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CIERMMI Women in Science Engineering and Innovation

MARROQUÍN-DE JESÚS, Ángel
ALONSO-ARROYO, Juana
CHAVERO-ESTRELLA, Zulma Flor
CRUZ-CARPIO, Luis Eduardo

Coordinators

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ECORFAN CIERMMI Women in Science

Volume XX

The Handbook will offer volumes of selected contributions from researchers who contribute to the scientific dissemination activity of the Colegio de Ingenieros en Energías Renovables de Querétaro A.C. in their areas of research in Engineering and Innovation. In addition to having a total evaluation, in the hands of the directors of the Colegio de Ingenieros en Energías Renovables de Querétaro A.C., the quality and timeliness of its chapters, each individual contribution was refereed to international standards (RESEARCH GATE, MENDELEY, GOOGLE SCHOLAR and REDIB), the Handbook thus proposes to the academic community, recent reports on new developments in the most interesting and promising areas of research in the Science and Technology.

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MARROQUÍN-DE JESÚS, Ángel. PhD
ALONSO-ARROYO, Juana. PhD
CHAVERO-ESTRELLA, Zulma Flor. PhD
CRUZ-CARPIO, Luis Eduardo. BsC

Coordinators

CIERMMI Women in Science T-XX
Engineering and Innovation
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Prologue

Worldwide, according to UNESCO, women represent 33.3% of the people who conduct research research. To recognize this effort, the UN invites to celebrate the International Day of Women and Girls in Science every February 11, Women and Girls in Science every February 11.

In this context, there are many examples of women who have participated and continue to participate in the development of science in the world development of science in the world and in our country, from Hypatia of Alexandria, philosopher, astronomer and the first woman mathematician on record, who lived in approximately 300 A.D., to the contributions made by Marie Curie in the field of radioactivity, radioactivity, the the field of radioactivity, physics and chemistry, on the other hand, Ada Lovelace is considered the first woman programmer in history. Ada Lovelace is considered the first woman programmer in history, who used punched cards to control the printing of shapes on textiles control the printing of shapes on textiles. Mexico also recognizes the legacy left by women such as Sor Juana Inés de Sor Juana Inés de la Cruz, writer and poetess, who paved the way for many women in the path of literature and philosophy literature and philosophy. Matilde Montoya was the first Mexican physician. Helia Bravo Hollis, the first qualified biologist. Alejandra Jáidar Matalobos, the first woman to graduate in physics all of them made contributions in the scientific, literary or philosophical fields in our country country.

Nowadays, the participation of women in Engineering and Innovation is increasing, an example of this is the present book, which is the first book of its kind to be published of this is the present book, which compiles the works of Amanda Garzón, Adriana Garambullo, Yasmin Soto, Rosalia Bones, Lizbeth Salgado, Laura Cano, Annel Alvarez, Elisa Gonzaga and Hernandez Maldonado. Hernandez Maldonado, their contributions are focused on Engineering and Innovation, whose themes address real solutions to their contributions are focused on Engineering and Innovation, whose topics address real solutions to current problems in the environment where they develop their research where they develop their research; these solutions are oriented to the protection of the environment, the use of renewable energy the use of renewable energies, proposals to improve the living conditions of indigenous women, among others.

MORALES-HERNÁNDEZ, Maricela. MsC
Tecnológico Nacional de México / Instituto Tecnológico de Oaxaca

Introduction

The Colegio de Ingenieros en Energías Renovables de Querétaro A.C. (Colegio de Ingenieros en Energías Renovables de Querétaro A.C.) (CIER-QUERÉTARO), and its chapters of Renewable Energy, Industrial Maintenance, Mechatronics and Computer Science, technical sponsors of the International Interdisciplinary Congress on Renewable Energy, Maintenance, Mechatronics and Computer Science, CIERMMI 2021 has as general objective to establish a space for discussion and reflection on issues related to the areas of: renewable energy, industrial maintenance, mechatronics and computer science with the participation of students, professors, researchers and national and international speakers, promoting the formation and consolidation of research networks. Contributing to provide a space for dissemination and discussion of the presentations of students, graduates, academics and researchers, representatives of various higher education institutions, research centers in our country, as well as educational institutions beyond our borders. Promoting the formation of research networks between different institutions. Offering a space for undergraduate, master's, doctoral and postdoctoral students, in which they can present the progress of the research they carry out in their different educational centers. Providing a space in which study groups and members of academic bodies, linked to the curricular program of renewable energy, industrial maintenance, mechatronics and computer science careers, can present the research work developed within their institution and in collaboration with other national or international educational institutions. Establishing a training space for the attendees, through the development of specific lectures and conferences.

This volume, Women in Science T-XX-2022 contains 10 refereed chapters dealing with these issues, chosen from among the contributions, we gathered some researchers and graduate students from the 32 states of our country. We thank the reviewers for their feedback that contributed greatly in improving the book chapters for publication in these proceedings by reviewing the manuscripts that were submitted.

MARROQUÍN-DE JESÚS, Ángel. PhD
ALONSO-ARROYO, Juana. PhD
CHAVERO-ESTRELLA, Zulma Flor. PhD
CRUZ-CARPIO, Luis Eduardo. BsC
Coordinators

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Capítulo 1 Efecto de la irradiación simultánea de microondas-ultrasonido en la síntesis de óxidos mixtos derivados de hidrotalcita para la eliminación de As(III)

GARZÓN-PÉREZ, Amanda Stephanie[1], PAREDES-CARRERA, Silvia Patricia[2], VELÁZQUEZ-HERRERA, Franchescoli Didier[3] and ZARAZUA-AGUILAR, Yohuali[*4]

[1]*Instituto de Metalurgia, Universidad Autónoma de San Luis Potosí*
[2]*Laboratorio de Nanomateriales Sustentables, Escuela Superior de Ingeniería Química e Industrias Extractivas, Instituto Politécnico Nacional*
[3]*Laboratorio de Materiales Bioactivos, Facultad de Ciencias Químicas, Benemérita Universidad Autónoma de Puebla*
[4]*Unidad Académica Profesional Acolman, Universidad Autónoma del Estado de México*

ID 1st Author: *Amanda Stephanie, Garzón-Pérez* / **ORC ID**: 0000-0002-2349-7115, **CVU CONACYT ID:** 742764

ID 1st Co-author: *Silvia Patricia, Paredes-Carrera* / **ORC ID**: 0000-0002-5388-7982, **CVU CONACYT ID:** 37605

ID 2nd Co-author: *Franchescoli Didier, Velázquez-Herrera* / **ORC ID**: 0000-0001-6011-055X, **CVU CONACYT ID:** 488215

ID 3rd Co-author: *Yohuali, Zarazua-Aguilar* / **ORC ID**: 0000-0003-3788-4682, **CVU CONACYT ID:** 447394

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A. Garzón, S. Paredes, F. Velázquez and Y. Zarazua

*yzarazuaa@uaemex.mx

A. Marroquín, J. Alonso, Z. Chavero and L. Cruz (Coord) Engineering and Innovation. Handbooks-©ECORFAN-México, Querétaro, 2022.

Abstract

Inorganic arsenic water contamination turns out to be a serious problem worldwide. According to the World Health Organization (WHO), more than 140 million people worldwide consume water with high levels of arsenic, causing diseases such as cancer. Arsenic is found as As^{3+} ($As(OH)_3$) mainly in surface water effluents, which increases the interest in its removal with low-cost materials and regeneration capacity. For this reason, in this chapter, the study of As(III) adsorption on hydrotalcite-derived mixed oxides ZnAl, synthesized by an alternative simultaneous microwave/ultrasound irradiation method, followed by the formation of mixed oxides by calcination. The specific surface area of the calcined sample obtained by simultaneous irradiation was about 59 m^2/g, being higher compared to the individually irradiated materials, ultrasound, and microwaves, 20 and 50 m^2 /g, respectively. This indicated that the increase in the specific surface area was attributed to a synergistic effect promoted by combining the irradiation methods (microwaves-ultrasound). SEM images show that the morphology of the mixed oxides also depends on the irradiation mode used during the hydrotalcite synthesis, generating an arrangement of two phases of particles. Simultaneous irradiation provides a simple way to obtain materials with better textural properties in a short synthesis time and favors a high adsorption capacity (0.52 mg/g), compared to individually irradiated materials.

Synergistic, Synthesis, Mixed oxides, Arsenite, Simultaneous irradiation

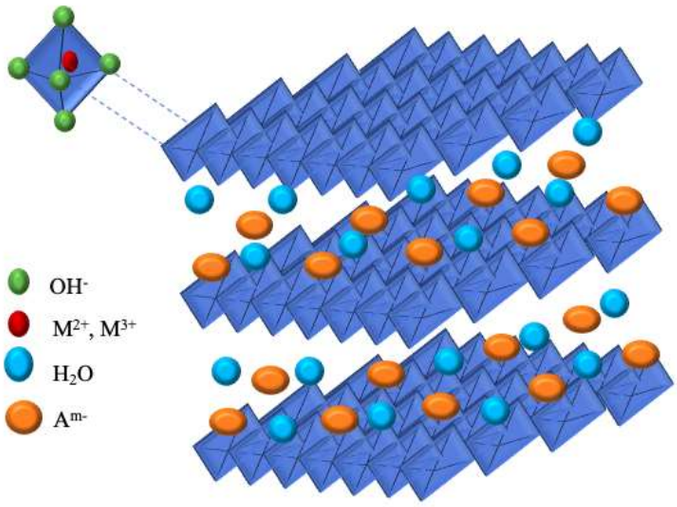
1 Introduction

Wastewater from the industrial production of glass, pesticides, pigments, textiles, and metallic adhesives, among others, usually contains inorganic contaminants like heavy metals (copper, aluminum, mercury, cadmium, and arsenic), are toxic in high concentrations and lead to serious health problems, mainly cancer (Sekabira et al., 2010). Therefore, arsenic removal from aqueous effluents is one of the most important challenges for industry and society. In general, treatment technologies are believed to be most effective using a two-step approach, consisting of the initial oxidation of As(III) to As(V), followed by a procedure for As(V) removal. Therefore, one-step As(III) removal is an excellent development for the industry because it can reduce process costs (Mohan & Pittman, 2007; Nicomel et al., 2015).

In recent years, various techniques have been tested for As(III) removal, such as physical-chemical and biological methods, ozonization, catalytic and photocatalytic degradation, and adsorption process. Adsorption is the most widely used removal method, as it is an easily applied technique and does not require the introduction of undesirable anions into the medium (Deschamps et al., 2003; Nicomel et al., 2015). Thus, it can be considered an economical and fast method for As(III) removal because adsorbent materials can be obtained on a large scale with low costs from nature or synthetically. The most commonly used adsorbents today are materials with large surface areas, such as alumina, silica gel, activated carbon, and clays (De Gisi et al., 2016) being anionic clays the most suitable due to their capacity to retain anions and, when calcined, they originate mixed oxides, which can be reconstructed in the initial structure of the hydrotalcite, capturing the anions during this process.

Anionic clays are natural or synthetic clays commonly designed as layered double hydroxides (LDH), hydrotalcite like-compounds or simply designed as hydrotalcites (HT). They are non-toxic, environmentally friendly and relatively inexpensive materials (Velázquez-Herrera, Lobo-Sánchez, et al., 2022). Its structure is similar to the brucite [$Mg(OH)_2$], where some Mg^{2+} atoms can be replaced by trivalent atoms, Figure 1, resulting in a general formula: $[M^{2+}_{1-x}M^{3+}_{x}(OH)_2](A^{m-})_{x/m} \cdot nH_2O$, where M^{2+} corresponds to a divalent cation (Mg^{2+}, Zn^{2+}, Ni^{2+}, Cu^{2+}) and M^{3+} corresponds to a trivalent cation (Al^{3+}, Cr^{3+}, Ga^{3+}, Fe^{3+}). A^{m-} is a compensation anion (CO_3^{2-}, SO_4^{2-}, Cl^-, NO_3^-), and x is the metal molar ratio $M^{3+}/(M^{2+}+M^{3+})$ (Ghashghaee et al., 2018; Nie, 2020; Velázquez-Herrera & Fetter, 2020).

Figure 1 Hydrotalcite structure representation



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As hydrotalcites are scarce in nature, they are usually synthesized through different methods such as coprecipitation, sol-gel, and urea hydrolysis (Conterosito et al., 2018; Lima-Corrêa et al., 2018). The most common method is coprecipitation at constant pH, followed by a crystallization step that can be proceeded by hydrothermal treatments in autoclaves or microwave or ultrasound irradiations apparatus (Garzón-Pérez et al., 2020; Zarazúa-Aguilar et al., 2018). Microwave and ultrasound irradiations allow obtaining particles of regular size and reduce crystallization times. With these irradiation techniques, textural and morphological properties of hydrotalcites can be controlled and improved for specific applications such as adsorption.

Another way to improve the adsorption capacity of the hydrotalcites is by the structural reconstruction method, *i.e.*, when hydrotalcites are calcined between 400−600 ºC, the layered structure breaks down, generating mixed oxides that are characterized by higher specific surface area and porosity compared to pristine materials. By rehydrating these oxides in the presence of anions such as those of As, the hydrotalcite regenerates its lamellar structure through the "Memory Effect" (Palomares et al., 2004; Velázquez-Herrera, Sampieri, et al., 2022).

Then, consider the adsorption characteristics of hydrotalcites and the increase of their specific surface area when calcined. In this work, ZnAl hydrotalcites in their mixed oxide form were synthesized by the coprecipitation method at constant pH, assisted by three different crystallization procedures: microwave irradiation, ultrasound irradiation, and synchronous irradiation mode (microwave and ultrasound), to compare their textural and morphological properties generated by the three crystallization methods in the retention of As(III) from aqueous solutions.

2 Methodology

2.1 Synthesis of hydrotalcites and mixed oxides

Hydrotalcite ZnAl was synthesized by coprecipitation at room temperature, constant pH 8 ± 0.5, and N_2 (42 psi) flow to avoid carbonates formation. Determining amounts of Zn (Sigma Aldrich, 98%) and Al (Caledon L.C., 98%) nitrates in a Zn/Al 1M solution with a molar metal ratio x=2.5. This solution was coprecipitated with a NaOH 1M solution (JT Baker, 97%). The resulting suspension was divided into three equal parts; each one was aged in a SBL CW-2000A reactor with microwave (800 W, 2.4 GHz), ultrasound (50 W, 40 kHz), and simultaneous (microwave/ultrasound) irradiation for 5 min. After crystallization treatment, the samples were washed with deionized water and dried in an oven at 70 °C. Subsequently, the samples were calcined at 450 °C in an air atmosphere for 8 h to obtain mixed oxides. Samples were identified with ZnAl to denote the pristine hydrotalcites, followed by U for ultrasound, M for microwave, and UM for synchronous irradiation. Letter C corresponds to calcined samples.

2.2 Materials Characterization

X-Ray Diffraction. The XRD spectra were obtained with a Rigaku Miniflex 600 diffractometer equipped with an X-ray tube with a copper anode with a linear focus of 0.60 W (40 kV and 15 mA). For calcined and uncalcined materials, the measurements were performed from 5 to 80º 2θ using a scan step size of 0.5º/min.

Fourier Transform Infrared Spectroscopy. Infrared spectra were recorded with a Perkin Elmer Spectrum 100 FT-IR with Universal ATR accessory fitted in a wavenumber interval of 4000 to 650 cm^{-1}.

Nitrogen Physisorption. The specific surface areas of the solids were determined by the BET method (Brunauer-Emmet and Teller) using a Gemini VII model 2390-t equipment. The sample pretreatment was carried out at 80°C for 2 h, followed by 12 h at 150°C with an N_2 atmosphere.

Scanning Electron Microscopy. Micrographics were obtained with a JEOL model JSM7800F scanning electron microscope at an acceleration of 3 eV.

2.3 As^{3+} adsorption

2.3.1 Adsorption experiments

The adsorption process was performed as follows: aliquots of 10 mL of an As(III) solution [$NaAsO_2$ (Sigma Aldrich, 90%)] (1 mg/L) were put in contact with 0.01 g of adsorbent for every contact time (30, 60, 90 min), for triplicated. All samples were stirred in a vortex shaker (Vortex-GENIE 2) and were filtered through a 45µm Teflon syringe filter. This procedure was repeated for each sorbent material. The filtered aliquots were quantified by forming iodine and measured by UV-Vis spectroscopy at 460 nm.

The adsorption capacity (q) of the materials was calculated according to the $q = (C_o - C_t)V/m$ *equation*, where V is the volume of the solution in litters, m is the mass of the adsorbent in grams, and C_o is the initial concentration and C_t the concentration at the desired time in mg/mL (Zhou et al., 2017).

2.3.2 Quantification of As^{3+}

The colorimetric detection and quantification of arsenic removal were performed by UV-Vis spectroscopy in a UV-Vis Halo DB-30 equipment with a10 mm quartz cells. The quantification process requires the formation of iodine (Pal et al., 1996; Pasha & Narayana, 2008). KIO_3 (Sigma Aldrich, 99.5%) at 2% and HCl (Fermont, 36.5%) at 1.8 mol/L were used for the formation of iodine. After filtration, 1 mL of KIO_3 and 0.5 mL of HCl were added to every As(III) remaining solution and were subjected to an ultrasonic bath for 5 min, obtaining yellow-colored species.

3 Results

3.1 Materials characterization

The XRD diffraction patterns of synthesized materials are shown in Figure 2. For uncalcined samples (Figure 2A), ZnAl-U, ZnAl-M, and ZnAl-UM samples spectra correspond to the layered zinc-aluminum double hydroxide material according to JCPDS 48-1023 pattern card at 10, 20, 34, 39, 60, and 61° 2θ corresponding to (003), (006), (012), (015), (110), and (113) crystallographic planes; this indicates that the synthesized samples present a rhombohedral crystalline symmetry (Cavani et al., 1991; Wu et al., 2012). Furthermore, the (110) and (113) crystallographic planes were shown as a single peak at 61° 2θ, attributed to an irregular distribution of the cations in the hydrotalcite lamellae (Velázquez-Herrera & Fetter, 2020). Figure 2B shows characteristic signals of ZnO according to the JCPDS 36-1451 reference card; reflections (400), (511), and (440) are observed at 44, 59, and 65° 2θ, corresponding to the spinel ($ZnAl_2O_4$). This indicates that the samples synthesized after calcined have mostly hexagonal crystalline symmetry (Macedo et al., 2017).

Figure 1 X-ray diffraction patterns of A) Hydrotalcites and B) Mixed oxides

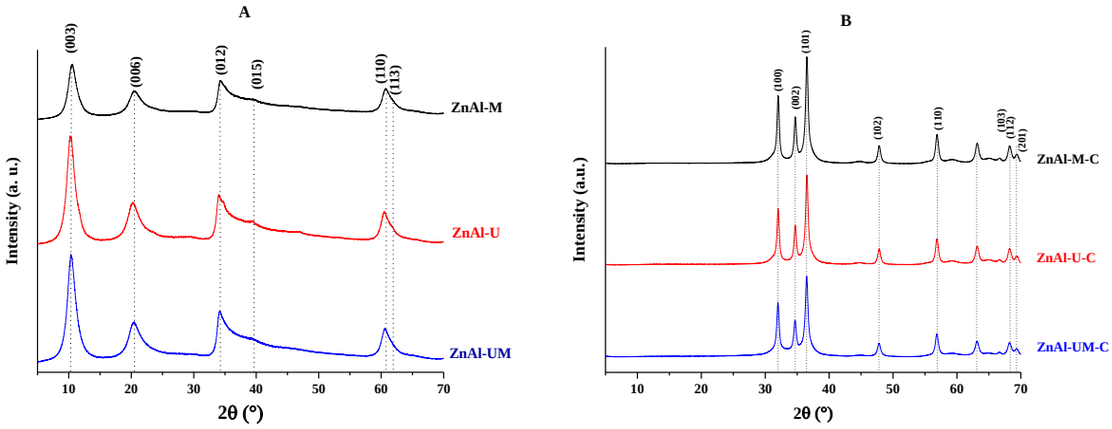

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Figure 2A shows that the crystalline ordering in the samples was affected by the irradiation type in the crystallization step. ZnAl-M sample exhibit signals with lower intensity and width peak, which corresponds to a lower ordering and crystal size, in contrast with ZnAl-U and ZnAl-UM samples, which present similar intensity and width signals (Paredes-Carrera et al., 2015), indicating that ultrasound irradiation favors the growth and crystals order due to the cavitation effect, which forms points of high pressure, and temperature, favoring the nucleation, orientation, and growth of the crystals in a greater proportion than microwave oven (Garzón-Pérez et al., 2020). In the case of simultaneous irradiation, ultrasonic irradiation was the predominant treatment, probably due to the application of a large amount of vibratory energy to small volumes, limiting the effect of the microwave (Flores-Cantera et al., 2022; Muñoz et al., 2017). In Figure 2B, the effect of the type of irradiation used during the crystallization stage is not appreciable for the mixed oxides.

Table 1 summarizes the structural parameters of the synthesized samples. The crystalline domain was calculated by the Debye-Scherrer equation, $D = 0.94\ \lambda/(\beta \cos\theta)$. Where D is the crystalline domain (nm), λ is the X-ray wavelength (0.15406 nm), β is the width of the peak at half the maximum height (rad), and θ is the Bragg angle (rad). Considering crystals with cubic symmetry and a spherical shape factor (Evans & Slade, 2006). For hydrotalcite, the 003 plane was considered, while for mixed oxides, the 002-plane belonged to ZnO.

Table 1 Structural parameters of samples synthesized

Hydrotalcites					Mixed oxides			
Sample	**$d_{(003)}$ (nm)**	**c (nm)**	**a (nm)**	**D (nm)**	**Sample**	**c (nm)**	**a (nm)**	**D (nm)**
ZnAl-M	0.83	2.56	0.304	4.6	ZnAl-MC	0.52	0.32	17.1
ZnAl-U	0.86	2.61	0.304	4.6	ZnAl-U-C	0.52	0.32	18.1
ZnAl-UM	0.85	2.58	0.304	4.8	ZnAl-UM-C	0.52	0.32	17.5
$d_{(003)}$ is the interlamellar space, a and c are structural parameters ($c = 3d_{(003)}$ and $a = 2d_{(110)}$ for hydrotalcite and, $c = 2d_{(002)}$ and $a = 2d_{(110)}$ for mixed oxides).								

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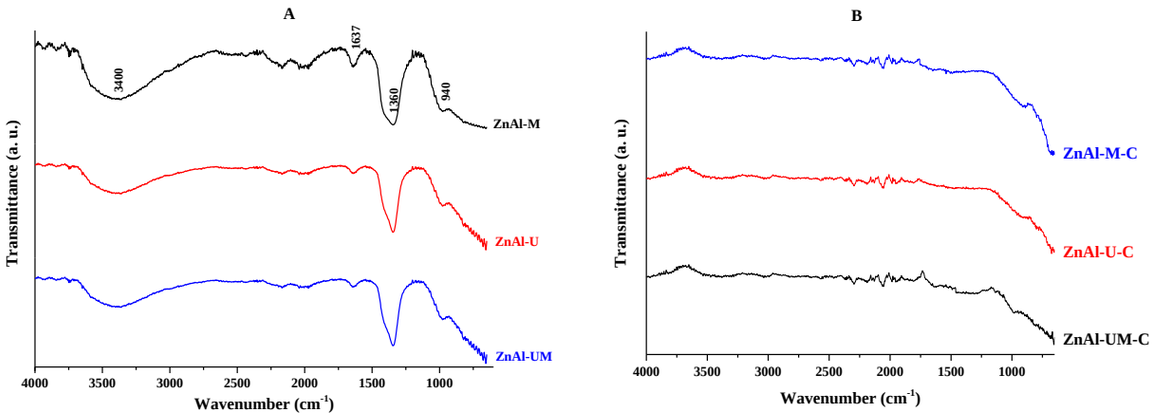
The crystalline domain, *D*, for the ZnAl-UM, ZnAl-U, and ZnAl-M samples is close to 4.7 nm, not showing a significant difference for the hydrotalcite, Table 1. Nevertheless, mixed oxides crystalline domains increased to 17.1, 18.1, and 17.5 nm for the ZnAl-M-C, ZnAl-U-C, and ZnAl-UM-C samples, respectively. It is common in mixed oxides as the hydrotalcite structure collapses, promoting an increase in the crystalline domain. Thus, large crystals of ZnO and $ZnAl_2O_4$ are obtained (Cavani et al., 1991). In the mixed oxides, these differences indicate simultaneous irradiation mostly favors the heterogeneous crystalline domain growth due to the cavitation effect of ultrasound. The temperature increase caused by microwaves generated a combined or synergistic effect in the crystalline domains (Garzón-Pérez et al., 2020).

The ZnAl-M, ZnAl-U, and ZnAl-UM samples had an interlayer distance (d_{003}) of 0.84 nm, showing that nitrates are the majority compensating anions. Thus, the lattice parameter *c* is about 2.6 nm, while the reflection (110) related to the lattice parameter *a* is 0.304 nm, corresponding to HT material (Velázquez-Herrera & Fetter, 2020). In the case of mixed oxides, the distance between planes of reflection (002) is related to the lattice parameter *c*. The distance between planes of reflection (110) is related to the lattice parameter *a*, being for all samples c = 0.52 nm and a = 0.32 nm, characteristic of mixed oxides derived from hydrotalcites (Aryanto et al., 2019; Macedo et al., 2017) and similar to zinc oxide.

Figure 3A shows the FTIR spectrum of the ZnAl-U, ZnAl-M, and ZnAl-UM samples. The bands at 3400 cm^{-1} and 1637 cm^{-1} are associated with the stretching and bending mode, respectively, of hydroxyl groups and interlayer water molecules. The strong signal at 1360 cm^{-1} is attributed to nitrates and carbonates in the interlaminar space (Wang et al., 2014). The bands that appear at 400-700 cm^{-1} correspond to the stretching of Zn-O and Al-O (Sommer et al., 2013). Figure 3B shows that the characteristic bands of hydrotalcite disappear for calcined materials, and only bands smaller than 1000 cm^{-1}, corresponding to the vibrations of metals with oxygen, are shown (Kirankumar & Sumathi, 2017).

Figure 3 FTIR spectra of the synthesized samples. A. Hydrotalcites and B. Mixed oxides



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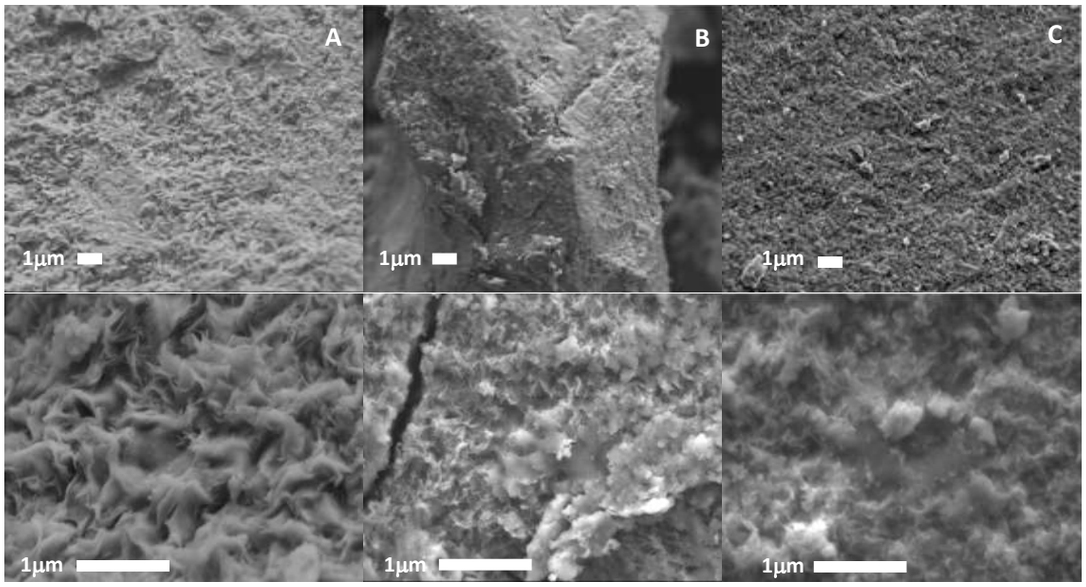
The differences observed in transmittance are dependent on the variation of the dipole moment of the molecules, with the coordinate of the vibration mode and the concentration of the molecules in the sample (Wang et al., 2014). Furthermore, samples do not show differences attributed to the crystallization method. Therefore, mixed oxides do not show differences concerning the synthesis method but confirm the correct formation of the hydrotalcite material.

Figure 4 shows the SEM images of the ZnAl-M, ZnAl-U, and ZnAl-UM samples. ZnAl-U sample, Figure 4B, shows a well-defined compact flake-like arrangement of hydrotalcite materials (Bergadà et al., 2007; Velázquez-Herrera et al., 2018). It can be appreciated lamellar sheets are about 50 nm. For the ZnAl-M sample, in Figure 4A, an irregular mix of flakes and chunks of particles on a smooth surface is observable (Zarazúa-Aguilar et al., 2018). Also, a low quantity of flake particles is barely perceptible. Furthermore, for the ZnAl-UM sample, Figure 4C, a homogeneous combination of flakes and chunks is obtained due to the variety of irradiations, which favors the heterogeneity of the particles. Furthermore, can be appreciated the characteristics of ZnAl-M and ZnAl-U samples in different zones.

Figure 4 SEM images of synthesized samples: A. ZnAl-M, B. ZnAl-U, and C. ZnAl-UM. Magnifications are presented in order from top to bottom at 10000 and 25000 X



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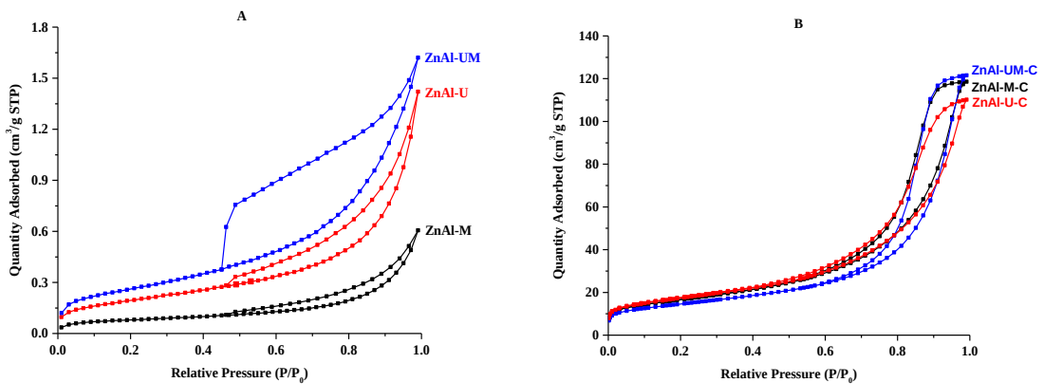
The ultrasound irradiation promotes platelet and compact particle arrangements due to the cavitation phenomenon (Morales-Zarate et al., 2018). On the other hand, the microwave method generates uniform surfaces with flakes that are attributed to the diffusion of ions and their rapid integration into the hydrotalcite sheets (Garzón-Pérez et al., 2020). Therefore, simultaneous irradiation (microwave/ultrasound) generates a regular distribution of particles from both irradiations (Garzón-Pérez et al., 2020). In general, morphological differences were attributed to the crystallization method

Figure 5A shows the nitrogen adsorption-desorption isotherms of ZnAl-M, ZnAl-U, and ZnAl-UM samples. All samples showed a Type IV isotherm (IUPAC classification) characteristic of mesoporous materials, with a hysteresis loop of the H1 type (IUPAC classification), which corresponds to aggregates of compact particles of lamellar materials (Seftel et al., 2008; Valente et al., 2009). The specific surface area BET of uncalcined samples was 1 m^2/g. These results agreed with those reported for hydrotalcite containing Zn cations and interlayer nitrate anions (Velázquez-Herrera et al., 2018).

Figure 5 Nitrogen adsorption-desorption isotherms of the samples. A. Hydrotalcites and B. Mixed oxides



Source: "By the Authors"

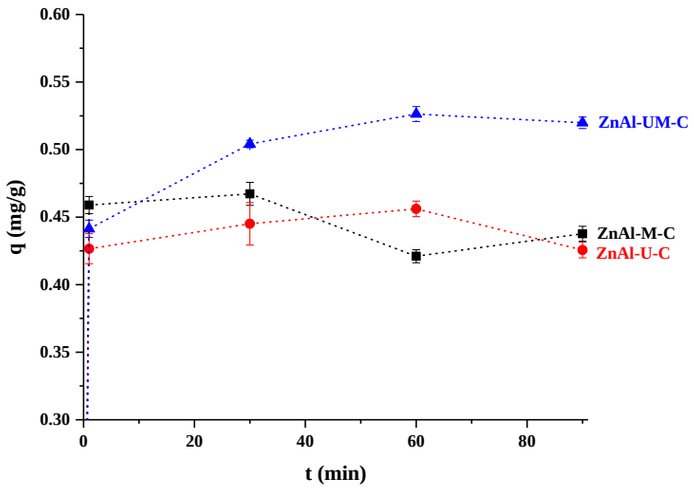
Mixed oxides, Figure 5B, showed a Type IV isotherm with a hysteresis loop of the H1 type (IUPAC classification) characteristic of mesoporous materials with large and narrow pore size distributions (Thommes et al., 2015).

The specific surface area BET increased from 1 to 20 m^2/g for the ZnAl-U-C, while for ZnAl-M-C increased to 50 m^2/g. As expected, ZnAl-UM-C surface area increased, achieving a value of 59 m^2/g, due to a combination of crystallization methods, *i.e.*, the well-defined particle arrangement of ZnAl-U-C is damaged after calcination, collapsing the porous hydrotalcite structure generating a compact arrangement and decreasing the specific surface area. However, for the ZnAl-MC sample, the surface particle arrangement is a mix of different irregular particles that, when calcined, preserve a disordered structure producing a large specific surface area (Rodrigues et al., 2003). Furthermore, tiny particles of both irradiation methods should be in a close, freely arranged interaction forming a cloud-like network, Figure 4C, as reported for composite materials where different mixed particles are obtained (Velázquez-Herrera et al., 2020). Thus, simultaneous irradiation in the crystallization step improves the specific surface area due to the agglomerate homogeneous particle distribution. In contrast, pore volume results similar for all ZnAl-M-C, ZnAl-U-C, and ZnAl-UM-C samples, about 0.18 cm^3/g, not showing the influence of the thermal treatment. However, the average pore size increased for the ZnAl-UM-C sample to 6.94 nm; this is in accordance with the specific surface area.

3.2 As (III) adsorption

Figure 6 shows As (III) adsorption capacity for the calcined samples expressed in mg/g *vs*. contact time. In the ZnAl-M-C and ZnAl-U-C samples, the adsorption capacity remained constant at 0.44 and 0.42 mg/g, respectively, while the ZnAl-UM-C sample increased adsorption capacity to about 0.52 mg/g.

Figure 6 The adsorption capacity of mixed oxides for As(III) removal



Source: "By the Authors"

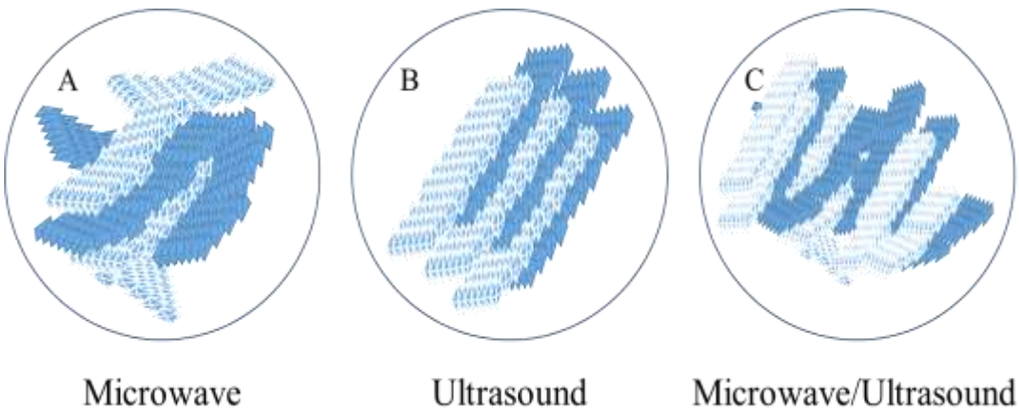
The simultaneously irradiated sample (ZnAl-UM-C) showed the highest adsorption capacity for As (III), which is attributed to the specific surface area, 59 m^2/g, and the heterogeneous dispersion of the particles. In addition, the differences found in the adsorption capacity per unit area, 0.021, 0.009, and 0.009 m^2/g for the ZnAl-U-C, ZnAl-M-C, and ZnAl-UM-C samples, respectively, suggest that the ZnAl-U-C sample presents a higher adsorption capacity per unit area than the other samples. This can be attributed to the type of physical adsorption that occurs in the pores, *i.e.*, the isotherms obtained are Type IV, in which the initial monolayer-multilayer adsorption occurs on the mesopore walls and is followed by pore condensation. On the other hand, the relative equality in adsorption per unit area of the ZnAl-M-C and ZnAl-UM-C samples agrees with the isotherms obtained, Figure 5, which are similar. Moreover, it is well known that the hydrotalcite adsorption properties increase considerably if the hydrotalcite is calcined to form mixed oxides (Blanch-Raga et al., 2014).

Therefore, the adsorption capacity can be explained by several factors; the first one is related to the nature of Zn, which, it has been demonstrated that in its oxide form, has a great affinity to adsorb heavy metals (Gu et al., 2020). Secondly, the pore size, which is related to the synthesis method, is observed to increase with simultaneous irradiation, as shown in the SEM images (Figure 4) and verified by nitrogen adsorption-desorption (Figure 5).

Then, simultaneous irradiation generates materials with better textural properties than materials using single irradiation. Consequently, the adsorption of As(III) from aqueous solutions was promoted. Thirdly, the specific surface area allows As(III) ions to distribute on the surface of the mixed oxides. Fourth, it has been reported that particle size influences the adsorption process (Yang et al., 2006). In this case, the calcined samples have a particle size close to 17.5 nm, larger than the uncalcined hydrotalcite, about 4.7 nm. However, the particle arrangement to form the agglomerates was different for each sample, *i.e.*, sample ZnAl-UM-C (Figure 4) showed a combination of two-particle phases generated by both irradiations, Figure 7C, which increases the probability of access of As(III) molecules to the pores of the material.

Ultrasound irradiation generated a uniform distribution of particles, generating a compact agglomerate, Figure 7B, which probably hinders adsorption, whereas microwave irradiation generates not highly ordered agglomerates, Figure 7A. In addition, another aspect being considered is the synthesis process of the hydrotalcite precursors of the mixed oxides. This aspect can be explained in terms of the nature of both irradiations: microwave electromagnetic radiation travels with the speed of light, providing an amount of energy lower than that needed to break a chemical bond (Kumar et al., 2020), which distorts the structure of the material, while ultrasound waves have a high frequency, 40 kHz, which, compared to microwaves is low, so this radiation is confined to the surface of the particles, hindering the cavitation phenomenon (Rezk et al., 2021) and favoring the size of the pores, generating two phases of particles. Thus, the adsorption process contributes to the synthesis method. A simultaneous irradiation method promotes a synergistic state between microwaves and ultrasound in terms of morphology and texture.

Figure 7 Irradiation effect in the particle distribution of the hydrotalcite agglomerate



Source: "By the Authors"

To get an idea of the actual adsorption capacity of materials, before calcination and considering the EDS technique, the synthesized ZnAl-hydrotalcites can exchange anions in the interlaminar space up to about 0.41 g_{AsO2}/g_{HT} in the lamellar space, which is higher than what has been reported by other authors (Ramos-Ramírez et al., 2014; Yadav et al., 2017).

4 Conclusion

To sum up, the As(III) removal process resulted from a contribution of particle size, surface adsorption, and the crystallization method (microwave, ultrasound, and simultaneous irradiation). In comparison, microwave irradiation promotes a compact uniform arrangement of particles that increase the specific surface area BET through the improvement of cation diffusion within hydrotalcite lamellae. At the same time, ultrasound generates a distortion in the hydrotalcite lamellae promoting an irregular arrangement of particles that decreases the specific surface area BET, which originated by the cavitation phenom. Therefore, the simultaneous irradiation, microwave/ultrasound, enhances the effect of both irradiations, generating two phases of particles within the agglomerate, which increases the specific surface area BET. This improvement allows obtaining superior materials for the As(III) adsorption process, with which adsorptions of up to 0.52 mg/g in 30 min.

Furthermore, this work provides a simple way to obtain superior materials in a short synthesis time with many potential applications such as catalysts, adsorbents, and others, inclusive in the pharmaceutical industry such as controlled drug liberation.

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Chapter 2 Detection of minor stoppages in the packaging area of a brewing company in the town of Tecate B.C.

Capítulo 2 Detección de paros menores en el área de envasado, de una empresa cervecera de la localidad de Tecate B.C.

GARAMBULLO, Adriana, ACOSTA-MARTÍNEZ, Alejandro, PLAZOLA-RIVERA, Teresa and APODACA-DEL ANGEL, Lourdes

Faculty of Engineering, Administrative and Social Sciences, Autonomous University of Baja California, Mexico

ID 1st Author: *Adriana, Garambullo* / **ORC ID:** 0000-0002-1440-2276, **CVU CONACYT ID**: 397642

ID 1st Coauthor: *Alejandro, Acosta-Martínez* / **ORC ID**: 0000-0001-5440-034X

ID 2nd Coauthor: *Teresa de Jesús, Plazola-Rivera* / **ORC ID**: 0000-0002-5266-7021, **CVU CONACYT ID**: 277923

ID 3rd Coauthor: *Lourdes Evelyn, Apodaca-Del Angel* / **ORC ID**: 0000-0001-9349-7754, **CVU CONACYT ID**: 215689

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Abstract

The present research consisted of analyzing the packaging area of a brewery company in the town of Tecate BC, in order to detect the root cause of the minor stoppages that occur more frequently in the sub-areas where glass bottles pass through, and thus generate a corrective measure at the specific point where the process stops, since this has a direct impact on the useful time of annual beer production in this presentation. This project consisted of developing a series of activities that allowed planning how to attack the previously explained problem. With the help of the Deming Cycle methodology, Kaizen and quality tools such as Pareto Diagrams, Check Sheets and Standard Operation Sheets, to provide an optimal solution to this problem. The results show that with the tools provided, 91% of the 285.15 minutes that to date are accumulated by minor stoppages were eradicated and notably decreased, this is equivalent to an economic saving of $ 76,990.50 pesos m.n., taking into account that currently each minute of production is valued at $ 270 pesos m.n.

Minor stoppages, Enterprise, Production engineering

Resumen

La presente investigación consistió en analizar el área de envasado de una empresa Cervecera de la localidad de Tecate B.C., con el fin de detectar la causa raíz de los paros menores que se presentan con mayor frecuencia en las sub-áreas por la que la botella de vidrio pasa, y así generar una medida correctiva en el punto específico en donde se detiene el proceso, ya que esto repercute de manera directa en el tiempo útil de producción anual de cerveza en esta presentación. Esta investigación consistió en elaborar una serie de actividades que permitieron planear como atacar la problemática previamente explicada. Con ayuda de la metodología de Ciclo de Deming, Kaizen y herramientas de calidad como los Diagramas de Pareto, Hojas de Verificación y Hojas Estándares de Operación, para dar solución óptima a dicha problemática. Los resultados demuestran que con las herramientas aportadas se erradico y disminuyó notablemente un 91% de los 285.15 minutos que a la fecha están acumulados por los paros menores, esto equivale a el ahorro económico de $76,990.50 pesos m.n. tomando en cuenta que actualmente cada minuto de producción está valorado en $270 pesos m.n.

Paros menores, Empresa, Ingeniería de la producción

1. Introduction

Maintenance and having the least amount of losses possible is a challenge that is worked on every day, it is one of the fundamental axes within the industry, it is quantified in the quantity and quality of production. It is an investment that helps improve and maintain quality in production.

This document gave way to the implementation of a project aimed at detecting, eliminating and reducing situations that are the cause of minor stoppages on the L-030 line (responsible for receiving the 355 ml glass bottles, filling them, placing their respective label and pack them according to the presentation with which you are working) which have a duration between 1 and 5 minutes in which production is interrupted to be attended and thus continue with production.

Within the brewing company, there are different production processes, there are lines that are aimed at brewing, others are responsible for packaging the product in its different presentations, either in aluminum cans or glass bottles. Line L003, also known as line number 30, is responsible for supplying the product in 355 ml glass bottles. For the company, this specific line has presented contingencies during the year, derived from failures in the machinery due to wear in its components, such as belts, gears, etc. As well as the so-called "minor stoppages", which occur when the equipment stops for a reason beyond its function, either due to broken bottles, stuck or non-compliance with the maintenance orders that the entity provides to the operators. These stoppages are called minor since they stop production for minutes, until the problem is fixed, for example, in the event that a bottle falls and jams more bottles, the stoppage will last until an operator correctly positions the cause of the problem. unemployment. Despite not having long durability, they occur frequently in the process, which should not happen, since it reduces the operational time of the line and, consequently, less final product is obtained.

Throughout the production day there are various minor stoppages on the line, which last between 1 and 5 minutes in which production is interrupted at one of the following points on the line: depalletizer, bottle transport, rinser, filler, pasteurizer, labeler, packer or palletizer.

This section 1 presents the scope of this research, which consisted of developing a series of activities that allowed planning how to attack the problem previously explained. Firstly, it was necessary to know the area where the work was carried out, in order to become familiar with the process, and at the same time to be able to observe what are the causes that cause minor stoppages or their origin.

For this, a series of theoretical foundations are presented in section 2, which provide the basis for the development of said project, in section 3 the activities developed to reach the established objectives are presented step by step, this through of Deming's methodology. In section 4 an analysis is presented indicating the results obtained, in section 5 the discussion is presented and finally, in section 6 the conclusions and future lines of research.

2. Theoretical foundations

To carry out this research, the methodology of the Deming Cycle or PDCA Cycle (Plan, Do, Check, Act) was selected, a methodology commonly used by the company for a long time. With this methodology, it was intended to identify areas of opportunity that the entity had, analyzing data provided by the company, about minor stoppages presented at the beginning of 2018, to date, allowing team members to become familiar with the causes of the strikes, and their sources of origin. In turn, the Kaizen philosophy was implemented to improve aspects of production, such as eliminating downtime.

Deming Cycle Methodology

It was created by W. Edwards Deming in the 1950s as an easy to follow cycle of problem solving. Deming was tasked with helping Japan rebuild its economy in the 1950s. His purpose was to use PDCA with a continuous improvement process to help rebuild Japanese industries so they can compete in the world market in the future. (EcuRed, sf).

E. Deming establishes that the PDCA cycle of continuous improvement is made up of four cyclical stages so that once the final stage is finished, one must return to the first and repeat the cycle again. In this way, the activities are periodically reassessed to incorporate new improvements (Bernal, 2013), states that some of the benefits provided by an adequate improvement of processes are the following:

- Times: times are reduced, increasing productivity.
- Quality: errors are reduced, helping to prevent them.
- Cost: resources are reduced, such as materials, people, money, labor, etc., increasing efficiency.

In order to obtain previous results in process improvement, the 4 stages of the Deming Cycle must be developed, which are the following:

Plan (Plan). Management, based on the measurements, data and information it possesses, plans the changes. Broadly speaking, in the PDCA cycle of continuous improvement, this planning consists of determining what is to be achieved and defining the methods and forms of action that will be applied to obtain the desired results. This is what is called Focus. At the same time, the approach must be related to the strategy of the organization and be grounded; with well-defined processes (Alteco Consultores, 2020).

Do (Do). The time has come to carry out the action plan, through the correct performance of the planned tasks, the controlled application of the plan and the verification and obtaining of the necessary feedback for the subsequent analysis. On many occasions it is advisable to carry out a pilot test to test the operation before making large-scale changes. The selection of the pilot must be made taking into account that it is sufficiently representative, but without assuming an excessive risk for the organization. (Bernal, 2013)

Verify (Check). The results are systematically evaluated and analyzed, identifying and developing improvements. The effectiveness of the deployment of the approach is measured by well-defined indicators. This phase must involve learning to identify best practices and detect opportunities for improvement (Alteco Consultores, 2020).

Act (Act). Finally, after comparing the result obtained with the initially set objective, it is time to carry out corrective and preventive actions that allow improving the points or areas for improvement, as well as extending and taking advantage of the learning and experiences acquired to other cases, and standardizing and consolidate effective methodologies. In the event that a pilot test has been carried out, if the results are satisfactory, the improvement will be definitively implemented, and if they are not, it will be necessary to decide whether to make changes to adjust the results without discarding it. Once the act step is finished, the first step must be returned periodically to study new improvements to be implemented.

In conclusion, a quality management system allows an organization to develop policies, establish objectives and processes, and take the necessary actions to improve its performance. In this context, it is very useful to use the PDCA methodology promoted by Deming, as a way of seeing things that can help the company to discover itself and guide changes that make it more efficient and competitive (Alteco Consultants, 2020).

Kaizen

Kaizen is a Japanese term that many authors have translated as continuous improvement; This word comes from a combination of two Japanese words: Kai (change) and Zen (improvement). The main idea is to solve problems through corrective measures with a view to improving the production system. This kaizen philosophy is based on eliminating waste or factors that cause production delays. To achieve the objective of this methodology, there is a need to change the attitude of people in the company. It is about encouraging this change of attitude towards improvement, using the skills of all staff with the constant aim of leading the company to success. Kaizen is divided into three main sections:

- The elimination of everything that is unnecessary, causes waste or is simply expendable.
- The correct maintenance of facilities, equipment, vehicles, etc., where preventive activities and cleanliness and order are especially relevant.
- The standardization of work processes.

On the other hand, Kaizen promotes Maintenance 5 where analysis is required to separate and place the most important equipment so that they are accessible and maintain cleanliness both in the facilities and in the environment. workplace, review and standardize common practices and standardize all of the above so that work guidelines are standardized so that they are continuous and can continue to improve (Tague, 2005).

Minor strikes

Also considered "quick fix chess", it is one of the Six Big Losses; They are frequent events that interrupt the production process without major mechanical failures, and they have a short duration (1-5 minutes) during which they must be detected, analyzed and corrected so that the production line can continue.

On a large scale and high production, they have a great impact both economically and through the accumulation of lost production time, since the line must be completely stopped to solve any of these problems.

Pareto chart

A Pareto chart is a bar chart, where the lengths of the bars represent frequency or cost (time or money), arranged with the longest bars on the left and the shortest bars on the right. In this way, the graph visually shows the most important situations (Tague, 2005). So, this chart is defined as a visual representation of issues in a higher priority process and when they are resolved or eliminated, TQM compliance is promoted.

The advantage of developing this type of scheme is that it is possible to identify the most common defects, the most common causes of defects and thus create priorities according to what the unit would like to achieve. To set up this graph, you need a data series that reflects major failures or unexpected events, to analyze how often they occur. The source of information can be historical data or obtained by sampling.

In Pareto analysis, interested and measured items are identified on the same scale, and then address themselves in descending order, as a cumulative distribution. In general, 20% of the factors are evaluated by 80% or more general processes; Therefore, this technique is often referred to as 80-20 rules (Niebel and Freivals, 2009).

Advantages, according to García, Rojas and Torrealba (2008):

- Simplicity: No complex calculations or sophisticated graphing techniques are required.
- Prioritization: The elements that have the most weight or importance within a group are identified.
- Visual impact: The Pareto Chart communicates clearly, evidently and at a glance, the result of the comparison and prioritization analysis.
- Unification of Criteria: Focuses and directs the efforts of the components of the work group towards a common priority objective.
- Objective character: The decisions to be made are based on data and objective facts and not on subjective ideas.

While Coronado (2007) mentions the following disadvantages:

- It is recommended to use when the data can be classified into categories.
- It is recommended to use when the range of each category is important.
- Provides a simple and quick overview of the relative importance of issues.
- Determine what is the main effect of a problem and not the main cause that causes it.

Production

It is called the relationship between the output obtained by a system that produces a good or service and the resources used to obtain it. Labor productivity, that is, annual production, is generally measured, thus determining the amount of a good or service that each machine is capable of producing in a given period. Productivity refers to the best or worst use of an economy's factors of production, which theoretically reflects the ability of that economy to compete effectively in markets. Therefore, it evaluates the quantity of a good a company produces based on the number of people employed in it and the time, materials, and resources needed to produce that product. Therefore, to measure your productivity,

Productivity depends on a multitude of factors: the availability of the natural resources necessary to manufacture the product, the level of training of the workers, the capacity of the machinery and the technology that helps speed up the production process, labor regulation, internal rules of the company, the national situation of that specific industry, etc. (Tague, 2005). Or as indicated Riggs (2015) production is the intentional act of producing something useful.

Productivity

In general, productivity is understood as the relationship between what is produced and the means used; therefore, it is measured by the ratio: results achieved divided by resources used. The results achieved can be measured in units produced, parts sold, customers served or in profits. While the resources used are quantified by the number of workers, total time spent, machine-hours, costs, etc. So improving productivity means optimizing the use of resources and maximizing results (Gutierrez & Vara, 2013).

Riggs (2015) determines productivity is the quality that indicates the work, materials, materials and energy used. This is how certain resources are achieved to achieve the appropriate objectives that are explained by quantity and quality.

Process

An industrial process or manufacturing process is the set of mutually related or interacting activities, which transform input elements into results. The process consists of several steps or sub-processes, while the input or output consists of materials, materials, products or equipment. The result or output can be the product itself or a modification of the input, which in turn will be the input of another process (Gutierrez, 2013).

According to D'Alessio (2004) to obtain a specific product, a set of operations will be required to transform the elements. It includes factories (machines and materials) and labor (manpower), that is, technology, production assets, indirect materials, and knowledge.

Management

Huergo defines management as the method to achieve the interconnection of points of view, through the ways in which the organization serves and aligns with the goals and objectives of the organization. While Jones and George (2014) define management as the method to achieve the interconnection of points of view, through the ways in which the organization serves and aligns with the goals and objectives of the organization. Huergo points out that management must adapt to corporate goals and objectives, while Jones and George explain the effects of managerial performance, ranging from planning to talent control.

Business management, also known as business management techniques, differs from business management by combining strategic management with the application of technology and innovation. It is the strategic, managerial and controllable process of managing the resources of a company to increase its productivity, competitiveness, effectiveness and efficiency.

Business management guarantees that supply meets demand through "creative destruction", that is, with constant innovation to increase productivity and competitiveness (Business Management, 2019).

Corrective action

According to Nuns (2015) corrective action is an action or action taken to eliminate the causes of a detected non-conformity, a defect or an undesirable situation to avoid its repetition, as stipulated in this ISO (International Organization for Standardization) standard. The treatment of a corrective action, according to the international standard ISO 9001:2008, is due to an investigation that the company must develop to identify the root cause that generates the non-conformity, and once the corrective action has been implemented, make sure that it does not occur. its recurrence. That is to say, once the investigation has been carried out, and the remedy established, the problem should not recur.

This treatment is a deductive method for the analysis and solution of problems in organizations. As if it were the work of the legendary detective Sherlock Holmes, the methodology for corrective action must be handled through a skill-based approach to be able to think logically about the cause-effect relationship and be able to take concrete actions based on this analysis (Revelle, 2004).

3. Methodology

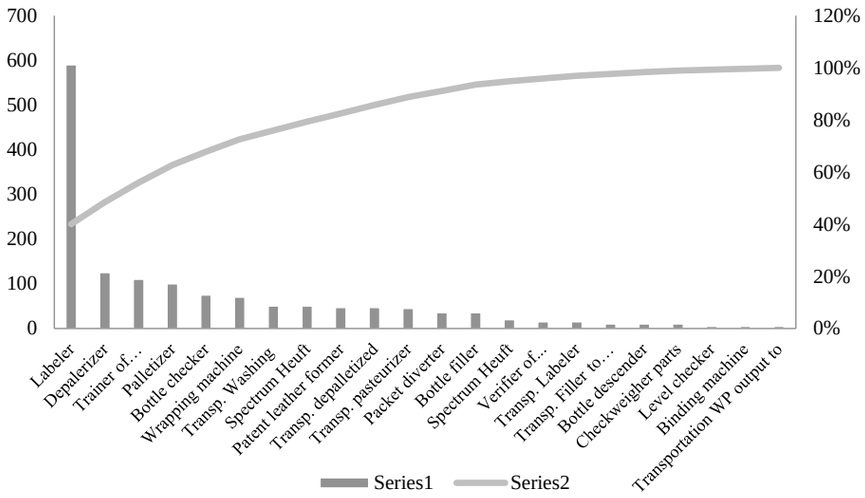
To carry out this research, the Deming Cycle was taken as a basis, which is explained in detail in section 2 of this chapter. The way in which each of its stages was developed is shown below:

To plan

Firstly, the information on the minor stoppages that occur in the different areas of line 30 was analyzed. This information is a log of failures registered by the operators since the beginning of the current annual period, where Registered information about the causes that cause minor stoppages in their respective areas, their origin, their frequency and the time they consume of the annually assigned available production period.

To perform a better analysis of the information, dynamic tables were used that allowed stratifying the strikes in their different areas where they occur. Once this was done, a Pareto diagram was drawn up (See graph 1), based on the information summarized in the tables.

Graph 1 Pareto diagrams showing the area with the most problem of minor strikes



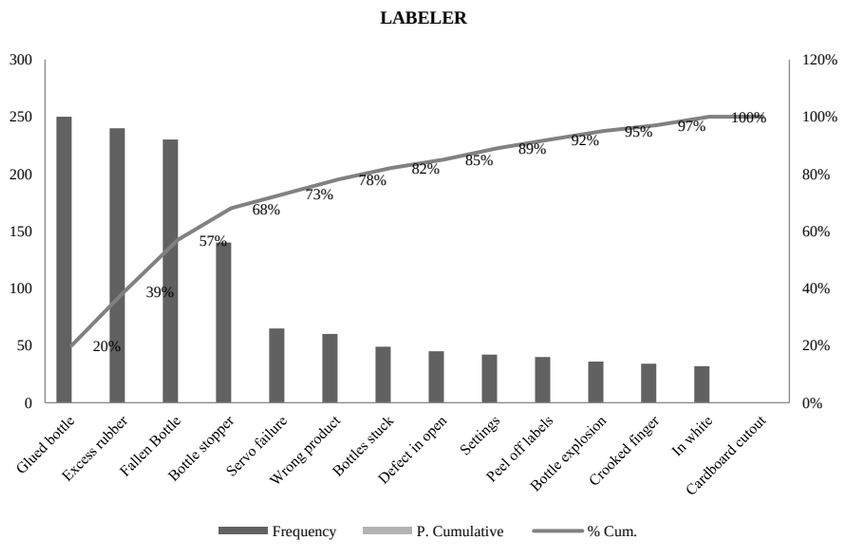
Source: Self Made

To make these graphs, the data were arranged from highest to lowest, then the relative frequencies were calculated (sum of times of the specific stoppage divided by the total time in which the area was stopped) and the absolute frequency (sum of relative frequencies) and with this, the main areas in which strikes occurred more frequently were determined. These areas were the labeling machine in charge of putting the labels on both the body and the neck of the bottle. This area was selected by the maintenance manager, who was interested in solving this problem of minor stoppages. Once the area where the improvement project would be implemented was detected, a face-to-face sampling was carried out, which focused on analyzing each of the areas to verify the veracity of the log data, and in turn , detect the presence of minor stoppages, and the exact place where they occurred, since the areas are made up of different sub-elements and processes where these contingencies can occur.

Do

Based on the data obtained, the next step was to make a series of Pareto diagrams showing the most frequent causes of each area. For these first, the failure modes were stratified with the areas in which they occurred, using the information from the period logs provided by the entity, see graph 2.

Graph 2 Pareto diagrams showing the most frequent causes of each area



Source: Self Made

The next step was to focus on the area where the improvement was applied, in order to filter only the causes of minor stoppages that were relevant to the project. Based on the descriptions that the operators write in the logs, categories were created that reflected the highest priority sub-areas and the most frequently occurring failure modes.

Once the causes that gave rise to most of the consequences were detected, the phase of recognition of faults and their detection was given. For this, samplings were carried out on different days and production days (See Table 1), with the purpose of understanding the origin and repetitiveness of the causes of minor stoppages. Being present in the area from the 12th of February, until the 27th of the same month.

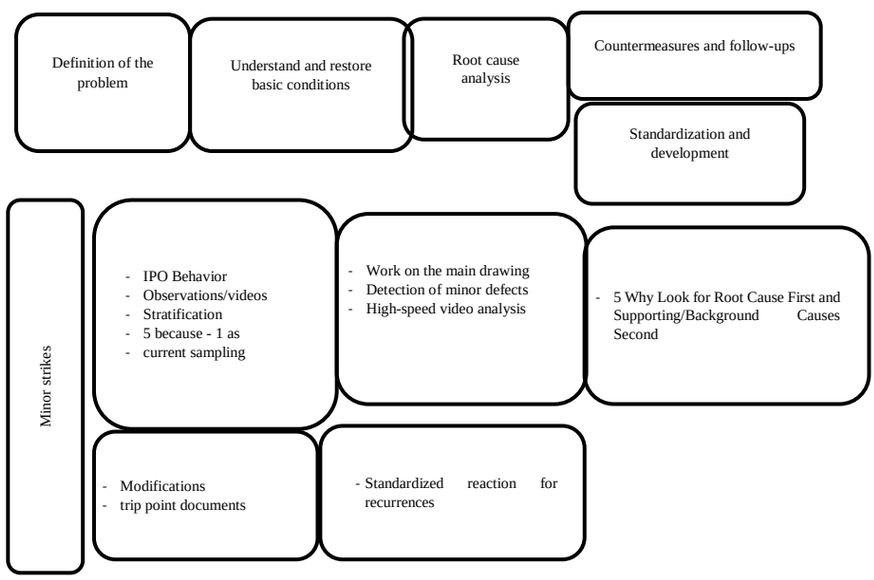
Table 1 Sampling Table

Registration Log Minor strikes					
Date	**Hour**	**Presentation**	**Type of unemployment**	**stop time**	**Stop Reason**
02/18 2019	4:10	indian exp	bottle stuck	2 minutes	excess rubber
02/18 2019	5:35	indian exp	Rubber	5 minutes	lack of rubber
02/18 2019	5:50	indian exp	misplaced label	5 minutes	Flow rate
02/20 2019	3:10	xx born	misplaced label	6 minutes	Flow rate
02/20 2019	3:23	xx born	misplaced label	4 minutes	Flow rate
02/25 2019	5:40	national indian	Rubber	6 minutes	lack of rubber

Source: Self Made

For the company there are 3 different causes for which the machinery loses useful production time, which are: breakdowns of the machinery, minor stoppages and loss of speed in the equipment. Said causes were previously divided by the entity with the purpose of stratifying the information. As explained above, for the purposes of this investigation, the focus was the resolution of the causes of minor stoppages. For the assembly of the action plan, 5 key stages were established that allowed the development of the project (See Figure 1).

Figure 1 Stages of the Action Plan against Minor Strikes



Source: Brewing Company

Definition of the problem

For this stage, the levels of the OPI (Overall Performance Indicator) indicator were verified, a sample was made which was prepared while in the areas of opportunity, once there, an observation of the line was made for two hours and a half. In the event that a minor stoppage occurred, its duration was timed, and its final duration was recorded in the sampling table that was prepared; The cause that caused the line to stop was also noted, either because of the bottle or a fault in the machinery.

In addition, an analysis was made with a video at low and high speed, and it allowed to observe the behavior of the line when there were no operators present. This analysis consisted of playing the video, observing the behavior of the bottles and detecting possible causes why they could fall or get stuck and stop the process.

Recognition and Restoration of basic conditions.

This phase consisted of carrying out a field reconnaissance, which was carried out by being present in the assigned line for 2 weeks in order to become familiar with it, as well as its areas, sub-areas and physically observe the causes of minor stoppages. and perform a recognition of the current state of the process and its behavior. While each area was analyzed, the registration log was filled.

Root Cause Analysis.

Once the line was sampled, it was observed that the most recurrent cause of minor stoppages was a stuck bottle and excess rubber due to the lack of inadequate maintenance provided to the parties involved in putting on both the rubber and the label. These parts are called Gum Pump and Gum Rollers.

Countermeasures and Follow-ups.

Upon determining the root cause, countermeasures were applied. Both the rubber pump and the gumming rollers were disassembled to give it a very complete maintenance, since previously it was only provided superficially (See Figure 2).

Figure 2 Rubber Pump and Gluing Rollers

Source: Brewing Company

For this, support was obtained from the maintenance team, since it was necessary to verify and perform a correct uninstall without affecting the components that were around it. In order for said rubber pump to have good maintenance, a series of steps were carried out, which in summary consisted of rinsing, lubricating and cleaning the entire pump, in addition to cleaning each of its hoses. In turn, the gluing rollers were provided with extremely optimal lubrication and cleaning maintenance which helped their operations to be in the highest conditions.

Verify

In order to create a standard that would allow the comparison between the current method and the proposed one, one of the process control tools was developed: the verification sheet (See Figure 3).

Figure 3 Check sheet

MINOR STOPS VERIFICATION SHEET				KEY CODE		
				REVIEW DATE		3/15/2019
				No. REVISION		1
ÁREA		ACTIVIDAD				RESPONSABLE DE
Line 03 Labeler		Verification of minor stoppages				OP. LABELER FRONT AND OP. LABELER
Presentation	TIME	MATERIAL AND/OR TOOL REQUIRED	STANDARD / POINTS TO CHECK			PPE NECESSARY
XX max	N/A	Verification Sheet	1.-During the standard product run, verify Minor Stoppages.			
SCHEDULE	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	Total	OBSERVATIONS
7: 00 - 8:00							
8: 00 - 9:00							
9: 00 - 10:00							
10: 00 - 11:00							
11: 00 - 12:00							
12: 00 - 13:00							
13: 00 - 14:00							
14: 00 - 15:00							
15: 00 - 16:00							
16: 00 - 17:00							
17: 00 - 18:00							
18: 00 - 19:00							
19: 00 - 20:00							
20: 00 - 21:00							
21: 00 - 22:00							
22: 00 - 23:00							
23: 00 - 24:00							

Source: Self Made

Said verification sheet allowed an auditor or operator assigned by the company to carry out a real-time sampling of the number of minor stoppages that were recorded in different periods of the day, this with the purpose of observing if the number of stoppages was reduced. minor in the areas where the improvement plans were implemented, since the objective was to create corrective measures for these contingencies. In turn, the verification sheet allows greater control over the information on the number of stoppages, as well as the times in which they commonly occur.

Act

In order to carry out corrective and preventive actions to improve the conflict areas, the pertinent Kaizen's were carried out, which in this company consist of minor stoppage analysis sheets with a format already standardized by them, these sheets allow describing and reporting in a detailed way the failure mode, in addition to the countermeasures that will be taken for its corrective action. For the failure mode that consisted of fallen bottles, it was detailed in the minor stoppage analysis sheets that the improvements of critical conditions was to implement a maintenance plan, since for the correction, prevention and normalization of this situation they did not have an order. standardized on your system. This plan was carried out with a format already pre-established by the unit, which helped to better adapt and structure the steps to follow for the maintenance of the conveyor guides, as well as explaining how to use the bottle simulator mold.

4. Results

The objective of this research was to implement improvements in the areas of the 030 line where there will be a greater number of minor stoppages, and thus achieve optimal use of the machinery in terms of productivity and available useful time. The result obtained was the creation of maintenance standards and give structure to the development of the Deming cycle methodology and continuous improvement. During the stay within the company, work was done on the design and application of said methodology in the analysis sheets of minor work stoppages.

When implementing the methodology, information bases were created, such as dynamic tables and Pareto diagrams, which allow operators to identify the highest priority areas of opportunity that have not yet been addressed, since the line has various sub-areas and in all there are minor strikes that must be reduced or eradicated.

Once the maintenance plans were created, the results were shared with the operators, since they are involved with production on a daily basis, and must be informed of the new standards that were created, in order to train them in behaviors that promote autonomous analysis, since that the company wants every operator to be able to contribute ideas that are consistent with the mission and vision of the company.

With the help of the maintenance plans and the tools provided, 91% of the 285.15 minutes accumulated to date due to minor stoppages in the labeling machine were eradicated and significantly reduced, this is equivalent to an economic saving of $76,990.50 pesos mn taking into account that currently each minute of production is valued at $270 pesos mn.

5. Discussion

It is of the utmost importance that the company continues with all the stages of this investigation, since by implementing this methodology it will be possible to meet all the objectives and benefits.

Being part of the development and implementation of this type of project is transcendental, since it allows the company to continue growing and better integrate all members. Making all members part of this methodology allows improvements to be created within the processes and in turn generates trust among them, since by being trained they acquire security for the execution of their activities. Having mentioned the above, it is recommended to monitor the project and maintain communication with the workers.

6. Conclusions

Implementing a project of minor stoppages allows detecting and eliminating situations that are causing the line to stop for very short periods of time, but must be attended to quickly, even so, unplanned production time is consumed, generating losses both economic and production. These stoppages are caused by the lack of maintenance provided to the production line. For this reason, the adaptation of methodologies such as the Deming circle is of the utmost importance, in order to create an efficient countermeasure against these problems.

Future lines of research

According to the results obtained in the Pareto Diagrams of both figure 1 and figure 2, there are several areas of opportunity, which turn out to be potentially very interesting to develop in complementary works and that should be analyzed, since their scope is beyond those planned in this project, for which it is recommended to continue with the research, analysis and development of items such as dropped bottles, or bottle jams, since they have a high rate of occurrence in the labeling machine, as shown in figure 2, for it to be more efficient, and in the same way to develop research is the rest of the areas as they aredepalletizer, box former and palletizer, since although they are not as critical as the labeller, they also present a significant number of minor stoppages, and if these can be reduced or eliminated, it would be of great importance for the company.

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Chapter 3 Implementation of quality control tools in the inspection-receipt area to reduce raw material rejections in electromechanical industries

Capítulo 3 Implementación de herramientas de control de calidad en el área de inspección-recibo para disminuir los rechazos de materia prima en industrias electromecánicas

SOTO-LEYVA, Yasmin†*, BONES-MARTÍNEZ, Rosalía and SANTOS-OSORIO, Arturo

Tecnológico Nacional de México/Instituto Tecnológico Superior de Huauchinango

ID 1st Autor: *Yasmin, Soto-Leyva* / **ORC ID:** 0000-0003-2652-7065, **CVU CONACYT ID:** 951464

ID 1st Coautor: *Rosalía, Bones Martínez* / **ORC ID:** 0000-0001-8829-9737, **CVU CONACYT ID:** 368744

ID 2nd Coautor: *Arturo, Santos-Osorio* / **ORC ID:** 0000-0003-3643-5770, **CVU CONACYT ID:** 951024

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Y. Soto, R. Bones and A. Santos

*yasmin.sl@huauchinango.tecnm.mx

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Abstract

The metalworking industry turns out to be a starting point for the manufacture of assemblies, subassemblies and circuits that are imported or exported to other work environments; these organizations contribute to the technological growth of the country in which they are established, for the case presented below, the electromechanical industry is evident, which is identified by showing quality problems in the manufactured products, derived from a null control in the inspection-receipt area, which is in charge of receiving supplies and shipments to the warehouse area. According to the project carried out, it is identified that the main cause is the lack of standardization of the activities carried out by the quality department, being of vital importance the implementation of an assertive methodology that ensures that suppliers supply the organization with top quality materials. . The applied quality control methodology is based on three stages: 1) Information gathering, 2) Quantitative and qualitative analysis of variables, 3) Solution implementation, 4) Measurement of solution effectiveness, are developed using the following techniques: Internal audit, Check List, Ishikawa Diagram, input control of raw materials and supplies and labeling of materials. The results obtained were beneficial, reducing raw material rejections by 7% and identifying through the traffic light technique the suppliers that meet the requested requirements, which will be maintained for future purchases, in the same way the economic benefit achieved after the project is $358,506.94 being a considerable amount for members of senior management.

Electromechanical industry, Inspection-receipt, Quality control, Quantitative

Resumen

La industria metalmecánica resulta ser un punto de partida para la fabricación de ensambles, subensambles y circuitos que son importados o exportados a otros ambientes de trabajo; estas organizaciones contribuyen al crecimiento tecnológico del país en el que se encuentran establecidas, para el caso que se presenta a continuación se evidencia a la industria electromecánica la cual se identifica por mostrar problemas de calidad en los productos fabricados, derivadas de un nulo control en el área de inspección-recibo, misma que es encargada de la recepción de insumos y los envíos al área de almacén. De acuerdo al proyecto realizado se identifica que la principal causa es la falta de estandarización de las actividades efectuadas por el departamento de calidad, siendo de vital importancia la implementación de una metodología asertiva que asegure que los proveedores abastezcan con materiales de primera calidad a la organización. La metodología aplicada de control de calidad se basa en tres etapas: 1) Recopilación de información, 2) Análisis cuantitativo y cualitativo de variables, 3) Implementación de solución, 4) Medición de efectividad de solución., son desarrolladas utilizando las siguientes técnicas: Auditoria interna, Check List, Diagrama de Ishikawa, control de entradas de materia prima e insumos y etiquetado de materiales. Los resultados obtenidos fueron beneficiosos reduciendo en un 7% los rechazos de materia prima e identificando mediante la técnica de semaforización a los proveedores que cumplen los requerimientos solicitados, los cuales serán mantenidos para futuras compras de igual forma el beneficio económico alcanzado posterior al proyecto es de $358,506.94 siendo una cantidad considerable para los integrantes de la alta dirección.

Industria electromecánica, Inspección-recibo, Control de calidad, Cuantitativo

1. Introduction

The electromechanical industries in Mexico promote technological growth, contributing to the economic development of the country; These productive organizations are responsible for providing materials and supplies to different sectors, with the automotive industry being the one that mainly benefits from their operational activities. Specifically, in the country, the impact of the electromechanical sector is seen in the export processes of integrated circuits, printed circuits and software programming or translation (manufacturing, testing) concentrating the technological impulse in the formation of subassemblies of components and parts, which promote the effectiveness in the value chain of final tests, quality control and packaging (Ordóñez, 2005).

It is important to mention that electromechanical organizations have two main objectives with respect to the products they manufacture or assemble: The first objective is based on obtaining profits from imports and exports, the second objective is to comply 100% with the requirements proposed by national and international clients, seeking to unite these approaches in two variables:

Time and form, to achieve user satisfaction. Sánchez (2007) indicates that if consumers are satisfied, it is very likely that they will recommend the products to a sequence of 5 more customers, so the value of a customer's perception is five times higher than initially expected, that is, the best recommendation to capture new markets is born with customer satisfaction; for this reason, it is essential that the product or service punctually meets the physical characteristics to maintain a high satisfaction rate. The physical characteristics of the goods are defined from the entry of the raw material, the reception area being a starting point for the control of the quantitative and qualitative variables that contribute to the manufacture of optimal products, for this reason the reception department It is characterized by being monitored with the highest levels of demand due to the fact that the raw material must comply 100% with the requirements of internal clients, considering that not complying with them generates quantifiable economic losses, the main objective of this reception department. is to ensure compliance with quality control standards and regulations for the inputs to be processed.

According to what has been described, there is a need to create effective methodologies that guarantee internal production processes, resorting to the conjunction of quality standards to eliminate the sources that originate raw material rejections, considering that the rejected inputs are those that do not comply with the required standards, causing production levels to decrease and products to be delivered outside the times established by customers, there are various sources that cause rejections, the main causes are: 1) Lack of standardization in quality control processes, 2) Null existence of audit plans, 3) Lack of training for personnel assigned to inspection processes in the area. If these factors are recurrent, the input input process will be incorrect, providing a high level of non-compliance for subsequent processes.

In accordance with the need raised in the previous lines, a system of standardization of quality controls is implemented in the receipt inspection area for the electromechanical industry, aligning the business goals with the objectives of the clients under an effective model of entry assurance. of raw material (polypropylene, polycarbonate, silicones, glass melamine, glass silicone, polyester film, etc.), making use of tools corresponding to quality control, which are: Audits (internal and external), check list, Ishikawa (Guzmán, 2019), these techniques are aimed at reducing raw material rejections by 5% and contributing to attracting customers by 5%, standardizing the reception process at a minimum level of 85% with regarding all the operational processes included in the area, programming that the benefit of the application be visible in the course of 2022 and be permanent as of annual period 2023.

2 Objectives

2.1 General Objectives

Implement a quality control process to reduce raw material rejections in the receiving inspection area by 10%, contemplating the standardization of the specifications of thickness, color, porosity and scratches of parts processed in the electromechanical industry, through the development of statistical control tools, making use of historical information and projecting a quantitative benefit, visible from 2021 and permanent from 2023.

2.2 Specific Objectives

1. Analysis of the inspection process that is carried out for the entry of raw material into the operating processes.
2. Implement statistical control tools.
3. Document the appropriate procedure, and the formats to keep a correct record of the quantity and conditions of entry of the raw material.
4. Establish the quantitative benefits obtained with the implementation of quality control for suppliers.

3. Rationale

The current demands to deliver the products in a timely manner to the client within the transformation organizations, originates the need to implement measurement methodologies that quantify and ensure that the actions carried out in the operating stations are effective; One of the actions considered to be of vital importance is inspection.

According to the conceptualization of ISO 9000, (2005) the inspection is defined as a quantitative evaluation of the conformity of a good, through observation and the issuance of an opinion, which is accompanied by a measurement methodology (tests, tests) with previously established patterns, this quantification in most cases absorbs large economic amounts and does not provide the expected results, for this reason business organizations require that it be validated in the areas that really require it. Considering that the companies are made up of different areas, which are subject to rigorous control, a quality control system is implemented for the section that releases the raw material to the operating processes. This area is known as the inspection area. receipt; Specifically, the main activities carried out in this area are: 1) Unloading of raw material, 2) Inspection of raw material, 3) Application of assurance sampling, 4) Registration of entries, 5) Output and shipment of raw material to the warehouse, these operations are vital for the assurance at the entrance and must be carried out following the strictest protocols, contemplating that when they are not complied with, the entry of raw material with defects is allowed, which originate non-conformities of one or several characteristics of the physical object. causing customer dissatisfaction (Polesky, 2006).

The dissatisfaction in a client is reflected by the decrease in future purchases and in the worst case scenario it ceases to be part of the potential clients of the organizations, this situation has been seen more frequently in electromechanical companies which are characterized by produce sub-assemblies or components that mainly supply the automotive industries. The case presented below shows a lack of control in the inspection-receipt area, resulting from the following actions: 1) Non-standardized operations, 2) Raw material receipt methodology is incorrect. 3) Raw material input validation system is incorrect, these factors cause the raw material that enters the process to present nonconformities that are reflected in a high rate of production stoppages, idle times, waste of raw material and supplies, late order delivery, order rejections, churn; How can we notice not having an effective quality process that quantitatively and qualitatively measures the entry of raw material triggers various factors that lead to economic losses for electromechanical organizations. The standardization of a quality control process in this industrial branch will bring with it the reduction of the sources that cause the entry of defective raw material, making the production lines more efficient and delivering the products to the final consumers in a timely manner.

4 Theoretical Framework

For a better understanding of the aspects that make up this research, the theoretical foundations that support the formulation of the standardized quality control process for electromechanical companies are described below.

4.1 Inspection-receipt area

The definition assigned by the acronym in English indicates the following nomenclature IGI (Incoming goods Inspection) this area quantifies all inspection-receipt services for the entry of goods, raw materials and supplies, establishes activities aimed at quality control to ensure shipments of goods to customers, as well as receipts from different suppliers (Juran, 2001)., the assurance that it includes is measured until the moment in which the products are delivered to the client. The main goal of this area is to detect failures or defects in components or assemblies, through the application of visual and dimensional inspections, gauge tests, unit accounting, packing and packaging review, these actions are carried out through the standardization of the batches of parts requested by the quality, logistics and engineering department (Acevedo, 2016).

4.2 IGI services and operation

The base of the inspection-receipt services is based on the international standards ISO2859 or ISO3951, in which the statistical methods and the operative rules for the quality control of the entrance of the industrial processes are established, in the same way in this methodology. control indicates that the inspection of parts received must be applied to a representative sample based on the military standard MIL-STD or MIL-SPE, emphasizing the importance of sampling plans and the elimination of 100% inspection, it is It is of vital importance to mention that the inspection service prevents the risks of rejecting materials, protecting the production lines under a JIT model, making use of a comprehensive policy that indicates the following:

If the receiving operator detects a defective lot, it must be considered as unsuitable material and must be sent to the corresponding area for its subsequent return or elimination, specifying that if the lot e is released this will cause a negative effect that will bring instability and subsequent problems in the assembly or manufacturing lines. The methodology developed in the incoming inspection-receipt area consists of taking random samples from the lot or shipment, without considering the period of time in which it was manufactured, each piece having the same possibility of being selected for the inspection process, a Once the inspection has been applied and the characteristics of the product have been validated, the acceptance of the lot or shipment is carried out.

It is important to mention that the IGI are applied around two variables, the first variable is represented by the functionality, the second variable is the one related to the type of sampling. The functionality is selected according to the historical analysis of the failures of the suppliers, within this variable is the light functionality (suppliers that expose less existence of defects in parts / assemblies), and the increased functionality (suppliers that expose greater existence of defects in parts/assemblies). The second variable referring to the sampling methodology consists in selecting the measurement system to carry out the acceptance or rejection of the lot, establishing as the optimal option the sequential sampling to ensure that the lot will be accepted by the final client. It is relevant to mention that the Correct implementation of IGI contributes to reducing process times that include the interaction of quality control with production processes by up to 50% and reduces risks due to failures in manufacturing procedures by 35%.

4.3 Process audit (inspection validation)

The audit has been contextualized over time from the end of the thirteenth century to the fourteenth century, mention is made that during this period audits were carried out, auditing the operations that were carried out within private companies and areas operated by public officials, that is, the audit has existed since time immemorial. According to Sánchez, (2005) the audit is a systematic process through which the set of evidence that is related to reports of economic activities and others, which are directly related to the operations carried out in a public body, is objectively evaluated. or private, for a correct designation these validation tools are classified as follows:

4.4 Internal audit

This audit model ensures the activities of an internal control system by establishing a set of measures, policies and procedures aimed at protecting assets, minimizing risks and improving efficiency, to optimize and make profitable business units, this methodology carries out a punctual follow-up in the management and administration of the businesses; encouraging the growth of the percentage of probability for organizations to increase the achievement of objectives and achieve the desired success (Prado, 2013).

To achieve success, the internal audit is carried out according to a work plan, based on the organizational goals and aimed at fulfilling the following aspects: 1) Comply fully with the plans and procedures indicated by management, 2) Review and evaluate the correct application of the operational, accounting and financial indicators, 3) Carry out an inventory control of the set of goods available to the organization, 4) Verify, evaluate and ensure the accounting information, which must be in accordance with the economic reality of the business unit, 5) Monitoring compliance with the findings and areas for improvement determined in the audit reports. , in the experience of Aroca, (2016) this management technique contributes to the fulfillment of the results in an interval of 86% to 100%.

4.5 External audit

This audit methodology is considered as a detailed examination, which is carried out by an external agent (company outside the institution, specialized auditor, public accountant); The role of the external agent is to provide a real opinion of the behavior of the communication systems of the audited organizations, as well as propose improvements observed during the audit process. In general, the external audit details the reliability and validity of the documents, programs, files and financial statements that make up the company.

The objectives pursued by the external audit are explained below:

1. Determine the optimal method so that the exchange of information of the organizational areas is exposed in a valid, truthful and correct way.
2. Expose the operational, administrative and financial problems that the company faces.
3. Objectively evidence the strengths and weaknesses for making assertive decisions.
4. Provide constructive suggestions.

However, the main characteristics of the external audit are: a) The resulting information is used by management to support future decisions, b) The audit is applied using work programs that include the phases of: Planning, evaluation, and application of reliable tests, c) It is applicable to all activities and areas of companies.

4.6 Types of external audit

According to their nature they are classified as:

- Second party external audit: This audit program results from a direct request by customers, who want to ensure compliance with the requirements contained in the products they purchase.
- External third-party audit: It is characterized by being carried out by certified organizations, which must be recognized nationally and internationally, to guarantee a quality service.

4.7 Check List

Cardona and Restrepo, (2010) affirm that this technique is made up of control lists, checks and verification sheets; are formats generated to monitor repetitive activities, assigned to ensure compliance with the requirements by collecting data in an orderly and systematic manner, the Check Lists are used to comply with the following actions: 1) Check that the activities are carried out in accordance with a previously established work method, 2) Monitoring of activities in which the tasks must be carried out in an established order, 3) Verifying and examining products/services, 4) Examining the existence and location of defects, 5) Verifying the source of origin of non-conforming products, 6) Verify and analyze the organizational operation. The lists that are part of the Check List verify routine actions and ensure that operators, supervisors and area managers obtain reliable information for the generation of statistics. It is important that the Check List include the variables that provide data of interest to the organization, it is recommended that a section be attached to attach the observations and in the case that it is required to obtain data, the construction of graphs or diagrams must be included to control the variables. individual characteristics of the process.

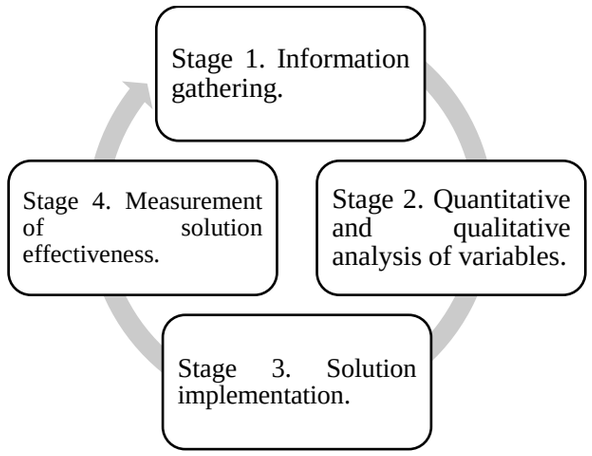
4.8 Ishikawa diagram

The Ishikawa diagram is a statistical tool through which the internal and external variables that affect a given problem are analyzed, considering the potential causes that lead to economic losses, this technique turns out to be effective in business environments because it combines emerging actions to the solution or reduction of the problem; The application methodology is based on a specific study of the factors exposed by the environment, machinery, labour, materials, method and measurement system. This diagram is a way of organizing and presenting the different theories that are proposed to solve a problem, as expressed by Gutiérrez, (2010) who concludes that this technique analyzes the relationship between the cause and the resulting effects.

5 Methodology

Below is the methodological description through which the standardization of the quality control process was carried out in the inspection-receipt area of the electromechanical company (Figure 1. Stages of the methodological process for the development of the application).

Figure 1 Stages of the methodological process for the development of the application

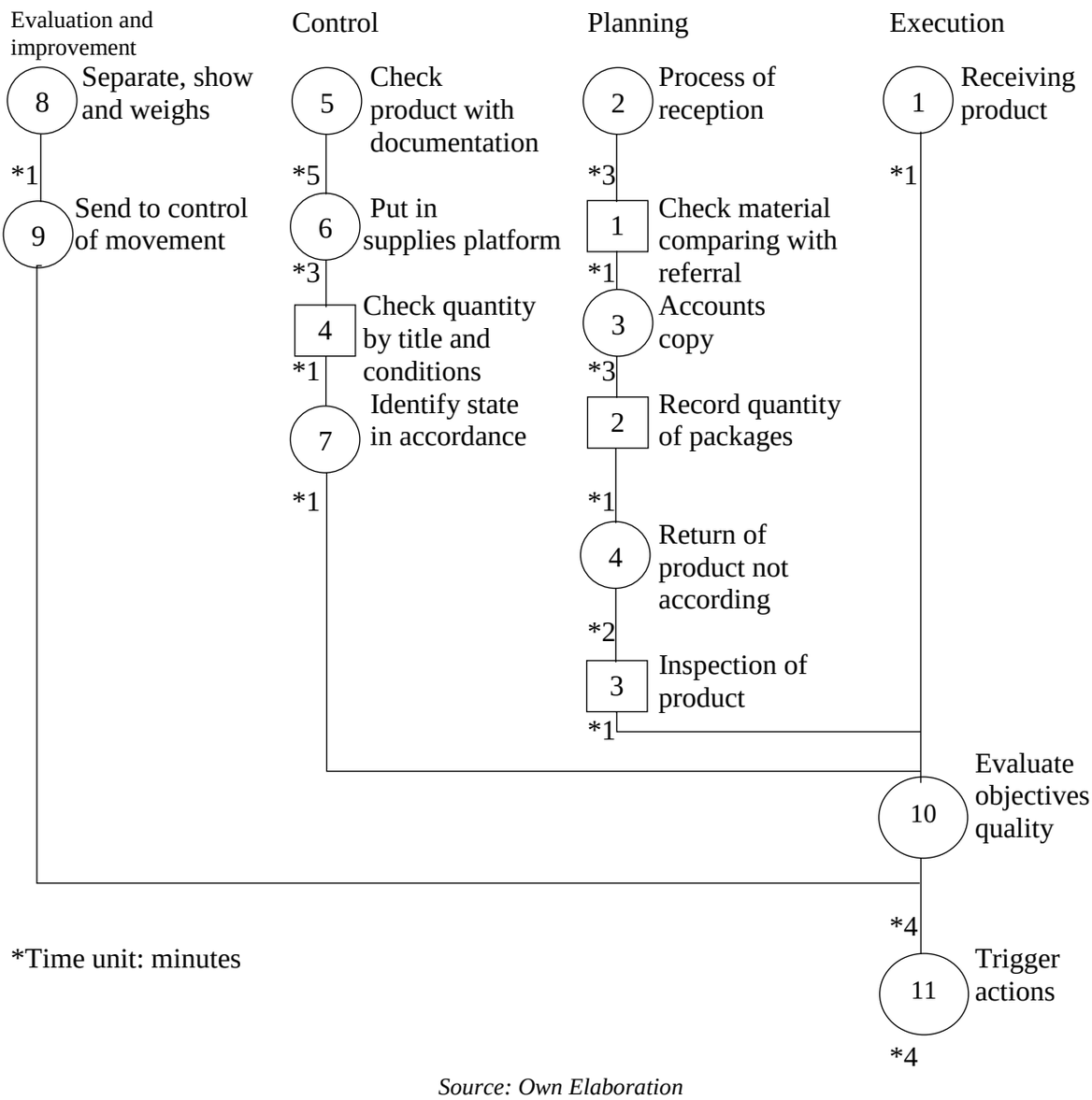


Source: Own Elaboration

5.1 Stage 1: Gathering information

An information survey is carried out to know the general procedure for the entry of raw material (Figure 2. Monitoring of the raw material entry process; Figure 3. Internal area of inspection-receipt of electromechanical company).

Figure 2. Monitoring of the raw material entry process



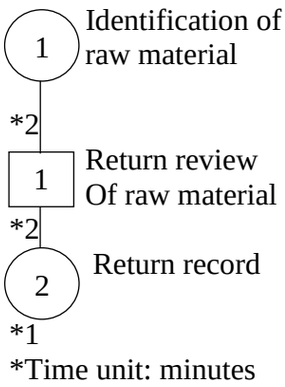
Source: Own Elaboration

Figure 3 Internal area of inspection-receipt of electromechanical company

Source: Own Elaboration

Being of vital importance the current process for the acceptance or rejection of the raw material, the process of rejection or return of supplies is documented (Figure 4. Raw material return/rejection process)

Figure 4 Raw material return/rejection process



Source: Own Elaboration

5.2 Stage 2: Quantitative and qualitative analysis of variables

We proceed to analyze the variables that cause the main problem, which in the first instance are visible through the number of raw material rejections in the inspection-receipt area (Table 1. Index of rejections by supplier 2021).

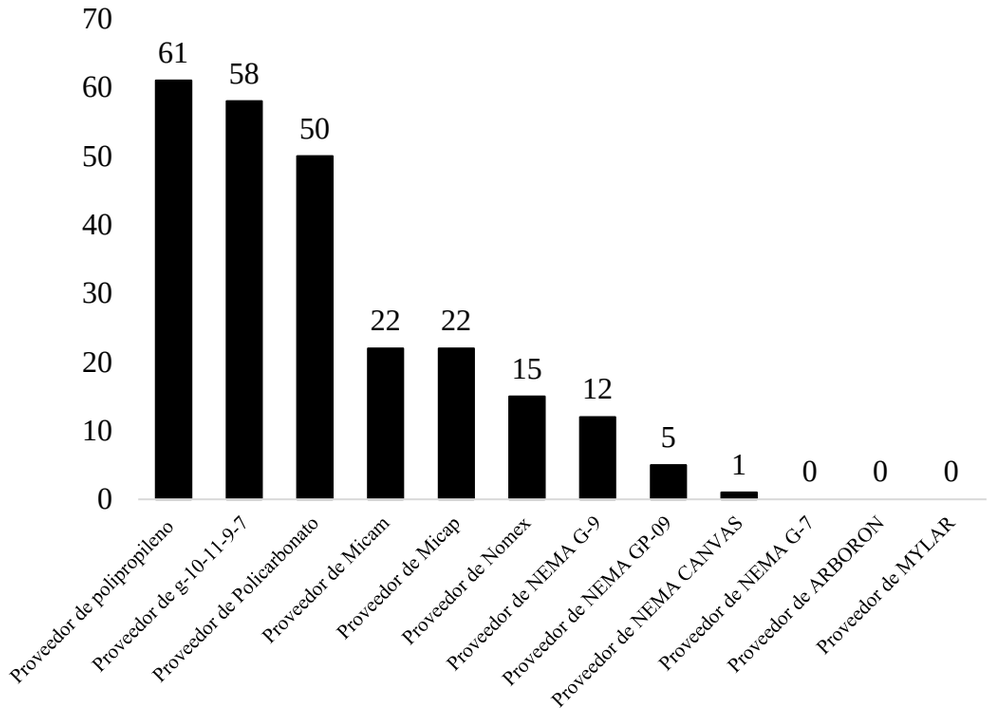
Table 1 Index of rejections by supplier 2021

Providers	Number of rejections initial status (lots)	Reported defect	% Accumulated
Polypropylene supplier	61	color fault	0.2479
g-10-11-9-7 supplier	58	color fault	0.4837
Polycarbonate Supplier	fifty	Porosity	0.6869
Micam provider	22	color fault	0.7764
Micap supplier	22	Porosity	0.8658
Nomex Supplier	fifteen	Porosity	0.9268
NEMA G-9 Supplier	12	color fault	0.9756
Supplier of NEMA GP-09	5	color fault	0.9959
Supplier of NEMA CANVAS	1	Porosity	1
Supplier of NEMA G-7	0	n/a	1
Supplier of ARBORON	0	n/a	1
MYLAR supplier	0	n/a	1

Source: Own Elaboration

The statistical analysis indicates that the supplier in 2021 that presented the greatest rejections is the supplier of polypropylene, which shows a level of affectation of 24.79%, followed by the supplier of raw material g-10-11-9-7, which exposes a monthly affectation level of 23.57% (Figure 5. Index of raw material rejections in the inspection-receipt area).

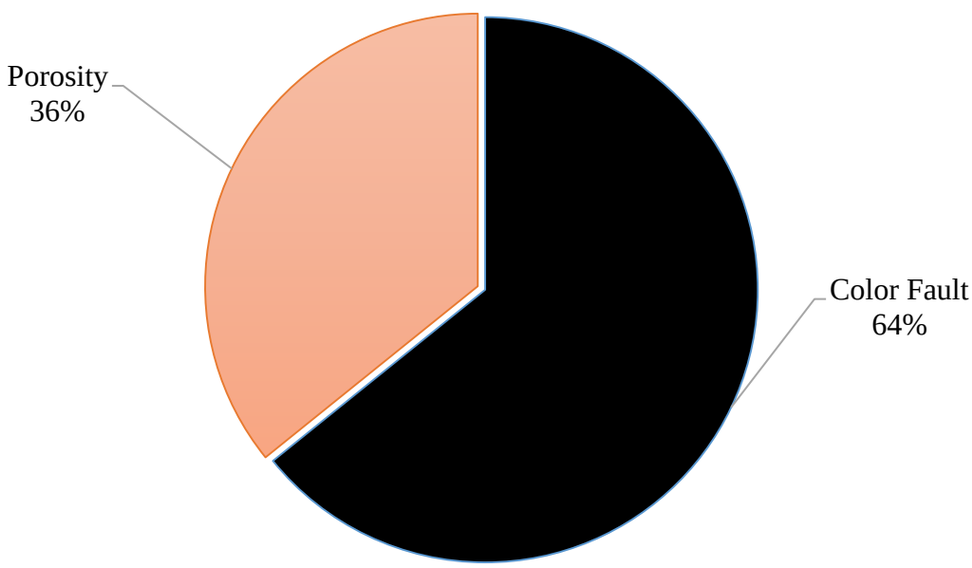
Figure 5 Index of raw material rejections in the inspection-receipt area



Source: Own Elaboration

According to the analysis carried out, which provides the investigation of the quantitative data, we proceed to determine the causes that cause the rejection of the raw material, as we can observe the two defects that are exposed are: Porosity and color failure, for which a statistical analysis is carried out to determine the affectation index of each non-conformity (Figure 6. Default affectation index).

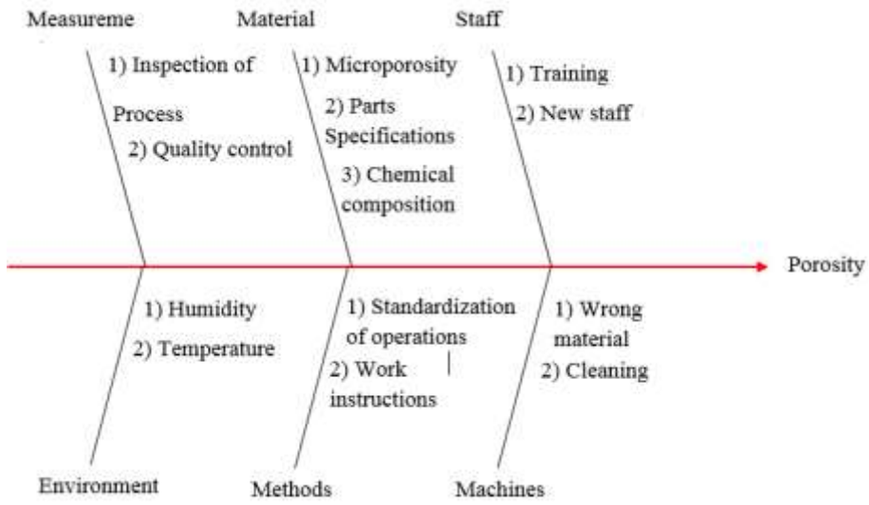
Figure 6 Default affectation index



Source: Own Elaboration

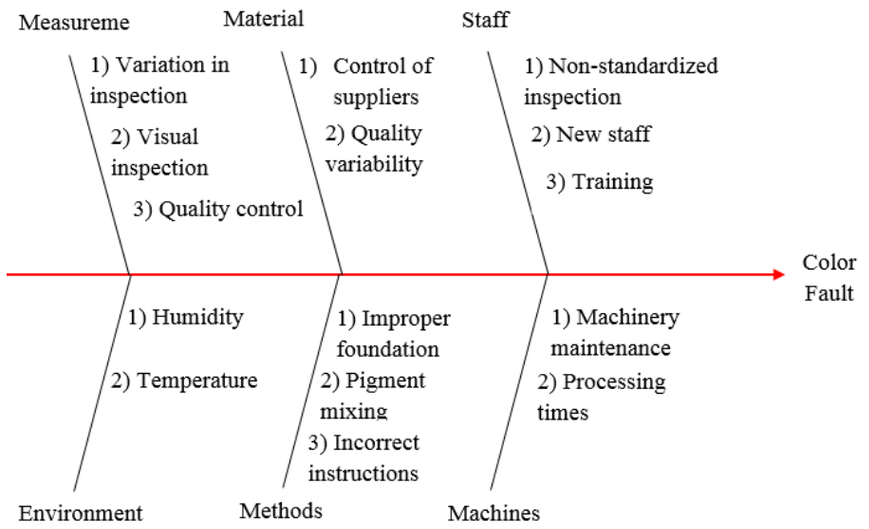
Once the main defects have been detected, a qualitative analysis of the sources that originate them is carried out, through the application of the statistical control tool called the Ishikawa Diagram (Figure 7. Ishikawa Diagram. Analysis of potential causes for the generation of defects due to porosity., Figure 8. Ishikawa diagram Analysis of potential causes for the generation of defects due to color failure).

Figure 7 Ishikawa Diagram. Analysis of potential causes for the generation of defects due to porosity



Source: Own Elaboration

Figure 8 Ishikawa diagram Analysis of potential causes for the generation of defects due to color failure



Source: Own Elaboration

5.3 Stage 3. Implementation of solutions

5.3.1 Solution 1) Design and implementation of Check List

Martín, (1989) defines the Check List as a set of guidelines in the form of a questionnaire, aimed at measuring the behavior of a system. Following this same line, a sequence of 16 questions is designed, which will be applied when the raw material and supplies arrive at the company's unloading ramp, this checklist's main objective is to ensure the entry of materials into the organization's internal warehouse (Figure 9. Check List of receipt of raw materials and supplies).

Figure 9. Check List of receipt of raw materials and supplies

business logo	**Company name** **Home address:** **Warehouse location:** **Warehouse number:**	**Document No:** **Version:** **Date of admission:** **Elaborated:** **Revised:**	
Check List: Receipt of raw material and supplies		Yes	No
1	Remove the padlock from the mid-trailer box.		
2	Check raw material according to the invoice.		
3	Use stop on the key once the trailer is positioned on the ramp.		
4	Unloading of raw material.		
5	Issue purchase order according to the invoice in Purchasing .		
6	Position raw material in receiving area.		
7	Attach purchase order to invoice.		
7.1	Check if the order matches the purchase order with the supplier invoice.		
7.2	Ensure that the raw material matches the invoice.		
7.3	Check that the prices of the invoice coincide with the purchase order (if not, ask if it is a partial shipment).		
7.4	Check that the amount of raw material on the invoice is the same as that indicated on the purchase order.		
7.5	Check that it contains the conformity sheet.		
8	Inspect the raw material using measuring tools (vernier, flexometer).		
9	Review of resins, threads and weight.		
10	In the event that the weights are lower for both containers, threads and totems, notify the area manager.		
10.1	For Angles and Channels: Check thickness, length, width, porosity, and edge chipping.		
10.2	Polycarbonates: Check thickness, length, width and that they do not show scratches or contamination.		
10.3	Sheets with hardness check: Inspect thickness, length, width, porosity and chipping on edges.		
10.4	Flexible in roll: Measure with vernier the diameters (interior, exterior) and height of the roll to determine its length.		
10.4.1	In (A) inside diameter.		
10.4.2	In (B) outside diameter.		
11	Make the receipt: Pass invoices to enter the system.		
12	Send invoice, purchase order and receipt label.		
13	Receipt label printing.		
13.1	Open Print station located on the task bar.		
13.2	Select the Recerving tag tag All Lines (in case the order has only one line):		
13.3	Print two labels, for warehouse and for invoice.		
13.4	Select Reserving tag Single Line (if the order has several lines)		
13.5	Indicate the number of pieces that were inspected (Lot simple Size).		
13.6	Indicate date of inspection (Date of inspection).		
13.7	Indicate the name of the person who made the review (Inspected by).		
14	Paste a label on the back of the invoice and pass it through to the system.		
15	Stick labels on pallets.		
16	Send to the warehouse area for racking.		
Date:	Observations:		

Source: Own Elaboration

5.3.2 Solution 2) Internal process audit

A process audit was implemented to monitor the reception and storage of the raw material, applied on a weekly basis, with the main objective that the area managers carry out the work processes in accordance with the procedures and work instructions (Figure 10. Internal audit checklist).

Figure 10 Internal audit checklist

Business logo	**Internal process audit**	Document No.: MEX-F-	
		Revision No.:01	
		Issue date: 02-15-2021	
		Review date:	
Data			
W.O: _____	Part No.: _____	Machine: _____	Date: _____
Operator: _____	Area: Warehouse	Supervisor: _____	Turn: _____

Check list					
Nope:	**Questionnaire**	**Yes**	**No**	**N/A**	**Comments**
1	Does the material have a technical specification sheet? (color, thickness, material, size, etc.).				
2	Is the raw material arrival inspection carried out? (Check List according to the technical sheet of the material).				
3	Are the appropriate standards for the handling of raw materials complied with?				
4	Do the stocks have the correct identification tag?				
5	Is there an inventory control check-in/check-out system?				
6	Is the material identified with an expiration date?				
7	Is there a physical or digital record of warehouse entries and exits?				
8	Are the materials ordered and located in a specific and easy to identify place?				
9	Is there verification of quantities received against production reports?				
10	Are stocks stored in an orderly and systematic manner?				
11	What is the periodicity with which physical inventories of materials are carried out?				

Source: Own Elaboration

6 Stage 4. Solution effectiveness measurement

To measure the effectiveness of the implemented solutions, a control format is generated, whose main function is to account for and monitor the quantities of rejected material, in order to know the current standards of the inspection-receipt area (Figure 11. Material control internal).

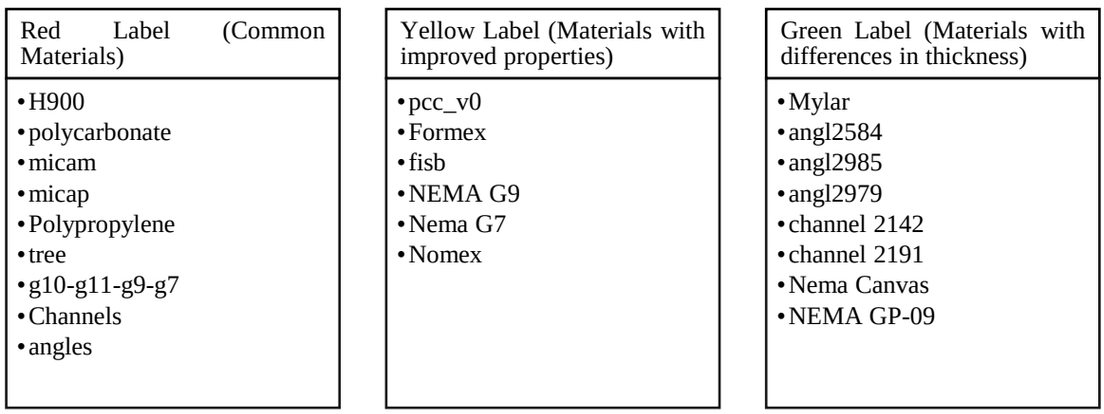
Figure 11 Material control internal

Company name: Address: RFC:					Business logo
Control of raw materials and supplies					
DATE	T1	T2	OPERATOR		
Work Order			Work Order		Work Order
Material			Material		Material
Quantity of rejected material			Quantity of rejected material		Quantity of rejected material
Quantity of material returned			Quantity of material returned		Quantity of material returned

Source: Own Elaboration

Once the control format has been implemented, the documentation and classification of the types of materials that are rejected or sent to scrap continues, according to the business history a color code is assigned to identify non-compliant products (Figure 12. Labeling of non-conforming materials).

Figure 12 Labeling of non-conforming materials



Source: Own elaboration

7. Results

According to the activities developed for the quality control process of the inspection-receipt area, the following results were obtained:

7.1 Result 1)

With the internal audits, the process of arrival of the raw material was controlled, standardizing the deliveries of material, the measurement is shown through the traffic lights of suppliers, which in the experience of Rosas, (2016) is an effective methodology that indicates an evaluation Quantitative of the deliveries in a timely manner, for the case analyzed, this signaling indicates the suppliers that managed to meet the requirements requested by the electromechanical company (Table 2. Current status of suppliers).

Table 2. Current status of suppliers

Providers	Traffic lights	Score obtained
Polypropylene supplier		90%
g-10-11-9-7 supplier		88.5%
Polycarbonate Supplier		92%
Micam provider		60%
Micap supplier		90%
Nomex Supplier		55%
NEMA G-9 Supplier		94%
Supplier of NEMA GP-09		74%
Supplier of NEMA CANVAS		89.4%
Supplier of NEMA G-7		95%
Supplier of ARBORON		95%
MYLAR supplier		95%

Source: Own Elaboration

As we can see, 75% of the suppliers represented by: Polypropylene supplier, g-10-11-9-7 supplier, polycarbonate supplier, Micap supplier, NEMA G-9 supplier, NEMA CANVAS supplier, NEMA G-7, supplier of ARBORON, supplier of MYLAR with an average rating of 92.1%; It is important to mention that with this assessment an improvement area was detected, represented by the Supplier of NEMA GP-09, which obtained a rating of 74% and a yellow traffic light. Although the aforementioned suppliers are adapted to the organizational needs, in the same way those that, according to their limitations, will be convenient to replace them to avoid problems of future rejections, contemplating Micam suppliers, Nomex suppliers as suppliers not suitable for later purchases.

7.2 Result 2)

After the application of the Check List, raw material rejections were significantly reduced, reaching an average reduction benefit of 7.7%, with respect to the rate reported at the beginning of the project (Table 3. Level of rejections in the inspection-receipt area).

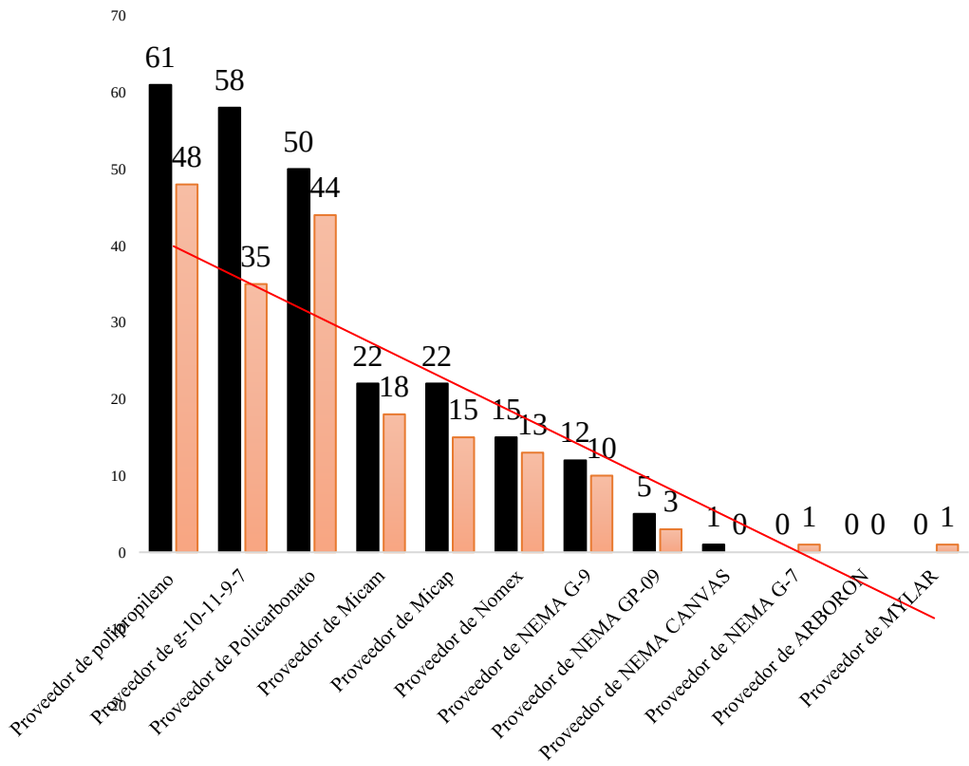
Table 3. Level of rejections in the inspection-receipt area

Providers	Number of rejects (lots) initial status	Reported defect	Number of rejections (lots) final status (after application)	Reported defect	% Decrease
Polypropylene supplier	61	color fault	48	Color Fault (32)/Porosity (16)	21.3%
g-10-11-9-7 supplier	58	color fault	35	Color Fail (35)	39.6%
Polycarbonate Supplier	15	Porosity	44	Porosity	12%
Micam provider	22	color fault	18	Color fault/ Porosity	18.18%
Micap supplier	22	Porosity	15	Porosity	31.8%
Nomex Supplier	15	Porosity	13	Porosity	13.3%
NEMA G-9 Supplier	12	color fault	10	color fault	16.6%
Supplier of NEMA GP-09	5	color fault	3	color fault	40%
Supplier of NEMA CANVAS	1	Porosity	0	n/a	100%
Supplier of NEMA G-7	0	n/a	1	Porosity	+100%
Supplier of ARBORON	0	n/a	0	n/a	0%
MYLAR supplier	0	n/a	1	n/a	+100%

Source: Own Elaboration

The statistical analysis allows us to observe a decreasing trend with respect to the initial period and the final period (Figure 13. Comparison of the initial and final index of raw material rejections in the inspection-receipt area).

Figure 13. Comparison of the initial and final index of raw material rejections in the inspection-receipt area



Source: Own Elaboration

7.3 Result 3)

Economic benefit: The economic impact that originates is notorious, for this reason a costing table is developed below, in which the costs per material and the savings achieved on a monthly basis are shown (Table 4. Cost analysis).

Table 4. Cost analysis

	Providers											
	Polypropylene supplier	g-10-11-9-7 supplier	Polycarbonate Supplier	Micam provider	Micap supplier	Nomex Supplier	NEMA G-9 Supplier	Supplier of NEMA GP-09	Supplier of NEMA CANVAS	Supplier of NEMA G-7	Supplier of ARBORON	MYLAR supplier
Initial cost per rejected lot	$345,621.15	$270,214.20	$195,600	$226,513.14	$254,300.18	$78,615.2	$93,745.19	$76,800.17	$10,400.22	$0.00	$0.00	$0.00
Cost achieved per rejected lot	$271,964.18	$163,060.29	$172,128	$185,328.93	$173,386.48	$68,133.17	$78,120.99	$46,080,102	$0.00	$23,600.12	$0.00	$11,500.24
Benefit achieved	$73,656.97	$107,153.91	$23,472	$41,184.21	$80,913.7	$10,482.03	$15,624.2	$30,720.06	$10,400.22	**-$23,600.12**	$0.00	**-$11,500.24**

Source: Own elaboration

According to the exposed costing, a net benefit of $358,506.94 is obtained, mentioning that an improvement area is detected for the NEMA G-7 supplier, and the MYLAR supplier, who show a rebound with 1 batch of raw material rejected by each provider.

8. Acknowledgments

To the Higher Technological Institute of Huauchinango and the Industrial Engineering Division for the facilities provided for the preparation of the presented chapter.

9. Conclusion

This application demonstrates the importance of developing projects that control quality processes in transformation industries, according to the case evidenced, it is the inspection-receipt area that exposes the greatest problems, causing quantifiable economic losses, this as a result of a lack of standardization in operational activities caused the different suppliers to return to the area of origin with rejected shipments; With the implementation of quality controls (internal audit, check list, input control of raw materials and supplies, and labeling systems), 85% of operating activities were standardized. It is important to mention that in order to achieve the proposed benefits, a training process was carried out for the staff that was part of the auditing group, which would make up the internal commission to carry out the audits on a monthly basis, as well as for the application of the Check List. to the training of personnel (inspection-reception operators) who are in charge of receiving the raw material and supplies; Finally, a follow-up methodology was designed to avoid the generation of future rejections.

However, according to the results obtained, it is verified that the tools that structure quality control are effective techniques, which, when applied correctly, allow obtaining quantitative (economic) and qualitative (standardization-monitoring) benefits for organizations. transformation.

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Chapter 4 Technological Implementation for rainwater harvesting

Capítulo 4 Implementación tecnológica para la captación de agua de lluvia

BONES-MARTINEZ, Rosalía†*, SOTO-LEYVA, Yasmin and SANTOS-OSORIO, Arturo

Tecnológico Nacional de México/Instituto Tecnológico Superior de Huauchinango

ID 1st Author*: Rosalía, Bones-Martínez* / **ORC ID:** 0000-0001-8829-9737, **CVU CONACYT ID:** 368744

ID 1st Co-author: *Yasmin, Soto-Leyva* / **ORC ID:** 0000-0003-2652-7065, **CVU CONACYT ID:** 951464

ID 2nd Co-author: *Arturo, Santos-Osorio* / **ORC ID:** 0000-0003-3643-5770, **CVU CONACYT ID:** 951024

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R. Bones, Y. Soto and A. Santos

*rosalia.bm@huauchinango.tecnm.mx

A. Marroquín, J. Alonso, Z. Chavero and L. Cruz (Coord) Engineering and Innovation. Handbooks-©ECORFAN-México, Querétaro, 2022.

Abstract

This project presents the collection and use of rainwater at the Higher Technological Institute of Huauchinango based on a physical model of water collection, with which water is collected and stored directly outdoors, providing real data on a daily. On the basis that rainwater can be used as an alternative to supply the water demand, in some of the daily activities. Primarily, the physical model of rainwater capture and collection is implemented, then it is stored in a water tank and from this data was collected in liters, during a period of time of 30 days, during this period of time different samples were taken, before and after passing through the filter, to determine some of its physical and chemical characteristics to define the use of water in the infrastructure of the Higher Technological Institute of Huauchinango.

Storm water, Sustainable, Ecological

Resumen

En este proyecto se expone la captación y uso de agua de lluvia en el Instituto Tecnológico Superior de Huauchinango a partir de un modelo físico de recolección de agua, con el cual se realiza la captación y el almacenamiento de la misma al estar directamente a la intemperie, proporcionando datos reales día a día. En base a que el agua de lluvia se puede emplear como una alternativa para abastecer la demanda de agua, en alguna de las actividades cotidianas. Primordialmente se pone en marcha el modelo físico de captación y recolección agua de lluvia, posteriormente se almacena en un tinaco y de este se tomaron los datos de volúmenes recolectados en litros, durante un periodo de tiempo de 30 días, durante este periodo de tiempo se tomaron distintas muestras, antes y después de su paso por el filtro, para determinar algunas de sus características físicas y químicas para definir el uso en las cabañas cotidianamente.

Aguas Pluviales, Sostenible, Ecológico

1. Introduction

It is made an investigation and distribution of rainwater, based on the fact that it can be used as an alternative to supply the water demand in some of the daily activities carried out at the Higher Technological Institute of Huauchinango. Particularly the presentation of a physical model of rainwater collection and filtering will provide the necessary data to determine the appropriate use in such facilities.

Based on the above, some problems that have arisen over time are presented. The main one is due to the growth of the urban population, and therefore to the increase in the demand for water consumption. These problems of water scarcity are rethinking the role of rainwater from being considered as a waste to being considered as a resource, capable of supplying several of the daily activities. This water resource can be depleted quickly, that said, it is intended to generate the implementation of a rainwater harvesting system to supply the required demand, making use of the water that we took as waste. This research work and for its development, different tests were elaborated to determine some physical and chemical characteristics of the collected water, and with these results to determine a good use of implementation for the utilization and optimization of captured water, following a series of phases within a methodology, a physical model is built which captures and filters the water improving its conditions for its use.

Objectives

General Objective

The construction of a physical model of rainwater harvesting in the Higher Technological Institute of Huauchinango.

Specific Objectives

- Investigation of materials to create a physical model.
- Research for correct model placement
- Build a physical model for rainwater harvesting.
- Analyze the quality of the collected water.

Justification

The objective is the construction of a physical model of rainwater harvesting, which has a filter that is made up of three different layers of granular materials, the collected water is intended to be used for the infrastructure of the Higher Technological Institute of Huauchinango.

After the model has been built, several samples of the collected water are obtained to carry out some analyzes of the physical and chemical characteristics such as apparent color, odor and taste, turbidity, pH, suspended solids, oxygen and conductivity. Once the results are analyzed, a comparison is made to make the best use of this water, thereby reducing the demand for this vital liquid.

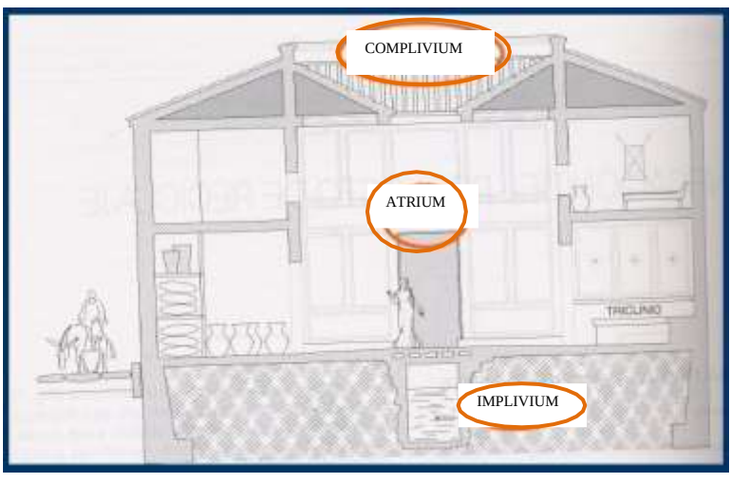
1.1 Chapter I Generalities

1.1.1 Historical background

The ancient civilizations grew demographically and some peoples occupied arid or semi-arid areas of the planet, the development of forms of rainwater harvesting began as an alternative for irrigation of crops and domestic consumption. Archaeologists found a sophisticated rainwater collection and storage system on the island of Crete, while working on the reconstruction of the Palace of Knossos (1700 BC). In Yemen, where rainfall is scarce, there are buildings (temples and prayer sites) that were built before 1,000 BC, which have patios and terraces used to capture and store rainwater. (Ballen S, et al; 2006).

Rainwater harvesting systems were considered when designing and building dwelling-houses, complementing them with the construction of cisterns for storing water for domestic use and thus satisfying the needs of man. During the Roman Republic (3rd and 4th centuries B.C.) the city of Rome was mostly occupied by single-family homes called "la Domus" (figure 1) that had a main open-air space ("atrium") and in it were installed a central pond to collect rainwater called "impluvium", rainwater entered through a hole in the roof called "compluvium". (Gallardo and Cornejo, 2008).

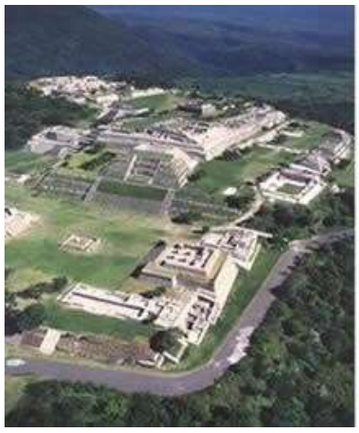
Figure 1.1 "La Domus" and its components of the rainwater harvesting system



Reference Source: (Gallardo and Cornejo, 2008)

In the pre-Hispanic Mexico there is evidence of these systems, such as in the archaeological zone of Xochicalco, Morelos, 650 to 900 AD, where there was no source of water supply, so efficient use of water was practiced. The central square and yard were designed to channel rainwater into cisterns, which stored the water for seven months. Figure 1.2 (Garrido 2006).

Figure 1.2 Left, Xochicalco Archaeological Zone. Right, Cistern built with stone for storage of rainwater




Reference Source: (Garrido, 2006)

As time passes and the accelerated increase of man advances, some problems began to appear, such as the great demand for water for daily consumption, evidencing a great decrease in the vital liquid, generating the change of some civilizations to other areas to supply this need.

With these arising needs, rainwater harvesting systems began to be presented in ancient times and there is no precise data on their origin, although authors agree on theories that these systems were generated from the first civilizations of the Middle East. (Rodríguez Negrete, and others, 2005).

1.1.2 Sustainability in the world

England and the United States were pioneers in the creation of associations and laws in defense of nature, an example followed later by France, Germany and Spain. The United States is where the idea of preserving large spaces in their original state, such as landscapes and "sanctuaries" for animal and plant life, leaving out the human presence, arises. In 1864 the government ceded, for this purpose, the Yosemite Valley and the Mariposa Grove, in California; and in 1872, the first national park in the country and the world, Yellowstone, was created.

Since then, some practices such as the use of renewable materials and/or the design of solar energy harvesting date back thousands of years. The contemporary green building movement grew out of the need for more energy efficient and environmentally friendly building practices. The oil price increases of the 1970s prompted significant research and activity to improve energy efficiency and seek renewable energy sources. This, combined with the green movement of the 1960s and 1970s, led to the first experiments with contemporary green building.

The U.S. Green Building Council (USGBC) promotes sustainability in the way buildings are designed, constructed, and operated. The USGBC is best known for the development of the rating system called LEED (Ledearship in Energy and Environmental Design), which promotes environmentally responsible materials, sustainable architecture techniques and public policies in the building industry (Greenbuilding, EPA, 2010).

1.1.3 Sustainability process in Mexico

Since 1988, Mexico has had the General Law of Ecological Balance and Environmental Protection, in which sustainable development is conceived as: "The process that can be evaluated through indicators of an environmental, political and social nature that tends to improve the quality of life and the productivity of people, which is based on appropriate measures to preserve the ecological balance, protect the environment and take advantage of natural resources, so that the satisfaction of the needs of future generations is not compromised."

Policy initiatives related to energy saving in buildings began only in the mid-1990s, when the National Commission for Energy Saving (Conae) promoted the formulation and application of mandatory standards on energy efficiency. energy for lighting and the envelope of non-residential buildings. The National Commission for Energy Saving (Conae) recently began working on the implementation of a solar water heater program; Such an initiative, together with the establishment of sustainability guidelines for public sector acquisitions, leases and services, will undoubtedly contribute to the promotion of more efficient construction.

1.2 Chapter II Rainwater harvesting

Implementing rainwater harvesting has been given different methods and systems, such as the trench method, this method allows rainwater to be retained and filtered regardless of its runoff surface. Several studies have been carried out on the retention trenches that have generated optimization in their use and an excellent process depending on the site to use this method, and for which they have generated questions to be resolved about these models, generally reaching all these devices. To the same question "what would be the time that both retention and infiltration trenches would be useful", this is the aspect with the greatest impact that can be resolved with this type of system to rehabilitate rainwater. (Proton and Chocat, 2007).

Different studies have been carried out which evaluate the hydraulic behavior of the retention and infiltration trenches, one of these was carried out by (Proton and Chocat, 2007) from an experimental setup which consists of generating a single conduit for rainwater, dividing filtration in various hatches or filter modules and delivering to a single conduit, which is the output of the model. Parallel to this (Proton and Chocat, 2007) they study and test modeling in order to generate projected results of the number of years of rainfall. To carry out this research work, a supply of real runoff water was taken, captured on a highway or urban road stored in a tank to optimize its use in these tests. The water obtained was recirculated in the model to produce representative volumes of periods projected to years of rainfall.

1.2.1 Catchment Area

Places where they are used to collect water can be roofs, patios, esplanades, paved roads, garages and any non-permeable surface where rainwater runs off and it is feasible to collect it. As a rule, in all the systems they use the catchment on the roofs, which must have an adequate slope and surface, which facilitate the runoff of rainwater towards the collection and storage system. As a rule, in all the systems they use the catchment on the roofs, which must have an adequate slope and surface, which facilitate the runoff of rainwater towards the collection and storage system. The quantity and quality of the collected liquid varies depending on the treatment technologies and the annual precipitation of the area and the collection area. This amount can be affected by roofing materials, splashing outside the catchment area, leaks, evaporation, and absorption.

1.2.2 Driving system

It is a set of gutters or pipes of different materials and shapes that conduct rainwater from the catchment area to the storage system, through drops with PVC pipe for current buildings for buildings already built. Gutters are installed on the lower edges of the roof, where rainwater tends to collect before falling to the ground; the material must be light, resistant, easy to join together, must match the finishes of the facilities (urban areas), and must not contaminate with organic or inorganic compounds; Therefore, it is recommended to place meshes that stop garbage, solids and leaves, to avoid obstruction of the flow in the conduction pipe; likewise, carry out cleaning tasks on the roofs at the beginning of the rainy season.

1.2.3 Storage and retention

The rainwater storage tank allows access to water close to the point of use, at the time and in the quantity required. It can be built above or below ground level (cisterns) and be made of materials such as plastic (which does not transmit odors or flavors to the water), cement, partition or block. One of the biggest challenges in installing this system is to lower the cost of materials and construction. In the Blue Schools (IRHA 2018) and Mazateca (Isla Urbana 2018) projects, geomembrane tanks with low labor cost metal supports were installed.

Advantage:

Can be used in community and family systems
Long life time
Low maintenance cost

Disadvantages:

Must have sufficient water supply from surface or catchment roof
Relatively high cost
Possibility of reproduction of disease transmission vectors (mosquitoes, flies, etc.)
Possible contamination to lack of maintenance.

The storage tank allows the collection of water during the rainy periods, making the water resource available near the houses, especially in periods of drought. They can be built above or below ground level (cisterns). The tank can be made of materials such as plastic (which does not transmit odors or flavors to the water), cement, partition, block or geomembrane. PAHO (2004) recommends using masonry for volumes less than 100 and 500 liters in rural areas. The interior of the tank must be insulated to keep out insects and sunlight, which leads to algae growth inside the tank. Some tank models may have buttresses.

1.3 Chapter III Design Considerations

To determine the size of the tank, the number of users, consumption habits and the collection capacity of the collecting surface must be considered. Ideally, the tank should have the capacity to supply water throughout the dry season plus an additional 5% volume, which is the minimum level that should always be in the tank to avoid damage due to decreased humidity within it. Details and formulas for calculating the volume of the storage tank are provided by PAHO (2004), who indicates that the size of the tank will depend on the supply and demand in each of the months of the year, so a volume must be counted that store water during periods of abundance to ensure water during periods of drought, without losing sight of the economic factor. According to PAHO (2004) "there is a direct relationship between the investment required to implement the rainwater system, and the catchment area and storage volume, often resulting in a restriction for most of the stakeholders.

The storage tank must have the following elements: an easily accessible door for cleaning, a turbulence reducer, an overflow, a household intake 10 cm above the bottom of the tank (which does not obstruct the passage) and a drain valve at the bottom of the tank (Gutierrez and Bulnes 2016). PAHO (2004) recommends that storage tanks be no more than 2 meters high to minimize overpressure. In some cases, the surface of the tank can be used to capture rainwater directly, as long as the filtering process of the water before it enters the tank is guaranteed. In the event that the tank is of the cistern type, a pumping system should be considered to extract the water, either mechanized or by human force, as well as the placement of a manifold at the end of the extraction tube. In addition, it is recommended to place a measuring ruler (García and Hernández 2017) with a level scale on the outside of the tank to be able to calculate the amount of water in the tank during monitoring or water purification work.

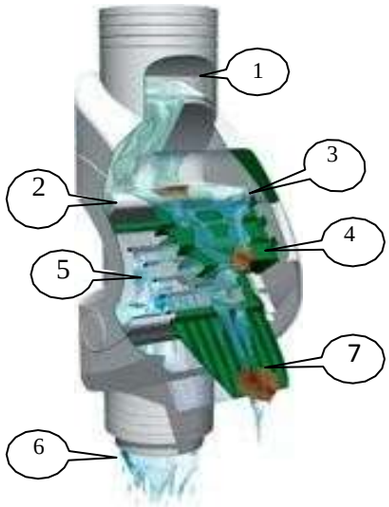
1.3.1 Operation and maintenance

It is important to keep the tank door closed. The inside of the tank should be cleaned every two years, at the end of the dry season, emptying it completely, cleaning the walls and the bottom with a soft broom and a mixture of water and chlorine (proportion 20/1), let it rest for half hour and then rinse, removing all the water inside. At the end, the tank must be filled by at least 5% (García and Hernández 2017). Next, it is recommended to check the quality of the water and that there are no leaks in the tank. If the latter occurs, a mixture of cement and water (with the previously prepared surface) should be applied to the outside.

1.3.2 Rainwater treatment

- The elements to guarantee the quality of the water captured in the treatment, can be the filters that are the most used today.
- The use of filters prevents the passage of solid waste dragged by precipitation into the tank, preventing its sedimentation or fermentation and bad smell of the water. The filter drain is directly connected to the cistern or storage tank.
- There are a large number of manufacturers of self-cleaning external filters for rainwater collected on the roofs of buildings. The capacity and dimensions of the filters depend on the catchment area.
- The first filter can be a grid placed in the pipe or gutters that carries the collected water and that serve to retain mainly the leaves of the trees or other large solids, as shown in the following.

Figure 3.1 3P Rainus filter, filter parts and their operation



Reference source :(image taken from www.3ptechnik.com.mx)

1. Connection to storm water downspout
2. Perimeter filter
3. Passage of filtered water
4. Fall and drag of removed solids
5. Perimeter collection
6. Lateral collector towards cistern
7. Collection of removed solids

The quality of the water collected is achieved by means of special devices, especially when the water is to be consumed directly, that is, it is to be drinkable in the first few millimeters of rain, a first runoff diversion trap can be used to drag polluting solids that have been deposited on the roofs. The implementation of traps for the first runoff allows the removal of the highest density particles. The trap for diversion of the first runoff of water also avoids the contamination of the water in the tank with the first precipitations, which are the most polluted. The water diversion device can be installed on each downspout supplying water to the cistern, or larger units that can handle multiple inlet pipes.

1.4 Chapter IV Technological implementation for rainwater harvesting

Scope

- Show the advantages of carrying out an implementation of rainwater harvesting generation systems as a viable solution for the sustainability of the infrastructure of the Higher Technological Institute of Huauchinango.
- Take advantage of the implementation of gutters to collect water and thus reduce the consumption of drinking water and take advantage of rainwater.
-

Limitation

– Lack of user participation.
– High cost to create sustainability.

1.4.1 Methodology

Current situation

The infrastructure of the Higher Institute of Huauchinango is in optimal conditions and its current water supply is not so critical, it is only a matter of focus since presenting our position with nature, it is convenient to work for it, take care of it, and reuse it. Working with rainwater harvesting is the solution to minimize the use of water supplied by the municipality, giving a plus to our ecology, making these benefits known and taking care of our environment by taking advantage of a vital liquid that is wasted to reuse it for purposes ecological.

Precipitation

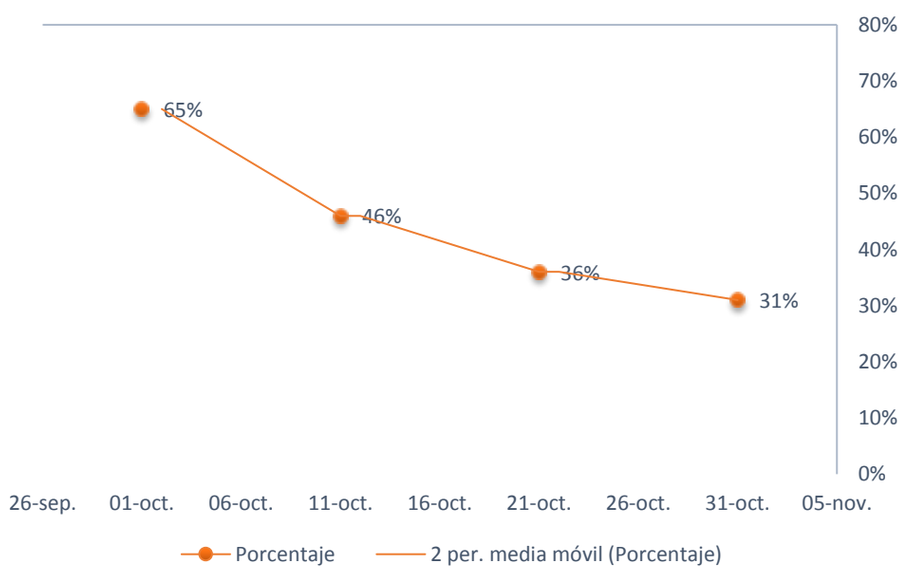
A wet day is a day with less than 1 millimeter of liquid or liquid-equivalent precipitation. The chance of wet days in Huauchinango, Puebla varies very significantly throughout the year.

The wetter season lasts 4.5 months, from May 28 to October 13, with a greater than 43% chance of a given day being a wet day. The maximum chance of a wet day is 77% on July 3.

The drier season lasts 7.5 months, from October 13 to May 28. The smallest chance of a wet day is 9% on January 13.

Among the wet days, we distinguish between those with only rain, only snow, or a combination of the two. Based on this categorization, the most common form of precipitation throughout the year is rain alone, with a maximum probability of 77% on July 3 (Ovacen, 2018).

Graph 4.1 Chance of Precipitation in October



Reference: (Own Elaboration, 2021)

1.4.2 Correct placement of the model for rainwater harvesting

Materials

Anthracite

For the main and first layer, this material is an excellent filtration medium, mainly for the elimination of chlorine and organic compounds present in the water that is captured.

Sand

As a second layer of the filter we find sand, with a lower density than gravel. Thanks to its round-shaped grain symmetry, it ensures porosity, letting the water flow easily, but retaining some suspended particles that continue to appear in the rainwater.

Gravel

As a third segment, this one below is used in the filters due to its density, the heaviest of these materials already installed previously, it has great characteristics which make it a very good material for filtration, which does not impart any characteristic to the water collected, passage of the water through the gravel will stop at these contaminants.

Geotextile NT1600

Finally, we have this material which, due to its fine conformation structure, its main quality is found in its faces, one of these is waterproof and the other is permeable, therefore, it is an excellent retainer of contaminants that water can bring. and fine particles, mentioning its properties above as a filter material, it is chosen to use between layers, this being one more layer of filter material in the rainwater harvesting model.

False bottom

It is like a type of storage tank where some suspended solids that may occur can settle, since the outlet of the collected water is located at a height of 0.10 m from the bottom, so the last contaminants end up here and let the water come out fully filtered for use.

1.5 Implementation prototype

Finally, we find the physical prototype to verify the operation since this is how the collected water samples were taken to see the difference and verify its usefulness of the collected rainwater. This physical prototype is made with glass walls to appreciate its operation almost in its entirety.

Figure 5.1 Physical Prototype

Reference Source :(Own Elaboration, 2021)

With the taking of samples for the study of the quality of the water to establish its use, we were able to realize that a notable difference can be seen with the naked eye with the use of this filter.

1.6 Results

1.6.1 Comparative physical and chemical properties

By taking into account the type of water to be collected, a comparison between rainwater is generated, measurements of these physical and chemical characteristics are made through an analysis of samples taken, before entering the model and at the exit of the model., the characteristics measured are the following: Determination of pH, Turbidity, Apparent Color, Suspended Solids, Odor and Taste, Oxygen and Conductivity.

In accordance with resolution 2115 of 2007, a comparison of its physical properties is made with a sample captured before and after the filter, obtaining the following results.

Figure 6.1 water Sample before passing through the Prototype (Filter)

Reference Source: (Own Elaboration, 2021)

Figure 6.2 water Sample after passing through the Prototype (Filter)

Reference Source: (Own Elaboration, 2021)

Table 6.1 Physical Properties

Physical Characteristics	Drinking water Maximum value Acceptable	Rainwater collected before filter	Rainwater collected after filter
apparent Color	15	12	10
Odor and taste	Acceptable	Acceptable	Acceptable
Turbidity	2	7,47	7,81
pH	6.5 a 9.0	5,33	5,57
Suspended Solids	100	116	111
Oxygen	3 ml/lt.	2,7	2,7
conductivity	250	217	208

Reference Source: (Own Elaboration, 2021)

Based on these results obtained, we can use this water for flushing toilets and general services such as cleaning the facilities without presenting any inconvenience.

1.6.2 Catchment area

The collection of rainwater is carried out through the roofs, taking advantage of its large collection area. In this case, the drop that the tin roofs have with the slope and gutters that it contains are good for capturing this liquid.

In this regard, the material of these sheets is selected due to its conditions of easy handling, cost and good handling when building this cover, another great feature that this polyethylene provides is that it maintains the characteristics of water without altering its conditions. initials, it offers us a great impermeability which provides a collection without losses at the time of precipitation that occurs in the area.

Table 6.2 Collection data by model in liters and duration in minutes

Day	duration minutes (m)	intake in liters (lt)
1		
2	180	182
3	90	88
4		
5		
6		
7		
8	95	99
9	42	54,5
10		
11		
12	50	82
13	45	66,2
14		
15		
16	50	111,5
17	40	92
18		
19		
20		
21	53	100,8
22		
23	65	80
24	21	86
25		
26		
27		
28	14	59
29		
30		
	Total	1101

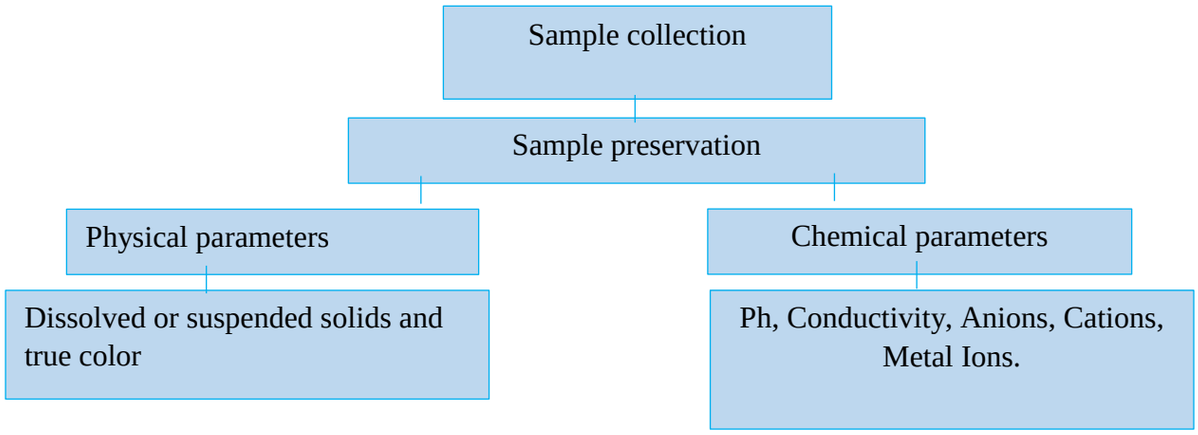
Reference Source: (Own Elaboration, 2021)

Volume captured during the month in m3.

Based on the data collected above, an equation will be used to see the volume captured in liters during the month.

V= 1101 Lt * $\frac{1m3}{1000\ Lt}$ = 1.10 M3

Figure 6.3 Comparative physical and chemical properties



Reference Source: (Own Elaboration, 2021)

The rainwater captured according to its characteristics will be used for the discharge of toilets and general services such as cleaning in the facilities, it is assumed that, of the total design volume, only a percentage of 65% of this will be used for the aforementioned uses.

Daily demand used for flushing toilets and general services.

D= 0.45 m^3/day * 0.65 = 0.2925 m^3/day

Monthly demand used for flushing toilets and general services.

D= 0.2925 m^3/day * 30 = 8.775 m^3/day

The month of 30 days is determined, according to this it is calculated that the monthly water demand for this type of use is 8,775 m3.

Financing

Without Financing

Gratitude

To the Higher Technological Institute of Huauchinango and the Industrial Engineering Division for the facilitations provided for the preparation of the presented chapter.

Conclusion

According to the situation presented, it can be shown that the use and exploitation of rainwater is becoming a great alternative that is not common, which allows reducing the impact caused by conventional supply sources.

So with this we can say that the rainwater collection and filtering model created provides a sustainable solution, it is also providing water of an acceptable quality according to resolution 2115 of 2007 to be used in daily activities such as the discharge of toilets and general services such as the cleanliness of the facilities, except for use for human consumption that could affect health.

The benefits that will be reflected when implementing it:

- Sustainability
- Environmental benefit
- Economic savings

Based on atmospheric data from the region, it is a project that fits perfectly since the area is humid-rainy, this puts our plan into operation most of the year, but in terms of collection, the total volume demanded for the determined use, this is due to the fact that the collection area is small in consideration to supply the required need, however, a significant saving potential is obtained of a percentage of 65% of the 8,775 m3 consumed in a month in these activities such as it is in W.C. and cleanliness of the facilities.

From the point of view, this type of alternative resources such as rainwater harvesting is one of the best projects that are currently being managed, due to various factors such as excessive consumption of drinking water, waste, increased payment fees, this It will generate more of the scarcity that already exists, opening the way to rationing at home regardless of how many inhabitants there are in it, and with this collection method, not only does it not affect your economy, you learn to take advantage of the environment without polluting and specifically satisfy your daily needs.

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Chapter 5 A systematic review on life cycle assessment of solar water heaters

Capítulo 5 Una revisión sistemática sobre la evaluación del ciclo de vida de los calentadores solares de agua

SALGADO-CONRADO, Lizbeth[1]†*, ÁLVAREZ-MACÍAS, Carlos[2], ESMERALDA-GÓMEZ, Alma Graciela[1], and PÉREZ-GARCÍA, Laura Andrea[2].

[1]Facultad de Ingeniería Mecánica y Eléctrica, Universidad Autónoma de Coahuila, Carr. Torreón-Matamoros, km 7.5, Torreón, Coahuila, México. CP. 27276
[2]Tecnológico Nacional de México/Instituto Tecnológico de La Laguna. C.P. 27000, Torreón, Coahuila, México.

ID 1st Author: *Lizbeth, Salgado-Conrado* / **ORC ID** - 0000-0002-2181-5861, **CVU CONACYT ID** 296620

ID 1st Co-author*: Carlos, Álvarez-Macías* / **ORC ID** - 0000-0002-2263-0316, **CVU CONACYT ID** 165872

ID 2nd Co-author: *Alma Graciela, Esmeralda-Gómez* / **ORC ID** 0000-0003-1998-0056, **CVU CONACYT ID** 322782

ID 3rd Co-author: *Laura Andrea, Pérez-García* / **ORC ID** 0000-0002-5880-6192, **CVU CONACYT ID** 887623

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L. Salgado, C. Álvarez, A. Esmeralda and L. Pérez

*lizbeth_salgado@uadec.edu.mx

A. Marroquín, J. Alonso, Z. Chavero and L. Cruz (Coord) Engineering and Innovation. Handbooks-©ECORFAN-México, Querétaro, 2022.

Abstract

The aim of this study is to provide an up-to-date literature review of Life Cycle Assessment (LCA) of solar water heaters, published in 2000-2021. A systematic review was chosen as the research method to achieve a comprehensive overview of existing studies in solar thermal systems, identifying the variability of the reported results due to the methodological choices such as functional units (FU), location, system boundaries, life cycle inventory, and impact methods. We conducted a quantitative analysis of the environmental impact of solar water heaters. The results show that there is a significant variability in studies for lack of data inventory, presentation of results in absolute or percentage terms, lack of normalization, and sensitivity studies. The major challenges in solar water heater LCA were identified as the lack of LCA studies in the American, Asian and Australian continents, lack of comparative studies of LCA with similar goals and scopes, lack of studies of evacuated-tube solar collectors, integral collector storage systems, and new solar water heaters.

Assessment, Systematic, Environmental issues, Solar water heater

Resumen

El objetivo de este estudio es proporcionar una revisión bibliográfica actualizada de la evaluación del ciclo de vida (LCA) de los calentadores de agua solares, publicado en 2000-2021. Se eligió una revisión sistemática como método de investigación para lograr una visión general completa de los estudios existentes en sistemas solares térmicos, identificando la variabilidad de los resultados informados debido a las opciones metodológicas, como unidades funcionales (FU), ubicación, límites del sistema, inventario del ciclo de vida. y métodos de impacto. Realizamos un análisis cuantitativo del impacto ambiental de los calentadores solares de agua. Los resultados muestran que existe una importante variabilidad en los estudios por falta de inventario de datos, presentación de resultados en términos absolutos o porcentuales, falta de normalización y estudios de sensibilidad. Los principales desafíos en el ACV de calentadores solares de agua se identificaron como la falta de estudios de ACV en los continentes americano, asiático y australiano, la falta de estudios comparativos de ACV con objetivos y alcances similares, la falta de estudios de colectores solares de tubo de vacío, almacenamiento de colector integral y nuevos calentadores solares de agua.

Evaluación, Sistemática, Cuestiones ambientales, Calentador de agua solar

1. Introduction

With the rapid population growth and industrial development, the energy demand has increased substantially. According to the International Energy Agency (IEA), world energy demand for this year is projected to increase by 4.6%, where energy consumption is centred on natural gas (3.2%) and electric energy (4.5%) (IEA, 2020). As energy plays a crucial role in the daily activities of humans, many efforts have been led to the use of conventional and no conventional energy sources to cover it. Under this context, the use of solar energy has become one of the most promising alternative energy options to cover part of energy demands at a low cost and without damaging the environment.

One of the solar technologies that has emerged is solar water heater (SWH) system, which is used to heat water for domestic and industrial applications. It offers significant advantages to their user such as cost reduction in gas and electricity bills and the carbon footprint, return on investment in a short time and reduced greenhouse gas emissions (Wang et al., 2015). It is a technology available today in both commercial and industrial scale. Despite the fact that energy technology is considered as a cleanest source, significant interaction with the environment take place throughout the life cycle of this technology. These interactions may result in an important environmental impact, especially during the manufacturing process and end-of-life phase.

As an answer to the growing interest for reducing the greenhouse gas emissions, the methodology LCA has been applied in solar technology projects. Life cycle assessment (LCA) is a valuable tool for quantifying the environmental and potential impacts of a product, process, or service. It is based on the extraction and processing of raw materials; manufacturing, transportation, and distribution; use, reuse, maintenance; recycling and final disposal (Horne et al. 2009, Kikuchi and Kanematsu, 2020).

The LCA methodology is standardised by two international standards, named ISO 14040:2006 and ISO 14044:2006 (ISO, 2006; Toniolo et al., 2020,). As described in ISO 14040/44, an LCA analysis consists of four phases: goal and scope definition; inventory analysis; lifecycle impact assessment (LCIA); and interpretation. The goal and scope definition phase determines the appropriate limits of the analysis. It establishes the functional unit, system boundaries, and quality criteria for inventory data. The life cycle inventory (LCI) analysis is the heart of the LCA process since it is involved with data collection, synthesis, validation, and calculation procedures. Life cycle impact assessment examines the process or product system from an environmental perspective, using several impact categories and indicators connected with LCA results. Different environmental impact categories are evaluated such as climate change, ozone depletion, ecotoxicity, human toxicity, photochemical ozone formation, acidification, eutrophication, resource depletion, and land use. Finally, the life cycle interpretation deals with the interpretation of results from both the life cycle inventory analysis and life cycle impact assessment (ISO, 1997, Haque, 2020).

A number of life cycle assessment studies have been carried out with the aim to cover the environmental impacts of SWH systems in the last decade. However, very few review studies have been published. An example of this is the study carried out Tsilingiridis and Martinopoulos (Tsilingiridis et al., 2010) which demonstrated the growing interest in the energy and environmental benefits of SWH of thirty years in Greece. Their analysis showed that CO_2 reduction exceeded by 44.7% the objectives of the Greek program of 'Climatic Change'. In 2015, Lamnatou et al. (Lamnatou et al. 2015) carried out a review on Life Cycle Analysis of solar technologies with emphasis on building-integrated (BI) solar thermal systems. Their paper revealed that is a need for solar thermal system LCA studies, especially for BI active configurations. In 2016, they studied in detail, the building-integrated solar thermal system based on vacuum-tube technology. The paper compiled all manuscripts related to this topic. The focus of this study was to analyse critical aspects of vacuum-tube technology through a case study. They showed that there are few LCA studies about this solar technology and most of them are based on embodied energy and CO_2 emissions (Lamnatou et al., 2015).

Therefore, the main objective of our research is to systematically organize and summarise published literature of solar water heating system LCAs. Our primary goal is to present an overview of the environmental impact and energy assessment of SWH. A striking feature of the solar water heating system LCAs is the variability of the reported results due to the methodological choices. These choices include functional unit (FU), location, system boundaries, life cycle inventory, and impact method. Our secondary goal is to analyse these methodological choices through qualitative analysis. It helps the research community to identify challenges and research gaps that need further exploration.

2. Research Method

We conducted a systematic review to gain an understanding of LCA on solar thermal systems. This review was done following the guidelines proposed by Kitchenham et al. (Kitchenham et al., 2007, Kitchenham et al., 2009) and Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019). The research includes several stages: i) development of a review protocol; ii) the search process for relevant publication; iii) identification of inclusion and exclusion criteria; iv) quality assessment; and v) data extraction and synthesis.

2.1 Review Protocol

Two research questions were formulated to discuss the aim of this review. The first question is directed at environmental concerns, 'In the analysis of solar water heater, what the environmental impacts are the most analysed and topics more researched?'. The second question is directed at the research community, 'In the analysis of the environmental impact assessment of solar water heaters, which methodological steps in the LCA can be sources of variation of results?'. A review protocol was developed to gather information on the specific question addressed by this study. As shown in Table 2.1, the review protocol consisted of two sections: bibliographic data and publication content. The bibliographic data include title, year, type of publications, and location. In the content of the publication, goal and scope definition, type of solar collector, FU, system boundaries, methodology, life cycle inventory, and impact categories were considered.

Table 2.1 Review protocol

Bibliographic data	
Author(s)	Who is/are the author(s) of the publication
Year	In which year was the work published?
Title	What is the title of the publication?
Type of publication	What kind of publication (journal/proceeding/book)?
Location	Where was the study carried out?
Focus and content of the publication	
Goal	What was the purpose/aims of the study?
Solar collector	Which is the solar thermal system studied?
Functional Unit (FU)	Which is FU used in this study?
System boundaries	Which life cycle phases were studied?
Methodology	What was the methodology used in this study?
Life cycle inventory	What were life cycle inventory used in the study?
Results	What were the environmental impacts reported?

Source: (Self Elaboration)

2.2 Data sources and search strategy

The literature search was carried out by searching for relevant articles published in Elsevier (www.sciencedirect.com), Springer (www.springerlink.com), Wiley (www.wiley.com), IEEE Xplore (http://www.ieee.org), and Google Scholar (scholar.google.com). The keywords used were related to synonyms and their acronym of LCA (‘Life Cycle Analysis', ‘Life Cycle Assessment', ‘LCA', ‘environmental performance/impact', ‘life cycle energy analysis' ‘energy assessment', and ‘LCEA'), and solar water heater (‘solar thermal collector/system', ‘heating systems', ‘domestic solar system', and ‘SWH'). The search words were connected by Boolean operators and applied to the title, abstract, and keywords.

In the first search, 2 685 studies were identified considering the diverse keywords for our systematic review. After removing duplicated publications, a second screening was based on information derived from titles and abstracts, in this stage, 325 relevant studies were identified. At the last count, a total of 38 articles were identified as primary studies.

2.3 Inclusion and exclusion criteria

In this review, journal papers, conference proceedings, and book chapters published in 2000 or later were considered in this analysis. We concentrate on English literature to make this review replicable for readers. Studies were eligible for inclusion if the focus of the study was based on the environmental and energy impact assessment of domestic solar water heaters.

Gray literature was excluded to ensure the quality of the selected articles such as research reports, thesis, presentations, and comments. These publications are usually not peer-reviewed and may represent preliminary research findings, reflecting in high variability of its quality (Costa et al., 2019). We also excluded studies on solar thermal plants, photovoltaic systems, studies presented in languages other than English, studies whose findings are unclear and ambiguous, studies that do not provide answers to the research questions, and duplicated paper of a study exist in different versions that appear as books, journal papers, conference and workshop papers.

2.4 Quality assessment

After using the inclusion and exclusion criteria, each research paper was based on four quality assessment criteria, shown in Table 2.2. Using the quality assessment, all the included papers contain high quality on Life Cycle Assessment (LCA) and Life Cycle Energy Assessment (LCEA) of solar thermal systems used in heating water.

Table 2.2 Quality assessment

Bibliographic data	
Study ID	Who is/are the author(s) of the publication
Author(s)	In which year was the work published?
Year	What is the title of the publication?
Title	What kind of publication (journal/proceeding/book)?
Type of publication	Where are they?
Country	What is the name of journal/proceeding/report?
Information about numerical simulator of thin film solar cells	
Name of the tool	What is the numerical simulation tool used in the analysis?
Features	What are the main features of the numerical simulation tools? Is the software free or licenced?
Name URL	What is the URL from which it can be downloaded?
Focus and content of the publication	
Goal	What is the purpose/aims of the study?
Topic of case study	What are the topics addressed with numerical simulation tools?
Dimensionality	What was the dimensionality addressed in the study?
Solar cell structure	What was type of structure simulated?
Type of study	What is the type of study address? (Optimisation, modelling, validation or comparison)
Date used	What were type of data introduced in the software? (Experimental/ Literature)
Simulated parameters	What were the parameters used in the simulation?

Source: (Self Elaboration)

2.5 Data extraction and synthesis

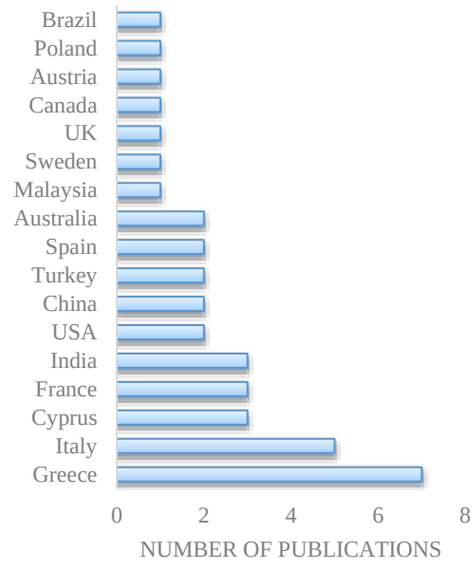
According to the review protocol, data extraction was conducted qualitatively for each of the 38 primary studies included in this review. This form enabled us to gather details of primary studies, such as aim, research methods description, findings, and conclusions. All the selected articles were analyzed in line with the research questions set for this review.

3 Results

3.1 Overview of selected studies

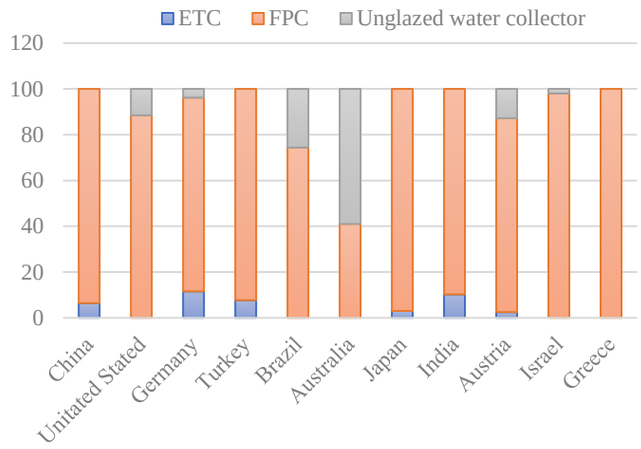
In general, we found that most LCAs of solar water heaters have been prepared in a European context, as shown in Graphic 3.1a. The country with the highest number of articles in LCA is Greece (7/38), evidencing the interest in developing and assessing environmental emissions of domestic solar water heaters. Italy (5/38) and Cyprus (3/38) also presented the largest number of case studies of the life cycle assessment methodology. From its part, North America is well represented with 2/38 studies of environmental impact analysis. As shown in detail in Graphic 3.1b (Qiu et al., 2015), Greece, Israel, India, Japan, Turkey and Germany are world leaders in the use of FPC systems, while China is world leader in ETC systems and United States is in unglazed water collectors. It can be seen that Israel, Brazil, Japan and Germany only report the installation of SWH and show few interests to develop and assess environmentally solar water heater systems.

Graphic 3.1 Solar water heaters in the world



a) Geographical distribution of LCA solar water heaters

Source: (Self elaboration)

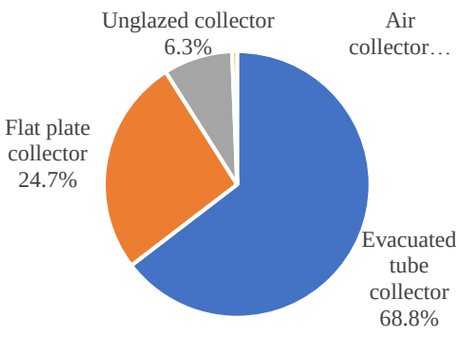


b) Ten leading countries in solar water heaters

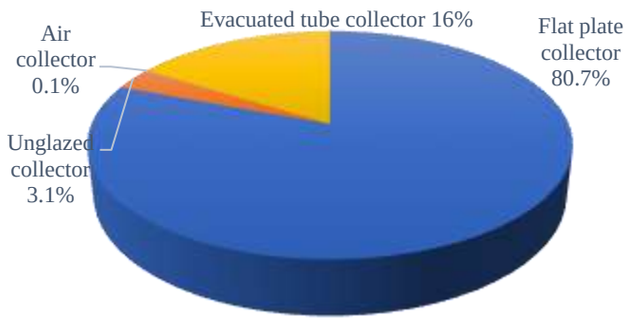
Source: (Qiu et al., 2015)

If we consider the type of solar technology, LCA methodology has been mainly applied in flat plate solar collectors (FPC), evacuated-tube solar collectors (ETC), integral collector storage systems (ICS), and new designs of solar water heaters. The emphasis is given to the life cycle impact assessment of the flat plate solar collectors (36/38), followed by ETC systems (5/38) and ICS systems (3/38). Few studies examine the environmental performance of new designs of solar water heaters (Lamnatou et al., 2014, Kicker et al., 2018). Our results are coherent with previous findings that also indicated that in the European continent FPC are most commonly used for water heating (84.9%) than ETC (9%) or unglazed water collectors (4.5%) (Graphic 3.2b) (Giama et al., 2018). However, the situation is different at the global level, ETC are the predominant solar thermal systems in the world (64.6%), followed by FPC collectors (26.4%) and then the unglazed ones (8.4%) (Giama et al., 2018), as shown in Graphic 3.2a, which indicates a lack of LCA analysis in ETC systems.

Graphic 3.2 Solar water heater distribution



a) Distribution of SWH in the World



b) Distribution of SWH in Europe

Source: (Solar Heat Worldwide, 2020)

Analysing the topics addressed in solar water heater LCAs, we identified three subjects: a) identification of the most polluting environmental impacts during some of the life cycle scenarios in solar water heaters, b) Comparison overall or in each stage of their life cycle of products or process and c) propositions of improvement across the product life cycle (eco-design alternatives). Among the 38 studies evaluated in this review, 11 manuscripts focused on the environmental impacts overall or in some stage of the life cycle of the SWH systems. 24/38 studies compared SWH with traditional heater systems or other different solar water heater design, and 4/38 papers gave eco-design alternatives.

This study reveals that one of the three most outstanding articles analysing the environmental impacts of solar water heaters was carried out by Kalogirou et al. (Kalogirou, 2009), which evaluated the thermal performance, economic and environmental life cycle analysis of thermosiphon solar water heaters. The authors focused on the pollution created for the manufacture process and installation of SWH systems. The analysis showed that the total energy used in the manufacture and installation of the system can be recouped in about 13 months. The annual solar contribution is 79% with a payback time of 2.7 years and the life cycle savings of 2240 € for electricity backup and 4.5 years and 1056 € for diesel backup. Similarly, Faizal et al. (Faizal et al., 2013) presented an energy, economic and environmental analysis of a flat-plate solar collector. According to this study, more than 70% of the embodied energy of the SWH system comes from the manufacturing of the collector. Both glass and copper influence the overall weight and embodied energy of the system. The use of a nanofluid based solar collector reduces 170 kg CO_2 emissions and 0.09 years of the payback period than a conventional solar collector. In (Koroneos et al., 2012), the researchers examined the manufacturing stages of an FPC and recorded resource consumption and waste streams to the environment. The study showed that the highest environmental effect is the acidification followed by the winter smog potential.

In the topic of comparison of their life cycle of products, Hang et al. (Hang et al., 2012) evaluated FPC and ETC collectors and compared them with natural gas or electricity boilers. The results showed that the FPC and ETC have the best energetic, economic, and environmental performance. Tsilingiridis et al. (Tsilingiridis et al., 2010) applied the LCA methodology to a hybrid-solar electrical system used in Greece and compared it with electricity and natural gas boilers. It was noted that the natural gas heater has a lower environmental impact than the hybrid-solar electrical system. Moore et al. (Moore et al., 2017) investigated the global warming potential (GWP) and primary energy demand (PED) of five standard hot water systems (gas, electric and solar systems). The results indicated that the carbon footprint was reduced in domestic hot water.

For the topic of eco-design alternatives, four manuscripts explored weak points of the SWH design and proposed different eco-design proposals related to the change of materials or design. Ardente et al. (Ardente et al., 2005) studied the energy balance between the employed energy during the collector life cycle and the energy saved. The main focus of this study was eco-profile of input materials, eco-profile of electricity and transport of raw materials, installation, maintenance, and disposal steps. The results showed that the production process affects the eco-profile about 5% of impacts. It was estimated that the energy consumption of raw material eco-profiles achieved from 8 to 15 GJ, CO_2 emission from 500 to 900 kg, and the energy and emission payback times could be lower than 4 years in the worst scenario. Battisti and Corrado (Battisti et al., 2005) evaluated the environmental impact of solar thermal collectors with integrated water storage.

They reported the environmental impacts of the production, operation and disposal phase. In Eco-design, the authors chose different materials and components, in order to improve the performance of solar collector. Thanks to the optimization of the collector, the impacts were reduced 40%, with an environmental pay back times from 5 to 19 months. Albertí et al. (Albertí et al., 2019) compared a solar thermal system used in conjunction with a traditional natural gas heating system, and the natural gas heating system and evaluated different eco-design scenarios for achieving a more circular economy. It was found that the water tank, the collector and the copper tubes are the components with the largest environmental impacts. The authors proposed the change of material in the tubes from cooper to galvanized steel, the use of recycled aluminium in the collector frame and replacing the cover glass with a polycarbonate cover to reduce the environmental impacts.

Also, we identified other studies that analyse the life cycle energy assessment (10/38). Within this category, the initial embodied energy and recurrent energy incorporate were examined. In the first case, it was analysed energy required for the manufacture of material together with the energy required for transportation of a material used for solar water heaters. In the second case, it was studied the energy embodied in the material use due to maintenance, repair during the service life of the solar water heater system (Kalogirou, 2009). A case study was presented by Menzies et al. (Menzies et al., 2010), in which demonstrated how the energy embody can be reduced the through increased use of recycled materials. Leckner et al. (Leckner and Zmeureanu, 2011) found that the incorporation of SWH in buildings gives significant energy savings with relatively quick energy payback times of 8–11 years. Michael et al. (Michael and Selvarasan, 2017) compared PV/T, PV, and FPC systems.

They found that the choice of material-of-construction plays a vital role in reducing the mass, cost, embodied energy, and embodied CO_2 emissions. In addition to this, it was found that 4/38 studies based their investigation on energy carbon methodology for knowing how 'clean' is the solar water heater system. The rest of the studies considered both analyses.

3.2 Functional Unit (FU)

According to the review process, we found three types of Functional Unit used in LCA solar water heaters:

a) Entire equipment: the results of the assessment are reported as global quantities concerning the whole collector. It can consider the solar collector, water tank, structure, and other components.
b) Impacts per unit of area: this type of functional unit is usually selected from studies that study the environmental impacts based on the collector surface.
c) Impacts per unit of energy output: this functional unit is generally the most common alternative to energy systems, due to the environmental impacts is based on solar collectors' energy performance.

As shown in Anexo, the great majority of solar water heater LCAs used the functional unit per unit of energy output, which was selected from around 14/38 of the references. In this category, it was found several types of FU, which is related to daily (Hang et al., 2012; Marimuthu et al., 2014; Zambrana et al., 2015) and annual (Moore et al., 2017) heating energy for a specific number of people at a temperature of 60°C the production of 1 kWh (Mahmud et al. 2018; Milousi et al. 2019; Alberti et al. 2019) and 1MW (Koroneos et al., 2012) of thermal energy; 1TJ of natural gas when the solar collectors cannot provide enough hot water (Rey et al., 2008), and production in litres of heated water (Piroozfar et al., 2016). However, three publications did not detail the functional unit in this category (Vechi et al., 2018; Uctug et al., 2018; Liu et al., 2019.) On the other hand, 10/38 publications used the functional unit of the entire equipment, from which 6 articles included the solar collector, water tank, and support (Ardente et al., 2005, Menzies et al., 2007; Martinopoulos et al., 2013; Comodi et al., 2014; Comodi et al., 2016; Arnaoutakis et al., 2017). Other authors such as Lamnatou et al. (Lamnatou et al., 2015; Lamnatou et al,. 2016) considered as FU the solar collector and additional components of the systems (storage tank, pump, external tubes with their installation, and glycol), while Giama et al. (Giama et al, 2018) considered gas low-temperature boiler, solar collector pipelines, circulating pump, and radiators in this FU. Battisti et al. and Souliotis et al. (Battisti and Corrado, 2005; Souliotis et al., 2018) did not provide a detailed list of the items studied.

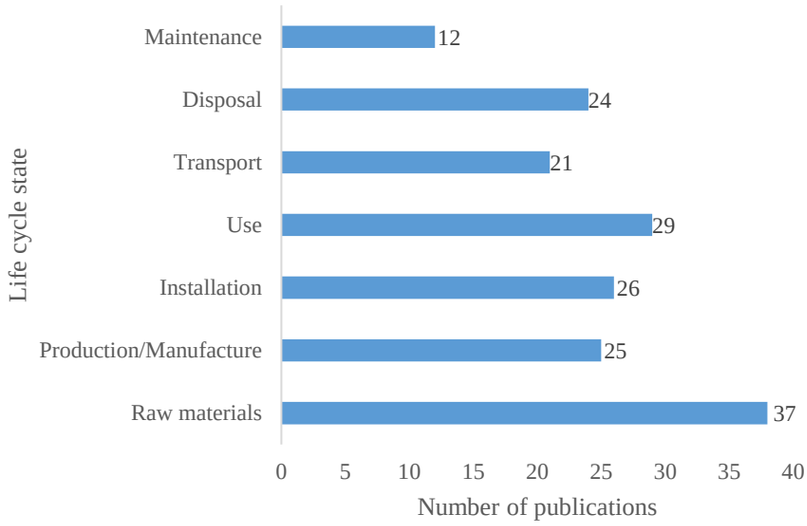
Concerning the functional unit of impacts per unit of the area, it was found that it was the least used in the LCA studies (3/38). For this functional unit, the authors (Carnevale et al., 2014; Anastaselos et al., 2016, Michael et al., 2017) defined m^2 of surface and m^2 of absorber area of a solar collector. The remaining studies provided an unclear description of the FU. It can only be implied, e.g., figure legends or tables of results, therefore, an ambiguous description of the FU can generate biased results from the LCA study.

3.3 System boundaries

In solar water heater systems, there is significant heterogeneity in the selection of system boundaries. Considering the system boundaries approached in the reviewed studies, it was found that the central focus of these publications was to examine the system boundary from cradle-to-grave (19/38), 2/38 publications specified the used of cradle to gate system boundaries (Michael et al., 2017; Mahmud et al., 2018), 1/38 conducted the LCA of a solar thermal system used cradle-to-use analysis (Kylili et al., 2018), and the remaining studies omitted one or several life cycles stages.

The consideration of all stages of the life-cycle is difficult due to the complexity to obtain data. As shown in Graphic 3.3, raw materials (37/38), installation (26/38), production (35/38), and use (28/38) phases are the most studied life cycle phases in the life cycle assessment of solar water heaters. A challenge commonly noticed in the production phase of SWH is related to the use of different materials or techniques without increasing the cost and reducing the efficiency. Moreover, it was noted that the maintenance phase was considered less frequently (12/38). Transportation is generally included in solar water heaters LCAs.

Graphic 3.3 Life cycle states



Source: (Self Elaboration)

Regarding the end-of-life phase, 24/38 articles included life cycle phase; however, a higher degree of heterogeneity can be observed in this stage. For example, some studies assumed that no recycling takes effects and the systems are put in landfill is made (Hang et al., 2012; Faizal et al., 2013; Lamnatou et al., 2016; Giama et al., 2018; Uctug et al., 2018). On the other hand, other studies such as Battirsti et al. (Battisti and Corrado, 2005) compared two different scenarios of the disposal phase: uncontrolled and controlled disposal. The controlled stage showed lower environmental impacts. Their research work did not show a detailed process of the environmental impact in eh end-of-life. For example, Carnevale et al. (Carnevale et al., 2014) considered two end-of-life scenarios for i) dismantling phase and ii) recycling treatments and disposal of residues. However, the authors focused on end-of-life of PV systems due to lacking data in SWH. On the other hand, Carlsson et al. (Carlsson et al., 2014) estimated the end-of-life-cost of a flat plate solar collector based on its expected value, considering its mental content and associated scrap metal prices. The results showed that its end-of-life valued could reduce the total cost of the system by roughly 5-10%.

3.4 Life Cycle Inventory (LCI)

The phase in which the input and output data of the system under investigation are gathered and/or calculated is known as the life cycle inventory (LCI). For the majority of the solar water heater LCAs, the inventory analysis adopted a national-level database. Some databases used in the literature were ELCD/PE International, ECODOM eco-sustainability report, PE international measured, Australian National Greenhouse Accounts, and others.

According to the review papers, the Ecoinvent database is the most used commercial database for environmental data. Fourteen articles adopted it. Other databases referred to the environmental data is the SimaPro database used in 6/38 studies (Battisti and Corrado, 2005, Hang et al., 2012, Comodi et al., 2014; Martinopoulos et al., 2013; Anastaselos et al., 2016; Souliotis et al., 2018) and the Gabi database used in the research of Comodi et al. (Comodi et al., 2016) and Moore et al. (Moore et al., 2017). From the total reviewed articles, 8/38 articles did not specify the sources of information used in their analysis.

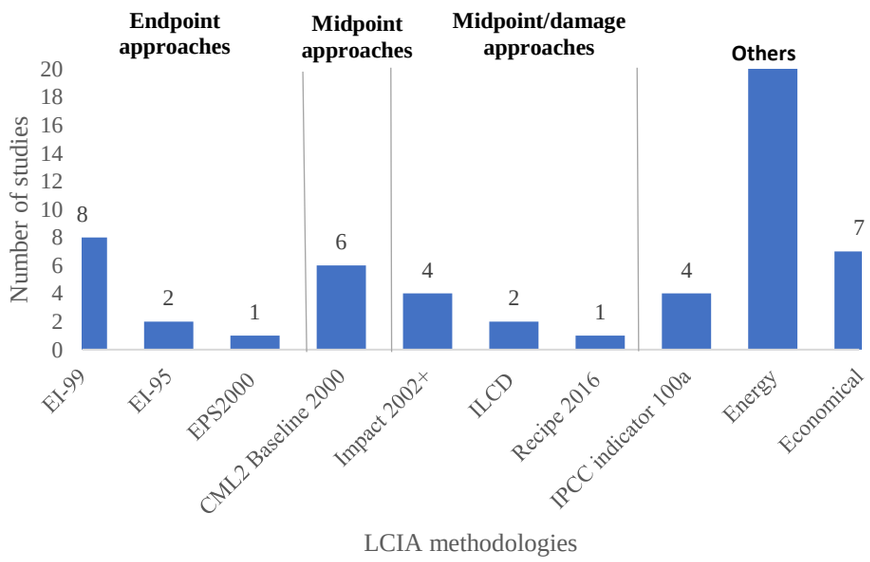
Moreover, by examining the 38 papers included in this study, it was found that 25/38 articles opted for the use of secondary sources for inventory data, which could not be reliable enough to describe the particular scenarios being modelled in solar water heater LCAs. 4/38 manuscripts used primary data such as laboratory analysis (Rey et al., 2008), lead take from collected in the field directly from the producers and verified jointly with the manager of process chains (Battisti and Corrado, 2005), information taken from manufactures' data-sheet (Martinopoulos et al., 2013; Kylili et al., 2018).

The remaining studies did not specify the collection of data inventory. Finally, it was found that out of reviewing studies of solar water heaters, only one study included an allocation scenario. It is based on the quantification of the benefits due to material recycling in system disposal (Battisti and Corrado, 2005).

3.5 Life cycle impact assessment

Life cycle impact assessment (LCIA) is used to establish a linkage between the inventory of elementary flows of a product and its potential environmental impacts. In practice, the selection of impacts categories is obtained into predefined methods, often referred to as life cycle impact assessment methods or LCIA methods (Hauschild et al., 2018). In the reviewed articles, 36 manuscripts applied LCIA methods, which are well known in the scientific literature. From these, the most used were Eco-indicator 99 in different versions with 10/38 studies, CML2 baseline 2000 method with 6/38 studies, IPCC indicator GWP 100a with 4/38 studies and Impact 2002+ method with 4/38 studies. Some manuscripts used the ILCD method (2/38), 2000 method (1/38) and ReCiPe (1/38) to evaluate the environmental impacts of SWH systems, as shown in Graphic 3.4. From the remaining articles, 23/38 studies focused on energy analysis, 7/38 studies included economic evaluations, and 3/38 did not explicitly state the characterisation method applied but reported impact categories.

Graphic 3.4 Life cycle assessment methodologies



Source: (Self Elaboration)

Considering the LCIA diverse impact categories in the studies, three main significant types of environmental impacts were found in LCA of solar water heater: i) human health, ii) ecosystem quality, and iii) resources. Based on these three categories, the ecosystem category was the most frequently studied in the SWH literature. This category was the topic of 19 publications of solar water heater LCAs. The second most commonly reviewed category, human health was included in 18 of the studies. Finally, the least frequently studied was resources. Only 13/38 studies examined this category, as shown in Anexo

Regarding the reported environmental impacts, it can be noted that 23 impacts categories were considered in the studies assessed in this review. From those, only eight impacts categories are common to at least 18 studies; acidification (17/38), ozone depletion (14/38), eutrophication (14/38), cancerogenic (10/38), fossil fuels (9/38), GWP (8/38), land use (8/38) and ecotoxicity (8/38). On the other hand, the least reviewed categories were energy resources, pesticides, and particle matter. Table 3.1 shows the results of the impact categories studied most frequent.

Table 3.1 Environmental impact categories

Author/ environment impact	Human Health										Ecosystem									Resources				
	OD	AD	SM	CA	RO	RI	RA	HT	EP	AP	GWP	GE	AC	CC	EC	LU	PE	PO	SW	MI	FF	ER	FW
Tsilingiridis et al. [16]										x													
Battisti et al. [17]	x		x						x			x	x						x				
Koroneaos et al. [26]	x		x	x					x		x		x										
Martinopoulos et al. [29]				x	x	x			x				x	x	x	x				x	x		
Comodi et al. [32]	x			x	x	x	x						x	x	x	x				x	x		
Carnevale et al. [34]	x		x	x					x				x				x		x			x	
Zambrana et al. [36]	x	x							x		x	x	x					x					
Anastaselos et al. [37]		x						x	x		x		x		x			x					x
Comodi et al. [38]	x			x	x	x	x						x	x	x	x				x	x		
Lamnatou et al. [39]	x			x	x	x	x		x				x	x	x	x				x	x		
Arnaoutakis et al. [42]	x			x	x	x	x		x				x	x	x	x				x	x		
Kylili et al. [44]	x							x	x		x		x					x			x		x
Mahmud et al [47]	x			x			x		x				x	x		x		x		x	x		x
Giama et al. [49]								x	x		x		x		x			x			x		x
Uctug et al [50]	x							x	x				x					x					
Souliotisa et al. [51]	x			x	x	x	x		x				x	x	x	x				x			
Liu et al. [52]								x			x												
Milousi et al [53]	x			x			x	x			x		x			x				x	x		x
Alberti et al. [54]	x								x		x		x					x					

OD= Ozone depletion, AD= Abiotic depletion, SM= Smog, CA=Cancerogenic, RO= Respiratory Organics, RI= Respiratory Inorganics, RA= Radiation, HT= Human toxicity, EP= Eutrophication, AP= Atmospheric pollution, GWP= Global warming potential, GE= Greenhouse effect, AC= Acidification, CC= Climate change, EC= Ecotoxicity, LU=Land use, PE= Pesticides, PO= Photochemical oxidation, SW= Solid waste, MI= Minerals, FF= Fossil fuels, ER= Energy resources, FW= Fresh water

Source: (Self Elaboration)

Results are presented according to the type of solar collector and unit. Also, 6/38 studies carried out sensitivity analysis (Ardente et al., 2005; Menzies et al., 2010; Hang et al., 2012; Moore et al., 2017; Uctug et al., 2018; Liu et al,. 2019) and 2/38 studies normalized their results (Koroneos et al., 2012; Hang et al., 2012). Therefore, in this review, it is not possible to fully compare the environmental impact of the selected studies. The range of impact categories covered is widespread, however, the assessed results for the various categories differ due to they are presented in absolute or percentage terms and with different units (Table 3.2), which hamper comparisons with other studies.

Table 3.2 Environmental impact categories

Author/ environment impact	Solar Collector	Acidification	Ozone Depletion	Eutrophication	GWP	Cancerogenic	Land use	Fossil fuels	Ecotoxicity
Battisti et al. [17]	ICS	4.045 kg SO_2	5.65E-05 kg CFC11	0.0627 kg PO_4					
Koroneaos et al. [26]	FPC	123.42	0	0.060		1.75E-04			
Martinopoulos et al. [29]	FPC	29.6 PDF*m^2 year		29.6 PDF*m^2 year		1.04E-04 DALY	34.2 PDF*m^2 year	727 MJ	8.13 PDF*m^2 year
Comodi et al. [32]	FPC	13.56 PDF*m^2 year	0 DALY			2.6E-01 DALY	0 PDF*m^2 year	25.71 MJ	2.34 PDF*m^2 year
Carnevale et al. [34]	FPC	-1.42E+01 kg SO_2	-4.89E-04 kg CFC11	-2.51 kg PO_4		-9.33E-05 kg B(a)P			
Zambrana et al. [36]	FPC	36.10 kg SO_2	5.93E-04 kg CFC11	10.50 kg PO_4	1.01E+04 kg CO_2				
Anastaselos et al. [37]	FPC/ ETC	0.233/ 0.2232 10kg SO_2	0.0356/ 0.0344 g CFC11	0.2796/ 0.2738 kg PO_4	0.3691/ 0.3597 Tn CO_2				0.0656/ 0.0610 100 kg 1,4DCB-eq
Comodi et al. [38]	FPC	1.1 PDF*m^2 year	0 DALY			0.3 DALY	0 PDF*m^2 year	25.7 MJ	2.3 PDF*m^2 year
Lamnatou et al. [39]	ICE	0.5 Pts/m^2	0 Pts/m^2	0.5 Pts/m^2		0.4 Pts/m^2	0.4 Pts/m^2	2.2 Pts/m^2	0.4 Pts/m^2
Arnaoutakis et al. [42]	FPC/ ICS	3 Pts	0 Pts	3 Pts		2.35 Pts	5 Pts	0 Pts	2.5 Pts
Kylili et al. [44]	FPC	1.77 E+01 kg SO_2	8.35E-07 kg CFC11	1.94 kg PO_4	7.07E+03 kg CO_2			9.72E+04 MJ	
Mahmud et al [47]	FPC	50%	55%	52%		53%	71%	30%	
Giama et al. [49]	FPC/ ETC	978/ 1.38E+03 kg SO_2		46.9/ 54.3 kg phosphate-eq	1.97E+05/ 2.04E+05 kg CO_2			2.37E+06/ 2.44E+06 MJ	525/676
Uctug et al [50]	FPC	5.82 kg SO_2	0.01 g CFC11	1 kg PO_4					
Souliotis et al. [51]	ICS	1 Pts/m^2	0 Pts/m^2	0 Pts/m^2		3 Pts/m^2	0.72 Pts/m^2		1 Pts/m^2
Milousi et al [53]	FPC/ ETC	2.07E-04/ 2.01E-04 kg SO_2	1.29E-08/ 1.6E-08 kg CFC11		2.38E-02/ 2.22E-02 kg CO_2	6.56E-03/ 6.53E-03 Kg 1,4DCB-eq	1.25E-03/ 1.52E-03 m^2a crop-eq		
Alberti et al. [54]	FPC	2.5E-04 kg SO_2	1.25E-08 kg CFC11	4.00E-05 kg PO_4	9.24E-02 kg CO_2				

Source: (Self elaboration)

Apart from environmental impacts, most of the studies carried out energy analysis in terms of embodied energy, embodied carbon cumulative energy demand (CED), greenhouse gas emission, and others. The embodied energy was calculated during the manufacturing, installation, maintenance phase of the solar water heater, and the transportation of material (Kalogirou et al., 2009; Menzies et al., 2010; Leckner et al., 2011; Arif et al., 2012). Of the 38 case studies reviewed, 4 studies only estimated the total embodied energy (Kalogirou, 2009; Faizal et al., 2013; Lamnatou et al., 2016; Michael et al., 2017), leading to significant differences in results. Also, the Energy Payback Time (EPT) and CO_2 Payback Time have been assessed within of LCA analysis. As shown in Table 3.3, they varied from 0.7 to 12 years and from 2 to 5 years, respectively. It will depend on different used materials, components, types and number of solar collectors analysed. Besides embodied energy, some studies included cumulative energy demand (CED) (Hang et al., 2012; Altun et al., 2016), CO_2 emission (Ardente et al., 2005; Menzies et al., 2007; Arif et al., 2012; Ozturk et al., 2012; Faizal et al., 2013; Carlsson et al., 2014; Comodi1 et al., 2016; Lamnatou et al., 2016; Altun et al., 2016; Michael et al., 2017, Kicker et al., 2018; Milousi et al., 2019) and carbon footprint (Hang et al., 2012; Kicker et al., 2018). The energy use for the dismantling of solar systems was not considered. Additionally, some authors included economic indicators that involved the solar water heater's initial and annual cost, pay-back period, net present value, internal rate of return, etc. (Leckner et al., 2011; Hang et al., 2012; Arif et al., 2012; Carlsson et al., 2014; Kylili et al., 2018). It was identified, that they have not been compared with other LCAs studies.

Table 3.3 LCA studies based on Embodied Energy (EE) and Payback Time

Reference	Results: Energy Payback Time	Results: Embodied Energy (EE)	Results: CO_2 Payback time	Others
Ardente et al. [18]	Less than 2 years		Less than 4 years	CO_2 emission= 500-900 kg Energy consumption= 8-15GJ CO_2 emission saving=407 kg-$_{eq}$ CO_2 yearly
Kalogirou et al. [20]	Less than 3.2 years	EE in production =2663MJ Total EE=6946MJ		
Menzies et al. [21]	6 months-2.5 years	EE in manufacture = 653.95MJ EE from transport= 227.8MJ EE in installation= 584.44 MJ EE in maintenance=888.13MJ	3.7-4.9 years	EC in Manufacture = 32.05 kg CO_2 EC from transport= 5.03 kg CO_2 EC in installation=36.94 kg CO_2 EC in maintenance=55.41 kg CO_2
Leckner et al. [22]	8-11 years	EE in manufacture=760kWh/m^2 EE in installation=7.9KWH/m^2 EE from transport= 0.0875kwh/ton km		EPR=36-4.8years
Hang et al. [23]				CED=600kwh-5000kwh per person CED payback time=1-2 months Personal carbon footprint=150-1100kg Carbon footprint payback time=1-4 months
Laborderie et al. [24]	1-1.5 years			
Arif et al. [25]	3.2-7.9 years	EE in manufacture=2924MJ		CO_2 emission reduction=2.5 tons
Ozturk et al. [27]	2 years		1.6 years	CO_2 emission=390kg
Faizal et a. [28]	2.4 years	EE=1183MJ		CO_2 emission=718.08kg
Carlsson et al. [30]	1.6-2.3 years			
Marimuthu et al. [31]	2.3 years		2.21 years	CO_2 emission=2643.34kg
Comodi et al. [32]	5-12 years		2-12 years	
Carnevale et al. [34]	1.2 years		1 year	
Yan et al. [35]	6.5 years			
Comodi et al. [38]	2-12 years		2-30 months	CO_2 emission=1213-1739kg
Lamnatou et al. [39]	Less tan 2 years	EE=7.2-46.66GJ		CO_2 saving=3.3-29.8 kg Embodied carbon=0.16t CO_2/m
Altun et al. [40]	3-4 years			CO_2 selective surface production= 0.3245kg CED=2.36E+04MJ
Michel et al. [43]	0.8 years	EE=6324.4MJ	0.13 years	CO_2 emission=424.1kg
Kicker et al. [46]	0.7-1.7 years			CO_2 footprint=101-250kg
Milousi et al. [53]				CO_2 emission=2.2-2.8E-02

Source: (Self Elaboration)

4. Summarised findings from previous studies and challenges

The results of this review indicate that there are still considerable divergences in the LCA analysis of solar water heaters. First of all, there is a notable difference between European, Asian, and Latin-American LCAs in regard to the SWH systems. We observed that most studies were developed in the European context, and a small portion of the reviewed studies belong to North America. Specifically, countries such as China, Turkey, India, Brazil and Germany that are leading the world in the installation and use of SWH are required the assessment the environmental impacts of SWH systems (Qiu et al., 2015; Gautam et al., 2017). Moreover, the results reveal that most of the LCA studies are focused on FPC systems, which is consistent with the usage popularity of the solar water heater collectors in Europe, but it is not coherent with worldwide solar water heater distribution. This distribution indicates that the most widely used solar water heater in the world is ETC systems. Therefore, it should be considered the increase of LCA studies in ETC systems and new solar water heaters.

Also, the topic of eco-design alternatives has received little attention in LCA of the solar water heater, which limits the option of identifying improvement opportunities in solar technologies in order to reduce environmental impacts along the production chain, increase the marketability of SWH through product innovation and reduce the cost of raw materials. The topic of comparison overall or in each stage of the life cycle of SWH systems is often limited to the comparison between SWH with traditional heater systems (PV, PV-T, electrical or gas boilers). The focus of the reviewed studies does not consider the comparison of a specific SWH in other locations with similar or different climatic conditions, or in different stages.

In the functional unit, we identified variations in each one of the three categories (impacts per unit of area, impacts per unit of energy output and whole system). For example, variations in the units, some authors considered MW of thermal energy, others TJ of natural gas, some others kWh; variations in the components of the SWH systems, in this point it was considered the solar collector with and without storage systems or with auxiliary systems, and variations in the surface area of SWH collector. All these variations can lead to difficulties in comparing the results of other studies with similar scopes. Given the diversity of products on the market in terms of size, components and design are impossible to establish a single functional unit to be used in all environmental assessments. However, it can be defined as a standardized set of characteristics that describes the SWH structure and its material properties, performance, and meteorological parameters helping to determine under which set to scenarios are applicable each of the functional units. Another inconsistency important in the FU was that some studies did not express their final results in terms of any specific unit, which could lead to ambiguous reference units. Under this context, it is recommendable to define this parameter to avoid misinterpretation of the results.

In the system boundaries, the majority of the studies addressed cradle-to-grave analysis. However, not all studies cover all stages of the life-cycle and exclude the end-of-life stage for a lack of data inventory and the complexity to obtain data. Also, most LCA studies do not consider financial feasibility or life cycle cost in their analysis, which can help the users to select the appropriate technology for their hot water needs. Therefore, the life cycle cost of SWH systems can be a research opportunity area.

Part of the accuracy of the LCA comes from the LCI. In this aspect, we identified that secondary data has been considered the first option in the LCA studies, which could not be reliable enough to describe the particular scenarios. In this sense, it is prudent to report the manufacturing process and materials information or collect the information in some international database or commercial software package, in order to reduce the variations in the LCA studies. Finally, in life cycle impact assessment, it was possible to identify the application of different LCIA methods, such as Eco-indicator 99, CML2 baseline 2000, IPCC indicator GWP 100a, Impact 2002+ method, and others. It allows the know the application and the differences between the methodologies. However, if we considered the LCIA diverse impact categories in the studies, studies show different categories resulting in a difficult to compare methods and results among similar studies of solar water heaters. Therefore, it is suggested use some normalization, grouping and weighting, and sensitivity studies for comparing the environmental impact.

5. Annexes

Key points of analysis of reviewed papers

Author	Year	Country	SWH	Scope	Type	FU	Methodology	R	P	I	U	T	D	M
Tsilingiridis et al. [16]	2004	Greece	FPC	To compare of environmental impact of SHW system vs electric boiler	LCA		EI-99	x	-	x	-	x	-	-
Battisti et el. [17]	2005	Italy	ICS	To calculate the energy and environmental pay back times of ICS, and providing hints for collector optimization, especially in the production step	LCA	Solar collector	EI-95	x	x	x	x	-	x	-
Ardente et al. [18]	2005	Italy	FPC	To synthesise the main energy and environmental impacts	LCA/ LCEA	Solar collector	EPT, EMPT	x	x	x	-	x	x	x
Rey-Martínez et al. [19]	2008	Spain	FPC	To evaluate the environmental impacts and quantify the financial cost of such emissions.	LCA	1TJ of natural gas when the solar collectors cannot provide enough hot water	EPS2000	x	-	x	-	-	-	-
Kalogirou [20]	2009	Cyprus	FPC	The environmental benefits of SWH	LCEA		EE	x	x	x	-	-	-	-
Menzies et al. [21]	2010	UK	FPC	To evaluate the lifecycle energy and carbon intensity	LCEA	Solar collector	EE, LCCA	x	x	x	-	x	-	x
Leckner et al. [22]	2011	Canada	FPC	To compare the life-cycle energetic, economic and environmental impacts	LCEA/ LCC		EE, LCC	x	x	x	x	x	-	-
Hang et al. [23]	2012	USA	FPC, ETC	To compare the energetic, economic and environmental impacts	LCEA/ LCC	The daily heating energy for a family of 2.53 persons (236 l of hot water at 60°C).	IPCC GWP100a	x	x	x	x	x	x	-
Laborderie et al. [24]	2012	France	FPC	To characterise the environmental performances	LCA	Production of DHW for a four-person household, for template climate (assessed to be 140 litres of 60°C) and tropical (assessed to be 200 litres of 50°C)	Impact 2002+	x	x	-	x	-	x	-
Arif [25]	2012	India	FPC	To estimate the primary energy and costs required in manufacturing process and in maintaining	LCEA/ LCC		EPF, EE	x	x	x	-	-	-	-
Koroneos et al. [26]	2012	Greece	FPC	To quantify the environmental and financial benefits of the installation of a SWH with electricity as auxiliary	LCA	1 MW of produced hot water	IRR, NPV, PBP	x	x	x	x	x	x	-
Ozturk et al. [27]	2012	Turkey	FPC, PV, PVT	To evaluate energy, exergy and LCA Analysis of a FPC, PV and PV-T collector	LCEA	The energy used by all the processes associated with the production of the materials	EE	x	x	-	-	-	-	-
Faizal et a. [28]	2013	Malaysia	FPC	To quantify the emissions from the manufacturing of the collectors and damage cost reduction	LCEA		EE, CS	x	x	-	-	-	-	-
Martinopoulos et al [29]	2013	Greece	FPC	To investigate of how different materials/techniques used in the manufacturing of DSHWS influence environmental performance	LCA	Solar collector	EI-99	x	x	x	x	x	x	-
Carlsson et al. [30]	2014	Sweden	FPC	To assess the suitability of solar collector systems	LCA/ LCEA/ LCC		IPCC GWP100a, CED	x	x	-	x	-	x	x
Marimuthu et al. [31]	2014	India	FPC	To compare FPC with electric water to quantify the environmental and energy benefit	LCEA	100 l per day solar water heater available	EPT, CPBP	x	x	-	x	-	x	x
Comodi et al. [32]	2014	Italy	FPC	To present both An LCA and a payback time analysis for a SWH	LCA	Solar collector	EI-99-EE	x	x	x	x	-	x	x
Lamnatou et al. [33]	2014	France	FPC	To study a patented solar thermal collector based on EE and EC methodologies	LCEA	Solar collector	EE, EPT, EC	x	x	x	x	x	x	x
Carnevale et al. [34]	2014	Italy	FPC	To compare the energy and environ- mental performances of PV and FPC	LCA/ LCEA	1 m^2 of roof surface.	EI-95, EPT, EMPT	x	x	x	x	x	x	x
Yan et al. [35]	2015	Hong Kong	FPC	To present a simplified method for optimizing the key parameters of solar water heating systems based on LCAE	LCEA		EPT	x	-	-	x	-	-	-
Zambrana et al. [36]	2015	Spain	FPC	To analyse the environmental implications of SHWS	LCA/ LCEA	Daily heating energy for HWD in each target building considered	CML 2 baseline 2000, EPT	x	x	x	x	x	x	-

Anastaselos et al. [37]	2015	Greece	FPC	To evaluate of the environmental performance of SWH	LCA	1 m^2 of FPC area	CML 2 baseline 2000	x	x	x	x	-	-	-
Comodi et al. [38]	2015	Italy	FPC	To evaluate energy, CO_2 and economic payback times	LCA/ LCEA	Solar collector	EI-99-EE, EPT, EMPT, ECPT	x	x	x	x	x	x	-
Lamnatou et al. [39]	2015	France	ICE	To examine three alternative configurations with EI99, IMPACT 2002+, embodied energy and embodied carbon	LCA	Solar collector	EI-99 IMPACT 2002+ EE EC	x	x	x	x	x	x	x
Altun et al. [40]	2016	USA	FPC	To show the effect of the production method on the manufacturing process of FPC	LCA	Area of 250,000 m^2	CED Greenhouse Gas Protocol EI-99	x	x	x	x	x	x	-
Piroozfar et al. [41]	2017	Cyprus	FPC	To gauge the environmental impacts of different types of residential water heating systems	LCA/ LCEA	The production of 392,448,000 litres of heated water with a temperature of at least 37° C	CML 2001	x	x	x	x	x	x	-
Arnaoutakis et al. [42]	2017	Greece	FPC, ICS	To present a detailed comparative experimental study of SWHs	LCA/ LCEA	Solar collector	EI-95	x	x	x	x	-	-	-
Michel et al. [43]	2017	India	FPC, PVT	To compare a solar PV/T, a PV system and a FPC based on economic evaluation and environmental assessment	LCA/ LCEA		EE EC	x	x	-	-	-	-	-
Kylili et al. [44]	2017	Cyprus	FPC	To quantify this unexploited potential and assess the environmental impact	LCA/ LCEA/ LCC	Aperture area [m²] Number of solar collectors Number of water storage tanks	CER	x	x	x	x	x	-	x
Moore et al. [45]	2017	Australia	FPC	To investigate the GWP and PED	LCEA	Annual hot water load of 34.4 MJ/d	IMPACT 2002+ ILCD, PED	x	x	-	x	x	x	-
Mahmud et al. [47]	2018	Australia	FPC	To present an LCA of a PV system and a solar-thermal system	LCA	1 kWh of energy	ILCD Impact 2002+ RMF CED IPCC	x	x	x	x	-	-	-
Vechi et al. [48]	2018	Brazil	FPC	To assess the environmental impact of electric, natural gas and SWH	LCA	2,803,200 litres of hot water at a temperature greater than or equal 37°	IPCC GWP 100a	x	x	-	x	x	x	-
Giama et al. [49]	2018	Greece	FPC, ETC	To compare and present an environmental evaluation of SWH	LCA	Solar collector	CML 2001, GPW	x	x	x	x	x	x	x
Uctug et al. [50]	2018	Turkey	FPC	To estimate and compare life cycle environmental impacts of supplying domestic hot water to households	LCA	100 l per day at a temperature of 60 °C	CML 2001	x	x	-	-	-	x	x
Souliotis et al. [51]	2018	Cyprus	ICS, PVT	To present am LCA study of two innovative solar water heating systems, integrated on the facades and the roof of a social house building	LCA	Solar collector	EI-99	x	x	-	x	-	x	-
Liu et al. [52]	2019	China	ETC, FPC	To estimate the life-cycle environmental impacts and costs of a SWH	LCA/ LCEA	Energy requirements for using DHW per person, per year, supplied by the DHW system in a typical three person Chinese household	PED	x	x	x	x	x	x	x
Milousi et al. [53]	2019	Greece	PV, FPC/ ETC	To present a holistic evaluation of the energy and environmental profile of PV and FPC	LCA	The saving of 1 kWh electricity for hot water production	ReCiPe 2016	x	x	x	x	x	x	-
Albeti et al. [54]	2019	China	FPC	To compare a SWH and a natural gas heating system	LCA/ LCEA	1 kW h of thermal energy to cover the DHW demand of a 6 persons house	CML 2001	-	x	-	x	x	x	-

LCCA=Life Cycle Carbon Analysis, LCC= Life Cycle Costs, EC= Embody Carbon, EE= Embody Energy, EPF=Energy Production Factor, CED= Cumulative Energy Demand, GWP= Global Warming Potential, Uncost= Annualized Uniform Cost, PED= Primary Energy Demand, ILCD=International Reference Life Cycle Data System, IE=Eco-Indicator, IRR= Internal Rate-of-Return, NPV=Net Present Value, CS=Cost savings, CER= Consumed Energy Ratio, EPT= Energy payback time, CPBT= Carbon Payback Time, ECPT= Economic payback time, RMF=Raw Material Flows, IPCC= Intergovernmental Panel on Climate Change, E= Raw materials, P= Production/Manufacture, I= Installation, M= Maintenance, D= Disposal, T= Transport,

Source: (Self Elaboration)

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7. Conclusions

This study presents a systematic review of environmental and energy assessment of solar water heaters, focusing on the variability of reported results due to methodological choices. The methodological choices include functional unit (FU), location, system boundaries, life cycle inventory, and impact method. Significant variations in the results were identified in terms of methodological choices (e.g., system boundaries, allocation procedures, or data quality). The most important aspects were related to the lack of studies in America, Asia, and the Australian continents. From a technological aspect, there is a need for LCA in evacuated-tube solar collectors (ETC), integral collector storage systems (ICS), and new designs of solar water heaters. From an LCA methodological perspective, there are limitations in studies on comparison overall or in each stage of their life cycle of products and the identification of possible opportunities for improving the solar water heaters through eco-design alternatives. Another critical aspect is that some studies provide an unclear description of the FU, which leads to discrepancies in the results. Moreover, it was observed that the significant discrepancies are in system boundaries and life cycle impact assessment, due to the authors excluding life cycle phases in the system boundaries. There is a lack of uniformity in the results unit (some studies presented in absolute or percentage terms), and a need for normalization, grouping, weighting and sensitivity studies.

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Chapter 6 Process standardization and its impact on the manufacture of amaranth products

Capítulo 6 Estandarización de procesos y su impacto en la fabricación de productos de amaranto

SOTO-LEYVA, Yasmin†*, BONES-MARTÍNEZ, Rosalía and SANTOS-OSORIO, Arturo

Tecnológico Nacional de México/Instituto Tecnológico Superior de Huauchinango

ID 1st Author: *Yasmin, Soto-Leyva* / **ORC ID:** 0000-0003-2652-7065, **CVU CONACYT ID:** 951464

ID 1st Co-author: *Rosalía, Bones Martínez* / **ORC ID:** 0000-0001-8829-9737, **CVU CONACYT ID:** 368744

ID 2nd Co-author: *Arturo, Santos-Osorio* / **ORC ID:** 0000-0003-3643-5770, **CVU CONACYT ID:** 951024

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Y. Soto, R. Bones and A. Santos

*yasmin.sl@huauchinango.tecnm.mx

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Abstract

Currently, the amaranth industrialization has become in an important activity to producer families of west-center region of Puebla State to increase their economic incomes. The objective of this study was propose a strategy based on the good practices and current applicable regulations of food industries, finding out the quality in the process and products of the microenterprises dedicated to create amaranth products. The analysis was applied to six microenterprises of Tochimilco and Atzitzihuacán, Puebla, to get the general characteristics of the families and agro-industrial activities that they realize. Results show that the economic and ignorance restricts the competitive grow in the agro-industrial market, due to deficiency of bases to guarantee the hygiene and safety during the elaboration processes. This project proposes to introduce the requirements of the food industry through improvement tools and methodologies and available resources from producers.

Industrialization, Amaranth products, Methodologies

Resumen

Actualmente, la industrialización del amaranto se ha convertido en una actividad importante para las familias productoras de la región centro poniente del estado de Puebla para incrementar sus ingresos económicos. El objetivo de este estudio fue proponer una estrategia basada en las buenas prácticas y normativa vigente aplicable de las industrias de alimentos, conociendo la calidad en el proceso y productos de las microempresas dedicadas a la elaboración de productos de amaranto. El análisis se aplicó a seis microempresas de Tochimilco y Atzitzihuacán, Puebla, para obtener las características generales de las familias y actividades agroindustriales que realizan. Los resultados muestran que la economía y el desconocimiento restringen el crecimiento competitivo en el mercado agroindustrial, debido a la deficiencia de bases para garantizar la higiene y seguridad durante los procesos de elaboración. El presente proyecto propone introducir los requerimientos de la industria alimentaria a través de herramientas y metodologías de mejora y recursos disponibles de los productores.

Industrialización, Productos de amaranto, Metodologías

1. Introduction

Alejandre and Gómez (1986), comment that, in Mexico, agriculture is one of the priority and most important activities, generating a large number of jobs and responding to the basic needs of millions of people. According to the 2019 Agrifood Panorama, of the 54.9 million Mexicans who work, 5.5 million do so in agricultural activities. According to the profile of agricultural and fishing workers, 45.9% are subordinate and paid workers, 35.8% are own-account workers, 12.1% do not receive payments, and 6.2% are employers.

According to data from INEGI (2014), the Mexican territory has an area of 198 million hectares, of which 14% (27.4 million) are considered to have agricultural vocation. Of the total agricultural area, the rainfed modality covers 79.7% (21.9 million), where basic crops stand out, such as corn, sorghum, beans, and wheat. However, the latter have presented various factors that hinder agricultural production, mainly due to the increase in prices of chemical inputs, of the labor that is used during the cultivation cycle, of the degradation of the land where it is produced and of climate change. Becoming some of the reasons why growers have decided to switch their crops to more adaptable alternatives, According to data from SIAP (2019), production is concentrated mainly in the central zone of Mexico, in the states of Puebla, Tlaxcala, Morelos, the State of Mexico and Mexico City. Highlighting the participation of the State of Puebla, contributing 61% (3,396 tons) of the national production (5,548 tons).

Amaranth stands out as an important alternative for small producers that allows economic income in addition to that provided by the cultivation of corn, since it has agronomic characteristics that allow it to adapt to adverse environmental conditions, where other crops do not prosper (Islas and Islands, 2001) and capable of developing in soils of all kinds of qualities. Currently, groups of residents dedicated to the cultivation of amaranth have explored new forms of activities in search of economic growth for their families and to enhance the development of this seed through industrialization. Based on its adaptability to different environments and its nutritional properties.

The small producers of these areas have adapted their homes in terms of equipment and infrastructure for the industrialization of amaranth, which has applications similar to that of basic crops, mainly corn, finding sweets and fried foods, such as joy sweets, atoles, flours with which breads, pastas, cakes and cookies are made, as well as its consumption as cereal. Despite the efforts, most of these microenterprises have notable deficiencies in terms of the design of their facilities, equipment and utensils, hygiene and sanitation practices both in the production process and in the establishment in general.

Due to the aforementioned, the present investigation seeks to carry out a general analysis in the micro-enterprises of the municipalities of Tochimilco and Atzitzihuacán, Puebla; to propose strategies that serve as a guide towards compliance with current regulations established for food companies and the search for products that guarantee safety and quality specifications for consumer safety (Casas, A. et al; 2001).

2. Objectives

2.1. General Objectives

Formulate an improvement strategy for the standardization in the production process of amaranth through the use of good practices and current regulations applicable to food industries, to generate a higher economic income in the producing families and create a higher level of competitiveness in the agro-industrial sector. microenterprises in the municipalities of Tochimilco and Atzitzihuacán.

2.2 Specific Objectives

- Define good practices for food processing to ensure their safety and innocuousness.
- Establish the current procedures and regulations applicable to establishments and processes for the production of food based on amaranth.
- Design a consultation document, which serves as theoretical support to improve the process of elaboration of amaranth products.

3. Statement of the problema

Amaranth, belonging to the Amaranthaceae family and the Amaranthus genus, is a crop that places its origin in Mesoamerica, more precisely in the Southwest of the United States of America and North of Mexico (Sauer, 1967). There are indications that tribes from those areas cultivated amaranth as food and later it was transferred to the Central Table due to migrations, where it reached greater relevance in times before the conquest (Sauer, 1967). During the last years, the cultivation and consumption of amaranth have increased, thanks to its good content of digestible protein, essential amino acids, fiber, with high nutritional and nutraceutical value (Contreras, Jaimez, Soto, Castañeda and Añorve, 2011).

In addition to being a promising economic livelihood, since the nineties, the basic crops of corn, beans, wheat, sorghum, among others; they have difficulties to continue their production due to problems of economic profitability (Ayala et al., 2014). Reasons that could have influenced the producers of the west-central region of the country to make changes in their crops, seeing amaranth as an opportunity for economic improvement due to its small cultivated area and its excellent agronomic characteristics, due to the fact that it adapts to environmental conditions. where other crops fail (Islas y Islas, 2001).

During 2019, Mexico registered a cultivated surface of amaranth of 4,227 hectares (INEGI, 2019) of which approximately 5,548 tons of amaranth were produced per year, of which the State of Puebla stands out as the largest producer, contributing 61% (3,396 tons) of the total national production of amaranth, according to the information published by the Agrifood and Fisheries Information Service (SIAP, 2019). Among the municipalities of Puebla dedicated to the production of amaranth are Tochimilco and Atzitzihuacán, who registered a harvest area of 1,127 and 208 hectares, obtaining a yield of 2,107 and 333 tons per hectare, respectively, according to the data obtained in SIAP (2019).

In the search for strategies of economic activities, the residents of these municipalities have seen the opportunity to add value to the cultivation of amaranth, through the production and sale of amaranth products, which allows improving economic income and improving the quality of life. For this reason, they have created family micro-enterprises, adapting their homes as workshops for the transformation of the seed, characterized by the presence of equipment, means and basic spaces for the small-scale production of amaranth products.

Thanks to its extraordinary properties, amaranth has a wide variety of uses. The usual way of consumption is as cereal or through amaranth bars, traditionally known as alegrías. Which follows a production process, starting with the mixture of amaranth with syrups or honey to later mold the mixture into rectangles, circles or other shapes; and finally be packaged for sale (Argüelles et al., 2018)

Despite efforts to obtain quality products, these microenterprises vary in the design of their facilities and practices during the production process, situations that limit obtaining products that adhere to quality regulations and, therefore, an obstacle to become competitive companies for the agribusiness sector. Some of the conditions found are listed below:

1. Staff.
1.1. Absence of personal protection equipment (gown, face mask, nets or caps).
1.2. Lack of knowledge on the part of production personnel about good hygiene and safety practices.
2. Physical facilities.
2.1. Establishment of workshops in conditions that cause contamination of the product and proliferation of pests, proximity to toilets, poorly stored equipment, growth of herbs, workshops used for activities other than the transformation of amaranth.
2.2. Ceilings that facilitate the formation of mold and bacteria, predominating the use of sheets. The existence of cables and beams predominates, constituting risks of condensation and accumulation of dust that contaminate the products.
23. Deteriorated walls, without plaster and without washable and waterproof paint. The joints between floors and ceilings do not facilitate the cleaning of the establishment.
2.4. Doors and windows without protections that prevent the entry of dust, rain and harmful fauna.
2.5. The bulbs and lamps established during any production process do not have the protection to avoid contamination in case of breakage.
3. Equipment.
3.1. Lack of equipment and utensils made of inert materials that do not transmit toxic substances, odors, flavors and that facilitate cleaning.
4. Raw material.
4.1. The manufacturing areas are not clean and there are materials foreign to the process.
4.2. The raw material is mixed with the already processed products.
4.3. The raw material containers are not covered or closed to avoid contamination by the environment.
5. Storage.
5.1. The raw materials stored in the establishments are not kept under specific conditions for each case.
5.2. There is storage of raw materials, ingredients, packaging material and finished products directly on the floor.
6. Pest control.
6.1. Lack of pest control systems and plans.
6.2. Entry of domestic animals is observed in the areas close to the product manufacturing processes.
7. Hygiene and sanitation.
7.1. Existence of garbage, scrap and waste in the product processing areas.
7.2. Deficiency in the cleaning and disinfection of the establishment, equipment and materials to reduce the number of microorganisms that can infect the products.
8. Labeling.
8.1. The labeling of the finished product does not have the commercial and sanitary specifications established by current regulations.
9. Ignorance of the marketing channels for amaranth products.

Situations that, according to the producers, are mainly caused by the lack of budget and government support for the improvement of technology, difficulty in accessing technical assistance to create the appropriate conditions.

Thus, the problem lies in the lack of strategies focused on improving quality, which allow control of the process in the production of amaranth products, thus offering microentrepreneurs a new source of food and income at the moment. of its commercialization, as well as to improve the quality of life of the rural and peasant population in the central west zone of the State of Puebla.

4. Rationale

Puebla is presented as the largest producer at the national level, however, the industrialization of amaranth is carried out mainly in the State of Mexico, Morelos and Tlaxcala. Although part of the grain used is obtained from their own plots, most of it is acquired through local producers or intermediaries who buy in the State of Puebla. Situation that affects economic growth in the municipalities of Atzitzihuacán and Tochimilco.

In order to generate strategies that improve economic support, the inhabitants of these two municipalities, who are dedicated to the cultivation of amaranth, have developed micro-enterprises dedicated to the production of amaranth-based products. Being among its variety mainly sweets or fried foods, such as alegrías, atoles, cookies, breads, among others. Despite the fact that this activity generates a higher income than dedicating themselves only to cultivation, there are quality problems that prevent their proper growth, which are mainly generated by the lack of knowledge of the appropriate practices to be carried out during the transformation processes. the lack of technical assistance, equipment and technology and the training of the workforce.

Through this project, the aim is to generate regulation strategies that serve as a guide to promote the use of good practices and regulations applicable to food industries in micro-enterprises in the municipalities of Tochimilco and Atzitzihuacán, to directly benefit around 50 residents of areas vulnerable members of family labor in these small industries. In addition to obtaining quality products that are integrated into the national market and make amaranth a viable option for the food industry, mainly due to its nutritional benefits.

5. Hypotheses

General Hypothesis:

The definition of good practices and current regulations in the food sector will increase the competitiveness opportunities of micro-enterprises dedicated to the production of amaranth products and generate a higher income for families belonging to the municipalities of Tochimilco and Atzitzihuacán.

Specific Hypotheses

1. The lack of knowledge about Good Practices in the micro-enterprises of the municipalities of Tochimilco and Atzitzihuacán dedicated to the elaboration of amaranth products, limits the guarantee of harmlessness and safety to consumers.
2. The application of current regulations and procedures to the food industry is conditioned by ignorance and lack of economic resources within micro-enterprises.
3. The definition of methodologies and process improvement tools are essential tools for the standardization of the production process in micro-enterprises.

6. Reference Framework

Since the point of study of this analysis will be focused on the strategies proposed for the search for quality management in the amaranth production process, it is necessary to elucidate what are the key concepts that guarantee action-oriented knowledge.

6.1. Origin and history

In relation to the origin of the species of the genus Amaranthus there are controversies, several authors point out that amaranth has been cultivated since ancient times in various countries. Sauer (1950) compiled information on its origin in the American continent, more precisely in the southwestern United States of America and northern Mexico.

There are indications that tribes belonging to these areas cultivated amaranth for food and later migrations moved it to the Central Table where it reached its greatest relevance. According to the explorations of MC Stevenson, it was found that the Indians of Arizona and the Suñiz Indians of New Mexico used this crop for food. During colonial times, the Jova and Tarahumara Indians cultivated amaranth under the name of the word guegui.

6.2 Nutritional Value

One of the main characteristics of amaranth is its high nutritional value, both in its leaves and seeds. The proximal composition of amaranth seeds shows that the protein content ranges from 13 to 18%, the fat from 6.3 to 8.1%, the fiber from 2.2 to 5.8%, and the ash content from 2.8 to 4.4%. However, the most important thing is their high degree of protein, they have a better balance of essential amino acids than most cereals and legumes (Table 1. Approximate composition of amaranth grain and some cereals) (Barba de La Rosa, Gueguen, Paredes and Viroben, 1992; Schnetlzer and Breene, 1994) in addition to being a value close to the optimum required in the human diet.

Table 1. Approximate composition of amaranth grain and some cereals

Copposition	Amaranth	Wheat	Mcorn	yesorgo	upoz
Huhage	8.0	12.5	13.8	11.0	11.7
Protein	15.8b	14.0c	10.3d	12.3e	8.5d
Rawa Grhandle	6.2	2.1	4.5	3.7	2.1
Fibera	4.9	2.1	23	1.9	0.9
Ashace	2.4	1.9	1.4	1.9	1.4
Calories/100 g	366	343	352	359	353

Source: Own Elaboration

Amaranth protein contains the eight essential amino acids in the essential quantities, according to the standards for adults reported by organizations such as the Food and Agriculture Organization of the United Nations (FAO, 1997), the United Nations University (UNU) and the World Health Organization (WHO).

Despite the foregoing, in Mexico amaranth does not occupy a place within the products that are considered basic and strategic (Article 70, Sustainable Rural Development Law), but it could position itself within the main grains used by the industry. food, mainly in the integration of precursor foods and health preservatives worldwide, especially because the nutritional and economic utilities are high.

6.3 Location and characteristics of the study site

6.3.1 Tochimilco

Its name comes from "tochtli", rabbit; "i", possessive that expresses yours, his; "milli", sementera heredad, and "co", in; means "in his field" or "in the rabbit field". Its geographical coordinates are parallels 18° 49'32.16" and 19° 01'42.24" north latitude and meridians 98° 42'51.12" and 98° 32'24.72" west longitude. It borders to the north with the states of Morelos and Mexico and with the municipalities of San Nicolás de los Ranchos, Tianguismanalco and Atlixco; to the east with the municipalities of Atlixco and Atzitzihuacán; to the south with the municipality of Atzitzihuacán; to the west with the municipality of Atzitzihuacán and the state of Morelos. It occupies 0.64% of the surface of the state (INEGI, 2009). The municipality has a population of 17,028 inhabitants, of which 7,910 are men and 9,112 women (INEGI, 2010). The main source of employment is the primary sector with 89.1%, followed by the secondary sector with 7.4% and, finally, the tertiary sector with 3.5% (INEGI, 2009). It presents a great edaphological diversity in its territory, identifying seven types of soil; Regosol (30%), Phaeozem (24%), Andosol (19%), Cambisol (12%), Durisol (5%), Leptosol (4%) and Fluvisol (3%).

6.3.2 Atzitzihuacan

It comes from Nahuatl and means "Place that has little water", it is formed from atl, water; tzitzi, apocope of atzitzini, duplicate of diminutive tzintli; hua, voice that denotes property or possession, and can, place. Its geographical coordinates are parallels 18° 44'16. 44" and 18° 53'18.96" north latitude and meridians 98° 42'04.32" and 98° 30'08.64" west longitude.

It borders to the north with the state of Morelos and the municipalities of Tochimilco and Atlixco; to the east with the municipalities of Atlixco and Huaquechula; to the south with the municipalities of Huaquechula and Tepemaxalco; to the west with the municipalities of Tepemaxalco, Acteopan, Cohuecan and the state of Morelos. It occupies 0.38% of the surface of the state (INEGI, 2009). It has a population of 11,684 inhabitants, 5,329 men and 6,355 women (INEGI, 2010). In the same way as Tochimilco, its main economic activity is the agricultural sector with 78.4%, the tertiary sector ranks second with 13% and the secondary sector third with 8.6% (INEGI, 2013). It presents a great edaphological diversity in its territory, identifying seven types of soil; Durisol (30%), Regosol (20%), Leptosol (18%), Fluvisol (10%), Cambisol (10%), Andosol (5%) and Phaeozem (4%) (INEGI, 2009).

7. Conceptual Theoretical Framework

During this chapter the theoretical-conceptual bases that will allow to base the project carried out are exposed. In this sense, concepts are addressed that allow understanding the importance of quality in the food industry, as well as methodologies and tools aimed at improving processes in general. In addition to helping the interpretation of the results obtained and the definition of the hypotheses.

7.1. Quality

From the perception of customers, companies and organizations have been created in order to provide products or services that satisfy human needs and expectations. These products are the results of a process, which is understood as a set of intertwined activities that receive certain raw materials or inputs (inputs) to be transformed into a result (outputs) or a product. A requirement of the clients is that the products or services have quality, which has different definitions. On the one hand, Juran maintains that: “Quality is that a product is suitable for its use. Thus, quality consists of the absence of deficiencies in those characteristics that satisfy the customer” (Juran, 1990).

7.2. Quality Management. Concept and Evolution

Quality Management is a new way of thinking about the management of organizations (Chorn, 1991), an approach to the management function that would adopt revolutionary ideas on traditional models, new principles on the design of the organization and culture corporate for the path to excellence. For Slater (1991), Quality Management represents customer-focused organizations that are organized by processes, function in teams, and are conducted more like a dance than a hockey game.

7.3. Inspection

The inspection emerges as a tool of great importance in the face of the rise of the manufacture of articles in series. It has various scopes: represent an information activity, also include a decision (acceptance, rejection or reprocessing) or lead to corrective actions. Its basic objective is to prevent defective products from reaching the customer. Product quality specifications are established that must be systematically verifiable, to verify conformity with the final product and separate defective products and allocate them as waste for reprocessing. According to ISO 8402 (1995), inspection is the "action of measuring, examining, testing or verifying one or more characteristics of a product or service and comparing them with the specified requirements in order to establish their conformity".

7.4. Total quality management

Dale, (1994) explains that the vision of quality has evolved towards a more global vision extending to the entire company in its conceptual growth and its objectives, reaching the level of company strategy. Quality becomes "total quality" applying to products, methods, organization, etc.

Gutiérrez, (2005) argues that, among its main objectives, it focuses on competitive advantage through the search for customer satisfaction, management leadership, internal cooperation and teamwork, good relationships with customers and suppliers, involvement and commitment of employees, training, learning and continuous improvement.

7.5. Continuous Improvement

Conti, T. (1993) comments, "Continuous Improvement is a philosophy that optimizes processes through incremental improvements and the elimination of operations that do not add value." The basis of this philosophy is that every aspect of an operation can be improved. The ultimate goal is perfection, which is never reached, but is always sought after.

7.6. The food industry

The food industry is the industrial production sector whose objective is the treatment, transformation, preparation, conservation and packaging of products intended for human consumption. This type of industry belongs to the group known as agro-industries or agro-processing industries, (Alma V. et al; 2016)

7.7. Quality in the agri-food industry

Jorge, (2016) comments that, in the food industry, the most important quality factor is the safety and reliability of the products offered. The hygienic-sanitary quality is an essential element, which is evaluated through the measurement of biotic components (pathogens such as bacteria, parasites, viruses, prions, toxins, allergens) and abiotic components (drug residues, pesticides, pesticides, contaminants, etc.) that are presented as a risk to the health of the consuming population.

7.8. Regulations

ISO 9000, (2015) The regulation is a set of rules by which a certain matter or activity is governed; In our country, these standards are mandatory, these being understood as the Official Mexican Standards.
According to the Ministry of Health, (2015) the Official Mexican Standards (NOM) are technical regulations of mandatory compliance issued by the competent agencies, whose purpose is to establish the characteristics that processes or services must meet when these may constitute a risk for the safety of people or harm human health; as well as those related to terminology and those that refer to its compliance and application.

8. Materials and methods

As is known, the methodology of a research project can have 4 types of studies. According to this project, the descriptive study will be used, seeking to specify and describe the research, experiences and points of view collected by the theory and experts on the subject.

8.1. Scope and Limitations

8.1.1. Scopes

This project covered microenterprises dedicated to the production of amaranth products in the municipalities of Tochimilco and Atzitzihuacán in the State of Puebla. A strategy was developed that allows microentrepreneurs to integrate into the agroindustrial sector, seeking to increase their competitiveness, as well as offer a higher economic income to the producer families of the aforementioned municipalities.

8.1.2. Limitations

- Due to the current SARS II-COVID 19 virus pandemic, only 6 of the existing micro-enterprises in the aforementioned municipalities were visited.
- Resistance to change by microentrepreneurs.
- Lack of commitment and organization within companies to properly structure their organization.

– Insufficient data on the handling and care during the industrialization of amaranth in companies of the same branch.

9. Determination of the universe and obtaining the simple

According to the data presented in the reference framework, the population under study comprised 20 micro-enterprises from the municipalities of Tochimilco and Atzitzihuacán, dedicated to the production of amaranth-based products. Which are characterized by having various levels of progress, but most are in the process of formation and consolidation.

For the purposes of this study, the sample was determined through convenience sampling, since due to the current SARS II-COVID 19 virus pandemic, visits to companies remained very limited.

10. Research techniques and data collection plan

Since it was sought to obtain a broader and deeper perspective of the phenomenon under investigation, a mixed research method was chosen. By generating a conjunction of qualitative and quantitative approaches, a data representation is obtained through texts; as well as the use of numerical variables, graphs, formulas and analytical models.

10.1. Questionnaire

Based on the data collected in the previous point, a structured questionnaire was carried out aimed at microentrepreneurs in the municipalities of Tochimilco and Atzitzihuacán, where general data on families, productive activities, knowledge about aspects of food quality, production process were collected. and products offered. In addition, the dialogue with the owners allowed us to understand the perception they have about their companies, the limitations and the opportunities for improvement according to their experience.

10.2. Pareto Chart

As part of the quantitative analysis, Table 2 shows the data obtained in the verification sheet of Good Manufacturing Practices and applicable regulations in micro-enterprises that produce amaranth products, in order to apply more complete systems related to safety management and quality in food production (Table 2. Comparative analysis of the percentages of compliance and non-compliance according to the verification sheet application applied to each of the companies).

Table 2 Comparative analysis of the percentages of compliance and non-compliance according to the verification sheet application applied to each of the companies

Areato study													
Personal		Instaalations		Equipation		Process		Storage		Control of plagas		Lclean and desinfection	
Compliant	Fails	Compliant	Fails	Compliant	Fails	Compliant	Fails	Compliant	Fails	compliant	Fails	compliant	Fails
4	5	6	13	6	5	2	8	2	2	0	4	1	1
3	6	5	14	4	7	2	8	2	2	0	4	1	1
5	4	6	13	3	8	2	8	1	3	0	4	1	1
5	4	10	9	7	4	3	7	2	2	0	4	1	1
4	5	6	13	5	6	2	8	1	3	0	4	1	1
6	3	9	10	7	4	2	8	1	3	2	2	1	1
27	27	42	72	32	3. 4	13	47	9	15	2	22	6	6
50%	50%	37%	63%	48%	52%	22%	78%	38%	63%	8%	92%	50%	50%

Source: Own Elaboration

For its analysis, the values of compliance (yellow boxes) and non-compliance (red boxes) were determined in each of the areas, to continue with the sum of total values of the micro-enterprises under study.

11. Results

The results obtained during the analysis of the current situation are presented through the techniques and tools proposed in the methodology, carried out on the micro-enterprises of the municipalities of Atzitzihuacán and Tochimilco. The results collected in the verification sheet show the data that will serve as the basis for the elaboration of the Pareto Analysis; quantitatively showing the areas to be treated to reduce 80% of the problems found (Table 3. Values of the current situation in companies for the Pareto Analysis).

Table 2 Values of the current situation in companies for the Pareto Analysis

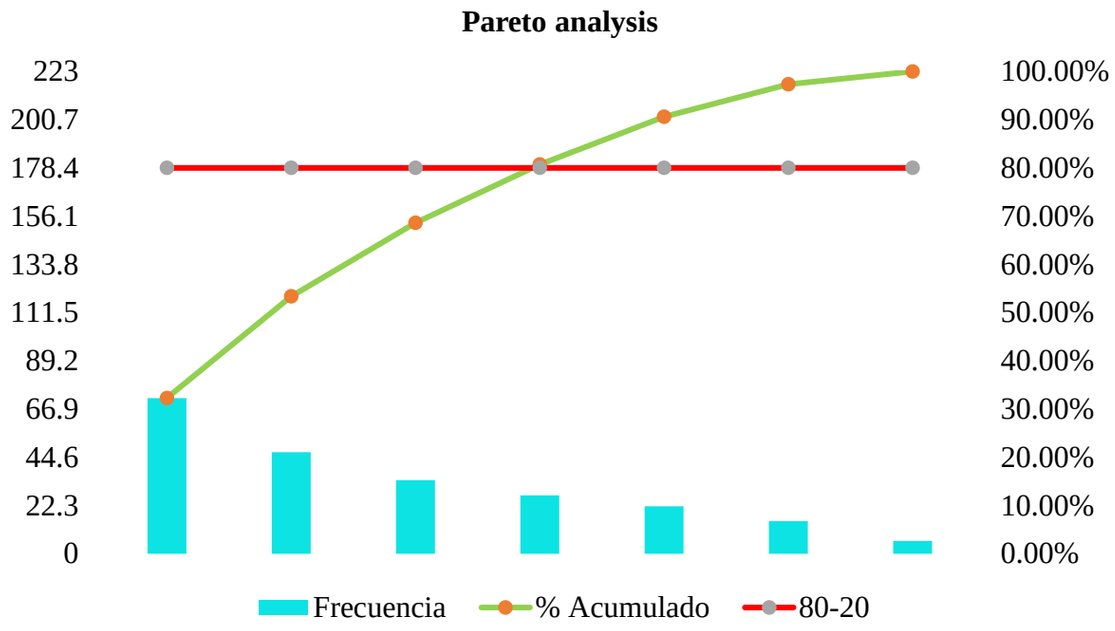
Areato study	Frequency	%	Accumulated	% Accumulated	80-20
Insfellings	72	32.29%	72	32.29%	80%
Process	47	21.08%	119	53.36%	80%
Equipment	3. 4	15.25%	153	68.61%	80%
Personal	27	12.11%	180	80.72%	80%
Cpest control	22	9.87%	202	90.58%	80%
To thestorage	15	6.73%	217	97.31%	80%
Cleaning and disinfection	6	2.69%	223	100.00%	80%
Total	223	100.00%			

Source: Own Elaboration

11.1 Pareto Analysis

For the Pareto analysis, the values of non-compliance by area of study in the micro-enterprises under study were taken as a basis (Figure 1. Pareto analysis of the micro-enterprises under study).

Figure 1 Pareto analysis of the micro-enterprises under study



Source: Own Elaboration

As a result of the analysis of the data through the Pareto analysis (Table 4. Pareto analysis of the microenterprise), it was obtained that the Facilities, Process and Equipment areas are the cause of 80% of the problems found. Therefore, the improvement strategy was aimed at solving them and this will help reduce the quality problems found in the remaining areas.

Table 3.Pareto analysis of the microenterprise

	Installations	Process	Equipment	Staff	Pest control	Storage	Cleaning and disinfection
Frequency	72	47	3. 4	27	22	15	6
% Accumulated	32.29%	53.36%	68.61%	80.72%	90.58%	97.31%	100%
80-20	80%	80%	80%	80%	80%	80%	80%

Source: Own Elaboration

12 Hypothesis testing

Based on the results described, it was sought to test the hypotheses defined at the beginning. Based on the general hypothesis that states the importance of the definition of good practices and regulations of the food sector for the economic and competitive growth of micro-enterprises, it is concluded that its specification will allow attacking the main problems found and specified in the tools to identify points of improvement. Considering the specific hypotheses, it is concluded:

1. It was verified that all the microenterprises visited present failures, considering as the standard that should be fulfilled according to what is established in the Good Manufacturing Practices, which establish the minimum requirements to reduce the risks of intoxication and ensure safe food.
2. According to the investigation, it was confirmed that ignorance and mainly the economic factor condition the application of current procedures and regulations. Given that the companies studied are dedicated to food production, the regulations require care in the design of their facilities, the use of equipment and utensils that are easy to clean and disinfect, correct storage of materials, among others. Situations that require an economic investment that many times is not among the possibilities of microentrepreneurs.
3. It was found that the problems found belong to the objectives sought by the continuous improvement methodologies and tools. Although your application will not be evaluated, these tools are the first step in standardizing processes.

In summary, the analysis showed that the areas found in the Pareto diagram fit the root causes Environment and Method found in the Ishikawa Diagram. Therefore, the improvement strategy was aimed at solving them.

13. Conclusions

During the last years, the cultivation of amaranth has caused an increase of interest at a national and international level, mainly due to its nutritional elements. Although this seed was of great food importance during pre-Hispanic times, the arrival of the Spanish made it a forgotten crop.

INEGI, (2016) indicates that the State of Puebla stands out as the largest producer of amaranth, mainly the municipalities of Tochimilco and Atzitzihuacán. Places where small producers have found a viable option to increase the income of their families. Not only carrying out cultivation activities of this seed, but also industrializing it.

Although this project has managed to contribute to the generation of income, they still have a long way to go. Reaching national and international markets entails the fulfillment of a number of requirements, especially due to the demand for hygiene and safety in companies in this area. To achieve this, an economic contribution is mainly required, but there are other activities that can be carried out as part of the search for quality.

Based on the elements analyzed in the results, it is concluded that there are a large number of deficiencies in the companies under study. Mainly because the producers do not comply with the requirements, regulations and minimum legal aspects established to reduce the risks of intoxication and thus ensure safe food for the consumer. As mentioned, their conditions are limited primarily due to the lack of economic resources and the lack of knowledge of the elements to be met.

Initially, industrial development can be achieved through the awareness of those involved about the demands involved in the preparation and sale of food, and the potential risks of not complying with adequate quality. Likewise, establishing the greatest effort to attack the main causes found, will be able to improve the conditions of the micro-enterprises found at the beginning and give way to position themselves in a competitive market.

14 Recommendations

14.1 Method

There is a relationship between the microenterprises under study. Regarding the method, the strategies are based on the training of its employees, application of 5'S and application of an ANDON system. Initially, it is necessary to make the members of the micro-enterprises aware of the benefits of adhering to the regulations that guarantee the quality of their products. Through the presentation of success stories, their scope, the demands that the food industry asks of companies to guarantee human safety and health, and faults for non-compliance with what is established (Krajewski, Ritzman and Malhotra, 2008).

Regarding training, current regulations indicate that the amaranth used as raw material must be inspected sensorially and, if necessary, establish laboratory tests. In the first case, the staff can be trained to sensorily verify that the amaranth grains meet the minimum requirements established in NMX-FF-116-SCFI-2010 and NMX-FF-114-SCFI-2009.

Integrate as part of the training the 5'S philosophy applicable to Method and Environment, through examples of its implementation and the benefits obtained by following its sequence correctly. Said training can be carried out through the use of technology with pre-recorded material or with the help of experts in the field of Good Manufacturing Practices.

Regarding the production processes, it is recommended to prepare a process manual available to employees, which establishes the order and development of operations to obtain standardized products. For the warehouse areas, the ANDON System must be applied when marking the specific spaces for raw materials and finished products and the use of signs based on the NOM-026-STPS-2008 standard, as well as the type of furniture that will be used for their storage. protection and its specific characteristics.

15. Acknowledgments

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Chapter 7 Meliponiculture in communities as a business unit for indigenous women

Capítulo 7 La meliponicultura en las comunidades como unidad de negocio para las mujeres indígenas

GONZAGA-LICONA, Elisa, GONZÁLEZ-MUÑOZ, Lilian and AHUACATITLA-PÉREZ, José Miguel

Tecnológico Nacional de México, Campus Huauchinango

ID 1st Author: *Elisa, Gonzaga-Licona*

ID 1st Co-author: *Lilian, González-Muñoz*

ID 2nd Co-author: *José Miguel, Ahuacatitla-Pérez*

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Abstract

Meliponiculture or breeding of native stingless bees (escaptotrigona) is an activity that economically benefits those who sell honey, as well as the generation of new colonies of melipona bees, it can also be an alternative medicinal source and good quality food. Rational management of domesticated hives, based on knowledge of the biology of the species, can increase honey production, thus improving the economic income of indigenous women in marginalized areas of the northern highlands of Puebla, since these ancient insects are not dangerous. A short and medium term project is proposed aimed at indigenous women as a business unit, meliponiculture is an ancestral activity and Mexican heritage, in which women will be the main authorsin the development of this interesting project, having an environmental, social, educational impact , economic and cultural for the northern mountains of Puebla.

Meliponas, Bees, Scaptotrigona, Honey, Pollen, Meliponario

1. Introduction

Bees or meliponas are a group of insects typical of tropical and subtropical areas, which play an importantrole as pollinators of native flora. Before the arrival of colonizers, who introduced the common Africanbee (A *pis mellifera*), stingless bees were the only bees that stored honey within colonies and were usedby many indigenous cultures of South and Central America, who used its honey, wax and pollen. Meliponiculture was particularly important within the Mayan culture, which developed interesting management processes. This type of management forms the basis of the guidelines for modern rational breeding.

Stingless bees represent a group of culturally very important organisms for the natives of the country, since they have historically been a source of food and natural medicine for thousands of years. Although,it is necessary to say it, now, in urban areas, the traditional knowledge about the uses and benefits of theproducts of these bees has been lost due to the separation of the city dwellers from the rural environment. Their nests (hives), of unique or original construction, are always densely populated. Many are built in natural cavities, usually in the ground or in the hollows of tree trunks, although it is common to find themin rare places such as animal skeletons or even in termite or ant nests.

These bees are part of our culture, since before the Spanish conquest the natives knew of the importancethat honey and wax had for their subsistence, products that provided them with food and elements for thehealing of their ills, in addition to other applications. The honey of these bees, known as "wood honey" or "wild honey", is attributed greater medicinal properties than that of domestic bees, being used to treatconditions of the nose, ear, throat, lungs, wounds and burns. , creating the first ancestral meliponaries bythe Mayan culture.

One of the many problems that the northern highlands of Puebla and the entire world are going throughis the lack of pollination of the ecosystem and the aggressive use of fertilizers in planting, as well as thelack of employment in marginalized communities and more so for women. natives.

2 Development

The implementation of meliponiculture in marginalized communities for indigenous women is of the utmost importance since they are used in something totally different from the everyday, without investing in the process of supervision or development of the hives, they are totally self-sustaining and for good management . It is essential to follow the following steps as mentioned(Amazon Conservation Team, 2020)

Sensitization and introduction to meliponiculture

In this activity it is very important to highlight the ecological function and present the main characteristics of the different kinds of bees, for their familiarization by the members of the community.

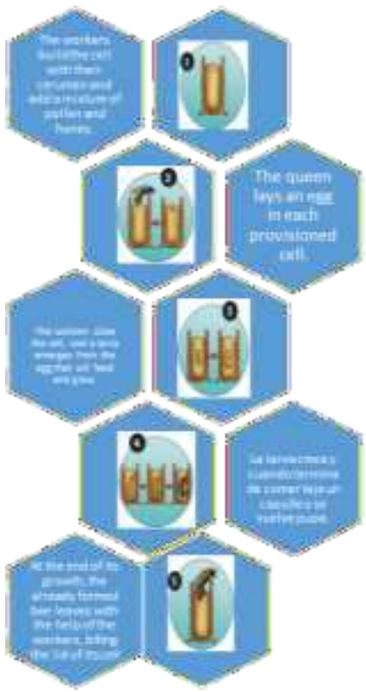
Subsequently, the participants are asked about the type of honey and bees found in the territory and the appropriate species to breed are identified. With this information, a list of potential meliponiculturists isprepared based on their disposition and the knowledge they have of native bees in favorable situations for their management.

Melipona Bees

Anyone interested in developing meliponiculture must first become familiar with some basic characteristics that define the biology of native bees. First of all, native bees are classified as insects and are close relatives of wasps and ants. The main difference between native bees, also called " meliponas " and European or African bees (*Apis mellifera*), is due to the fact that they do not have a poisonous stinger as a defense mechanism. In addition, native bees tend to be hairier and more robust (with the exception of angel bees) and the wings are generally shorter than the body.

Another important characteristic is honey and the way it is stored; In this sense, each type of bee producesa different honey, even some bees produce honey that is not suitable for human consumption, which is why it is very important to know which bees we must breed to produce excellent quality honey. For thisreason, below, we will delve a little more into the life cycle of native bees and the organization of the hive, followed by a brief description of some of the most suitable native bee species to develop meliponiculture in the Huauchinango region.

Figure 1 Melipona bee life cycle Consultation



Source :(Amazon Conservation Team, 2020)

Selection of the most suitable native bees for honey production in the Huauchinango region

Some species of native bees use droppings or carrion and produce unpleasant and even toxic honey for humans. For this reason it is very important to know how to identify what type of native bee should be managed in the meliponary.

Transfer or racking

Transfer or transfer is a management practice that consists of moving a colony of native bees from one place to another. For example, transfer should be made when a swarm of native bees has colonized a temporary nest and has been properly established for a period of approximately two months. At this time the colony must be transferred to a technified box so that it can continue to grow fully.

Obtaining new hives by the division method

The hive division or multiplication method is a management practice that allows us to obtain two colonies from a large hive with a large population, causing the least possible impact thanks to the use of technified boxes. This method also allows meliponiculturists to select the reproduction of their best hives, when they want to increase the number of colonies they have in the meliponary.

The products of the hive and their harvest

The quality and quantity of the honey harvest and of the other products of the hive will also depend to a great extent on the climatic conditions and the vegetation that surrounds the meliponary , being the summer time the most favorable for the native bees to obtain the largest amount of food that allows them to fill their reserves.

Another factor of crucial importance at the time of harvesting is to be especially careful with the hygieneof the utensils to avoid contamination of the honey, which after being extracted should be bottled in a sterilized glass container with an airtight lid and preferably, it should be keep refrigerated to prevent fermentation. Under these conditions, stored honey can last for several years without losing its properties.

Management of natural enemies of native bees

Meliponary area very clean and prevent the boxes from coming into contact with the surfaces where the ants walk. An ant trap can be installed at the base of the posts that support the breeding boxes, where small amounts of grease or oil mixed with some natural ant repellent are periodically placed.

Follow-up of the meliponario and monitoring of the floral calendar

All meliponarios that want to grow in an orderly and efficient manner must keep a complete inventory, as well as a detailed record of the management practices carried out in each hive. This exercise will allow the meliponiculture family to plan and coordinate the necessary activities for each of their hives at the appropriate time of the year.

Colony inventory: Allows you to keep track of each meliponary hive , as well as its age and origin. Thisinformation is vital and must be constantly updated (Annex 1).

Follow-up of the meliponario **:** It allows keeping a detailed record of the state and the management practices carried out in each of the colonies. This information facilitates the planning and coordination of the necessary activities at the correct times of the year (Annex 2).

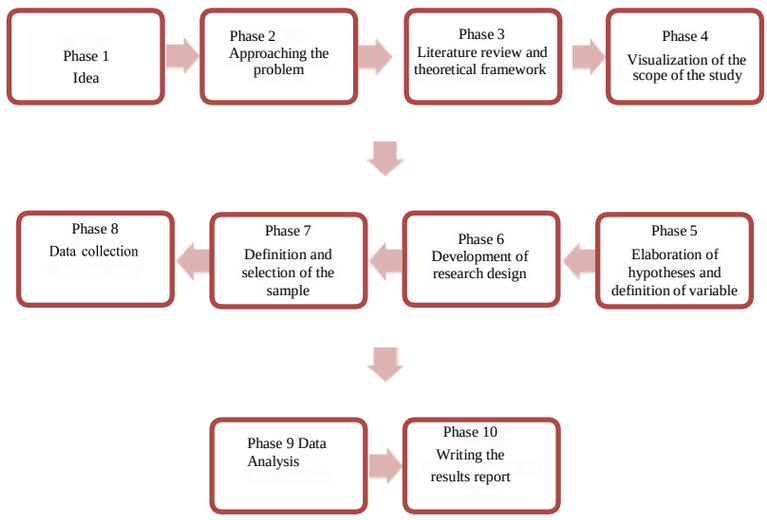
Floral calendar: The monitoring and registration of the floral calendar should also be considered valuabletools to be able to estimate which plants our native bees are visiting at each moment of the year (Annex3).

3 Methodology to be developed

It is aware that everything is changing at great speed, from the way of knowing to the way of investigating; You must be attentive to these changes, otherwise you will not be able to understand the world around us and the phenomena that will impact your professional and personal life.(Paz, 2017)

According to what Sampieri establishes (Sampieri, 2014)in this research, the quantitative approach is used, which consists of data collection to test a hypothesis based on numerical measurement and statistical analysis, in order to establish behavior patterns and test theories. The phases of this process areshown in Figure 2.

Figure 2 Quantitative process



Consultation Source: (Sampieri, 2014)

4 Results

The result of this project will be reflected one year after its implementation, it depends on the care and timely monitoring of the aforementioned points for good management and control of hives, as well as a good harvest of honey and its derivatives in accordance with the ecosystem in which melipona bees develop .

Table 1 shows the investment for 20 hives.

Description	Cost
1. Infrastructure	$8,300
2. Hives (20 pcs)	$24,000
3. Training	$3,500
4. Lodging (instructor)	$800
5. Meals (instructor)	$600
Total:	$37,200

Table 1 Project investment for 20 hives Consultation source: personal information

Table 2 shows the income after one year starting with 20 hives

Table 2 Income at one year with 20 hives

Description	One year income
Honey (20 hives)	20 lt.(1500 x liter) =$30,000
20 hives	20 new ($2,600 x hive) =$52,000
Total:	***$82,000***

Source: Own Elaboration

5 Annexes

It is worth mentioning that the formats shown below (Amazon Conservation Team, 2020)served as a reference for monitoring, data collection and inventories for this project.

Colony Inventory
Name of the Meliponiculturist:
Location:

Code of the Beehive	Name	Source	Date	Observations

Follow-up of the meliponario:
Name of meliponiculturist:
Local:

Date	**Code of the beehive**	**Source**	**Strong location Weak mature Breeding**		**Exercise**				
					Transfer	Division	Harvest	Food	Others

6 Thanks

My appreciation and affection to the indigenous women of the Cuacuila community for their desire to get ahead in the implementation of the meliponiculture project as a business model to be able to contribute economically to marginalized families and achieve good for both the environment and society.

.

7 Financing

This project was a donation by Engineer José Miguel Ahuacatitla Pérez, who had the initiative to contribute 20 beehives to 10 indigenous women from the community of Cuacuila , Huauchinango, Pue.

8 Conclusions:

The economy in indigenous communities is very difficult to maintain or have employment opportunities on a constant basis and even more so for indigenous women, who with effort and dedication lead the integration of a family, which is why this project called " Meliponiculture " is implemented. in communities as a business unit for indigenous women", with the aim of contributing to the activation of the economy for marginalized communities. Below is a projection of recovery of the initial investment in one year, with the sale of hives.

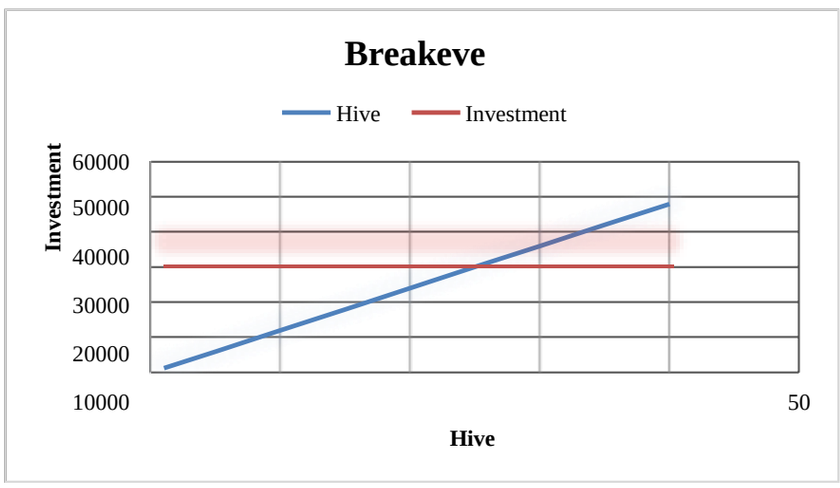
Table 3 Price per number of hives

Years	Nope.	Number of hives	$ sale
1 year	1	1	1200
	2	5	6000
	3	10	12000
	4	15	18000
	5	20	24000
2 year	6	25	30000
	7	30	36000
	8	35	42000
	9	40	48000

Source: Own Information

As a proposed break-even point, it is shown below:

Graphic 1 Balance point



Consultation Source: Own Information

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Chapter 8 Optimization of the rainbow trout rearing process (O *ncorynclius mykiss*). Case- study

Capítulo 8 Optimización del proceso de crianza de trucha arcoíris (O*ncorynclius mykiss*). Estudio de caso

HERNÁNDEZ-MALDONADO, Evelia†*, GONZAGA-LICONA, Elisa and VILLA-BARRERA, Víctor

Instituto Tecnológico Superior de Huauchinango, Av. Tecnológico No. 80 Col. 5 de Octubre, Huauchinango, Puebla, Mexico

ID 1st Author: *Evelia, Hernández-Maldonado* / **ORC ID**: 0000-0001-9648-289X, **CVU CONACYT ID**: 1220738

ID 1st Co-author: *Elisa, Gonzaga- Licona* / **ORC ID**: 0000-0002-7970-7855, **CVU CONACYT ID**: 904035

ID 2nd Co-author: *Víctor, Villa-Barrera* / **ORC ID**: 0000-0001-6118-9474. **CVU CONACYT ID**: 951194

DOI: 10.35429/H.2022.8.98.106

*evelia.hm@huauchinango.tecnm.mx

A. Marroquín, J. Alonso, Z. Chavero and L. Cruz (Coord) Engineering and Innovation. Handbooks-©ECORFAN-México, Querétaro, 2022.

Abstract

The rainbow trout (Oncorynclius mykiss), is a species belonging to the Salmonidae family, native to the Pacific coast of North America, due to its easy adaptation to captivity, its breeding has been widely spread almost throughout the world. In Mexico, the cultivation of trout began at the end of the 19th century, in the first natural nursery in Chimea Lerma, state of Mexico, in order to carry out repopulation in national water bodies. There are several species of this fish that can be farmed, but what has achieved the greatest success is the rainbow trout, due to its rapid growth, lower oxygen content in the water, and resistance to disease.

Referring to trout farming in the problems that producers in the Huauchinango region have in terms of overpopulation of specimens in ponds, generating uncertainty in the inadequate distribution of trout affecting their size and weight, it is carried out an extra activity known as "unfolding", which consists of the transfer of trout through a net from a pond that passes through a trout selector who determines the size and destination of each of the specimens, with the aim of dividing them according to to the stages of growth; this operation generates additional costs that are not recoverable at the final point of sale of the specimen, knowing these factors arises the need to optimize the process of rearing and fattening trout by standardizing the ponds, establishing a model to develop a hatchery of trout. Thanks to the results obtained in the analysis of the La Barranca hatchery, the optimal conditions were defined for the design of the hatchery ponds that will be located in the "Piedras Pintadas" river within the region corresponding to the property of the Preeminent Technological Institute of Huauchinango, Puebla, located in Colonia 5 de Octubre of the same city.

Optimization, Process, Rainbow trout, Research, Standardization

1. Introduction

Rainbow trout (Oncorhynchus mykiss), is a species belonging to the Salmonidae family, native to the Pacific coast of North America, which due to its easy adaptation to captivity, its breeding has been widely spread almost all over the world. In South America, it is distributed in Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, Peru and Venezuela.

Starting in the 1970s, several fish farms or fish farming centers began to be installed, which were built following traditional breeding systems, using concrete ponds; currently in the technical advances and new farming technologies, trout farming has become an alternative for the mass production of fresh fish, as well as for the generation of job opportunities directly and indirectly.

There are several species of this fish belonging to the Salmonidae family, which can be farmed, but what has achieved the greatest success is the rainbow trout, due to its rapid growth, lower oxygen content in the water and resistance to disease.

The cultivation of trout in Mexico began at the end of the 19th century, in the first natural nursery in Chimea Lerma, state of Mexico, in order to repopulate national water bodies. In 1973, the reproduction of rainbow trout was formalized, and by decree, the fish farming center in Salazar was created in the state of Mexico, which in 1943 became the "el zarco" aquaculture center.

In 1950, the aquaculture center in Pucuato , Michoacan began operations, which is currently operated by INAPESCA. The activity is considered profitable; however, it is affected by different crop diseases and in some cases by the lack of good quality and volume of water. The trout farming activity is carried out mainly in areas with temperate to cold climates and in places with an attitude greater than 1,200 meters above sea level (INAPESCA, 2013).

Likewise, rainbow trout is classified as category "E" or "Established space in Mexico" according to NOM-059 (SEMARNAT, 2010).

The Law defines aquaculture as the set of activities aimed at the controlled reproduction, pre-growth and fattening of species of fauna and flora carried out in facilities located in fresh, marine or brackish water, through breeding or cultivation techniques, which are susceptible to commercial, ornamental or recreational exploitation.

However, as has been shown, aquaculture, in addition to being important in providing foods rich in protein, has social and economic importance, its purpose is to support sustainable development, avoiding fishing and environmental overexploitation of aquatic resources; providing alternative or complementary work in the fishing sector and other related activities, especially in fishing regions in crisis or rural areas with a high degree of marginalization; generating roots in the communities of origin, obtaining income, foreign exchange with the goods for use and consumption demanded by developed countries. Referring to trout farming in the problems that producers in the Huauchinango region have in terms of overpopulation of specimens in ponds and as a consequence generates uncertainty in the inadequate distribution of trout affecting the size and weight of the same, generating an extra activity known as "unfolding", which consists of the transfer of trout through a network of a pond that passes through a trout selector that determines the size and destination of each of the trout. specimens, with the aim of sectioning them according to growth stages, it is worth mentioning that this operation results in the generation of additional costs that are not recoverable at the final point of sale of the specimen, knowing these types of factors arises the need for optimize the process of raising and fattening trout by standardizing the ponds by establishing a model to develop a hatchery trout river in the location in the "Piedras Pintadas" river located within the territory belonging to the Higher Technological Institute of Huauchinango.

2. Methodology

2.1 Study area

It is located in the northwestern part of the state. Its geographical coordinates are the parallels 20º 05´ 30” and 20º 17´06” north latitude of the meridians 97º 57´ 00” and 98º 08´06” west longitude. Its boundaries are: to the North with Xicotepec de Juárez and Juan Galindo, to the South with Ahuazotepec and Zacatlán, to the West with Juan Galindo and Tlaola and to the West with Naupan, Ahuazotepec and the State of Hidalgo.

Two climates can be identified in the municipality: humid temperate climate, with rains all year round; average annual temperature between 12 and 18º C; temperature of the coldest month between -3 and 18º C; precipitation of the driest month greater than 40 millimeters, percentage of winter rain with respect to the annual is less than 18. semi-warm sub-humid climate, with rains all year; average annual temperature greater than 18º C; precipitation of the driest month greater than 40 millimeters, percent of rain, winter with respect to the annual less than 18. It occurs in the lower parts of the municipality to the east. The municipality belongs for the most part to the hydrographic basin of the Necaxa River; the extreme northeast to that of the San Marcos or Tecolutla River.

The Necaxa River rises under the name of Totolapa in the south of Huauchinango, runs through steep mountains running through the municipality in a southwest-northwest direction and plunges to the bottom of deep ravines forming the Salto Chico and Salto Grande waterfalls, used in power generation. On their way to the Tenango or Necaxa dams (the last two in Huauchinango territory) they are fed with its waters, collecting the flow of small tributaries and then mighty currents such as the Texcapa, Chapultepec, La Malva, Hayatlaco, Dos Puentes, Xoctongo. , Mazontla, Cuacuila, etc., that bathe the municipality in all directions. Subsequently, the Necaxa River continues to run through the mountains, crosses the territory of Veracruz and, with the name of Tecolutla, flows into the bar of the same name, in the Gulf of Mexico. To the north, the municipality is crossed by the Naupan River, a tributary of the San Marcos, which originates in the Sierra de Pahuatlán and with the name of Cazones, flows into the Gulf. Intermediate between Naupan and the Necaxa, the Alseseca river crosses the north of the municipality, which disappears when it leaves the municipality.

In short, it is a municipality that has a large hydrological flow. (INAFED, ENCYCLOPEDIA OF MUNICIPALITIES AND DELEGATION OF MEXICO)

2.2 Data collection

As referenced in the particularity of Mexican aquaculture is that the information that has been generated is scientifically based which is based on approaches with areas of nutrition, health, physiology and technology. Mitigating the lack of specialized research on historical, economic, or social analysis is reflected in the little or no existing information.

The documents with the greatest content on these topics are from the state or federal development plans, technical reports, statistical yearbooks or informative bulletins, published by the various government agencies in charge of promoting aquaculture and fishing, such as the Secretary of Agriculture, Livestock , Rural Development, Fisheries and Food (SAGARPA), the National Aquaculture and Fisheries Commission (CONAPESCA) and the National Fisheries Institute (INAPESCA), among others.

Due to the scarce and generic information existing by these dependencies, it was established through an analysis of the area to determine the source of information and training on aquaculture to one of the largest predominant producers, the trout farm "La Barranca" located in the community of Teopancingo belonging to the municipality of Huauchinango, Puebla. Developing descriptive research through surveys, according to García Ferrando (1993), a survey is an investigation carried out on a sample of representative subjects of a larger group, which was carried out in the context of daily life, using standardized procedures of interrogation, in order to obtain quantitative measurements of a wide variety of objective and subjective characteristics of the population.

3 Results

3.1 Biological material

Consisting of 10,000 to 15,000 rainbow trout, the population of the trout farm has 8 rectangular ponds of two different sizes according to the size of the specimens.

3.2 Infrastructure

The study sample hatchery has:

1. 3 incubators with dimensions of .615 meters long by .52 meters wide by a depth of .085 meters with a storage capacity of 100,000 to 120,000 eggs.
2. 2 circular ponds for fry stage I with dimensions of 1.8 meters in diameter by 1.2 meters deep.
3. 7 ponds for the juvenile stage II to the adult stage and harvest with dimensions of 15 meters long by 3 meters wide by 3 meters deep.
4. 1 pond for the juvenile stage I which has the dimensions of 10 meters long by 2.5 meters wide by 1 meter deep.

The ponds are structured in a staggered manner by the dimensions of the land, highlighting the conditioning factor of overpopulation in them, generating that in the same pond there are specimens with different sizes, generating the variable to be eliminated of splitting that consists in the transfer of trout through a network of a pond that passes through a trout selector that determines the size and destination of each of the specimens, in order to select them according to growth stages, said operation brings as a consequence the generation of costs for activities that do not generate value to the final product.

3.3 Unfolding operation

Splitting is understood as the correct distribution of rainbow trout specimens, sectioning them according to their size and weight. This operation consists of two activities which are described below:

1. Select: an average of 5 kg of fish is taken with a net and passed through the selector previously calibrated to the correct size and weight specifications, if it is not carried out the specimens do not develop properly, the operation lasts approximately 50 and 55 seconds.
2. Return: once the specimens have been correctly selected by size and weight, they will remain in the pond and those that do not meet these variables will be placed in another pond.

Specimens that do not meet the appropriate size and weight are transferred to a cage in order to standardize them. For the unfolding operation, 2 operators work an 8-hour shift with one meal, generating a base salary of $200 per day. During this operation, about 6 ponds of 2 reproduction stages (juvenile and fattening) are processed.

Juvenile stage: includes specimens between 68 and 100 grams in weight, the number of specimens is 15,000 per pond.

Fattening stage: includes specimens between 100 and 250 grams in weight, the number of specimens is 10,000 per pond.

It was established to measure the time of the splitting operation by inspecting two operators considering the amount of trout in each pond and determining the number of splittings that will be carried out in relation to the average weight that is extracted per sample.

The sample size 333 was calculated for a pond of average size for 10,000 specimens, the following table summarizes the number of samples necessary to select 10,000 trout per pond of a size between 100-250 grams according to the splitting times in select and return operations. See Table 1 Fattening split of 100-250 grams (select) and Table 2 Fattening split of 100-250 grams (return)

∑ fish by splitting = 10792 trout

∑ Time in minutes to select = 292.15

Active minutes / hour = 55 minutes

$$Real\ time\ select\ by\ pond = \frac{\sum time\ in\ minutes\ to\ select}{active\ minutes/hour} = \frac{292.15\ minutes}{55\ minutes/hour} = 5.31\ hours$$

∑ Fish by splitting = 3844 trout

∑ Time in minutes to select = 36.8 minutes

Active minutes / hour = 55 minutes

$$real\ return\ time\ = \frac{\sum return\ time\ in\ minutes}{active\ minutes/hour} = \frac{36.8\ minutes}{55\ minutes/hour} = 0.67\ hours$$

$$unfold\ time = real\ time\ select + real\ return\ time = 5.31 + 0.67 = 5.98\ hours$$

$$cost\ of\ unfolding\ fattening\ stage\ = unfold\ time * operator\ cost\ per\ hour * number\ of\ ponds$$

$$cost\ of\ unfolding\ fattening\ stage = 5.98\ hours * \frac{200}{8} * 2\ operators * 3ponds = \$\ 897$$

3.4 Juvenile stage

The same procedure was carried out to determine the sample size, which was 251 for a tank with a capacity for 15,000 specimens, establishing a size between 68-100 grams in relation to the unfolding times in the selection and return operations, obtaining the following results:

3.4.1 Operation Select

∑ Fish by division = 15291 trout

∑ Time in minutes to select = 220.36

Active minutes / hour = 55 minutes

$$real\ time\ select = \frac{\sum time\ in\ minutes\ to\ select}{active\ minutes/hour} = \frac{220.36\ minutes}{55\ minutes/hour} = 4.01\ hours$$

3.4.2 Return Operation

∑ Fish by splitting = 5953 trout

∑ Time in minutes to select = 26.41 minutes

Active minutes / hour = 55 minutes

$$real\ return\ time\ = \frac{\sum return\ time\ in\ minutes}{active\ minutes\ /hour} = \frac{26.41\ minutes}{55\ minutes/hour} = 0.48\ hours$$

$$unfold\ time = real\ time\ select + real\ return\ time = 4.01 + 0.48 = 4.49\ hours$$

$$cost\ of\ unfolding\ fattening\ stage = unfold\ time * operator\ cost\ per\ hour * number\ of\ ponds$$

$$cost\ of\ unfolding\ juvenile\ stage = 4.49\ hours * \frac{200}{8} * 2\ op * 3ponds = \$\ 673.5$$

$$total\ unfolding\ cost\ = cost\ of\ unfolding\ fattening\ stage + cost\ of\ unfolding\ juvenile\ stage$$

$$total\ unfolding\ cost = \$897 + 673.5 = \$1570.5$$

According to the results obtained, the cost of carrying out the unfolding operation in 6 tanks of two different stages is $1570.5

$$monthly\ unfolding\ cost = total\ unfolding\ cost * unfold\ number\ per\ month$$

$$monthly\ unfolding\ cost = 1570.5 * 2 = \$3141$$

The monthly cost for the unfolding operation corresponds to $3141

$$annual\ unfolding\ cost = monthly\ unfolding\ cost * 12\ meses$$

$$annual\ unfolding\ cost = \$3141 * 12\ months = \$37692$$

As it could be demonstrated, executing the unfolding operation periodically twice a month throughout the year will have an annual cost of $37,692.00 for an activity that does not generate value in the production process, but nevertheless it is necessary to carry it out. Due to the overpopulation of specimens in each of the tanks, the calculation of the cost generated by the splitting activity has the purpose of optimizing the process by eliminating the splitting operation.

4. Conclusions

Using the results of the study carried out at the La Barranca hatchery, the optimal conditions for the design of the hatchery ponds were determined, which will be located within the territory belonging to the property of the Higher Technological Institute of Huauchinango, Puebla, located in Colonia 5 de Octubre de the same city.

This location is located at 1601 meters of altitude, we can also find within it an influx of water derived from a river. The corresponding plant facilities (ponds) that are intended to be developed in the project will be located within the premises of the Higher Technological Institute of Huauchinango, specifically at latitudes 20°09'35.7" North and 98°02'23.6" West (20 °09'35.7"N 98°02'23.6"W).

According to the needs for the incubation of eggs and development of fingerlings, the incubation room and fingerling ponds must be established (see annex 1) within an infrastructure protected from variations in environmental temperatures, the door should preferably be located in the north façade to prevent the entry of sunlight. For the installation of an incubation room and fingerling ponds, the use of an area of 10.9 mx 5.4 m is projected, having a total area of 58.86 m.

To cover the needs of the fattening stage, three ponds with dimensions of 8.8m *4.4m *1m each are established (see annex 2)

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Boards

Table 4 Fattening split of 100-250 grams (select)

Fattening split of 100-250 grams (select)				
Sample number	time(s)	unfold weight	Average by unfolding	Fish by unfolding
1	50	5	173	29
2	51	5	227	22
3	50	5	229	22
4	52	5	182	27
5	51	5	145	3. 4
6	54	5	181	28
7	50	5	147	3. 4
8	54	5	142	35
9	51	5	157	32
10	53	5	151	33
323	55	5	216	23
324	54	5	203	25
325	50	5	217	23
326	54	5	139	36
327	52	5	238	21
328	50	5	128	39
329	50	5	247	20
330	54	5	100	50
331	54	5	247	20
332	53	5	149	3. 4
333	54	5	153	33

Source: Self Made

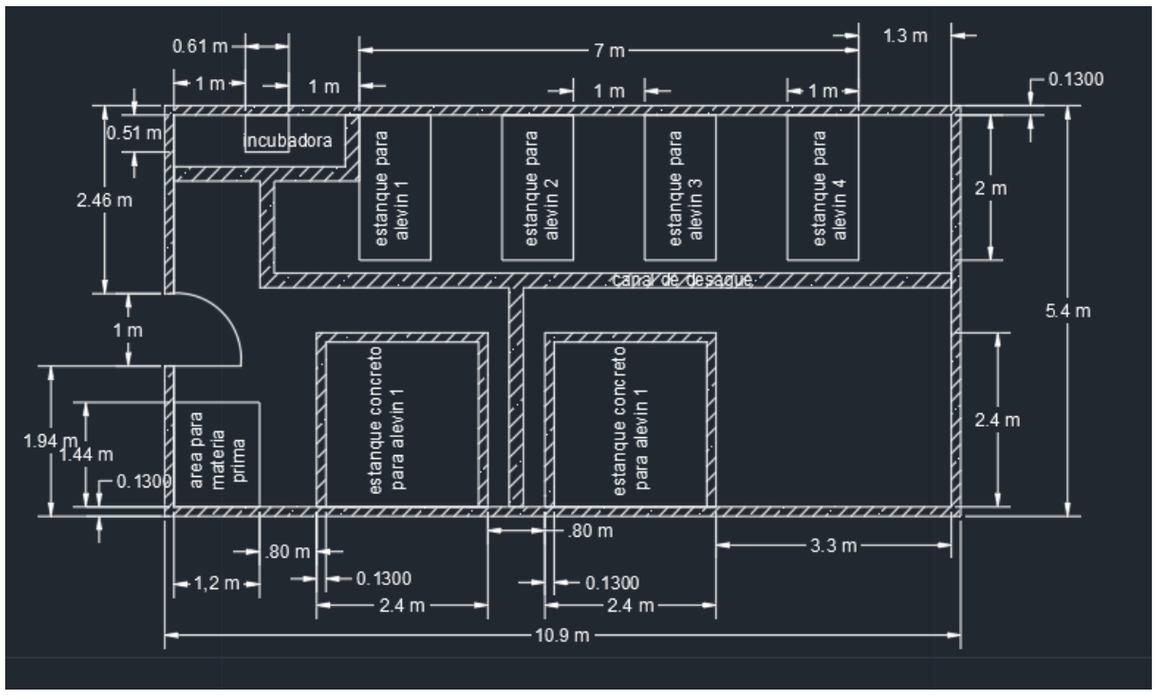
Table 2 Unfold fattening of 100-250 grams (return)

Fattening split of 100-250 grams (select)				
Sample number	time(s)	unfold weight	Average by unfolding	Fish by unfolding
1	52	16.00	110	145
2	47	16.00	174	92
3	41	18.00	161	112
4	53	13.00	210	62
5	46	16.00	124	129
6	54	18.00	126	143
7	50	18.00	220	82
8	40	13.00	119	109
9	52	14.00	198	71
10	53	17.00	248	69
36	50	14.00	216	65
37	51	16.00	124	129
38	48	13.00	107	121
39	41	17.00	143	119
40	44	17.00	142	120
41	53	13.00	182	71
42	52	15.00	186	81
43	50	15.00	199	75
44	53	13.00	226	58
45	46	17.00	242	70
46	47	16.00	176	91

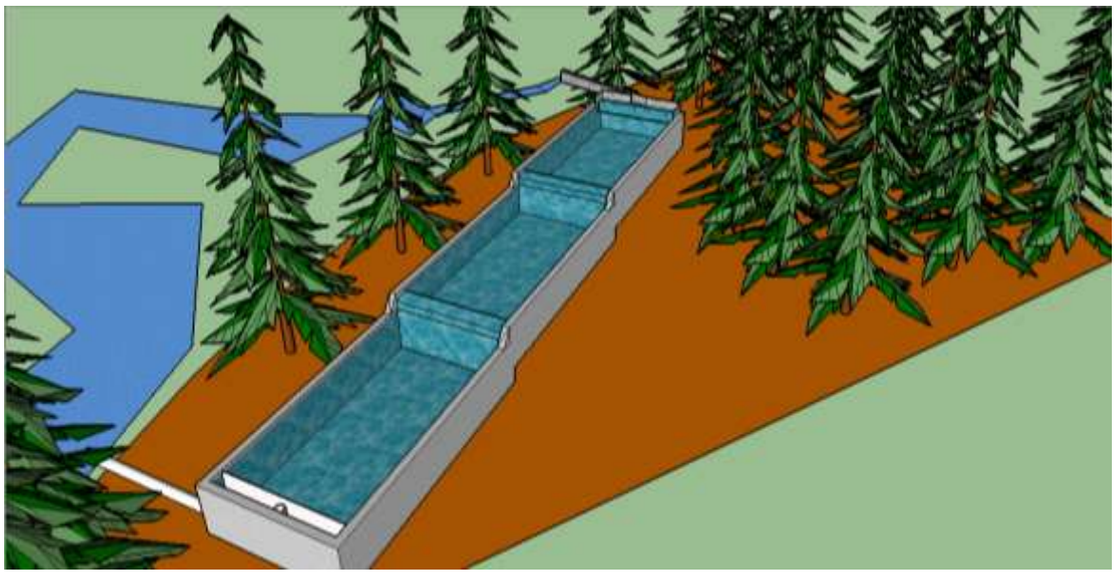
Source: Self Made

Annexes

Appendix 1



Appendix 2



Chapter 9 Market research to identify the viability of using solar stoves in the municipalities of Peñamiller and Jalpan de Serra, in the state of Querétaro

Capítulo 9 Estudio de mercado para identificar la factibilidad de uso de las estufas solares en los municipios de Peñamiller y Jalpan de Serra, del Estado de Querétaro

ÁLVAREZ-ORTEGA, Annel Angelia†*[1], MORADO-HUERTA Ma. Guadalupe [2], CASTILLO-MARTÍNEZ, Luz Carmen[3], MARROQUÍN-DE JESÚS, Angel [4].

[1,2]Universidad Tecnológica de San Juan del Río / División de Negocios y Gestión Empresarial. Av. La Palma no. 125. Col. Vista Hermosa. San Juan del Río, Querétaro, México.
[3,4]Universidad Tecnológica de San Juan del Río / División de Química y Energías Renovables. Av. La Palma no. 125. Col. Vista Hermosa. San Juan del Río, Querétaro, México

ID 1st Author: *Annel Angelia, Álvarez-Ortega* / **ORC ID**: 0000-0001-6177-6345, **CVU CONACYT ID**: 676492

ID 1st Co-author: *Ma. Guadalupe, Morado-Huerta* / **ORC ID**: 0000-0003-0029-4208, **CVU CONACYT ID**: 251130

ID 2nd Co-author: *Luz Carmen, Castillo-Martínez* / **ORC ID**: 0000-0001-6544-5279, **CVU CONACYT ID**: 412614

ID 3rd Co-author: *Ángel, Marroquín-De Jesús* / **ORC ID**: 0000-0001-7425-0625, **CVU CONACYT ID**: 81204

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A. Álvarez, M. Morado, L. Castillo and A. Marroquín

*aaalvarezo@utsjr.edu.mx

A. Marroquín, J. Alonso, Z. Chavero and L. Cruz (Coord) Engineering and Innovation. Handbooks-©ECORFAN-México, Querétaro, 2022.

Abstract

Based on a study carried out, through the application of 115 surveys to heads of families in the rural area of the municipalities of Peñamiller and Jalpan de Serra, in the state of Querétaro, the main market parameters for the use of of solar cookers for the area of influence. The people who answered the surveys were chosen according to a series of homogeneous characteristics such as rural geographic area, social and economic vulnerability, uses and customs. The selected localities were: Valle Verde, San Antonio Tancoyol and Las Ánimas of the municipality of Jalpan de Serra, while, for the municipality of Peñamiller, the surveys were applied to the inhabitants of the following localities of Peña Blanca, Alto Bonito and Mentiras. It should be noted that the instrument underwent a pilot test which made it possible to validate that the wording of the questions was adequate, that there was a clear understanding in the wording, the use of simple language and that, of course, the application time will be found in the recommended parameters. For the pilot test, a small sample was chosen that represented 2% of the representative sample under study. In addition, other results of the survey have made it possible to obtain information regarding the main energy sources used for cooking food, the number of inhabitants per household, knowledge about the existence of solar cookers, the availability of trying this type of cooker, as well as such as the type of food that would be cooked in the appliance and the prices willing to pay. However, it must be considered that the cost the user is willing to pay is less than one thousand pesos in order to be attractive, the product must also be weather resistant. In this research stage, no product presentation variables such as weight, volume or appearance were considered. The scope of this study is exploratory and market tests on physical prototypes are required, which are planned in the near future.

Renewable Energy, Market research, Solar stoves, Solar cooking

Resumen

Con base en un estudio realizado, a través de la aplicación de 115 encuestas a jefas o jefes de familia en la zona rural de los municipios de Peñamiller y Jalpan de Serra, del estado de Querétaro, se determinaron los principales parámetros de mercado para el uso de cocinas solares para la zona de influencia. Las personas que contestaron las encuestas fueron elegidos de acuerdo a una serie de características homogéneas tales como, zona geográfica rural, vulnerabilidad social y económica, usos y costumbres. Las localidades seleccionadas fueron: Valle Verde, San Antonio Tancoyol y las Ánimas del municipio de Jalpan de Serra, mientras que, para el municipio de Peñamiller, las encuestas fueron aplicadas a los habitantes de las siguientes localidades de Peña Blanca, Alto Bonito y Mentiras. Cabe señalar que el instrumento pasó por una prueba piloto la cual permitió validar que la redacción de las preguntas fuese adecuada, que se tuviera una comprensión clara en la redacción, uso de un lenguaje sencillo y que por supuesto el tiempo de aplicación se encontrará en los parámetros recomendados. Para la prueba piloto se eligió una muestra pequeña que representó el 2% de la muestra representativa objeto de estudio. Además, otros resultados de la encuesta han permitido obtener información respecto a los principales energéticos utilizados para la cocción de alimentos, el número de habitantes por hogar, el conocimiento sobre la existencia de las cocinas solares, la disponibilidad de probar este tipo de cocinas, así como el tipo de alimentos que se cocinaría en el artefacto y los precios dispuestos a pagar. Sin embargo, se debe considerar que el costo dispuesto a pagar por el usuario es menor a mil pesos para poder ser atractivo, el producto también debe ser resistente a la intemperie. En esta etapa de investigación no se consideraron variables de presentación del producto como peso, volumen o aspecto. El alcance de este estudio es exploratorio y se requieren pruebas de mercado sobre prototipos físicos, los cuales están previstos en el futuro cercano.

Energía renovable, Estudio de mercado, Estufas solares, Cocción solar

1. Introduction

The Sun is a star that was formed approximately 4.65 billion years ago and it is estimated that it still has fuel for another 5.5 billion years. A person requires the consumption of food that serves as fuel to carry out vital processes, to perform the work necessary to survive; until approximately 200 years ago the power required by man was 3 kWh per day-1 (González-Velasco, 2009). It is estimated that each year the earth's surface receives approximately 1017 Wh of solar energy. The consumption of current human energy worldwide is estimated at 13 × 1012 W/h per year (Scheller et al., 2010).

Considering the above and according to (Miller, 2002), 99% of the energy used to heat the earth and what is inside it comes directly from the sun, without this inexhaustible input of solar energy, the average temperature of the earth would be -240 °C and life as we know it would not exist, the remaining 1% corresponds to commercial energy. About 1.5 billion people worldwide still lack access to electricity, and approximately 2.6 billion rely on wood, straw, charcoal or dung to cook their daily meals, (RENN21, 2010) which shows that cheap energy that is generated by the environment is necessary.

Much of Mexico's territory receives sunlight about 300 days a year. Mexico enjoys, on average, 300 days of sunlight per year, an enormous energy potential of which only a portion is used. When it is used, it is usually through photovoltaic power generation or to heat water in single-family homes. However, when it comes to cooking or processes such as distillation, drying or pasteurization, the first choices of Mexican companies are still fossil fuels (gas and diesel) and sometimes wood, which contribute to global warming and are harmful to health.

In Mexico, the use of firewood represents 33.7% of total energy consumption in the residential sector, only below the use of LP gas (SENER, 2015). Approximately a quarter of households (27.2 million people) cook with firewood (Masera et al, 2005). It is estimated that about 28 million m3 of fuelwood is extracted by rural communities (Caballero, 2010). Firewood is often collected by women and children who use up their energy and time; however, there are also families who need to buy it, which represents an expense of 15-20% of total household income (Masera, Díaz, & Berrueta, 2005).

Solar energy and its manifestations (wind, hydro, biomass, ocean waves and others) are renewable energy sources (RES) or clean energies, which for thousands of years man has used to perform many tasks. They have used biomass to cook their food and more than 6,500 years ago, wind energy was used to propel boats. Unfortunately, the systems for harnessing FRE fell into disuse with the discovery of large fossil fuel deposits that offered abundant and cheap energy for industrial development (Mejía, 1999).

For this reason, a project has been proposed to develop solar stoves that can be produced industrially. The first stage of the project consists of measuring through a survey the expectations of potential users about solar stoves in terms of their current knowledge of their existence, possible acceptance, potential use, as well as the price they are willing to pay for the stove.

Figure 1 Traditional wood-burning stove in Santa María Yacochi, Mexico

Photo: Sandra Weiss

The added value of this work is to develop an instrument that allows to know information regarding the main energy sources used for cooking food, the number of inhabitants per household, the knowledge about the existence of solar stoves, the availability to try this type of stoves, as well as the type of food that would be cooked in the appliance and the prices willing to pay. There is an important market in the area of Peñamiller and Jalpan de Serra in the state of Querétaro, where the people surveyed would be willing to try and buy solar stoves.

Cooking with solar energy is a wonderful experience. It means not only a daily saving in gas, coal, firewood or electricity, but also a change in people's consciousness and a learning process that is oriented towards sustainable human development. It is a new way of taking care of our lives, which is being applied in more and more countries every day. When the sun's energy is used, it is proven that fire is not necessary for cooking. The ability of sunlight to be transformed into heat, thanks to small and simple devices allow finding alternative solutions to everyday problems around the world, such as:

- The lack of firewood and charcoal,
- The effort involved in their transportation, mainly by peasant and indigenous women;
- The deforestation of forests;
- Pollution from smoke from firewood or charcoal during cooking, which is harmful to the lungs and the environment;
- The high cost of gas for daily food preparation.

Solar stoves and ovens, of which there are a large number of designs and models, are examples of a new technology that is inexpensive, easy to reproduce and most importantly: it is environmentally appropriate! They are easy to operate, easily transportable and do not require costly maintenance. The cooking time, however, is generally longer than with conventional stoves, since it depends on the intensity of solar radiation and, to a lesser extent, on the ambient temperature, i.e. it is possible to cook in summer and in winter.

1.1 To cook with firewood and charcoal is to die a little every day.

The habit of collecting and using firewood prevents us from realizing what this means for humanity and for the environment. However, it is important to think about why we use wood and charcoal:

- Money is not always enough to buy gas;
- You live so far away from urban centers that it is the only fuel available;
- You want to make the gas cylinder last as long as possible.
- Besides, it has always been thought that firewood is free... but it is not!

1.2 Firewood is not free, it has a cost in terms of environment, health and time.

Families have to walk farther in search of firewood, which means a very significant expenditure of time. If they were to work during that time, how much would the economic income amount to? It has been calculated that a family of 5 people can spend half a ton of firewood per month on cooking. This explains the decrease or disappearance of trees and shrubs that beautify the mountains and hills some time ago. It means that many forests are disappearing or have already disappeared and what was once green is now desert. This decrease in vegetation is changing the climate. Today it is drier and hotter and when it is cold, it is much colder. Collecting firewood from the banks of the streams is taking away their natural containment, allowing sand, soil and leaves to be washed down the river. This can dry up the stream and destroy plants and animals, in short, it damages the environment in which we live.

Look for other economic and easy to obtain fuels, which allow us to consume less firewood or charcoal. At the same time, reforest the soils and recover nature for future generations. But... What to do then, if you need to cook and keep your house warm in the most economical way possible?

The solution lies in the sun, it is a good alternative: natural, inexhaustible, clean, free and if you take advantage of it, it can replace, partially or totally, the wood that is burned or save on the purchase of other fuels.

1.3 Cooking with the sun

It is possible to cook with the luminous energy produced by the sun, but it is not enough to simply put a pot in the sun. It requires a specially designed device that transforms solar radiation into sufficient heat through accumulation or concentration. It is similar to playing with a mirror directing the rays towards an object, burning paper or wood with a magnifying glass or leaving a hose full of water in the sun for a certain period of time.

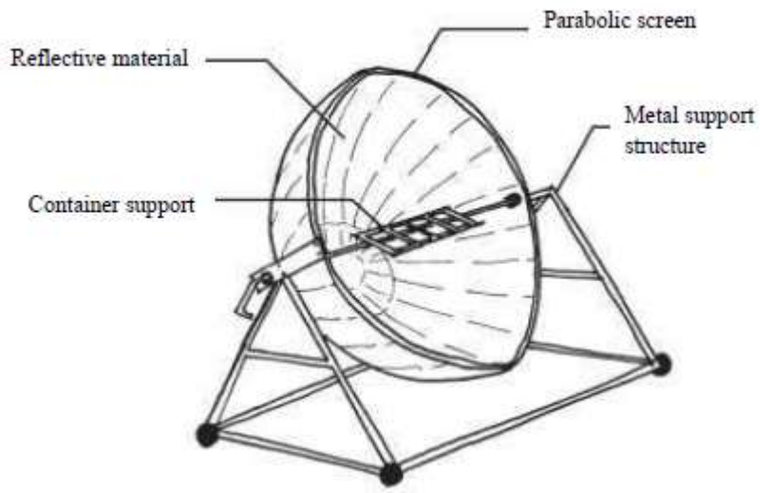
The phenomenon of heating the interior of a car parked in the sun with the windows closed is also similar. One of the alternatives are solar stoves, devices that have been used for years to cook food with the help of the sun's energy; they are thermo-converters, i.e., devices that transform the sun's radiation into sufficient calorific power to cook food. There are multiple designs of solar stoves in the world, but there is still a lot of research to be done (González-Avilés et al., 2017).

1.4 What types of solar stoves are there?

Basically two types are distinguished:

– The parabolic solar stove, which is similar to an antenna with the same name, but covered with a reflective surface. It heats by concentrating the sun's rays on a single point, called a focus, where the cooking container is located.
– The solar oven, which is a hermetically sealed box with a transparent lid, which allows the sun's rays to be captured. It heats by the so-called greenhouse effect or heat trap.

Figure 2 Parabolic solar stove



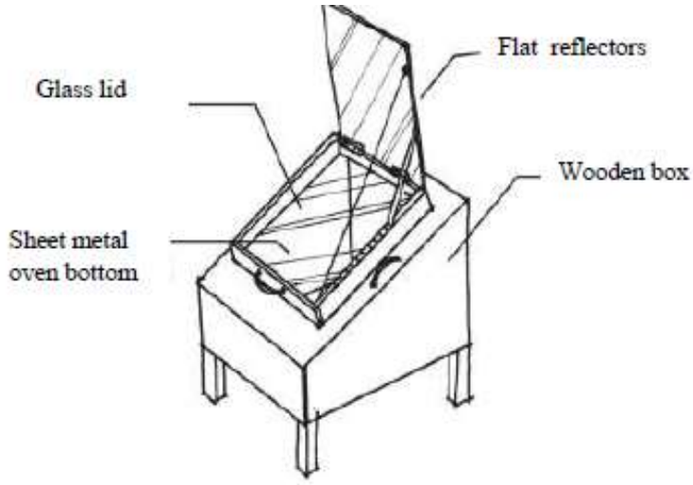
Source: Guide for the use of solar stoves and ovens. Recetario Solar Fundación Celestina Pérez de Almada, 2005

Parabolic solar stoves have a structure generally made of metal, basically composed of a support and a parabolic screen supported by the support. Normally the support is equipped with wheels so that the stove can be moved easily without the need to lift it. The parabolic screen is fixed in such a way by the support, so that it is easy to change its inclination according to the angle of incidence of the sun. The inner surface of the screen is covered with a reflective material, which can be made of strips of a special aluminum sheet or composed of a large number of small pieces of mirror glass. In the center of the screen, slightly separated from it is the holder for the cooking vessels, the defined size and shape of which may vary from one model to another. The size of the stove can vary according to requirements. For family use, the parabolic screen has a diameter of approximately 1 m. to 1.50 m. The larger the size, the greater the heat output and consequently the cooking capacity.

1.5 What does a solar oven look like?

The solar oven box can be made of a wide variety of materials and of different sizes depending on the need. The simplest and cheapest ovens are made of cardboard boxes and the more expensive ones of wood, plastic or metal. The transparent lid is usually made of glass, but acrylic or polyester plates or sheets can also be used, which have the advantage of being less fragile, with the disadvantage that they do not retain heat as well as glass (greenhouse effect).

Figure 3 Solar oven. Source: Guide to the use of solar stoves and ovens. Recetario Solar Fundación Celestina Pérez de Almada, 2005



Source: Guide for the use of solar stoves and ovens. Recetario Solar Fundación Celestina Pérez de Almada, 2005

By using a double glass lid, the oven retains more heat. To minimize heat loss through the walls and bottom of the box, a thermal insulator several centimeters thick is used. To capture more of the sun's rays, the sides of the glass lid can be equipped with flat reflectors. The inside of the oven generally consists of a sheet metal box with an opaque black painted bottom, which absorbs the sunlight to transform it into heat. Here's the golden fact: A good solar oven can reach temperatures of up to 150°C. It's a marvel! To make its use more comfortable, the oven can be mounted on a raised support with wheels. This will make it easy to move and orient it towards the sun.

1.6 When can the solar stove and oven be used?

Solar stoves and ovens work only when the sun is shining. When it is dark, cloudy or raining, the solar stove and oven will not work. However, when it is cold and sunny, you can cook, regardless of the outside temperature. The proper functioning of the solar stove and solar oven depends on the good collection of the sun's rays. It is therefore necessary to ensure that the solar stove and solar oven are always oriented towards the sun and that the collection surfaces (reflectors and glass) are always clean.

1.7 What are the advantages of solar stoves?

Saving money while there is sun you can cook with it - the sun is free! People who use solar stoves and ovens save between 50 to 80% of gas, coal or firewood. This means that a large part of the energy used for cooking food can be saved.

Time savings

You don't have to fetch firewood or buy gas or other fuel as often. Cooking, especially in the solar oven, does not require constant attention. As the food does not burn, you do not have to stir it constantly as when cooking with fire. You can then have more time for other activities that you do not have time to do now.

Better health

Not having to walk for long hours looking for firewood and carrying it on your back is beneficial to your health. The smaller amount of smoke that one has to breathe during the cooking with firewood also contributes to better health.

It allows to take care of the environment.

Using less wood and charcoal means cutting less trees and maintaining our forest. Burning less wood reduces smoke pollution in the air, which is beneficial for our health and for animals and plants.

1.8 What are the disadvantages of solar stoves and ovens?

They do not work without the sun

Solar stoves and ovens ONLY work when there is SUN. At night or when it is cloudy they cannot be used. Therefore, it is good to have an auxiliary stove.

Cooking is done outside the house

This means, you have to walk from the house to the patio and expose yourself more to the sun and wear a nice straw hat.

You have to move it from time to time

It is necessary to keep it focused towards the sun.

It is uncommon

It takes time to get used to its use and this is only achieved by practicing with it. The more you use it, the better you get to know it!

2. Market research

Market research for (Malhotra, 2008) is the "identification, collection, analysis and dissemination of information in a systematic and objective way, with the purpose of improving decision making related to the identification and solution of marketing problems and opportunities" Market research is a technique used to collect data on any aspect that you want to know and then interpret them and finally make use of them for proper decision making (QuestionPro, 2019). (QuestionPro, 2019).

There are two types of market research, the first with a qualitative approach that is based on feelings and thoughts, the second with a quantitative approach that allows making use of statistical and mathematical techniques. The main tool of quantitative research are surveys, which can be face-to-face, telephone, mail, online.

In particular, the face-to-face survey, also known as "Face-to-face", is the survey that allows collecting information without a large amount of bias since the researcher is present and can verify at all times that the participant answers from start to finish and that they provide adequate answers to each question.

Market research has 3 different types of objectives.

Administrative: To help the development of the company or business through proper planning, organization and control of both material and human resources, in order to meet specific needs within the market at the right time.

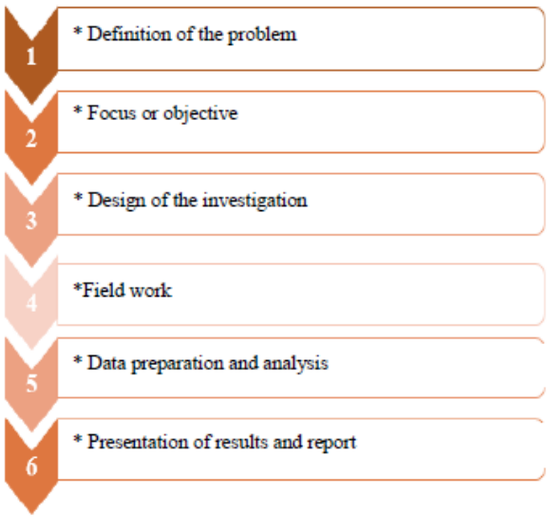
Social: To satisfy the specific needs of the client by means of a required good or service, that is to say, that the product or service fulfills the requirements and desires of the client when it is used.

Economic: Determine the economic degree of success or failure that a company may have when it is new in the market, or failing that, introduce a new product or service in order to know for sure the actions to be implemented. (QuestionPro, 2019).

2.1 Market research process

To carry out market research it is vital to plan the activities and execution actions, therefore, the process allows to know what to do when faced with various situations that arise and thus make time efficient. The following structure indicates the sequence of the six research steps to follow according to (Malhotra, 2008):

Figure 4 Market research process



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Source: (Malhotra, 2008)

2.2 Geographic location of the municipalities

Figure 5 shows the location of the municipalities of Peñamiller and Jalpan de Serra, in the state of Querétaro.

Figure 5 Map of the state of Querétaro

Source: INEGI. Geostatistical Framework, December 2018

The municipality of Peñamiller is geographically located in the north of the state of Queretaro, in the middle of the Queretaro semi-desert and has been defined as the gateway to the Sierra Gorda. It is located between the geographical coordinates 20° 57' and 21° 14' North latitude and 99° 42' and 100° 02' West longitude of the Greenwich meridian; with altitudes ranging from 1,280 to 3,000 meters above sea level. To the north it borders the municipalities of Xichú and Atarjea in the state of Guanajuato; to the south with the municipalities of Tolimán and Cadereyta de Montes; to the east with the municipalities of Pinal de Amoles and Cadereyta de Montes; and to the west with the municipality of Santa Catarina in the state of Guanajuato. The municipal seat is located at 21° 03' North latitude and 99° 49' West longitude of the Greenwich meridian, 127 km from the State Capital. It has an altitude of 1,330 meters above sea level. The municipality of Jalpan de Serra is located in the northern part of the state of Queretaro, between the geographic coordinates: 21° 06' and 21° 41' North latitude and 99° 05' and 99° 33' West longitude and has altitudes ranging from 420 m to 2900 m. It has a territorial extension of 1,121km2. It is part of the Pánuco and Santa María river basins.

The climate is warm and humid and it is part of the Sierra Gorda Biosphere Reserve (1997), it has two of the five Franciscan Missions declared Cultural Heritage of Humanity by UNESCO (2003) and as of 2010 it is part of the Magical Towns Program of the Federal Tourism Secretariat. In 2005 it had a population of 22,025 inhabitants (INEGI, 2020).

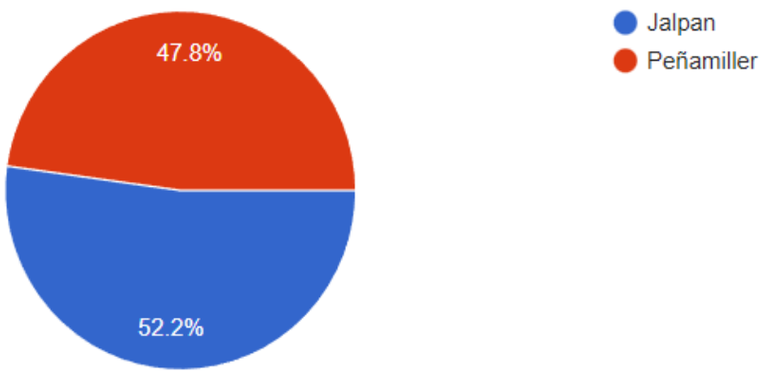
2.3 Results

Fieldwork was conducted in the municipalities of Jalpan de Serra and Peñamiller in the state of Querétaro, during a period of two weeks from March 21 to April 1, 2022, the surveys were answered by 115 participants, the confidence level is 95% with a margin of error of 5%, the tool was a face-to-face survey, the surveys were conducted by students of the Business Development career area Marketing, of the academic unit Jalpan de Serra, of the Technological University of San Juan del Río, coordinated by Dr. Guadalupe Morado Huerta, and the students of the academic unit Jalpan de Serra, of the Technological University of San Juan del Río, coordinated by Dr. Guadalupe Morado Huerta. Guadalupe Morado Huerta, on the other hand, in the municipality of Peñamiller, the surveys were applied by the students of the Business Development Marketing area of the Peñamiller campus of the Technological University of San Juan del Río, coordinated by Professor Francisco Javier Fabian Balderas. The pilot test lasted three days, in the execution of the pilot test, participated the students of the 2nd semester of the Marketing Research I course, of the Business Development career in the Marketing area of the Technological University of San Juan del Río. The results are shown below:

Section I "Identification Data".

Question 1. Municipality to which you belong.

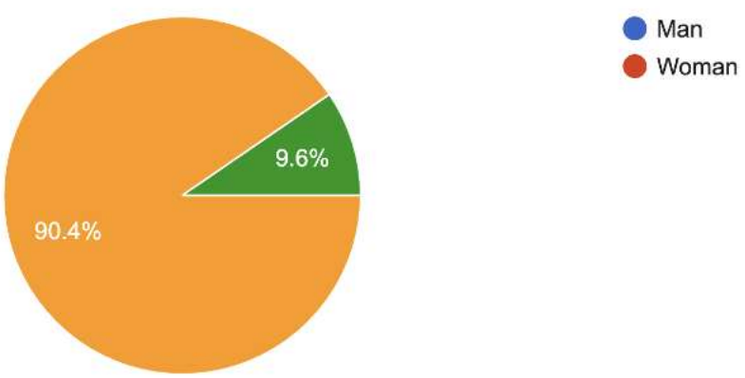
Graph 1 52.8% of respondents belong to the municipality of Peñamiller while 47.8% belong to the municipality of Jalpan de Serra



Source: Own elaboration, using google forms

Question 2 Sex of participants

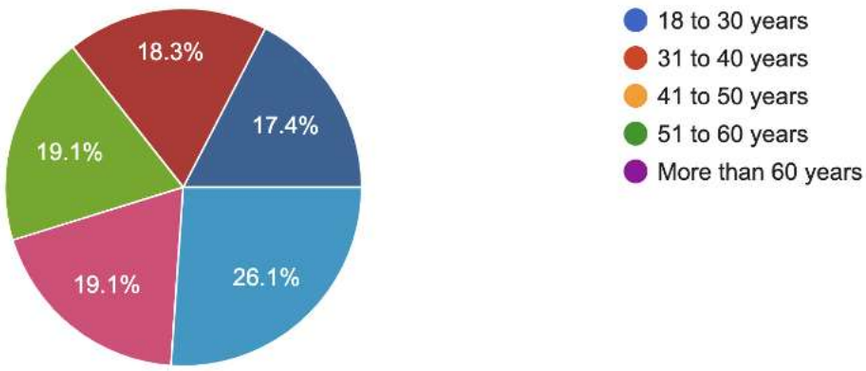
Graph 2 90.4% of respondents are female and 9.6% are male



Source: Own elaboration, using google forms

Question 3. Age range of participants

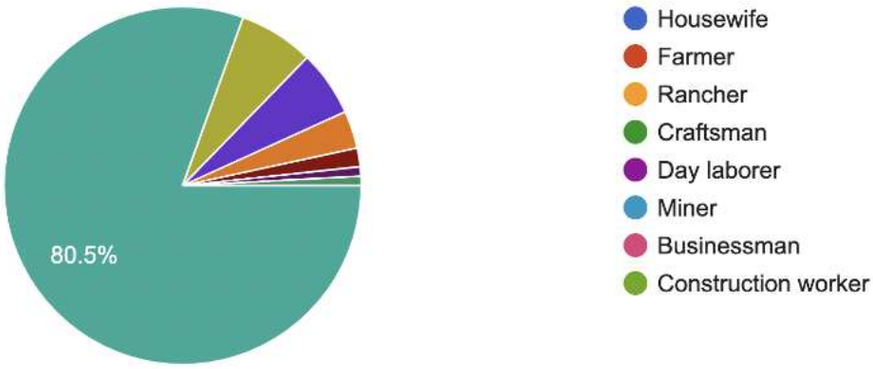
Graph 3 26.1% of the participants are between 31 and 40 years old, while 17.4% are over 60 years old



Source: Own Elaboration, using google forms

Question 4. Occupation of the participants

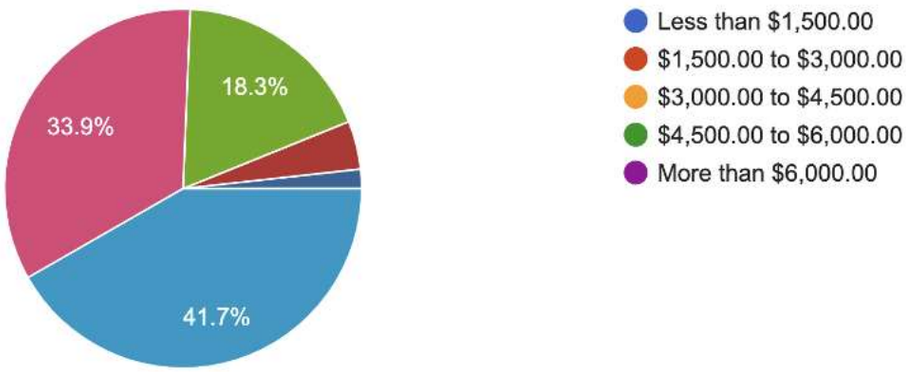
Graph 4 80.5% of the participants are householders, the remaining 19.5% of the respondents are farmers, cattle ranchers, artisans, day laborers, miners, merchants and bricklayers



Source: Own Elaboration, using google forms

Question 5. Range of family income

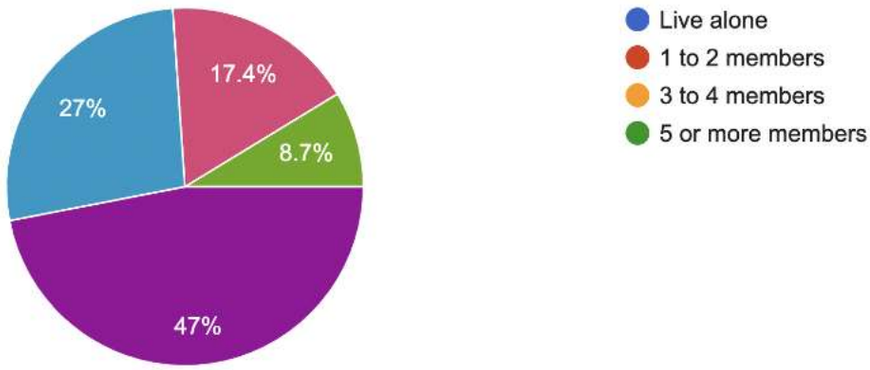
Graph 5 41.7% of the people surveyed have incomes of less than $1500.00 per month, 18.3% have incomes between $3000.00 and $4500.00



Source: Own Elaboration, using google forms

Question 6. Number of family members

Graph 6 47% of the respondents are part of a family composed of 3 to 4 people; it is important to note that 27% of the respondents stated that their family is composed of 5 or more members, while 8.7% of the respondents live alone

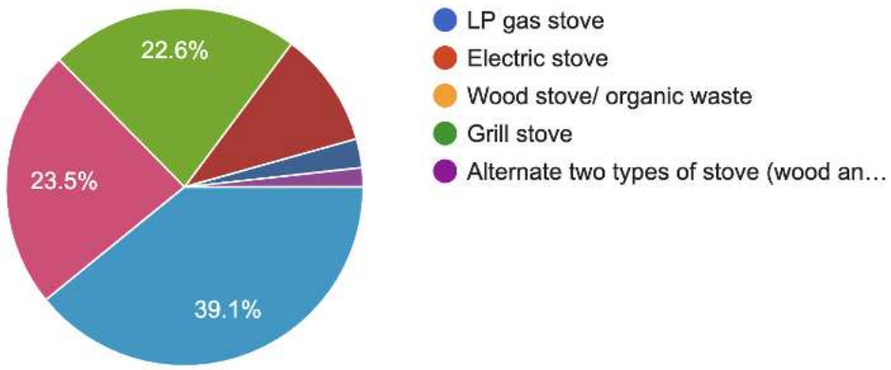


Source: Own Elaboration, Using Google Forms

Section II "Use of Stoves

Question 7. What type of stove do you use in your home?

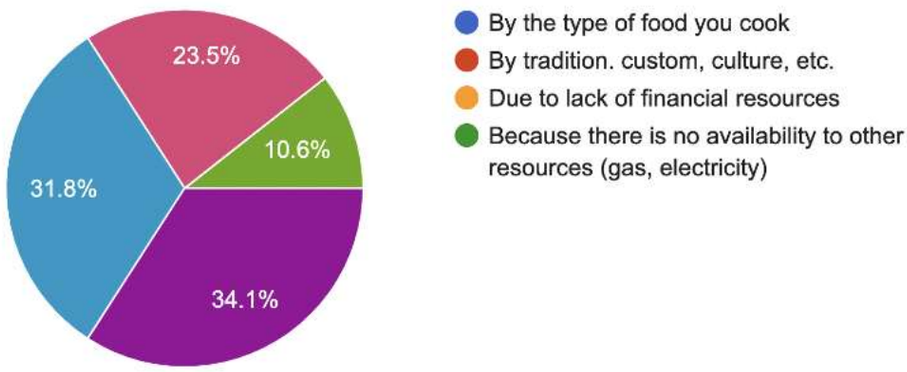
Graph 7 39.1% of the respondents answered that they use LP gas stove, while 10.4% alternate the use of L.P gas stove with wood stove, the use of grill stoves is below 10.4%



Source: Own elaboration, using google forms

Question 8. If you use firewood or any other organic waste for cooking, what is the reason you continue to use firewood for cooking?

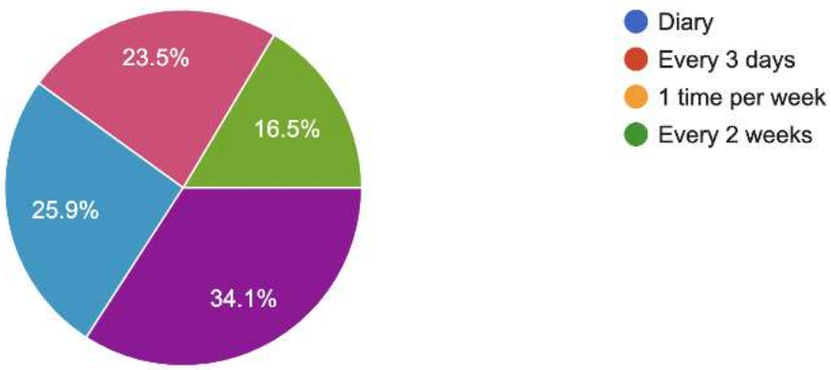
Graph 8 34.1% of the respondents commented that they mainly use firewood and organic waste because of the type of food they cook while 10.6% use these resources because other resources such as gas and electricity are not available.



Source: Own elaboration, using google forms

Question 9. If you use firewood for cooking, how often do you cut down or purchase organic waste?

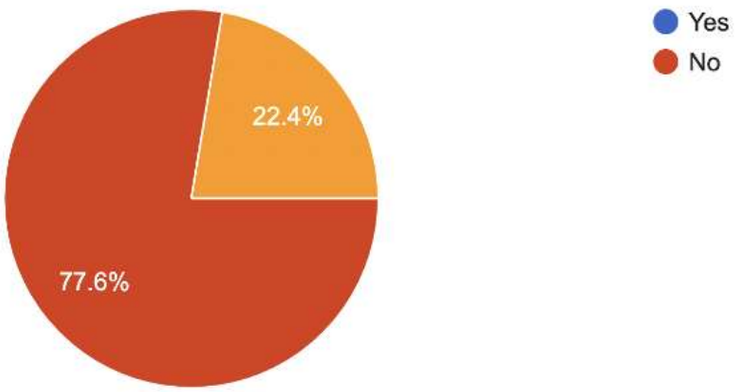
Graph 9 The frequency with which families cut trees or acquire organic waste is every 2 weeks represented by 34.12 % while with 16.5% daily they have the need to use such resources



Source: Own elaboration, using google forms

Question 10. In case of cooking with firewood, have you had any health problems?

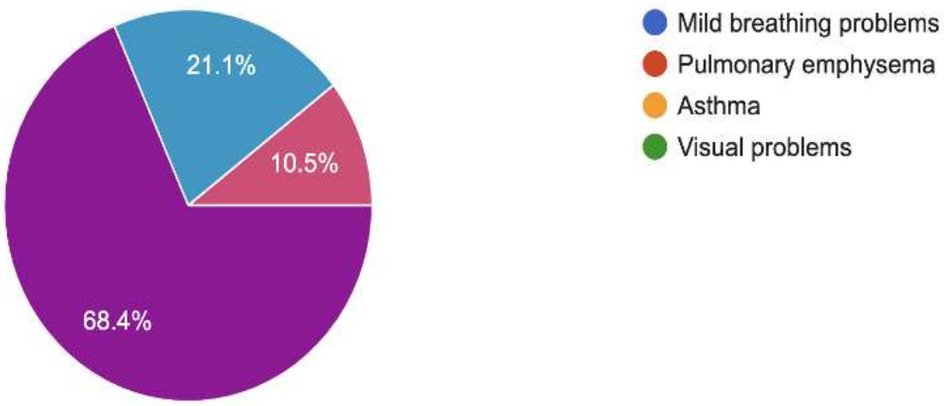
Graph 10 77.6% of the people who cook with firewood have presented health problems, while 22.4% have not fallen ill due to this cause



Source: Own elaboration, using google forms

Question 11. In the case of cooking with firewood and having presented health problems, which illness was manifested?

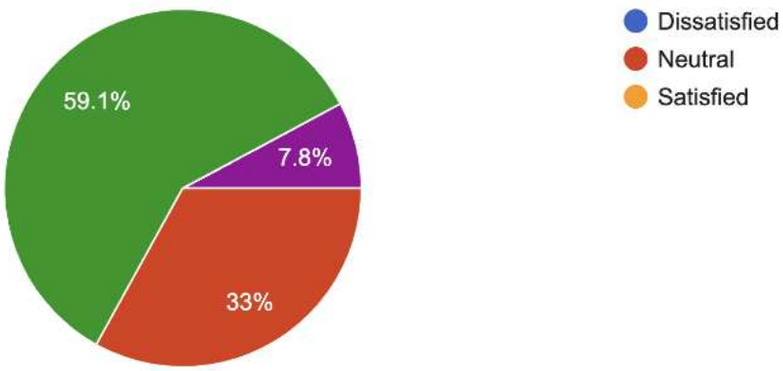
Graph 11 With 68.4%, mild respiratory problems are the main ailment reported by people who cook with firewood, while asthma was the least common cause with 10.5%



Source: Own elaboration, using google forms

Question 12. Regarding the level of satisfaction, how satisfied do you feel with your current stove?

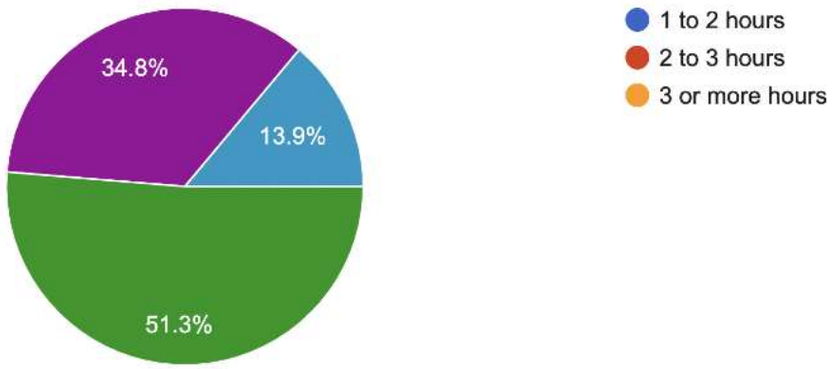
Graph 12 59.1% of people are currently satisfied with the type of stove they have in their homes and only 7.8% are dissatisfied



. *Source: Own Elaboration, using google forms*

Question 13. On average, how much time do you spend cooking per day?

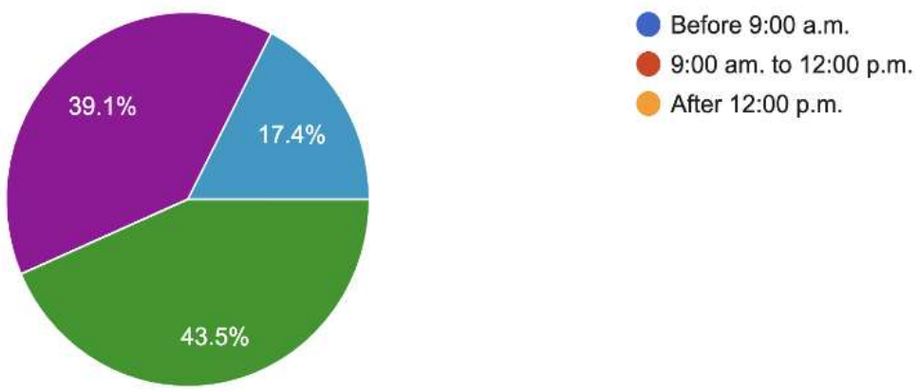
Graph 13 51.3% of the people invest 1 to 2 hours a day to cook their food and only 13.9% spend 3 or more hours to cook



Source: Own Elaboration, using google forms.

Question 14. At what times of the day do you usually cook?

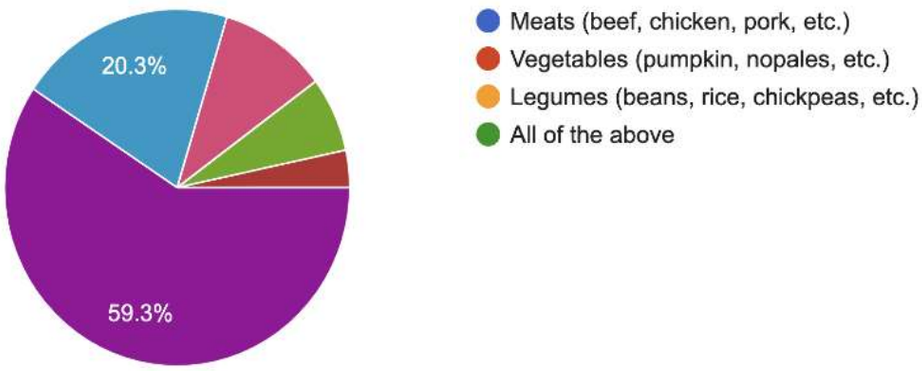
Graph 14 43.5% of the people affirm that they prefer to cook from 9:00 a.m. to 12:00 p.m. and only 17.4% do it after 12:00 p.m



Source: Own elaboration, using google forms

Question 15. What type of food do you usually prepare most frequently?

Graph 15 59.3% of people answered that the foods they prepare most frequently are meats, vegetables and legumes.

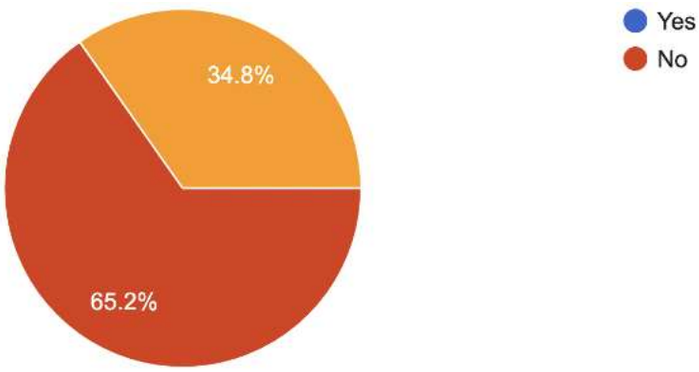


S
ource: Own elaboration, using google forms

Section III "Solar Cookers".

Question 16. Have you heard about renewable energies?

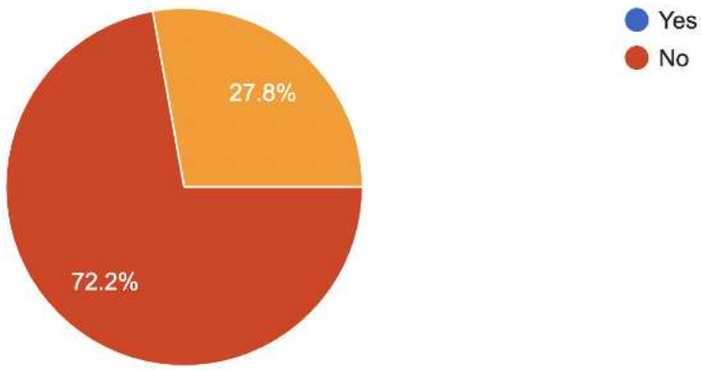
Graph 16 65.2% of the people affirmed that they have heard of renewable energies while 34.8% have not heard of renewable energies.



Source: Own elaboration, using google forms

Question 17. Do you know or have you heard about solar stoves and their benefits?

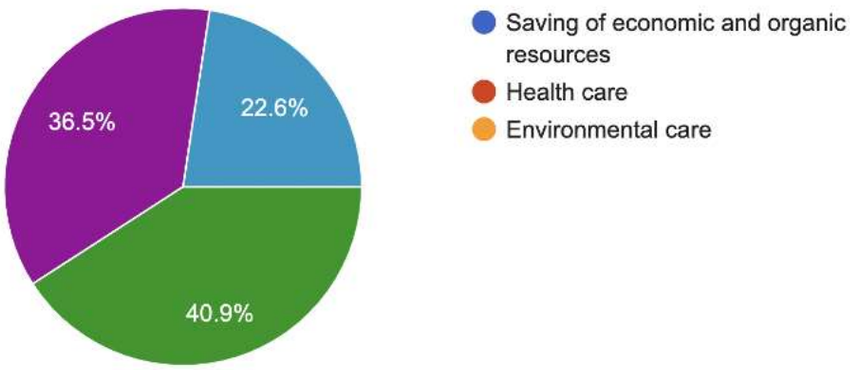
Graph 17 72.2% of the people have heard of solar cookstoves and their benefits, while 27.8% do not know about solar cookstoves or their benefits



Source: Own elaboration, using google forms

Question 18. Of the following benefits provided by the use of solar cookstoves, which do you find most interesting?

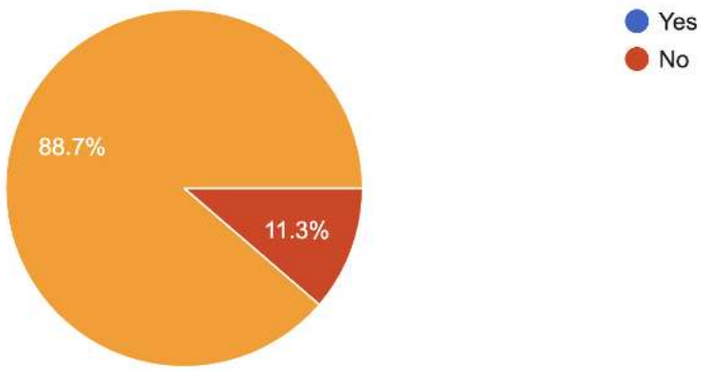
Graph 18 40.9% answered that the main benefit of solar stoves is health care, while 22.6% answered that they are beneficial for the environment



Source: Own elaboration, using google forms

Question 19 Would you like to cook on a solar stove?

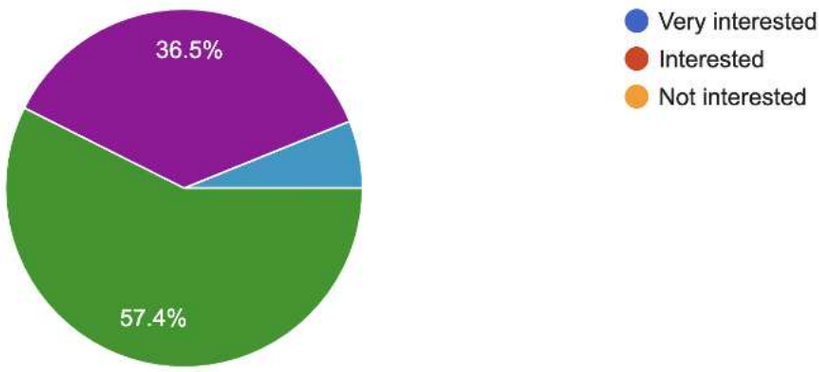
Graph 19 88.7% of the people stated that they would like to cook on a solar cookstove and only 11.3% stated that they would not like to cook on solar cookstoves



Source: Own elaboration, using google forms

Question 20. How interested are you in learning how to use a solar cookstove?

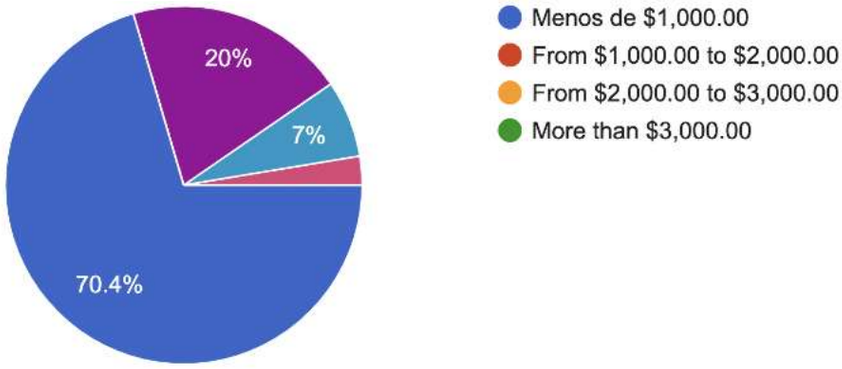
Question 20 People's interest in learning how to use solar cookstoves represents 57.4% and 6.1% answered that they are not interested at all in learning how to use a solar cookstove.



Source: Own elaboration, using google forms

Question 21. If you had the opportunity to buy a solar cookstove, how much would you be willing to pay?

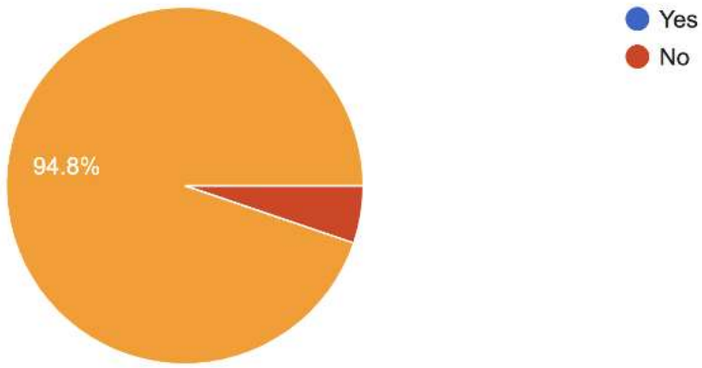
Graph 21 With a majority of 70.4% of people are willing to pay less than $1000 for a solar cookstove and only 2.6% of people would be willing to pay more than $3000 for a solar cookstove.



Source: Own elaboration, using google forms

Question 22. If a government institution gave you a solar cookstove, would you use it?

Graph 22 94.8% of the people are willing to use a solar stove if it were a gift from a government institution and 5.2% would not use the solar stove



Source: Own elaboration, using google forms

2.4 Results and discussion

For section 1 of the instrument, identification data, the following is a summary of the highlights.

A sample of 115 surveys were conducted among the inhabitants of the municipalities of Jalpan de Serra and Peñamiller in the Sierra Gorda of the State of Querétaro; 47.8% of the total number of surveys carried out corresponded to the inhabitants of Peñamiller and 52.2% of the total number of surveys carried out to the inhabitants of Jalpan de Serra. Of those surveyed, 90.4% were women and 9.6% were men. 26.1% of the participants are between 31 and 40 years of age, while 17.4% are over 60 years old. 80.5% of the participants are householders, the remaining 19.5% of the respondents are farmers, cattle ranchers, artisans, day laborers, miners, merchants and bricklayers. 41.7% of the people surveyed are women and 9.6% are men. Of those surveyed, 41.7% have incomes of less than $1,500.00 pesos per month, 18.3% have incomes between $3,000.00 pesos and $4,500.00 pesos per month. Forty-seven percent of those surveyed are part of a family made up of 3 to 4 people; it is important to note that 27% said that their family has 5 or more members, while 8.7% of those surveyed live alone.

For section 2 of the instrument, use of cookstoves, the following is a summary of the highlights

39.1% of the respondents answered that they use LP gas stove, while 10.4% alternate the use of L.P gas stove with wood stove, the use of grill stoves is below 10.4%. 34.1% of the respondents comment that they mainly use firewood and organic waste because of the type of food they cook while 10.6% use these resources because other resources such as gas and electricity are not available. The frequency with which families cut down or acquire organic waste is every 2 weeks represented by 34.12% while 16.5% use these resources daily. With 77.6% of the people who cook with firewood have presented health problems while 22.4% have not gotten sick because of this cause.

With 68.4%, mild respiratory problems are the main ailment reported by people who cook with firewood, while asthma was the least common cause with 10.5%. 59.1% of the people are currently satisfied with the type of stoves they have in their homes and only 7.8% are dissatisfied. 51.3% of the people spend 1 to 2 hours a day cooking their food and only 13.9% spend 3 or more hours cooking. 43.5% of people affirm that they prefer to cook from 9:00 a.m. to 12:00 p.m. and only 17.4% do so after 12:00 p.m. 59.3% of the people responded that the foods they prepare most frequently are meats, vegetables and legumes.

For section 3 of the instrument, solar cookstoves, the following is a summary of the highlights

65.2% of the people affirmed that they have heard of renewable energies while 34.8% have not heard of renewable energies. 72.2% of the people have heard of solar cookstoves and their benefits, while 27.8% have not heard of solar cookstoves or their benefits. 40.9% answered that the main benefit of solar cookstoves is health care, while 22.6% answered that they are beneficial for the environment. 88.7% of the people stated that they would like to cook on a solar cookstove and only 11.3% stated that they would not like to cook on solar cookstoves. People's interest in learning how to use solar cookstoves represents 57.4% and 6.1% answered that they are not interested in learning how to use a solar cookstove at all. With a majority of 70.4% of the people are willing to pay less than $1000.00 for a solar cookstove and only 2.6% of the people would be willing to pay more than $3000.00 for a solar cookstove. 94.8% of the people are willing to use a solar cookstove if it were a gift from a government institution and 5.2% would not use the solar cookstove.

2.5 Conclusions

There is an important market niche in the area of Peñamiller and Jalpan de Serra in the state of Querétaro, where the people surveyed would be willing to try and buy solar stoves, an important niche are households with less than 4 inhabitants for a specific product that can cook meats (beef, chicken, pork, etc.), vegetables (pumpkins, nopales, etc.), legumes (beans, rice, chickpeas, etc.), representing the possibility of satisfying 47.8% of the total 17.8% of the total.), vegetables (pumpkins, nopales, etc.), legumes (beans, rice, chickpeas, etc.) representing the possibility of satisfying approximately 47.8% of the total 17,040 inhabitants, which represent more than 4,260 households in Peñamiller, and could satisfy 52.2% of approximately 22,050 inhabitants, which represent more than 5,512.5 households in Jalpan de Serra. A market research allows to know the purchase intentions of consumers, or provides feedback about the growth of the market to which it belongs.

Through research, valuable information can be discovered, which can be used to estimate the prices of a product or service and find a point of equilibrium that benefits the creators and consumers. The use of solar stoves is feasible in these rural areas because families can see the stoves as an alternative that benefits their health, their economy, the environment in general, and most importantly, solar stoves can be alternated with the use of their traditional stoves.

The people surveyed are willing to pay less than $1,000.00 pesos for a solar cookstove and only 2.6% of the people surveyed would be willing to pay more than $3,000.00 pesos for a solar cookstove. Therefore, the challenge is to develop a very low-cost product that can be easy to use. Product presentation variables such as weight, volume or appearance were not considered at this stage of the research. The scope of this study is exploratory and market tests on physical prototypes are required, which are planned in the near future.

2.6 Acknowledgements

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Chapter 10 A study of the Apollonian Gasket

Capítulo 10 Un estudio del Tamiz de Apolonio

CANO-CORDERO, Laura Angélica†*& DOMÍNGUEZ-SOTO, Patricia

Benemérita Universidad Autónoma de Puebla

ID 1st Author: *Laura, Cano-Cordero* / **ORC ID**: 0000-0002-2849-7616, **CVU CONACYT ID**: 218811

ID 1st Co-author: *Patricia, Domínguez-Soto* / **ORC ID**: 000-0003-1297-9300, **CVU CONACYT ID**: 16010

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L. Cano & P. Domínguez.

*lcano@fcfm.buap.mx

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Abstract

The present expository work sought to familiarize the reader with a well-known geometrical object obtained as the recursive application of the solution of the Apollonius' problem known as the Apollonian gasket. This object appears in Geometry, but also in other branches of mathematics such as Continuum Topology and Kleinian Groups. The work contains some properties of this object, the statement and partial solution of the famous Apollonius' problem

Apollonius' Problem, Apollonian Gasket, Continuum

1. Introduction

In the third century B.C., Apollonius of Perga wrote two books on Contacts. Since no copy of Apollonius' Contacts has survived the ages, Pappus of Alexandria deserves credit for eternally linking Apollonius' name with the tangents problem.

The tangency problem is well known, however, and unlike many of the classical Greek geometric construction problems, this one has a solution: given three geometric objects, each of which may be either a point, a line, or a circle, under what conditions is possible to construct a circle which passes through each of the points and touches the given lines and circles.

Since the conditions of the problem allow for any combination of circles, lines, and points, this rises to ten possible cases. As Coxeter (1968) mentions Euclid's Elements already cover the most straightforward (three points and three lines). Apollonius treated these two cases together with these other six (two points and a line; two lines and a point; two points and a circle; two circles and a point, two circles and a line; a point, a line, and a circle) in Book I of the Tangences, and the two remaining cases (two straight lines and a circumference, and three circumferences) in Book II of the Tangences. Although unfortunately, these books were lost through Pappus of Alexandria (4th century A.D.). It is known that Apollonius solved the first nine, and today it is believed that Isaac Newton was the first mathematician who solved the problem of finding the circle tangent to three other circles through the rule and the compass.

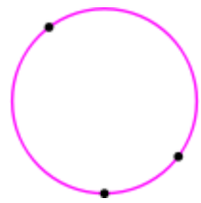
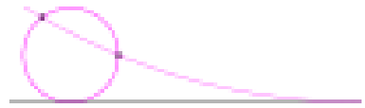
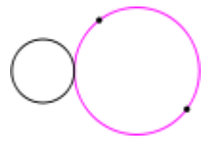
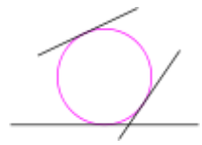
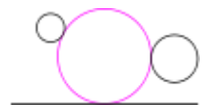
A particular case of Apollonius' problem is known today as the three coins problem, or kissing coins problem. In this variant, the three circles of possibly different radii are taken to be mutually tangent. There are two solutions to this particular case of Apollonius' problem: a small circle where all three given circles are externally tangent and a large circle where the three given circles are internally tangent. In 1643 Renè Descartes sent a letter to Princess Elisabeth of Bohemia in which he provided a solution to this particular case of Apollonius' problem, and his solution became known as Descartes' circle theorem.

In the present expository work, we study the solution to Apollonius' problem with different Geometry approaches such as the Euclidean, Analytic, Conformal and Geometry of the invariants. Section 1 deals with the solution to Apollonius' problem.

In section 2, we study the famous Descartes' four-circle theorem. In section 3, we explore the existence of the apollonian Gasket through Conformal Geometry and finally, in Section 4, we study the Apollonian Gasket through the consistent geometry approach.

2. Solution to Apollonius' Problem

Apollonius' problem requires to construct one or more circles tangent to three given objects in a plane, which may be either circles, points, or lines. This gives rise to ten types of Apollonius' problem, one corresponding to each combination of circles, lines, and points, which may be labeled with three letters, either **C**, **L**, or **P**, to denote whether the given elements are a circle, line, or point, respectively (see Table 1). As an example, the type of Apollonius problem with a given circle, line, and point is denoted as **CLP**.

Table 1: Ten Types of Apollonius' Problem				
Case	**Code**	**Given Elements**	**Solution**	**Example (solution in pink; given objects in black)**
1	**PPP**	three points	The problem is reduced to constructing a circle that contains them	
2	**LPP**	one line and two points	The problem is reduced to constructing a circle tangent to the line and containing the two points	
3	**LLP**	two lines and a point	The problem is reduced to constructing a circle that is tangent to the two lines and contains the point	
4	**CPP**	one circle and two points	The problem is reduced to constructing a circle that contains the two points and is tangent to the given circle	
5	**LLL**	three lines	The problem is reduced to constructing a circle that is tangent to the three lines	
6	**CLP**	one circle, one line, and a point	The problem is reduced to constructing a circle that passes through the point and is tangent to the line and the given circle	
7	**CCP**	two circles and a point	The problem is reduced to constructing a circle that contains the point and is tangent to the two given circles	
8	**CLL**	one circle and two lines	The problem is reduced to constructing a circle that is tangent to the lines and to the given circle	
9	**CCL**	two circles and a line	The problem is reduced to constructing a circle that is tangent to the line and to the two given circles	
10	**CCC**	three circles (the classic problem)	Construct a circle that is tangent to three given circles	

For the solution of the problem we need to consider the configuration of the given objects, i.e., the position in which the objects are situated in the plane lo which arises to the number of solutions of the problem for each case, which makes this problem more interesting. In our case we will give the constructions for two cases: Cases 8 and 10 use rule and compass.

Case 8: Given two lines and a circle, we must construct a circle that is tangent to the lines and to the given circle.

Construction (step by step, see Figure 1):

Configuration 1: When the lines are parallel, and the circumference is tangent to the two lines.

Configuration 2: When the circumference is between two straight lines L and M

1. Determine the radius of the given circle O.

2. Draw parallels to each side of the line L, at a distance equal to the radius of the circumference.

3. Draw the bisector of the angle formed by the lines L and M.

4. Find the symmetrical point of the center O with respect to the bisector. (Point O').

5. Draw the line OO'.

6. Mark the intersection between the line OO' and the parallel line L1. (point M).

7. From M, draw tangents to the circle of diameter OO'. Mark the points of tangency D and E.

8. Draw the circle with center at M and radius MD.

9. Find the intersections of the parallel L1 with the circle CM with center M.

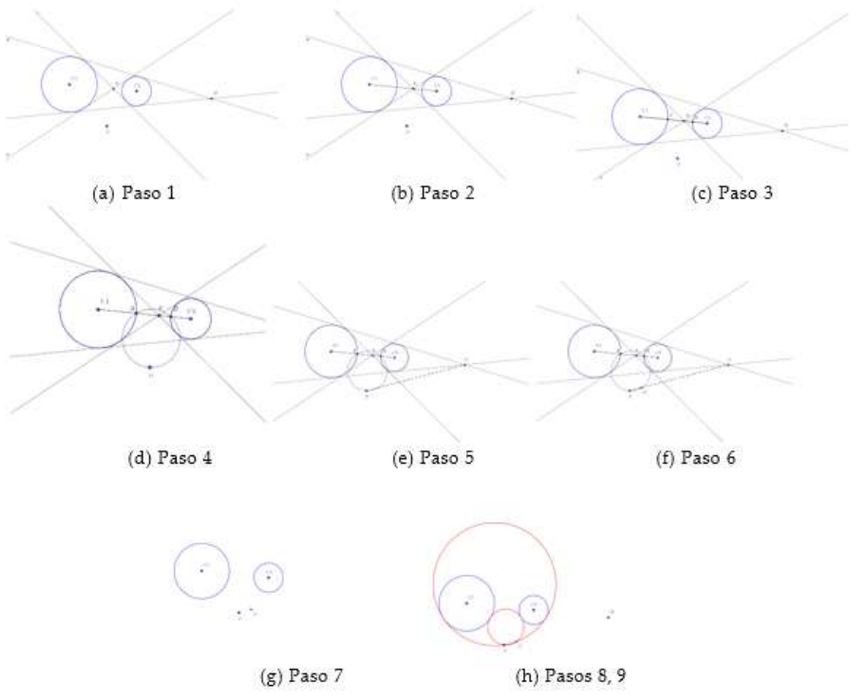
10. Draw the perpendiculars to the parallel L1 through points A and B.

11. Find the intersections of the perpendiculars found with the bisector.

12. The points P and Q are the centers of the circles sought. Draw circles with centers at P and Q tangent to lines L and M.

13. If these steps are followed for the parallel line L2, two other circles are obtained.

Figure 1 Case 8 Configuración 2



Case 10: Given three circles, we must construct a circle that is tangent to the three given circles.

Construction with steps (see Figure2):

1. Draw two auxiliary circles with center at O2 and O3 and radius r2 r1 and r3 r2 respectively. Aux1, Aux2.

2. Unite the centers O2 and O3 and find their intersection with the circles Aux1, Aux2. (R, S).

3. Draw a segment perpendicular to center O2 and center O3.

4. Find the intersections of the segments with their respective auxiliary circles.

5. Join the intersections, find the point of intersection (M) this will be the center of inversion.

6. Join point M with center O1 (MO1).

7. Join center O1 with points R and S.

8. Draw the circumference that passes through R, S, O1 (O4).

9. Find the point of intersection of O4 with the line MO1 (O1′).

10. Draw a line that passes through the points of intersection of the circumference O4 and the circumference Aux2.

11. Find the intersection of the previous line with line MO1.

12. Draw the PO2 segment.

13. Find the midpoint of the segment PO2 (h).

14. Draw an arc of circumference with center at h and radius hO2.

15. Find the intersection points of the arc with the circumference aux2 (T 1, T 2).

16. We draw the perpendicular bisector of the segment O1O1′.

17. Join the points T 1, T 2 with the point O2 and find the points of intersection with the perpendicular bisector of O1O1′ (O5, O6).

18. Join the points O5, O6 with the initially given centers O1, O2, O3 and find the points of intersection T 3, T 4, T 5, T 6, T 7, T 8 (points of tangency).

19. Draw the circles with center at O5, O6 and radius towards one of their tangency points.

20. Those circles are the solutions to the problem.

Figure 2 Steps for Case 10

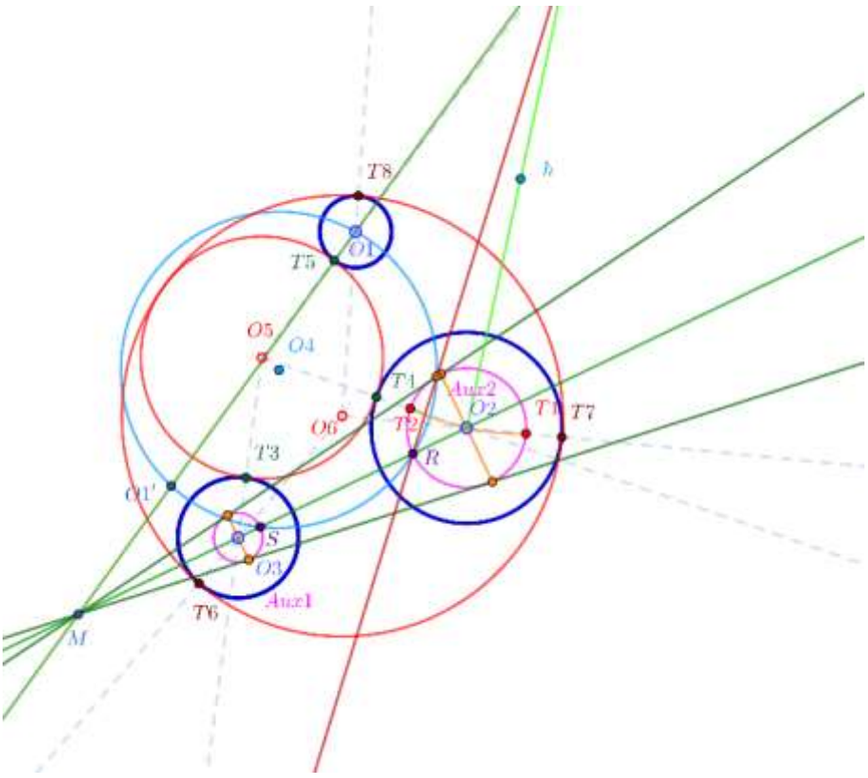
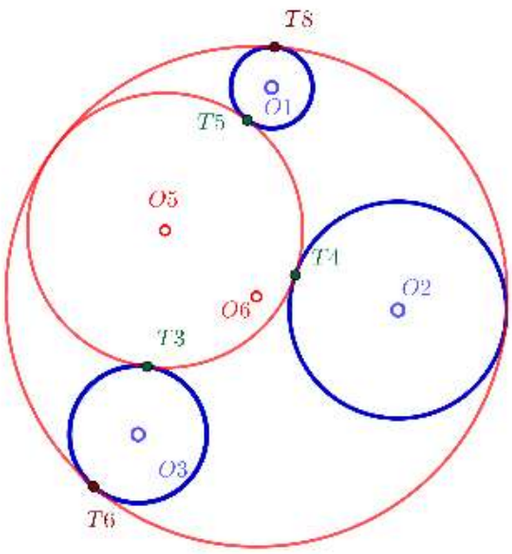


Figure 3 Solution for a configuration for Case 10



3. Descartes' circle theorem

In 1643, Descartes wrote to Princess Elizabeth of Bohemia (1618-1680) stating formula he had established on the radii of the tangent circles, and for which she independently provided a proof. The radii are related by the following formula.

Theorem 2.1 (Descartes-Princess Elizabeth). Assume that the radii of the original circles are $a, b, c, >$ 0 and the fourth mutually tangent circle has radius d > 0, then

$$2\left(\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}+\frac{1}{d^2}\right)=\left(\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}\right)^2.$$

Proof. Suppose four circles lying in a plane, such that any two of them touch each other externally (meaning that in each pair of touching circles each center is external to the other circle of the pair). If the centres of a pair are P, Q, then the point of tangency lies on the line PQ, and the length PQ is equal to the sum of the radii. So, if P, Q, R, S are the centers of the four circles, and a, b, c, d are their radii, we have the six following equations:

$$\boldsymbol{PQ = a + b} \quad \boldsymbol{QR = b + c} \quad \boldsymbol{RP = c + a}$$

$$\boldsymbol{PS = a + d} \quad \boldsymbol{QS = b + d} \quad \boldsymbol{RS = c + d}$$

Now, suppose that S is inside the triangle PQR and let

$\theta = angle\ PSQ \quad \phi = angle\ QSR \quad \psi = angle\ RSP,$

then

$\theta + \phi + \psi = 2\pi$

Applaying to the triangle PSQ the cosine rule we have

$(a+b)^2 = (a+d)^2 + (b+d)^2 - 2(a+d)(b+d)\,cos(\theta)$

Therefore

$cos(theta) = \frac{2d^2+2ad+2bd-2ab}{2(a+b)(b+d)} = \frac{AB-2ab}{AB} = 1 - \frac{2ab}{AB}$

where we have written A for a + d and B for b + d. Hence

$s = sin(\theta/2) = \sqrt{\frac{1-cos(\theta)}{2}} = \sqrt{\frac{ab}{AB}} = \sqrt{\alpha\beta}$

where we have written α for a/A and β for b/B. As before we obtain:

$t = sin(\phi/2) = \sqrt{\frac{bc}{BC}} = \sqrt{\beta\gamma}$

$u = sin(\psi/2) = \sqrt{\frac{ca}{CA}} = \sqrt{\gamma\alpha}$

where we have also set C = c + d and γ = c/C.

Now, since the angles θ/2, φ/2 and ψ/2 add up to π , this implies that

$s = sin(\theta/2) = sin(\pi - \phi/2 - \psi/2) = sin\left(\frac{\phi+\psi}{2}\right) = t\sqrt{1-u^2} + u\sqrt{1-t^2}$

This relates *s*, *t* and *u*, but the equation is difficult to follow. It can be improved by getting rid of the square roots. Thus, squaring both sides of the equation and simplifying we obtain that

$s^4 + t^4 + u^4 - 2(s^2t^2 + t^2u^2) + 4s^2t^2u^2 = 0$

This is much better, being nicely symmetrical between s, t and u. We can get that the equation becomes

$2(s^4 + t^4 + u^4) - (s^2 + t^2 + u^2)^2 + 4s^2t^2u^2 = 0$

Substituting the expressions for *s*, *t* and u derived from the cosine rule, we obtain

$2(\alpha^2\beta^2 + \beta^2\gamma^2 + \gamma^2\alpha^2) - (\alpha\beta + \beta\gamma + \gamma\alpha)^2 + 4\alpha^2\beta^2\gamma^2 = 0$

Dividing through by $\alpha^2\beta^2\gamma^2$,

$$\left(\frac{1}{\gamma}+\frac{1}{\alpha}+\frac{1}{\beta}\right)^2 = 2\left(\frac{1}{\gamma^2}+\frac{1}{\alpha^2}+\frac{1}{\beta^2}\right)+4.$$

Now

$$\frac{1}{\alpha}=\frac{A}{a}=\frac{a+d}{a}=1+\frac{d}{a}$$
$$\frac{1}{\beta}=1+\frac{d}{b}$$
$$\frac{1}{\gamma}=1+\frac{d}{c};$$

and so, writing σ for *d/a + d/b + d/c*, τ for *(d/a)² + (d/b)² + (d/c)²*, the equation becomes

$$(3+\sigma)^2 = 2(3+2\sigma+\tau)+4.$$

Therefore,

$$2\tau = -1+2\sigma+\sigma^2 = (\sigma+1)^2-2.$$

And

$$2(\tau+1) = (\sigma+1)^2$$

Thus,

$$2\left(1+\frac{d^2}{a^2}+\frac{d^2}{b^2}+\frac{d^2}{c^2}\right) = \left(1+\frac{d}{a}+\frac{d}{b}+\frac{d}{c}\right)^2.$$

Dividing through by d^2, we get

$$2\left(\frac{1}{d^2}+\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}\right) = \left(\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}\right)^2.$$

and we are done.

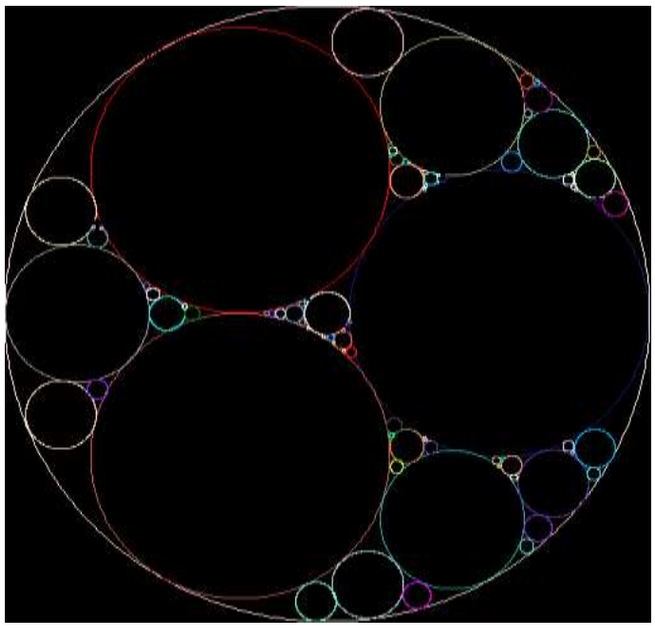
An immediate consequence of Descartes' circle theorem is the following: given the curvature of three mutually tangent circles, C1, C2 and C3 we can solve for the curvatures of the two circles that are mutually tangent to the three original circles. From this new collection of four mutually tangent circles, we can arbitrarily choose three of them and solve for the curvature of two new circles that are mutually tangent to this selection of three circles, these are called Apollonian circles. Adding the two Apollonian circles C4 and C5 to the original three, now we have five circles.

Take one of the two Apollonian circles, say C4. It is tangent to C1 and C2, so the triplet of circles C4, C1 and C2 has its own two Apollonian circles. We already know one of these, it is C3, but the other one is a new circle, say C6.

Similarly, we can construct another new circle C7 that is tangent to C4, C2 and C3, and another circle C8 from C4, C3 and C1. This gives us 3 new circles. We can build another three new circles from $C_5,$ giving six new circles in total. Together with the circles C1 to C5, it gives a total of 11 circles.

Continuing the construction stage by stage in this way, we can add 23n new circles at stage n. The sizes of the new circles are determined by Descartes' theorem, the limit set is called Apollonian Gasket or Apollonian packing as Leibniz named it, who was the first to carry out the construction, see Figure 3.

Figure 3 Apollonian Gasket



4. Apollonian Gasket and Möbius transformations

In this section we will construct the Apollonian gasket using Conformal Geometry through Möbius transformations.

A Möbius transformation of the complex plane is a rational function of the form

$$T(z) = \frac{az+b}{cz+d}.$$

With *a, b, c, d* complex numbers. Non-identity Möbius transformations are in generall classified into four types; parabolic, elliptic, hyperbolic and loxodromic, with the hyperbolic being a subclass of the loxodromic. The classification has both algebraic and geometric significance. The four types can be distinguished by looking at the trace, denoted by tr T= $a+ d$. In Table 2 there is a resume of the the general classification of the Möbius transformations.

Table 2 Classification of Möbius transformations

Transformation	Trace squared	Multipliers	Class representative	
Circular	$\sigma = 0$	$k = -1$	$\begin{bmatrix} i & 0 \\ 0 & -i \end{bmatrix}$	$z \mapsto -z$
Elliptic	$0 \leq \sigma < 4$	$\lvert k \rvert = 1$	$\begin{bmatrix} e^{i\theta/2} & 0 \\ 0 & e^{-i\theta/2} \end{bmatrix}$	$z \mapsto e^{i\theta}$
Parabolic	$\sigma = 4$	$k = 1$	$\begin{bmatrix} 1 & a \\ 0 & 1 \end{bmatrix}$	$z \mapsto z + a$
Hyperbolic	$4 < \sigma < \infty$	$k \in R^+$ $k = e^{\pm\theta} \neq 1$	$\begin{bmatrix} e^{\theta/2} & 0 \\ 0 & e^{\theta/2} \end{bmatrix}$	$z \mapsto e^{\theta} z$
Loxodromic	$\sigma \in C \setminus [0,4]$	$\lvert k \rvert \neq 1$ $k = \lambda^2, \lambda^{-2}$	$\begin{bmatrix} \lambda & 0 \\ 0 & \lambda^{-1} \end{bmatrix}$	$z \mapsto kz$

Theorem 4.1. There exists a unique Apollonian Gasket.

Proof. Consider three circles with equal radii r and centers at cubic roots of unity: 1, ω,ω^2. Label the circles X_1, X_2, X_3 in counterclockwise order starting with the one whose center is at 1. We seek a fourth circle X_0 and three Möbius maps T_1, T_2, T_3 such that:

$$T_i(X_j) = X_j, j \neq i, i, j = 1,2,3$$

$$T_i(X_i) = X_0$$

$T_2 = RT_1R^{-1}$

$T_3 = R^{-1}TR,$

where R is a rotation of H around the origin. It follows that X_0 will have center at 0 because it is invariant under R.

One can construct T_1 as a composition: $T = SJ,$ where S is the reflection through the axis of symmetry of $X_2$and $X_3$and J is the inversion with respect to a circle orthogonal to X_2 and X_3. Moreover,

$T_1(z) = \frac{I-1}{2}\frac{2z-I}{z+I}.$

The fixed points f and $f^*$of $T_1$are the points of intersection of the inversion circle J with the axis of symmetry of X_2 and X_3. Moreover, $f = -\frac{1}{2} + i\beta$ where $\beta = \sqrt{\frac{3}{4} - r^2} = \frac{1}{2}\frac{\sin\alpha}{\sqrt{\cos^2\alpha - 2/3}}.$

The angle α is defined by $\cos\alpha = \frac{1}{2}\sqrt{\frac{9-8r^2}{3(1-r^2)}}.$

The radius ρ_0 of X_0 is given by $\rho_0 = \frac{2r^2-3+\sqrt{9-8r^2}}{2r}.$

Consider $X_\infty := T_1^{-1}(X_1)$ and since T_1 is Möbius transformation and X_1 is invariant under T_1, it follows that X_∞ is a circle. We can reduce that its radius is given by $\rho_\infty = \frac{\sqrt{\cos 2\alpha + 1\sqrt{3\cos 2\alpha - 1}} + \sqrt{3}\cos 2\alpha}{\sqrt{2(2\cos 2\alpha - 1)(3\cos 2\alpha - 1)}}$ and center 0. Therefore, $X_\infty = T_i^{-1}(X_i), i = 1,2,3$ and $T_1 = \begin{pmatrix} \frac{2(I-1)}{\sqrt{6I(I-1)}} & \frac{-I(I-1)}{\sqrt{6I(I-1)}} \\ \frac{2}{\sqrt{6I(I-1)}} & \frac{2I}{\sqrt{6I(I-1)}} \end{pmatrix}$ which is:

(i) parabolic if and only if $r^2 = \frac{3}{4}$;
(ii) elliptic if $r^2 \geq \frac{9}{8}$ o $r^2 < \frac{3}{4}$.

For further details of this affirnation the reader can consult Lagarias J., Mallows C. & Wilks A. (2002). Thus, when T_1 is a parabolic transformation, we obtain that X_0 and X_∞ are the desired circles. Furthermore, if we consider any other triad of circles, it is possible to construct a Möbius transformation that sends the three given circles into the given circles. Therefore, the Apollonius Gasket is unique.

5. Apollonian Gasket and Kleinian groups

To establish how the Apollonian Gasket is related to Kleinian Groups first we remind some basic notions of group theory.

Recall that SL(2, C) is a topological group with the Euclidean metric topology. Hence, we obtain that PSL(2, C) = SL(2, C)\{±I}, where {±I} is a normal subgroup of SL(2, C), is a topological group with the quotient topology.

Suppose Γ is a group acting on a set X and let x ∈ X. We define the following:

(i) The stabilizer of x in Γ is the subgroup Γx = {γ ∈ Γ: γx = x}.
(ii) The Γ-orbit through x is the subset Γx = {γx: γ ∈ Γ} of X.
(iii) The orbit space of Γ on X is the set of all Γ-orbits X/Γ = {Γx: x ∈ X}.
(iv) A subset U of X is called Γ-invariant if γU = U for all γ ∈ Γ.

5.1 Discrete subgroups

A topological group is discrete if and only if all its elements are open.

There are other useful ways to determine discreteness. For example, if the identity element {1} is open in Γ then γ1 = γ is open for all γ ∈ Γ and so Γ is discrete.

A Kleinian group is a discrete subgroup of PSL (2, C).

The set of accumulation points of Γp in $\mathbb{C} \cup \infty$ is called the *limit set* of Γ, and usually denoted Λ(Γ). The complement $\Omega(\Gamma) := (\mathbb{C} \cup \infty) \setminus \big(\Lambda(\Gamma)\big)$ is called the domain of discontinuity or the ordinary set or the regular set.

Theorem 4.1. Let Γ be a Kleinian group. Then

(i) The limit set Λ(Γ) is the smallest non-empty, closed and Γ-invariant set in $\mathbb{C} \cup \infty$.
(ii) The ordinary set Ω(Γ) is open, Γ-invariant in $\mathbb{C} \cup \infty$.
(iii) Let P denote the set of the fixed points of no elliptic elements of Γ, then $\Lambda(\Gamma) = \mathrm{P}$.
(iv) The limit set Λ(Γ) is uncountable.
(v) If $\Omega(\Gamma) \neq \emptyset$, then Ω(Γ) is dense in $\mathbb{C} \cup \infty$ and Λ(Γ) is nowhere dense in $\mathbb{C} \cup \infty$.

5.2 Apollonian group

Let $\mathcal{A}$ denote an Apollonian gasket. Then, the residual set of $\mathcal{A}$ is defined by

$$\Lambda(\mathcal{A}) := \overline{\cup_{C \in A}\, C}.$$

Equivalently, if we take the complement in $C \cup \infty$. of the interiors of all circles in $\mathcal{A}$, we are left with the residual set $\Lambda(\mathcal{A})$.

Let us start with the Descartes configuration $\mathcal{D}_0 = \{C_1, C_2, C_3, C_4\}$ of an Apollonian gasket $\mathcal{A}$. Consider the group of Möbius transformations $S =< i_1, i_2, i_3, i_4 >$ acting on $\mathbb{C} \cup \infty$, where i_k is defined as an inversion with respect to the circle $C_k^{\sim}$ that passes through the tangency points of the circles C_l, for $l \neq k$. In other words, each inversion i_k fixes three of the initial circles in $\mathcal{D}_0$ (not pointwise) and acts reciprocally on the two tangent circles to those three. The set of the circles $C_k^{\sim}$ is called the dual Descartes configuration.

Notice that S leaves the gasket $\mathcal{A}$ invariant and there are four S-orbits of circles in $\mathcal{A}$. Hence, the group S generates the whole packing $\mathcal{A}$ through these inversions and the limit set $\Lambda(S)$ is equal to the residual set $\Lambda(\mathcal{A})$ of A. For this reason, the group S has been named the Apollonian group.

If we take the circle C_1 of the Descartes configuration $\mathcal{D}_0$ to be the unit circle, we can then easily calculate the analytic expression of the $i_k' s$. The general expression of an inversion in a circle with radius r and center w is given by

$$i(z) = \frac{w\overline{z} + r^2 - w\overline{w}}{\overline{z} - \overline{w}}.$$

Then, the generators of the Apollonian group are

$$i_1(z) = \frac{\overline{z}}{-4iz+1}, i_2 = \overline{z}$$

$$i_3(z) = \frac{(1+i)\overline{z}-1}{\overline{z}-1+i}, i_4(z) = \frac{(-1+i)\overline{z}-1}{\overline{z}+1+i}$$

The $i_k's$ are conformal, orientation-reversing maps. However, we can rewrite them as compositions of orientation-preserving maps, that is elements of PSL(2, C), and the complex conjugation map *j*. So,

$$i_k = \alpha_k \square j,$$

where the $\alpha_k's$ are represented by the following matrices,

$$\alpha_1 = \begin{bmatrix} 1 & 0 \\ -4i & 1 \end{bmatrix}, \alpha_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \alpha_3 = \begin{bmatrix} 1+i & -1 \\ 1 & -1+i \end{bmatrix}, \alpha_4 = \begin{bmatrix} -1+i & -1 \\ 1 & 1+i \end{bmatrix}.$$

Which are parabolic Möbius transformations.

6. Conclusions

The Apollonian Gasket is a fascinating geometric object that was constructed by iteration using Descartes's circle theorem. In this work was exposed the solution of Apollonius' problem from the perspective of the Greek school to the perspective of Felix Klein, that is, from the construction with ruler and compass to a topological categorization of the Apollonian Gasket.

We also know that by studying the recursion of the Apollonian problem we obtain the Apollonian Gasket which is a geometric object that can be constructed computationally; and in which, without a doubt, it is possible to appreciate the strength of the geometric study through complex functions.

The Apollonian sieve is a fractal structure of great interest to many mathematicians, who using Dynamical Systems, Number Theory, Measurement Theory and Dimension Theory tools know that:

(i) The Hausdorff dimension of Apollonian Gasket is bounded.
(ii) There exists a rational function whose Julia set is homeomorphic to the Sieve of Apollonius.

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P_V	Postura de venta	490.61
V_C	Volumen de Compra	20000
P_c	Postura de Compra	485.39
P^{Uh}	Precio último Hecho	491.61
V_o	Volumen Operado	1241979
P_u	Precio/Utilidad	0
P^{VL}	Precio/Valor Libro	0
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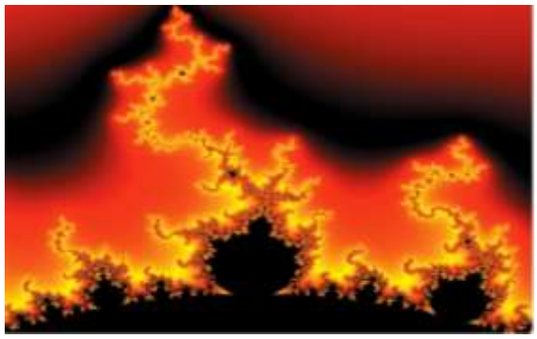

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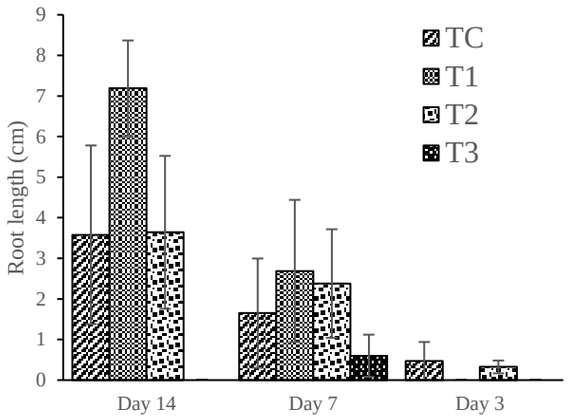

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