it was 5.38 min., therefore the manufacturing time of 120 min. was reduced to 112 min., therefore it was reduced by 6.3% vs. 20% targeted (Graphic 1 and 2).



Graphic 1 Result of operator movements
Source: Own elaboration with information from the company Muebles Quiché



Graphic 2 Lead time before and after improvement
Source: Own elaboration with information from the company Muebles Quiché

The improvement points are follows:

(1) Machinery that was not being used was removed.

(2) Worktables were relocated between operations.

From 56 chairs that were produced with the improvement, now will be produced 60 chairs per day, with a difference of seven pieces, which impacts the utility of the company.

The methodology of 5 was implemented, which is a lean manufacturing in order to improve production processes considering the steps: Classification, cleaning, standardization and discipline (Seiri, seiton, seiso, seiketsu and shitsuke) (Martínez Saavedra & Arboleada Zuñiga, 2021); starting with the training in order to make the operators aware of their scope of work since their commitment is required.

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Before the implementation of 5's	After the implementation of 5's
	
	
	

Figure 11 Before and after in the Warehouse Area
Source: Own elaboration with information from the company Muebles Quiché

Obtaining as a result the elimination of unnecessary movements since these were caused by the lack of a tool near your workstation (Figure 11).

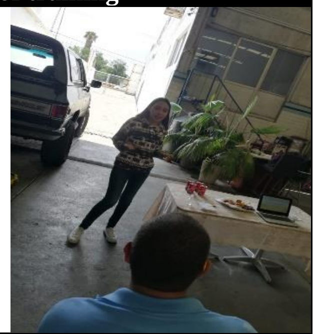
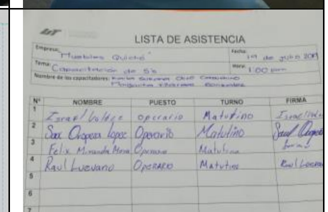
Evidence of training	
	
	

Figure 12 Evidence of the training for the implementation of the 5's
Source: Own elaboration with information from the company Muebles Quiché

After the training, with the support of the staff, the cleaning caused by sawdust was carried out, the location of the tools through standardization (Figure 12).

Conclusion

We thank the company Quiché for having trusted the staff of the Technologic University of Aguascalientes and students who participated in field work, López Valdez Luis Eduardo, Villarreal González Margarita, Atilano Gutiérrez Ignacio Antonio, Díaz Sara Eli, and Suarez Hernández María Guadalupe.

For the moment it is recommended that the 5's practices be maintained, for a more organized production, the standardization (Chilón Aguilar, Esquivel Paredes, & Estela Tamay, 2017).

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Dynamics of a plastic aging chamber with PI temperature control

Dinámica de una cámara de envejecimiento de plástico con control de temperatura PI

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Abstract

Plastic pollution has become a global environmental problem, as rapidly increasing production of plastic products, increased international measures are being taken to reduce the problem. This paper aims to present the dynamics of a plastic aging chamber with PI temperature control, this study was conducted according to ASTM D-4329 standard. In this work, three transfer functions are obtained which represent the different times (morning, noon, and night), the results of the transfer functions parameters are analyzed using Matlab PID Tunner to show the effectiveness of the proposed method. Finally, the temperature-time graph for a cycle is shown in the results.

Transfer function, Digital control, Thermal systems, Aging chamber

Resumen

La contaminación plástica se ha convertido en un problema ambiental a nivel mundial, debido a que la producción de productos plásticos aumenta con rapidez actualmente se están tomando medidas internacionales para reducir el problema. Este artículo tiene como objetivo presentar la dinámica de una cámara de envejecimiento de plástico con control de temperatura PI, este estudio se realizó de acuerdo con la norma ASTM D-4329. En este trabajo, se obtienen tres funciones de transferencia que representan los diferentes horarios (mañana, medio día y tarde), los resultados de los parámetros de las funciones de transferencia se analizan utilizando Matlab PID Tunner para mostrar la efectividad del método propuesto. Finalmente, el gráfico de temperatura-tiempo para un ciclo se muestra en los resultados.

Función de transferencia, Control digital, Sistemas térmicos, Cámara de envejecimiento

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Introducción

Plastic is an indispensable raw material in human life due to the properties it possesses, it is used for the manufacture of automobile accessories, clothing, electronic equipment, construction, medicine, tools, etc., with an annual production in 2019 of 369 million tons worldwide. (Plastics Europe, 2021), but plastic also represents an environmental problem because the waste ends up in the sea or in landfills causing environmental pollution which produces greenhouse gases and toxins called dioxins that cause serious problems to human health (Bahl, Dolma, Jyot Singh, & Sehgal, 2020).

For this reason, the United Nations Environment Organization held its fourth assembly in 2019 seeking with other countries a sustainable consumer production using a "Circular Economy" for the search to create lightweight, versatile and durable plastics and to develop guidelines that inform the end consumer about the use, production, standards and labels of plastic. (International Institute for Sustainable Development, 2019) (PlasticsEurope, 2021).

In the creation of new polymers, laboratory tests are carried out to determine the useful life cycle, by means of an aging chamber which has a thermal system that causes an accelerated degradation of the plastic. In this work we propose the development and implementation of a PI controller obtaining the dynamics of the temperature system in a practical way.

The PID system is widely used in companies to control their industrial processes because it is reliable and intuitive to use. Some examples are:

- Water heating in a bathtub using a water heater, a valve that regulates the water inlet to the bathtub and a temperature sensor. (Kavita, Naga, Lavanya, & Arivalagan, 2015).

- Temperature control system using fuzzy PID of a mushroom culture, where temperature and humidity are controlled manually by means of an algorithm to determine the high, medium and low fuzzy function. (Kaewwiset & Yodkhad, 2017).

- Temperature control in an incubator (Yue, Fuqiang, Lifeng, Jun, & Benke, 2020).

- ON/OFF heating system (Sánchez, Dessì, Duffy, & Lens, 2020).

In order to understand the dynamics of the system in this work, it is proposed to perform the temperature control by means of the transfer function (TF):

$$\frac{\Theta(s)}{\mathrm{H_i}(s)}=\frac{R}{RCs+1} \tag{1}$$

Where $\Theta(s)$ is the final temperature in ℃, $\mathrm{H_i}(s)$ is the heat flow input in $\left(\frac{kcal}{seg}\right)$, R is the thermal resistance in $\left(\frac{℃\,seg}{kcal,}\right)$, C is the thermal capacitance in $\left(\frac{kcal}{℃}\right)$ (Ogata, 2010). The laboratory application of FT is possible by means of the convection principle which states that, if the characteristics of the building materials are known, then the radiated energy and energy loss can be obtained by equation (2) and equation (3) respectively.

$$P=\delta A\epsilon T^4 \tag{2}$$

Where P is the radiated energy in Watts (W), δ is the Boltzmann constant in $\frac{\mathrm{W}}{\mathrm{m^2°K}}$, A is the area of the inner wall material of the aging chamber (m^2), ϵ is the emissivity constant of the material and T is the surface temperature of the material °K.

$$P_{lost}=kA\Delta Tt \tag{3}$$

Where P_{lost} corresponds to the energy loss inside the aging chamber, k is the constant of the thermal conductivity of the material between the outer and inner wall of the aging chamber in (Wm°K), ΔT is the temperature difference between the inside and outside of the aging chamber in °K and t is the thickness of the material on the walls in m^2.

One drawback is that when controlling the temperature using equations (2) and (3), a temperature calibration process must be performed each time the temperature value is to be changed. (Ezike, Alabi, Ossai, & Aina, 2018).

To obtain the dynamic behavior by characterizing the temperature inside the aging chamber, an input $u(t)$ is applied to the thermal system to obtain the temperature response until it reaches the steady state $c(t)$ as shown in Figure 1.

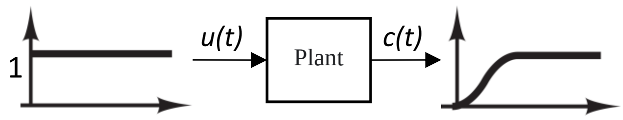

Figure 1 Response to a unit step of a plant
Source: Ogata, 2010

With the characterization of the thermal system, the transfer function can be obtained using the Ziegler-Nichols method or by means of a computational approximation (Fuentes, Castro, Medina, Moreno, & Sepúlveda, 2018) resulting in equation 4:

$$\frac{C(s)}{U(s)} = \frac{Ke^{-Ls}}{Ts+1} \quad (4)$$

Where L is the delay, T is the time constant and K is the system gain. Once the FT of the thermal system is obtained, it is possible to design the PI controller. As described below.

Method

Algorithm of a complete cycle

The plastic aging chamber consists of a thermally insulated container of stainless steel sheets with two infrared luminaires at the ends of the specimens that perform the chamber heating function, as shown in Figure 2.

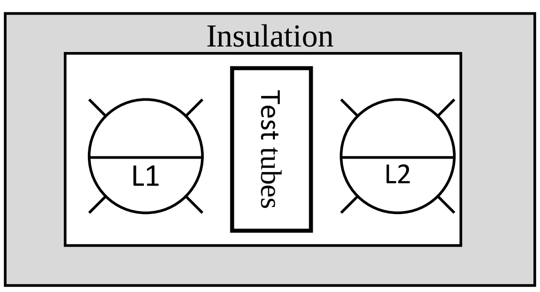

Figure 2 Plastic aging chamber with two infrared luminaires
Source: Own elaboration

ASTM D-4329 establishes a complete aging cycle which is divided into 4 sequences with different: lamp ignition cycles, temperatures and drive percentages, as shown in Table 1.

Sequence	Temperature	% aging cycle	L1	L2
Sunrise	60±3 °C	22.22	On	Off
Half day	60±3 °C	22.22	On	On
Sunset	60±3 °C	22.22	Off	On
Nightfall	50±3 °C.	33.33	Off	Off

Table 1 Characteristics of a chamber cycle.
Source: Own elaboration

In Figure 3, the control temperature is established by applying the ASTM D-4329 standard, then the response of the thermal system inside the chamber is obtained in a practical way, using an analog-to-digital converter and storing the information in a database to be processed through a computational numerical method (4) (MathWorks, 2021).

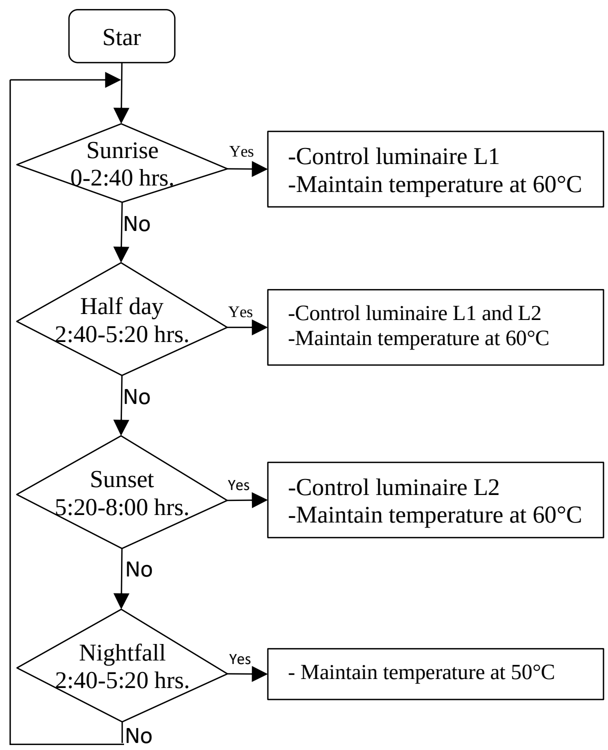

Figure 3 Flow diagram of a complete cycle
Source: Own elaboration

Development of the PI control

With the transfer function of equation (4) the PID Tuner tool of Matlab is used which will result in a continuous time parallel PI as shown in figure 4.

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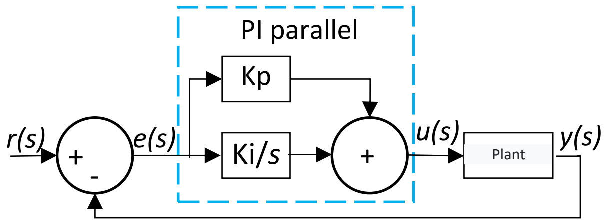

Figure 4 Parallel PI control
Source: Own elaboration

Where r(s) is the setpoint, y(s) is the output of the plant to be controlled, u(s) is the controller output, e(s) is the difference between u(s) and y(s), with the PI equation defined by equation (5). with the PI equation defined by the relation of equation (5).

$$\frac{u(t)}{e(t)}=K_p+\frac{K_i}{s} \quad (5)$$

K_p is the proportional gain, K_i is the integral gain. Once the continuous time controller is obtained, it can be converted to digital using Tustin's method to be able to program it in the microcontroller, which consists of substituting $s=\frac{2}{T_s}\frac{z-1}{z+1}$ in equation 5 resulting in a discrete controller of the following form:

$$\frac{u(z)}{e(z)}=K_p+\frac{K_iT_s}{2}\frac{z+1}{z-1} \quad (6)$$

Where T_s is the sampling time and z is the discrete function. The discrete controller of equation 6 by itself cannot be input to a microcontroller so it needs to be converted to a difference equation by applying the inverse z-transform to obtain equation (7).

$$u_k=u_{k-1}+k_p(e_k-e_{k-1})+\frac{K_iT_s}{2}(e_k+e_{k-1}) \quad (7)$$

Where u_k is the result of the current controller, $u_{k-1}$the result of the previous controller, e_k the current error, e_{k-1} the previous error. By entering the difference equation into a microcontroller, the thermal system of the aging chamber can be controlled.

The implementation of the PI controller is shown in Figure 5 where the microcontroller is in charge of obtaining the temperature information inside the aging chamber and by means of the cycle assignment the difference equation is implemented in the PI controller resulting in a PWM signal that controls the system.

As can be seen in Figure 5, the prototype is divided into the following three phases:

1. **Storage**: where a history of the chamber temperatures is stored.

2. **Control**: integrated by the microcontroller

3. **Drive stage:** consists of the plastic aging chamber

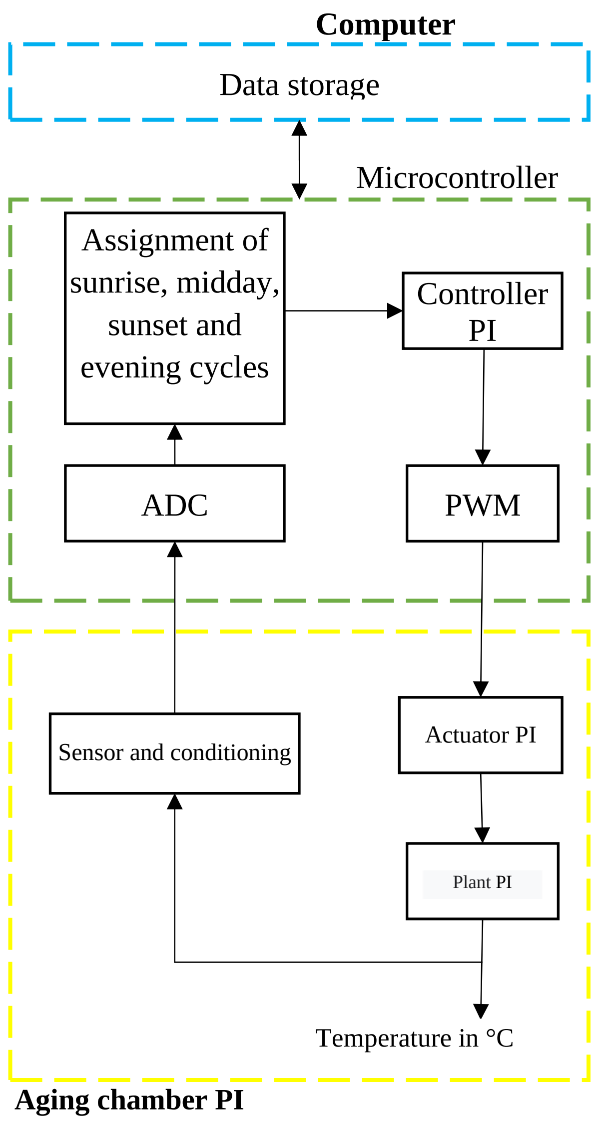

Figure 5 Block diagram of the PI controller implementation
Source: Own elaboration

The characterization of the sunrise and sunset sequence is obtained by applying 50% of the PWM signal, for the case of the half-day sequence a 24% signal is applied to the aging chamber in an approximate time of 890 seconds, the results obtained are shown in Table 2 and Figure 6.

The results obtained are shown in Table 2 and Figure 6.

Time	Sunrise Sequence °C	Sequence Half day °C	Sunset Sequence °C
2.5	22.97	21.51	21.99
3	22.97	21.51	22.48
3.5	22.97	23.46	23.46
4	24.44	21.51	21.99
4.5	24.44	21.51	21.99
5	23.95	21.51	21.99
5.5	23.95	21.51	21.99
6	23.46	21.51	21.99

Table 2 Stored data for the characterization of the thermal system in the aging chamber
Source: Own elaboration

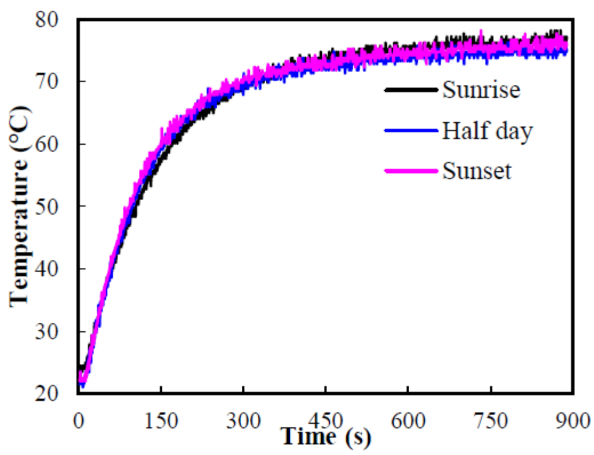

Figure 6 Characterization of the thermal system
Source: Own elaboration

With the practical characterization of the thermal system and using the Matlab System Identification Toolbox, the FT parameters described in equation (4) can be obtained as shown in Table 3.

Sequence	K	L	T
Sunrise	1.5	10.5	172.6
Half day	3.15	6.4	137.68
Sunset	1.5	12	172.6

Table 3 FT parameters of the required temperature time sequence
Source: Own elaboration

Using the Matlab PID Tunner tool and the results in Table 3, the parameters for the PI controller of equation (5) are obtained as shown in Table 4.

Sequence	K_p	K_i
Sunrise	3.76	0.0737
Half day	1.52	0.0159
Sunset	4.42	0.0350

Table 4 PI controller parameters of the sunrise, sunset and midday sequence
Source: Own elaboration

Once the PI control of Table 4 is obtained for each of the cases of interest, they are changed to discrete time using equation (6) as shown in Table 5.

Sequence	K_p	$\frac{K_i T_s}{2}$
Sunrise	3.76	0.1837
Half day	1.52	0.03975
Sunset	4.42	0.0875

Table 5 Discrete-time PI controller
Source: Own elaboration

Finally, from the results in Table 5 and using Equation 7, a discrete PI controller capable of being implemented on a microcontroller as in Table 6 results.

Sequence	Difference equation
Sunrise	$u_k=u_{k-1}+3.76(e_k-e_{k-1})+0.1837(e_k+e_{k-1})$
Half day	$u_k=u_{k-1}+1.52(e_k-e_{k-1})+0.0397(e_k+e_{k-1})$
Sunset	$u_k=u_{k-1}+4.42(e_k-e_{k-1})+0.0875(e_k+e_{k-1})$

Table 6 Difference equation of the PI controller
Source: Own elaboration

Results

To verify the effectiveness of the implemented method, the results of the aging chamber control are compared individually with respect to the simulation, the equations in Table 3 are implemented. For the case of the sunrise, midday and sunset cycle, the equations in Table 6 are programmed in a microcontroller according to the aging cycle shown in Table 1, following the ASTM D-4329 standard, where it can be observed that they have a similar behavior with respect to the simulation and reaching a temperature of 60 °C in an approximate time of 250 seconds for the dawn sequence the temperature in the establishment time has an error of less than 1% as shown in figure 7, similarly happens in the half day cycle as shown in figure 8 in the case of the sunset sequence has an establishment time of 400 seconds as shown in figure 9 with an establishment error similar to the previous cases.

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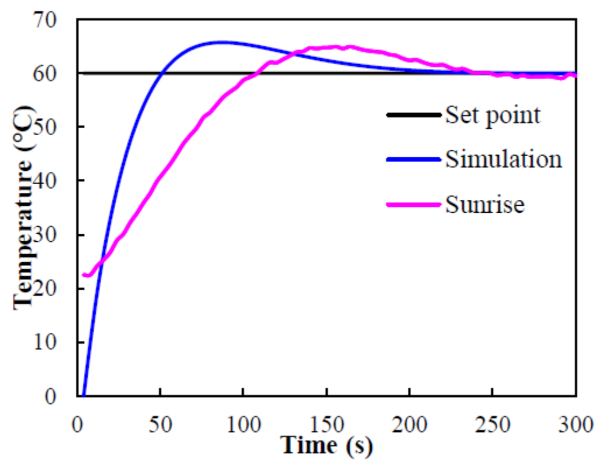

Figure 7 Simulation vs. real system of the sunrise cycle
Source: Own elaboration

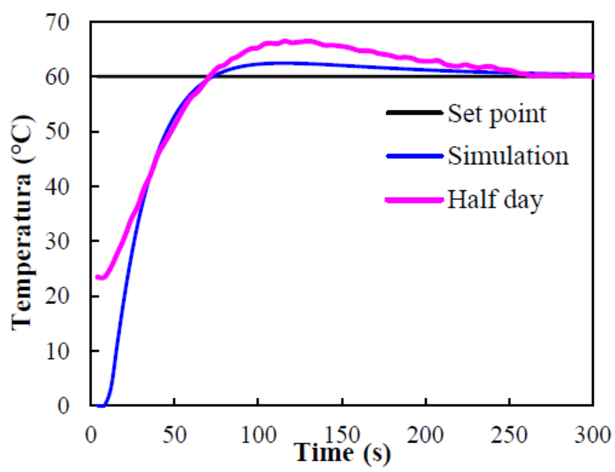

Figure 8 Simulation vs. real system of the half-day cycle
Source: Own elaboration

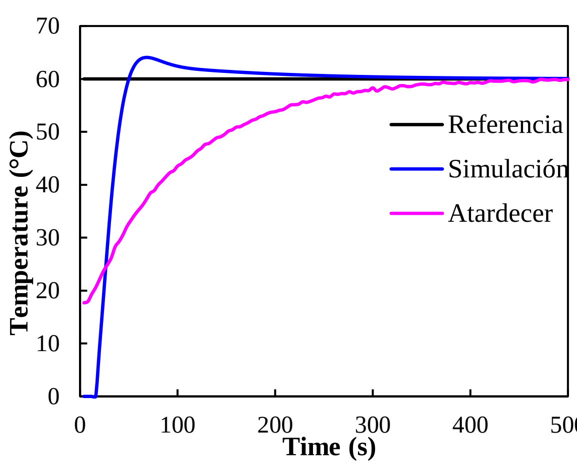

Figure 9 Simulation vs. real system of the sunset cycle
Source: Own elaboration

Finally, the control is implemented in the plastic aging chamber as shown in Figure 10, which shows the effectiveness of the method.

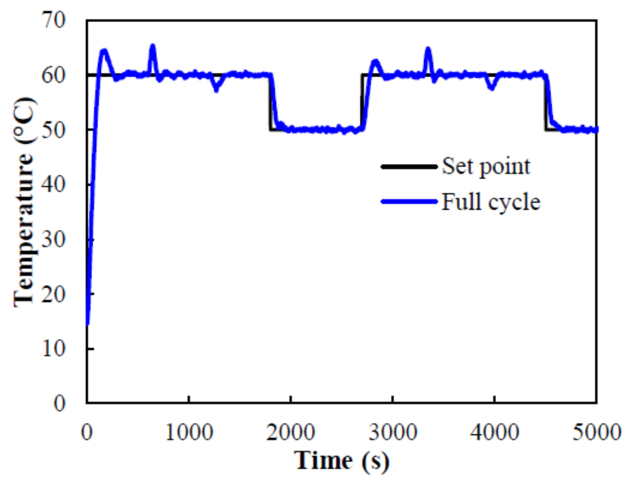

Figure 10 Cycle inside the aging chamber
Source: Own elaboration

Figure 10 shows two operating cycles of the chamber where the operating ranges were maintained within the parameters of the ASTM D-4329 standard, the algorithm used takes into account the different lighting sequences for the luminaires (see Table 1).

Conclusions

In this work a PI control is developed for a plastic aging chamber under the ASTM D-4329 standard, which consists of the development of three transfer functions that are used as the work cycle develops.

Having a different system dynamics for each half duty cycle (dawn, midday and dusk) it is necessary to implement in the microcontroller three actions or duty controls, this is possible by converting the PI controller in discrete time (z) and by a difference expression that can be interpreted by the microcontroller as a PWM value of the luminaires drive.

Temperature plays an important role in plastic aging, but it is not the only factor affecting degradation, other elements contributing to plastic degradation are humidity and UV rays, which will be considered and included in the control routine in future work.

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Saponification index determines the efficiency in the transesterification process in the production of biodiesel

Índice de saponificación determina la eficiencia en el proceso de transesterificación en la producción de biodiesel

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Abstract

For the production of biodiesel from a mixture of used edible oils, the saponification index has played an important role in the elaboration and particularities of biodiesel in its transesterification process by alkaline methanolysis, reaction temperature 35 ° C and molar ratio 6 :1. The objective is to determine the saponification index of used edible oils, from the El Cafecito cafeteria located in the ITCancún, to prevent the free fatty acids from the transesterification process from saponifying, being the causes of saponification the excess of catalyst, or Due to poor treatment in the elimination of the water content in the used edible oil samples, it considerably affects the biodiesel process. The methodology used was based on the analysis of national and international standards in the Determination of the Saponification index by means of the Covenin 323 standard of the NMX-F-174-SCFI-2014, - AOCS Cd 3-25, to the 6 samples of used edible oils. The results of the saponification index test are not acceptable since to saponify said raw material requires a large amount of potassium hydroxide. The contribution is to prevent used edible oils from contaminating the water table, due to its poor disposal.

Saponification index, Biodiesel, Used edible oils

Resumen

Para la producción de biodiesel a partir de una mezcla de aceites comestibles usados, el índice de saponificación ha jugado un papel importante en la elaboración y particularidades del biodiesel en su proceso de transesterificación por metanolisis alcalina, temperatura de reacción 35°C y relación molar 6:1. El objetivo es determinar el índice de saponificación de los aceites comestibles usados, procedentes de la cafetería El Cafecito ubicado en el ITCancún, para evitar que los ácidos grasos libres del proceso de transesterificación saponifique, siendo las causas de la saponificación el exceso de catalizador, o por mal tratamiento en la eliminación del contenido agua en las muestras de aceite comestibles usados, afecta de forma considerable al proceso del biodiésel. La metodología usada se basó en el análisis de las normas nacionales como internacionales en la Determinación del índice de Saponificación mediante la norma Covenin 323, de la NMX-F-174-SCFI-2014, - AOCS Cd 3-25, a las 6 muestras de aceites comestibles usados. Los resultados de la prueba de índice de saponificación no son aceptables ya que para saponificar dicha materia prima requiere de una gran cantidad de hidróxido de potasio. contribución es evitar que los aceites comestibles usados lleguen a contaminar el manto freático, por una mala disposición de este.

Índice de saponificación, Biodiesel, Aceites comestibles usados

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Introduction

Currently in Mexico, the lack of regulation for the proper disposal and management of used edible oils, has made the business of cheap kitchens not a system of good disposal and storage of their residual oils, as in homes, school cafeterias. They regularly dump them down the kitchen sinks and drains or, failing that, because they have been requested to do so, they are stored in containers that are not suitable, they may contain some residue, or after water, they take them to collection centers or to hire a company that goes through such wastes, see figure 1. It is considered that the properties depend on their temperature high caloric power of these used edible oils turn out to be a potential for the production of biofuels. Table 1 indicates the amount of oil collected for the development of this work

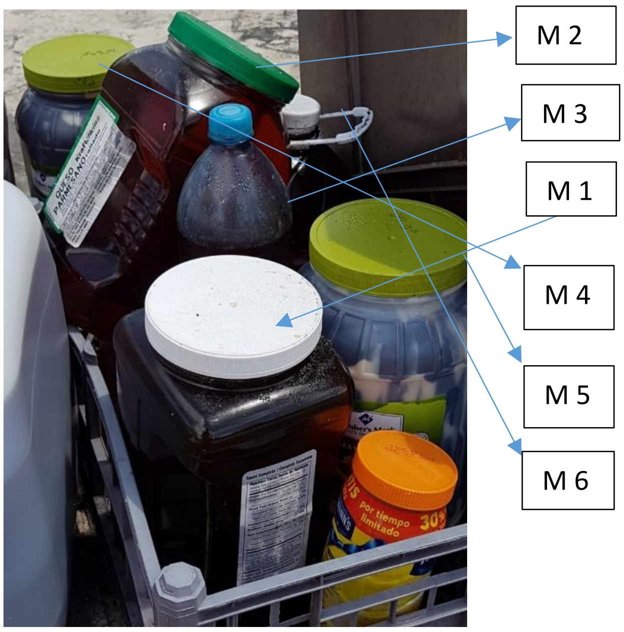

Figure 1 Disposition of used edible oils, in different types of containers, that they have at their disposal
Source; Own source

Oil collection (Samples)	Quantity	Remarks	Container
M 1	8 liters	Waste, black, musty odor, leaked from large amount of food waste	Plastic container, contained candy
M 2	8 liters	Unpleasant odor, black color,	Plastic container, residue contained candy
M 3	10 liters	Severely burned	2.5 l soft drink container
M 4	8 liters	Honey colored, low residue	Recent dark colored plastic
M 5	8 liters	Honey color, residues, unpleasant odors	Container contained juices
M 6	8 liters	Brown color, coarse residue The oil was filtered.	Mayonnaise and juice plastic container

Table 1 Oil collected in the Cafecito del ITCancún for 4 weeks, 2 liters of oils were collected, one week we collected up to 15 liters of oil distributed in the 6 samples, which was used to determine the IS (index saponification) parameter that we had not considered, to produce Biodiesel

The spills in the kitchen sinks cause the obstruction in the plumbing system, due to the adhesion of the fats, the residues end up in surface water bodies generating contamination of said bodies. Pan American Health Organization PAHO (2019) Others are dumped into bodies of water, wetlands, cenotes since there is no place to dispose of them or any company that collects these oils, this problem generally occurs in areas of irregular settlements, being one of the main pollutants in aquifers concerns oils and fats from urban areas. Taking into account that 1 L of oil contaminates around 1000 L of water. The effects generated by this pollutant are the proliferation of bad odors, infestation of execrations, damage to the ecosystem. Used cooking oil has to undergo a previous treatment in order to be transformed into biodiesel.

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The treatment necessary for this conversion begins with the filtration and decantation of the oil, its objective is to eliminate any possible solid food residue in the oil and then it is.

We proceed to eliminate the water content that it may have. Filtering is done with filters for coffee makers. Being of great importance that the oil does not contain water residues since during the alkaline reaction it becomes soap and a complete reaction does not occur to produce biodiesel, figure No.2.

Biodiesel Production is currently one of the best resources available, given that the food industry and the hotel and restaurant sector generate daily

Figure 2 Excess alkali in the transesterification process, soap formation
Source: Own source

High volumes of used vegetable oil, forming a problem from environmental perspectives, it has been estimated that each liter of edible oil that is discharged into the drain contaminates 1'000,000 liters of water (UNAM, 2016).

For this reason, the edible oil used is an excellent raw material in the elaboration of Biofuel with the processes of esterification, acid treatment, transesterification, alkaline treatment, and neutralization to obtain a biodiesel that complies with international parameters and standards.

Biodiesel is a highly biodegradable and water-friendly biofuel, much of it mineralizes in up to 30 days under aerobic or anaerobic conditions, it is also a carbon-free biofuel, since plants and seeds serve as raw material. For their production, they absorb all the carbon from which it is released during the burning of this Esquivel J. (2014), Durán, Torres, Sanhuenza, 2015 mention that the properties of the vegetable oils used depend on the type of oil, it is generally a low-cost oil, duration of cooking, temperature of the oil to which it is subjected during the frying process, time of exposure to air, storage period and conditions in which they are stored and sometimes have content of water and other types of substances such as the type of cooked food.

This does not lead to the transesterification process not being carried out satisfactorily, generating soaps due to water content, or the formation of an excess of glycerin formation, see figure no.3

Figure 3 Formation of soaps by water content when doing the alkaline treatment
Source: Own source

Methodology

Raw material

It is obtained in various places to obtain biodiesel, currently oil-producing algae and sargassum are being handled that in recent years have landed on the coasts of Mexico, the Caribbean Sea, used cooking vegetable oils and fats, it is obtained from school cafeterias, inexpensive kitchens.

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Physicochemical properties of the oil

Oils are characterized according to their physical properties: density, viscosity, melting point, refractive index, flash point, moisture index or chemical: acid number, iodine number, peroxide number, saponification number, unsaponifiable material.

Physical properties

Density:

According to the EN-14214 standard, density is defined as the quotient between the mass of a body and the volume it occupies.

Calculations

$\rho = R + .723 * (T° M-15)$

Where:

ρ = Density (Kg / m^3)
R = Hydrometer liquid level recorded (Kg / m^3)
T ° = Sample temperature (° C).

Kinematic viscosity

This method consists of measuring the time that takes a given volume of the liquid to flow through gravity through a calibrated glass capillary type viscometer at a temperature viscometer, C, by means of the following equation:

V 1.2 = C * t1.2

Where:

V1, 2 = Kinematic viscosity values determined for v1 and v2 (mm^2 / sec)

C = Viscometer calibration constant (mm2 / sec)

Melting point

Melting point (in open capillary tubes); slip point: temperature at which a column of fat in an open capillary tube begins to rise under the conditions specified in this Colombian technical standard NTC 213.

The immersion, in water or oil to a specific depth, of the capillary tube containing a column of fat, which has been crystallized under controlled conditions. The temperature is increases to a specific degree. The temperature at which the fat rises in the column.

Chemical Parameters

Saponification

The triglyceride reacts with the basic catalyst, consuming it, in the presence of water, giving rise to the formation of soaps (saponification reaction) when the amount of the catalyst has not been adequate, whether the catalyst is in excess and it has absorbed humidity from the environment, as can be seen in the chemical reaction as indicated stoichiometrically, see figure 4:

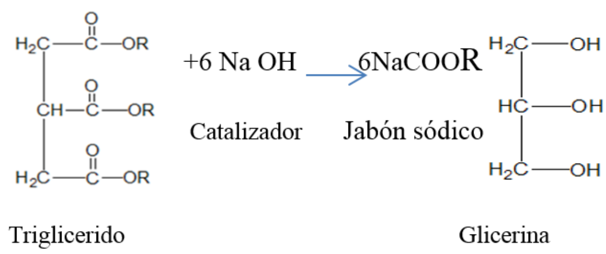

Figure 4 Stoichiometry of the reaction in soap formation
Source: Chang Raymond

Saponification index

The saponification value or index of an oil is the number of milligrams of potassium hydroxide (KOH) needed to completely saponify 1g of oil. Since oils are mainly made up of triglycerides, and each triglyceride needs 3 KOH molecules to saponify, the saponification index can be used to roughly estimate the average molecular weight of the oil used.

Saponification is essentially based on an alkaline hydrolysis of the glyceric esters of fatty acids present in a fatty substance, with the consequent formation of a soap. The above reaction is carried out in practice by the hot action of alcoholic potassium hydroxide, approximately 0.5 N, in sufficient quantity to achieve complete saponification. Uncombined excess alkali is determined by acidimetry in the presence of a suitable indicator, simultaneously a blank is performed for calculation purposes. Timberlake Karen C, 2013

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Unsaponifiable material

The unsaponifiable material comprises all the compounds contained in the oil or fat that do not react with KOH to produce soaps, that is, they are not fatty acids or glycerides but are soluble in organic solvents. Among the unsaponifiable materials most found in oils and fats are different compounds that contain phosphorus, such as Phospholipids and phosphates. If the oil has a high phosphorus content, emulsions are formed ´see figure no. 3 during the decantation process, separation of glycerin after transesterification and during biodiesel washing, which ultimately leads to losses in process performance.

A control of this parameter must be kept in each batch of oil that is taken to the collection center to produce biodiesel.

Oil pretreatment

There is a large amount of lower quality and lower cost oils and fats generally used in cheap kitchens, school cafeterias, crude vegetable oils, animal fats (lard) that become used oils, used in the production of biodiesel. The problem with processing this type of cheap raw material is that they usually contain free fatty acids, gums, humidity and other impurities that affect the alkaline transesterification process, since they present greater problems of emulsion, the washing process, drying, to eliminate the gums to avoid emulsions in the process, eliminate phosphates to reduce treatment costs and time, eliminate free fatty acids, performing the acid number analysis to facilitate the transesterification process based on the purification of the glycerin obtained.

Figure 5 Formation of emulsions in the process of transesterification of used edible oils, due to excess phosphates, presence of gums that were not eliminated with the washing treatment
Source: Own source

The raw material used edible oil provided by the Cafecito cafeteria, approximately 50 liters were collected which we use in the production of biodiesel in a period of one month as indicated in table No. 1, it was first filtered by gravity using a double coffee machine filter which allows to retain solids contained in the oil of up to 25µm, and to facilitate filtering, it was subjected to heating at a temperature of 80 ° C for 30 minutes to reduce the viscosity, as well as eliminate the water contained in the oil. Once the oil was filtered, we proceeded to characterize it and for this we proceeded to prepare the assembly of the experiments according to the following Mexican Standards (NMX) and / or international standards, ASTM and AOCS Ca 40, Covenin 323, OACS Cd 3-25 IRAM 5517/88 NMX-F-174-SCFI-2014, to choose the one that we would use before proceeding with the production of Biodiesel, and we do not have soap production when the alkaline catalyst is added.
Six samples that were collected in different weeks from the cafecito cafeteria located in the ITCancún were analyzed. From which a 100ml sample was taken from each one and given the filtering treatment to remove food remains, and the presence of any other substance present and washing to remove gums See figure 5

Figure 6 *Treatment of oil samples, to determine the saponification and unsaponifiable matter indices*
Source: Own source

The figure no. 6 indicates the amount of sample used after the treatment carried out to determine the saponification index.

Where the saponification index is inversely proportional to the value of the molecular weights of the fatty acids of the glycerides present in oils or fats. which is defined as the number of mg of KOH needed to saponify 1g of fat, it should be noted that it is not totally accurate for appreciate the molecular weight, since free fatty acids are included together with glycerides (OACSCd 3-25).

The Saponification index refers to the amount of potassium hydroxide expressed in milligrams, necessary to saponify a gram of oil or fat. To determine this parameter if you referenced the NMX-F-174-2006 standard, the method is based on the chemical reaction of triacylglycerols or triglycerides with an alkali, forming soaps or alkaline salts of fatty acids and glycerin. Saponification is used with potassium hydroxide, since its molecules contain the OH groups responsible for this reaction. In any case, essentially anhydrous oils and alcohols should be used since water favors the formation of soaps by saponification.

For this reason, the water must be removed, by evaporation, from the oils with high moisture contents before carrying out the transesterification. On the other hand, there are two ways to remove the free fatty acids present in the oil.

One by neutralization, since the fatty acids present in the vegetable oil can react with the basic catalyst NaOH in the presence of water, an undesirable reaction also occurring, producing soap as in the previous case, as can be seen in figure 3. Another is to eliminate the free fatty acids is carried out by the esterification reaction with an acid catalyst (H_2SO_4) with which the methyl ester is formed.

For the determination of the saponification index, the sample is heated under reflux with an alcoholic KOH solution for the time specified in the revised standards where the selected conditions depend on the difficulty of saponifying the sample. Once the sample is saponified, it is titrated until the end point of the retro valuation titration, which is clearer than that of the rapid direct titration. The equivalence point of the titration is determined by means of a pachymeter or, failing that, with pH paper strips, it greatly improves the repeatability of the tests.

The alcohol used is ethanol, it allowed us to manipulate the reaction temperature, the increase in the normality of KOH (0.5N) allows us to use saponification conditions, the increase in reaction time, to have quantitative saponification’s.

To do this, the reagent is added to the dissolved sample, and it is allowed to react for 10 min and 100 ° C for potassium hydroxide, heated under reflux for saponification for approximately 2 hrs or it can be less than 100 ° C. After the reaction is complete, a reagent is added to prepare the sample for titration. With .5M HCl, adding drops of phenolphthalein, a 5 g low-cost virgin sunflower oil blank was prepared with 25 ml of KOH, titrated with HCl at .5 N, with phenolphthalein until color change. See figure No.8.

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Figure 7 Reflux system for 2hrs of the sample with KOH

Saponification index: the analysis of this test was evaluated according to the Mexican Standard NMX-F-174-2014, 5 g of the samples were weighed, 25 ml of potassium hydroxide in alcoholic solution were added exactly measured with a volumetric pipette. A reflux condenser was adapted as shown in figure no.7, and it was placed in a boiling water bath for 60 minutes, stirring frequently. Once the 60-minute saponification was finished, 1ml of 1% phenolphthalein indicator solution was added, titrating it cold, with 0.5N hydrochloric acid. The end point of the titration was determined when the solution solidified due to the formation of soap, change of coloration, as indicated in the following figure No. 8 A control test is made using the same amount of reagent, the saponification index is calculated based on the following equation for the case of the three standards

$$Is = \frac{\text{B – M) x (N)}_1}{P} \times 56.1$$

Where:

B is the volume, mL 0.5 N HCl required to titrate the blank

M is the volume, mL 0.5 N HCl required to titrate the sample

N is the normality of the HCl solution

P is the weight of the sample in grams, and 56.1 is the equivalent of potassium hydroxide

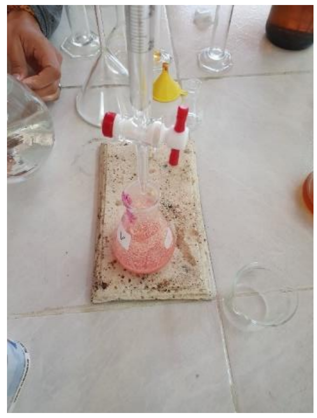

Figure 8 Titration of the sample with HCl with phenolphthalein color change, soap formation, sample no. 5

Source: Own source

The acid number of the reaction oil is determined to evaluate the amount of alkali to be added. In the process, it must be neutralized to a slightly acidic pH, in a range between 5 and 6, to avoid the formation of soaps that can affect the separation of the phases.

Results

The results obtained from the Saponification index parameter of the 6 samples of used edible oil from the cafecito cafeteria of ITCancún, 3 of the samples formed soaps, when subjected to the reflux process for 2 hours at 100 ° C in a Kjeldahl apparatus to that the heat is homogeneous for the sample, see figure 8. They were evaluated using the methods of the Official Association of Analytical Chemists (AOAC, for its acronym in English), Covenin 323, OACS Cd 3-25, NMX-F-174 -SCFI-2014.

The AGL reacted with the alkaline catalyst to produce soap and water, inducing the formation of emulsions. The presence of water can also cause the ester to saponify at alkaline pH. These reactions increase the amount of catalyst required to carry out alkaline transesterification and make biodiesel recovery and purification processes more difficult.

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Figure 9 Reflux system in the Kjeldahl apparatus in a time of 2 hrs, T = 100 ° C, samples 1, 5 formed soaps from the heat treatment
Source: Own source

The evaluation of the samples by titration with HCl .5M with phenolphthalein indicator, three replications were made, at the time of adding the phenolphthalein indicator, the titration changed from pink to completely white, as shown in the following figure no. 10 after adding phenolphthalein and titration, a white precipitate formed as shown in the figure, the volume used of 30 ml.

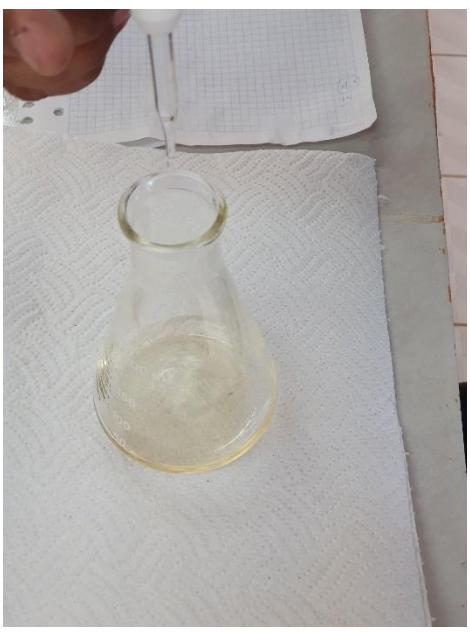

Figure 10 Titration of samples 1.5 with 0.5M HCl with the indicator, to indicate the change of vire, presents solid particles, which now of titration are completely white
Source: Own source.

When carrying out a search on the maximum permissible limits on the saponification index, and the composition of fatty acids, their limits are not set by virtue of being in this case a variable mixture of different oils, in the case of the standard. Different bibliographies manage that for saponification they have been manipulated compounds where the products are known, according to the theoretical value of the saponification index of 345 and 508 mg KOH / g sample respectively. The value of the saponification index is determined by means of the following formula:

$$Is = \frac{\text{B} - \text{M}) \text{ x } (\text{N})_1}{P} \times 56.1$$

This parameter being of utmost importance since it determines the presence of humidity. It could not be carried out, due to pandemic conditions, since the yield of the reaction decreases, since the water reacts with the catalyst forming soap. Soaps are harmful because they contaminate the final product, and because they form very stable emulsions. For this reason, the least amount of water possible must be ensured during the process, which implies drying of the oil, which is more demanding when using used oil.

STANDARDS	RESULTS KOH mg/L		
OACS Cd 3-25	260		
	360		
	176		
	125		
	90		
	260		
Covenin 323	210		
	350		
	190		
	126		
	189		
	269		
NMX-F-174-SCFI-2014	200		
	329		
	180		
	132		
	198		
	278		
White	185	180	182
	OACSCd3-25 Covenin 323 NMX-F-174-SCFI-2014		

Table 2 Results obtained through the analysis carried out by the different international standards, such as the Mexican one, of the 6 oil samples from the Cafecito cafeteria of ITCancún, which does not show that the results of the 4 standards are very similar between. it is.
Source: Own source

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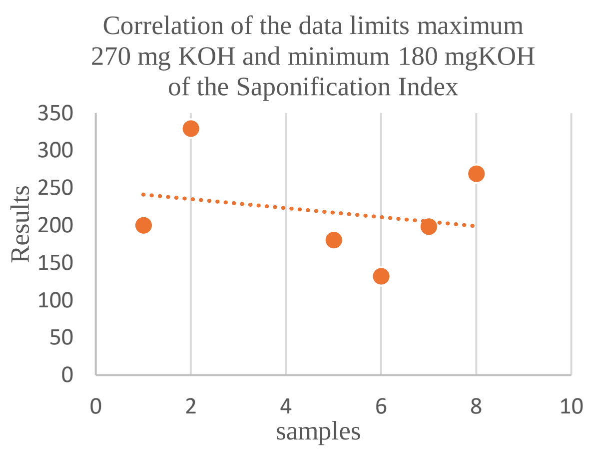
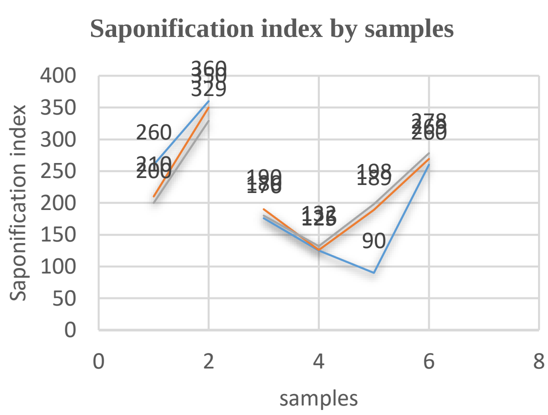
The following table no2 shows the results obtained for each sample of the oil collected from the Cafecito cafeteria of ITCancún by the standards used to choose which one is the best adapted to our experimental development. In the characterization of the physical-chemical parameters and to obtain a better quality of the biodiesel.

The following graphs show us the behavior of each sample with respect to each compared to the behavior of the results of the determination of the saponification index, to obtain a complete transesterification process without the formation of emulsions or soaps.

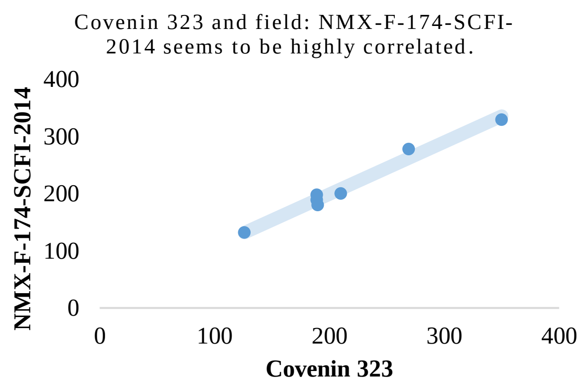


Graphic 1 comparison of the results obtained from the 6 shows with respect to the blank indicating maximum limits of 270 mg KOH and minimum of 180 of minimums. In accordance with the Ecuadorian regulation, of the physicochemical parameters in the production of biodiesel
Source: Own source



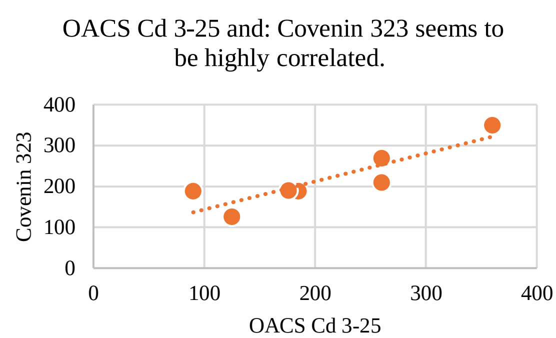
Graphic 2 The behavior of the 6 samples is observed with the data in relation to maximum and minimum limits
Source: Own source

We observe in the graph no. 2 that sample 5 has the lowest saponification index, which presents an excellent transesterification reaction, and therefore a good biofuel was obtained, with a molar ratio of 6: 1, reaction temperature of 40 ° C. In the graph no. 3, we establish a relationship between the Covenin 323 standards and field: NMX-F-174-SCFI-2014. We observe that the use of the methodology proposed in both standards we obtain similar results as well as the behavior in the treatment of each sample.



Graphic 3 According to the results obtained when using the methodologies proposed by each standard, we observe that the results are similar in 350 and 329, it may be the number of reagents used in each treatment. In the 200 and 210KOH mg data the difference is minimal
Source: Own source

When we compare the standards OACS Cd 3-25 and field: Covenin 323 we observe as in the case of the standards Covenin 323 and field: NMX-F-174-SCFI-2014, there are results that coincide 185, 188 KOH mg, although in both they have scattered points of the samples, 90, 125 KOH mg as indicated in graph number 4



Graphic 4 We can see that the standards that we choose to determine the saponification index are adequate, and they give us the same result, with minimal differences, with a similar behavior
Source: Own source

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The saponification index refers to the probability that a residual oil turns into soap, therefore, the higher the saponification index, the greater the probability of the presence of soap in the final transesterification product. The result obtained from the saponification index shows a decrease of almost 50% compared to the index of the oil with the highest presence in the raw material used in this project. This result allows us to intuit that our performance in obtaining biodiesel will be high as a consequence of the low soap index. Similar values were also observed with the work of Enweremadu & Mbarawa (2009), which report values of 0.921-0.937 as specific gravity and 193.9-204.3 for saponification index

Gratitude

I wish to express my gratitude TECNM / Campus ITCancún for the support it has provided for this work, in the use of the Water Laboratory and Chemistry laboratory

Conclusion

Saponification is a chemical reaction; the main product is a salt. constitute a very useful process for the transformation of fats and oils into soaps. The index that is calculated serves to assess the necessary quantities of potassium hydroxide to be used. It contains the edible oil used to produce biofuel and glycerin, we cannot fully deduce about the quality of the oil that has been used in the Cafecito cafeteria since they They take it to the laboratory for the production of biofuel, the used edible oil shows that it presents a higher degree of saturation in samples 2 and 6, since you do not know the conditions in which it was stored.

Regarding the maximum and minimum limits, assuming that the oil in the samples is girasol, la bibliografía consultada reporta que índice de saponificación 188 ,194 (mg KOH/g de aceite), ya que los aceites comestibles usados se they try a mixture of different types of oils, so each. Saponification index NMX-F-74-2006 90mg of KOH with respect to the author 190 mg of KOH (Bejumbea, 2003)

The soap content constitutes a parameter that evaluates the quality of the oil or fat and the edible oil used is a mixture of many oils. It is said that if an oil does not contain soap it has good quality, in this case the analyzed oil will obtain a better quality of the biofuel. Due to epidemiological conditions, acidity index, unsaponifiable matter could not be determined.
Any of the techniques used in the determination of the Saponification index we obtained results that national and international standards with small adaptations can reach the same result in terms of the quality of biodiesel.

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Classification and counting system for bacteria in microbiological culture media using image processing

Sistema de clasificación y recuento de bacterias en medios de cultivo microbiológicos mediante el procesamiento de imágenes

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Abstract

Monitoring water quality requires microbiological methods with the aim to provide to population, access to this essential source in appropriate conditions. Currently, conducting microbiological tests involves long periods of time and a high economic investment with the aim to identify and quantitatively determine the microorganisms in the medium. In this work, the use of image processing techniques involving K-means algorithm, Python language and OpenCV library are proposed in order to, through devices such as smartphones or conventional cameras, the samples can be analyzed through images, basing results on the morphological features of microorganisms in a specific growth medium, involving low cost as well as a reduced period of time. Specifically, the results obtained of *Escherichia coli* and *Salmonella Typhimurium* bacteria in Red Bile Violet agar are presented. The developed system was carried out detection and quantification of colonies of these microorganisms correctly. Also, it was possible to identify influencing factors during its operation, which allow to implement improvements to the proposed system.

Processing, Bacterial-counting, Classification

Resumen

El monitoreo de la calidad del agua requiere de métodos microbiológicos, con el propósito de brindar a la población el acceso a este recurso esencial en las condiciones adecuadas. Actualmente, la realización de ensayos microbiológicos involucra largos períodos de tiempo y una alta inversión económica para lograr identificar y determinar cuantitativamente, los microorganismos que se encuentran en el medio. En el presente trabajo, se propone como alternativa, la utilización de técnicas en procesamiento de imágenes que involucran el algoritmo K-means, el lenguaje Python y la librería OpenCV para que, a través de dispositivos tales como teléfonos inteligentes o cámaras convencionales, puedan ser analizadas las muestras a través de imágenes, basando los resultados en las características morfológicas que presentan los microorganismos en un medio de cultivo específico, implicando con ello, una disminución en el costo y un período de tiempo reducido. Concretamente, se presentan los resultados obtenidos para las bacterias: *Escherichia coli* y *Salmonella Typhimurium* en ágar Rojo Bilis Violeta. El sistema desarrollado realiza la correcta detección y el conteo de colonias de estos microorganismos; adicionalmente, se lograron identificar aquellos factores que influenciaban durante su operación, lo cual permitirá implementar mejoras a lo propuesto.

Procesamiento, Conteo-bacteriano, Clasificación

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Introduction

According to experts of United Nations, universal access to water is vital for the human being, in enough quantity and under stablished quality standards (ONU-DAES, 2014). Despite this, in 2019 the World Health Organization declared that, globally, 842,000 people died annually as a result of unsafe water, poor sanitation or inappropriate hygiene during hand washing; additionally, in vulnerable countries it was detected that 22% of hospitals did not have water supply and more than 2 billion people satisfy their needs from contaminated sources containing feces.

The pandemic caused by Covid-19 has shown that, availability of water source is essential for the consumption and hygiene of everyone and at the same time, it represents an important vulnerability factor in health. Water problem was significantly accentuated due to confinement; for those who lacked an adequate water supply, the situation became extremely complex because this resource was required to attend to basic preventive measures such as hand washing and ensuring cleanliness of spaces in order to reduce the contagion from Covid-19 to the maximum extent possible (Maganda, 2020). Additionally, those who used contaminated water trying to prevent virus were exposed to diseases caused by other pathogenic microorganism contained in it (UN, 2020).

In this respect, microbiological monitoring plays a determining role in water quality and, it is important to ensure that supply of the source does not imply a risk health for population. Its implementation requires different stages among which, experimental tests are carrying out for identification of microorganisms contained in water and their corresponding concentration (Colony Forming Units, CFU).

Figure 1 presents the scheme to follow the implementation of the plate count technique applied to water (Sánchez *et al.*, 2017). In it, from a water sample of interest, 1:10 serial dilutions are prepared. Subsequently, from each dilution, 100 µL volume of aliquot is extracted, emptied and distributed into a Petri dish containing the solidified culture medium, in order to carry out the inoculation through the uniform spreading of liquid.

Then, Petri dish is inverted and entered into the incubation process. After the period under appropriate conditions, qualified personnel must manually, with the support of a counting camera, quantify hundreds of bacteria colonies, as well as verify their characteristics in order to contribute to the emission of a reliable microbiological diagnosis (Chen and Zhang, 2009). It is important to consider that, for each dilution, the inoculation in culture medium must be carried out in triplicate.

The microbiological procedure in general, requires long periods of time and a significant economic investment in terms of reactants and material requirements, it is therefore necessary to guarantee that the results generated are safe and reproducible.

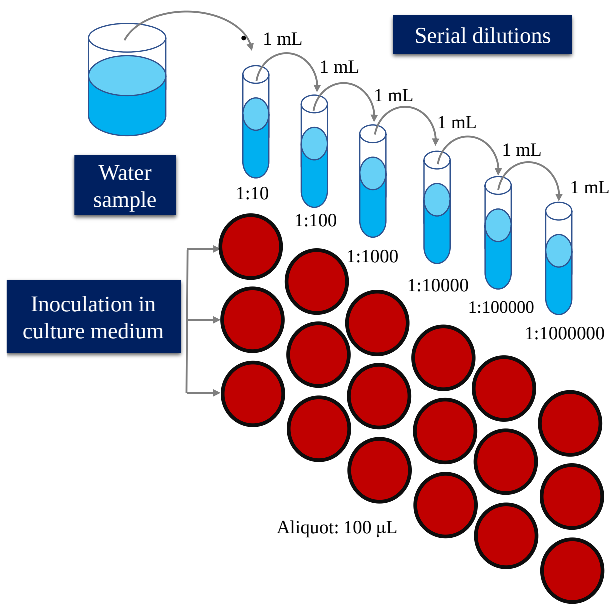

Figure 1 Implementation in plate count technique to a water sample

Currently, there are equipment on the market that has the technology to perform the task of detecting microorganisms and counting them; however, their cost is high, they require specialized maintenance as well as the allocation of a space under certain conditions and, are designed to operate only under stablished standards; eg. The size of Petri dish (Chen y Zhang, 2009; Sánchez *et al*., 2017).

Considering the above, the objective of this work is to contribute to the implementation of a system for detecting, classifying and counting bacterial colonies through image processing using K-means algorithm, Python language and the OpenCV library.

The tests carried out in this study were based on the growth on the culture medium Red Bile Violet Agar (RBV), of the bacterial microorganisms detected in a water sample generated from poultry activities: *Escherichia coli* (*E. coli*) and *Salmonella Typhimurium* (*S. Typhimurium*).

Stages for system development

The counting, morphological analysis and the growth response in a specific medium of bacterial colonies found in laboratory cultures, are repetitive and demanding tasks that require significant time to perform, even for the expert human eye.

This work focuses on the implementation of a system for the segmentation and counting of bacterial colonies through the use of image processing techniques, applied in color photographs, taken to bacterial cultures using smartphones or any conventional camera.
The first stage consists of testing a set of segmentation techniques to separate the bacterial colonies from the rest of the image sections that are not of interest. These techniques include: thresholding, edge extraction by Canny algorithm and clustering by K-means.

The second stage consists in the implementation of an automated bacterial colony detection and counting system that indicates in the original image the contour found for each of the colonies and, in turn, displays the final count of their number.

Testing techniques for segmentation

In this work, color images taken from a proprietary database were analyzed with cultures of *E. coli* and *S. Typhimurium* bacteria on RBV agar, whose coloration is reddish. This culture medium is characterized by being selective and differential, allowing only the growth of gram-negative and enteric bacteria. It is differential because it allows the type of bacteria to be distinguished by the color tones acquired by the colonies, which ranging from intense red through pink to colorless.

In the particular case of *E. coli* bacteria, the colonies are red or pink in color, while for *S. Typhimurium* colorless colonies are obtained.

Figure 2 shows an image belonging to the own database with a culture of *E. coli* and *S. Typhimurium* bacteria in 150 mm diameter of Petri dish using RBV agar.

The first method implemented for the separation of bacterial colonies is thresholding, corresponding to the simplest way of performing a segmentation process. The thresholding carried out consists of converting a RGB image to grayscale, performing an analysis of the frequency of intensities by means of the histogram in order to determine the possible range in which the intensities of the objects to be segmented are found. Once this has been done, a threshold is determined. If the intensity of a pixel exceeds the threshold, it will take the value of 255 (white); on the other hand, if it is below the threshold, it will take the value of 0 (black). Each pixel has an intensity set between 0 (black) and 255 (white) in a grayscale image.

Figure 2 *E. coli* and *S. Typhimurium* bacteria culture.

The thresholding carried out consists of converting a RGB image to grayscale, performing an analysis of the frequency of intensities by means of the histogram in order to determine the possible range in which the intensities of the objects to be segmented are found. Once this has been done, a threshold is determined. If the intensity of a pixel exceeds the threshold, it will take the value of 255 (white); on the other hand, if it is below the threshold, it will take the value of 0 (black). Each pixel has an intensity set between 0 (black) and 255 (white) in a grayscale image.

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The algorithm was applied to a subset of the culture database, resulting in the generation of a significant number of false positives, produced by bubbles, shadows, reflections, labeling marks, among others. The results are in agreement with those reported by Chen and Zhang (2009). Elements of different class, but with similar intensities in the histogram, can be easily segmented as of the same type.

Another important issue is the lighting conditions, which can considerably affect the performance of this approach. Additionally, color information is also lost when converting to grayscale, preventing the subsequent separation of different types of bacteria. Figure 3 shows the binary image produced by the thresholding algorithm applied to the culture in Figure 2.

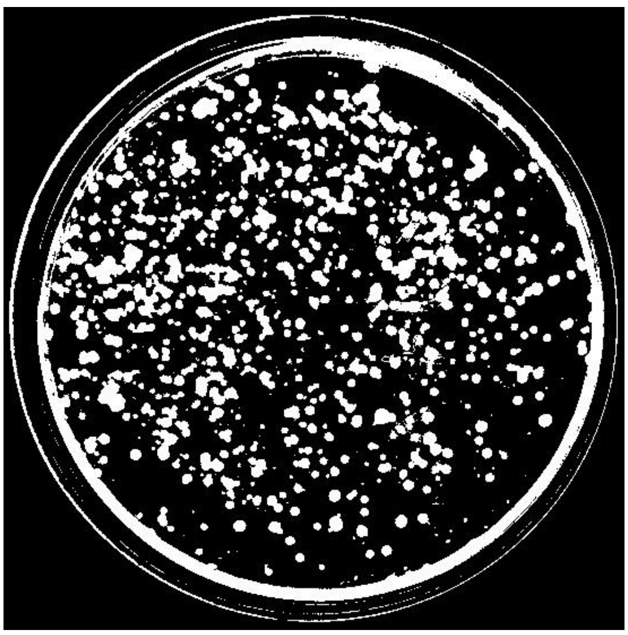

Figure 3 Segmentation produced by the thresholding algorithm applied to the culture in Fig. 2.

Traditional segmentation methods can temporarily solve a detection or counting problem under controlled conditions, always taking into account changes in the initial conditions and their calibration. Changes in brightness, agar type, bacterial class can lead to erroneous results if not taken into account.

There are more advanced techniques that enter the field of pattern recognition and artificial intelligence, capable of grouping pixels by their similarity of characteristics and proximity, without any a priori knowledge. Such algorithms fall into a type of learning known as unsupervised.

The image of a bacterial culture can be divided into an undetermined number of groups of pixels, related to each other by their nature. These groups may represent the type of bacteria or colony, background, culture medium, container vessel or some other class.

K-means corresponds to one of the simplest and most robust unsupervised learning clustering techniques used in data analysis. Because of this, it was chosen to be implemented in this work with the objective of separating the bacterial colonies from the rest of the image and not only that, to separate the colonies by the type of bacteria that make them up.

K-means clustering algorithm attempts to separate an anonymous data set without any class information, into a fixed number of K groups. The letter K corresponds to the number of centroids which are points at the center of each cluster.

Automatic system for classifying and counting bacteria

The results obtained by the K-means algorithm, allowed the segmentation of two different bacteria types, as shown in Figure 4 b) and c). Item b) corresponds to the segmentation of colonies for *S. Typhimurium* and c) corresponds to *E. coli*.

These images clearly separate both groups and therefore will be used in the implementation of the automatic colony counting and classification system, although they still need to be processed to be used effectively in this task.

The first step consists of converting images 4 a) and 4 b) into binary type images to be used as masks. For this purpose, a thresholding algorithm is implemented, whose threshold is set to a very low value.

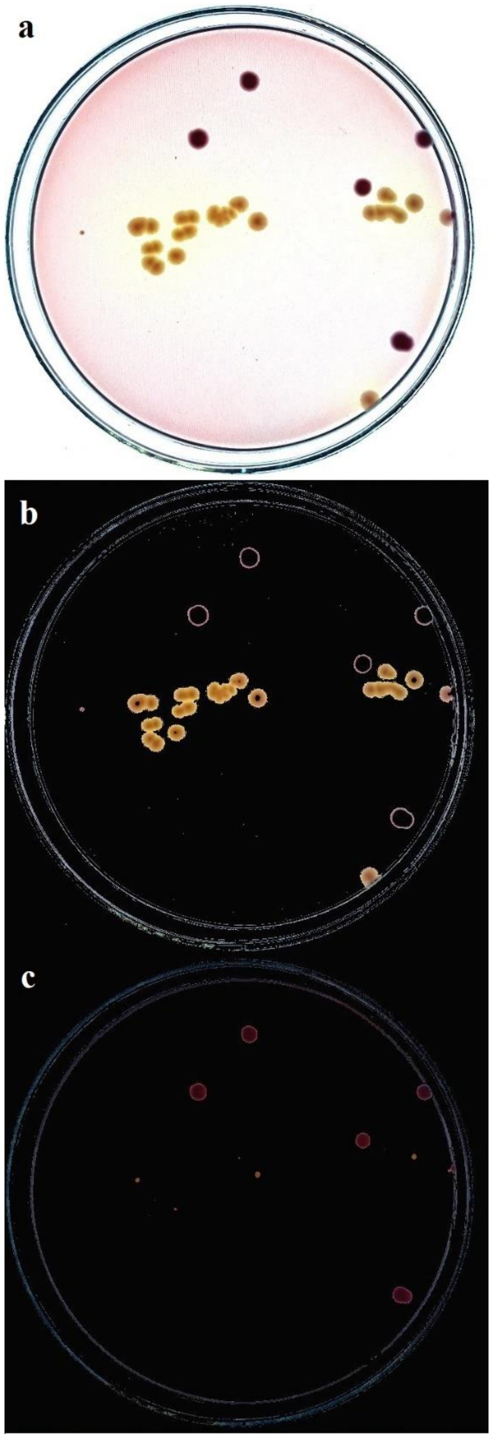

Figure 4 Segmentation produced by the K-means algorithm, showing a clear separation between colonies of a) *S. Typhimurium* and b) *E. coli*

The result can be seen in Figure 5. The masks obtained in the previous step contain noise generated in the classification process by K-means or even due to noise generated by the contours of the Petri dish, reflections and imperfections of the agar. That is why the masks need to undergo a filtering process, which is performed by morphological operations: erosion, dilation, opening and closing.

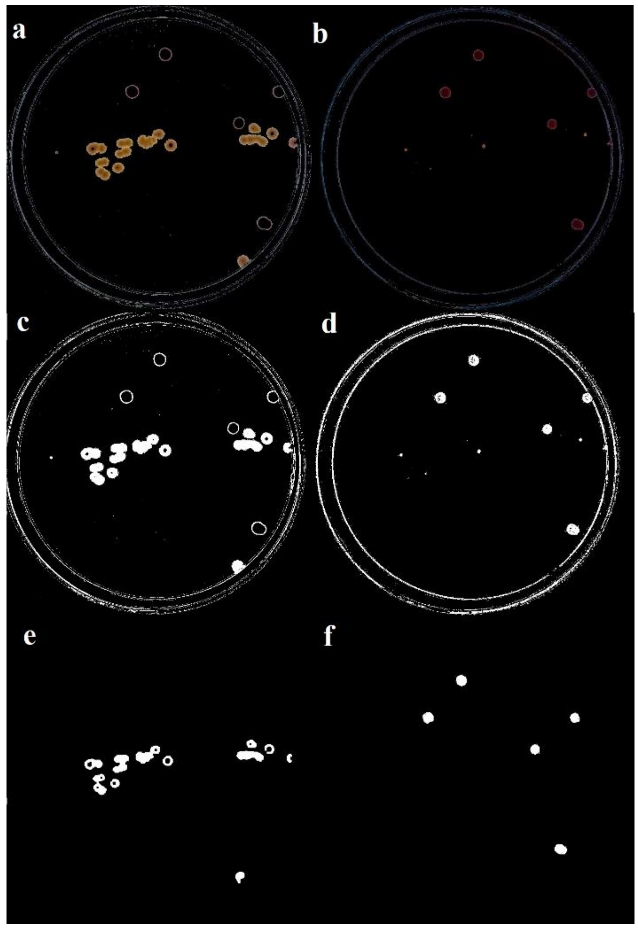

Figure 5 Implementation of binary masks: a) and b) K-means results. c) and d) Thresholding. e) and f) Application of morphological operations: erosion, dilation, opening and closing

The binary masks shown in Figure 5 e) and f) will be used for the classification of bacterial colonies corresponding to *S. Typhimurium* and *E. coli* in the original image, as well as allowing the separate counting of each type of colony. This was implemented using a contour detection and counting tool provided by the vision library: open CV.

Figure 6 shows the result of the classification and counting of bacterial colonies. Colonies belonging to *S. Typhimurium* were enclosed in a blue outline, while those belonging to *E. coli* were indicated by a green outline. The count of each colony type is displayed in the upper left part of the image, achieving a compatibility similar to manual counting.

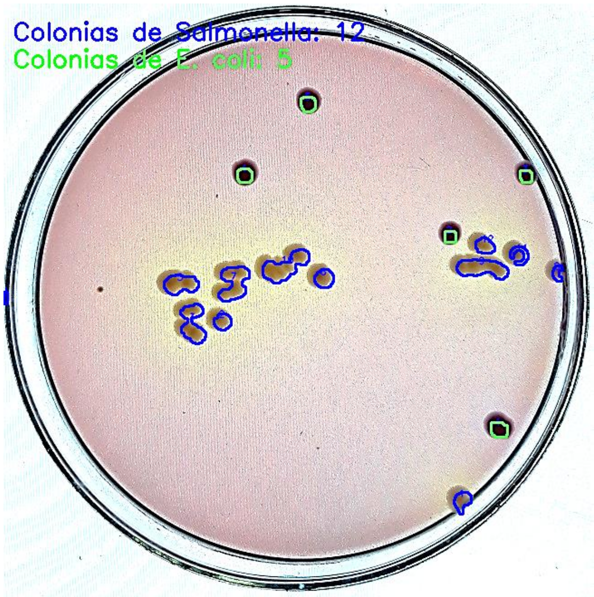

Figure 6 The culture image is submitted for analysis. The system draws an outline around each bacterial colony and distinguishes between two types of existing colonies, blue corresponding to *E. coli* and green to *S. Typhimurium.* The system counts each type of colony separately and displays the result on the image.

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Conclusions

In this work, a classifier and counter of bacterial colonies in laboratory cultures was successfully performed by processing images obtained with a smartphone.

The implementation of an unsupervised learning algorithm allowed, without prior training, to separate the bacterial colonies from the other elements of the image such as: the Petri dish, the agar, the background objects and the artifacts generated by the capture conditions. It was even possible to successfully segment the types of existing colonies, allowing their classification and counting by type.

The system was implemented using open source software, employs low-cost hardware and can be easily scaled for real-time operation through video analysis.

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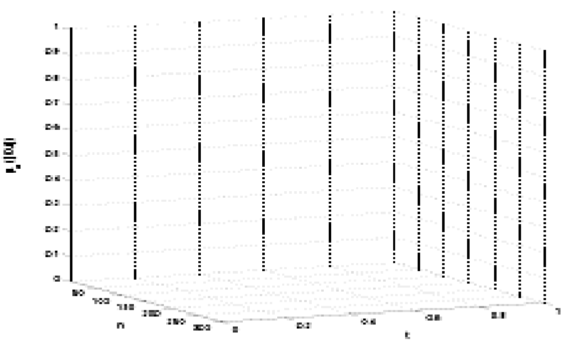

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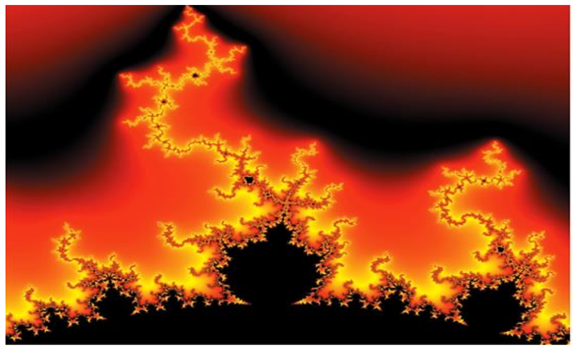

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