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EDITOR'S LETTER

Dear collaborators and readers

We present this new issue with which we inaugurate volume 13 of the *Espacio I+D Innovación más Desarrollo* Journal. After 11 years, we are very excited to continue this work of disseminating science and knowledge from our highest house of studies.

In this issue 35, we bring together specialized articles and present the following materials: Gastroprotective activity of Hamelia patens Jacq. in the ethanol-induced gastric injury model; Study of Antimicrobial Potential of Verbena litoralis Organic Extracts; Analysis of the basic strategic crops of Mexico through the Food Self-Sufficiency Index, 2011-2020; Nature Tourism and Space Production. Case Study in An Indigenous Community in The Highlands Region Of Chiapas; E Evaluation of the polyol/diisocyanate molar ratio in the physicochemical properties of biopolyurethane produced from poultry fat; as well as two academic documents called: Innovative Entrepreneurial Initiatives Promoted at a Public University of Ciudad Juárez; and Improving Energy Storage Conditions through Supercapacitor Banks: A Bibliographical Review. The previous articles are from various institutions, including IPN, Politécnica de Chiapas, Tecnológico Nacional de México (Tuxtla Gutiérrez and Comalcalco Campus), Universidad Michoacana de San Nicolás de Hidalgo, Universidad Intercultural de Chiapas, and Universidad Autónoma de Ciudad Juárez. We also present the English version of number 34 of our previous volume.

As part of our responsibility as an institution, we hope this year to meet the demands and challenges that the publishing world and the dissemination of science will pose to us, always with the same focus of being a space open to reflection to approach society and for Mexico to be an informed nation.

We hope you will continue to accompany us throughout this fruitful 2024.

The editors
Espacio I+D, Innovación más Desarrollo journal.

"*Por la conciencia de la necesidad de servir*"
Universidad Autonoma de Chiapas

ARTICLES

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Gastroprotective activity of *Hamelia patens* Jacq. in the ethanol-induced gastric injury model

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Sánchez Mendoza, M. E., López Lorenzo, Y., García Machorro, J., & Arrieta Valencia, J. Actividad gastroprotectora de Hamelia patens Jacq. en el modelo de lesiones gástricas inducidas por etanol. *Espacio I+D, Innovación más Desarrollo, 13*(35). https://doi.org/10.31644/IMASD.35.2024.a01

— Abstract—

Peptic ulcers affect about 10 % of the population worldwide and in some cases lead to the development of peritonitis, which can cause death. Since the diverse drugs used for the treatment of peptic ulcers all have serious adverse effects, it is necessary to seek new therapies. The scientific study of medicinal plants is important because they represent an important source for obtaining new drugs. *Hamelia patens* is utilized empirically to treat gastric ulcers in Mexico, but this practice is not based on a scientific foundation. The current contribution aimed to examine the possible gastroprotective effect of *Hamelia patens* with the model ethanol-induced gastric lesions in Wistar rats. The leaves of *Hamelia patens* were macerated to prepare the hexane, dichloromethane, and methanol extracts, which were administered orally at doses of 10, 30, and 100 mg/kg. Carbenoxolone (the reference drug) was given to the animals at 3-100 mg/kg. The most active extract was separated by column chromatography and the four fractions obtained were evaluated on the rats at 100 mg/kg. Whereas the dichloromethane and methanol extracts were active at all three doses tested, the hexane extract only showed gastroprotective activity at the highest dose (100 mg/kg). At 10 mg/kg, the dichloromethane extract was more effective than carbenoxolone at the same dose ($p<0.05$). Three of the four fractions of dichloromethane extract displayed gastroprotective activity ($p<0.05$), with ulcer index values of 42, 37, and 55 mm^2. In conclusion, *Hamelia patens* demonstrated gastroprotective activity in Wistar rats with ethanol-induced lesions and proved to have more than one active compound.

Keywords:

Medicinal plants; Hamelia patens; gastroprotection; gastric ulcers.

A peptic ulcer is an acid-induced lesion of the digestive tract that extends to the submucosa or the mucosal muscle and can generally be located in the lower part of the esophagus or stomach and the upper part of the duodenum (Kuna et al., 2019; Dunlap & Patterson, 2019). It is estimated that it occurs in 5 to 10% of the general population (Kuna et al., 2019) and can trigger serious complications such as bleeding or perforation, with a high risk of mortality due to peritonitis (Sverdén et al., 2019). Peptic ulcer originates from an imbalance between the mechanisms that contribute to mucosal integrity (prostaglandins, nitric oxide, sulfhydryl groups, mucus bicarbonate barrier, and decreased gastric motility) and aggressive factors (Kuna et al., 2019; Dunlap & Patterson, 2019). Risk factors for this disease include *H. pylori* infection, prolonged use of non-steroidal anti-inflammatory drugs (NSAIDs) and other drugs (corticosteroids, potassium chloride, chemotherapeutic agents) as they modify some protective factors of the gastric mucosa, tobacco and alcohol use, stress after an injury or intense physical illness, radiation therapy, viruses, and metabolic disorders. (Dunlap & Patterson, 2019; Kuna et al., 2019). Diagnostic and treatment protocols have not changed in the last 20 years (Brătucu et al., 2021). Proton pump inhibitor drugs (Perry et al., 2020) are the most promising for the treatment of gastric ulcers. However, its prolonged use triggers adverse effects such as gastric hypochlorhydria and hypergastrinemia, alterations in the absorption of calcium, iron, magnesium, and vitamin B_{12}, and/or gastric or pancreatic cancer (Kavitt et al., 2019; Peng et al., 2018), so it is necessary to seek other therapeutic alternatives. Medicinal plants are considered the main reservoir of potential drugs (Kuna et al., 2019) and it has been shown that studies based on ethnobotanical information have produced many useful drugs. However, research validating the empirical use of medicinal plants is still scarce (Jiménez-Suárez et al., 2016). The *Hamelia patens* Jacq. plant (Rubiaceae), commonly known by the names of trumpet, coralillo, or coral grass, which is traditionally used in the state of Chiapas to treat peptic ulcer, there is no scientific research available in this regard, so the objective of this study was to determine the gastroprotective effect of *Hamelia patens* using the model of ethanol-induced gastric lesions in Wistar rats.

METHODOLOGY

Animals

Male Wistar rats weighing between 180-220 g purchased from Universidad Autónoma Metropolitana, Xochimilco campus, Mexico City, were used. The care and management of the animals were carried out by official Mexican guidelines (Mexican Official Standard [NOM-062-ZOO], 1999). The study

was approved by the Internal Committee for the Care and Use of Laboratory Animals (CICUAL) of the Escuela Superior de Medicina del Instituto Politécnico Nacional, with registration number: ESM.CICUAL 14-03-01-2018. The animals were placed in individual cages provided with a metal mesh floor, 24 hours before carrying out the evaluations they were deprived of food, but with free access to water (Sánchez-Mendoza et al., 2022). All experiments were carried out with 7 animals per group.

Vegetal Material

The *Hamelia patens* Jacq. plant (Rubiaceae) was collected in April 2021, in the municipality of Copainalá, Chiapas, Mexico. The plant was identified by biologist Manuel de Jesús Gutiérrez Morales, from the Department of Flora of the CHIP Herbarium, and assigned the registration number: 27762.

Extraction and fractionation

The leaves of *Hamelia patens* were dried at room temperature in the shade and then ground with the help of a mechanical mill. Five kilos of dried and ground leaves were extracted via maceration, for which the leaves were first put in contact with hexane for three days. After this time, the solvent was filtered and concentrated with the help of a rotary evaporator, this operation was repeated twice more to obtain the hexane extract. Subsequently, the plant residue was extracted with dichloromethane and methanol, respectively, following the methodology described above to obtain the dichloromethane and methanol extract (López-Lorenzo et al., 2022). Extracts were evaluated in the ethanol-induced gastric lesion model in Wistar rats. The most active extract, dichloromethane, was separated by silica gel column chromatography with large changes in polarity, giving four fractions. As elution system, F1 = hexane/ethyl acetate 9:1, F2 = hexane/ethyl acetate 8:2, F3 = hexane/ethyl acetate 5:5 and F4 = ethyl acetate 100 % was used.

Ethanol-induced gastric lesions

Extracts (10, 30, and 100 mg/kg), fractions (100 mg/kg), carbenoxolone (3-100 mg/kg), and vehicle 80 Tween 0.05% were administered to Wistar rats orally (0.5 mL/100 g) to the different groups of animals. Thirty minutes later, 1 mL ethanol was administered orally (independent of weight) to all animals to cause gastric lesions. After 2 hours, the animals were sacrificed in a CO_2 chamber. The stomachs were dissected immediately and, subsequently, filled with formaldehyde (2%), five minutes later, they were opened by the greater curvature to measure the area of the gastric lesions with the

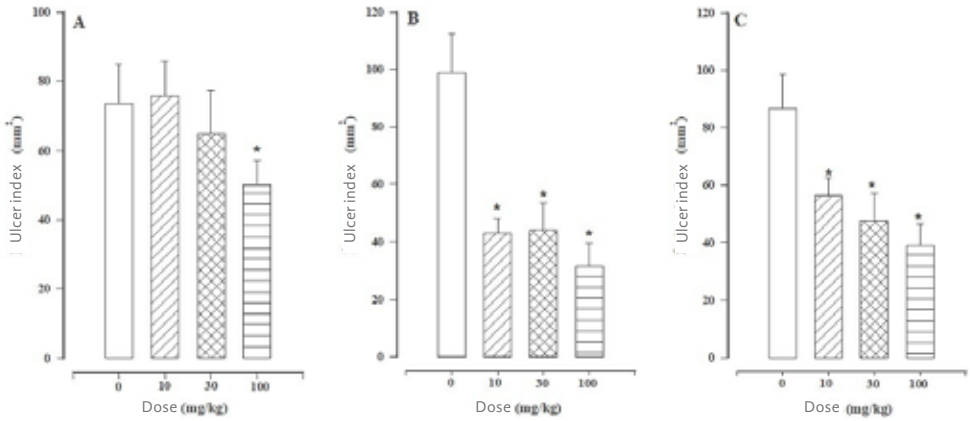
help of a stereoscopic microscope equipped with an ocular micrometer. The ulcer index was calculated as the sum of all lesions in mm2 of each stomach (Sánchez-Mendoza et al., 2022).

Statistical Analysis

Data are expressed as mean ± SEM (Standard error of the mean; n = 7). Differences between treatment groups were analyzed using the Kruskal-Wallis test followed by the Dunn test. The Mann-Whitney U test was used to compare the two groups. A significant difference was considered with a p-value< 0.05.

RESULTS

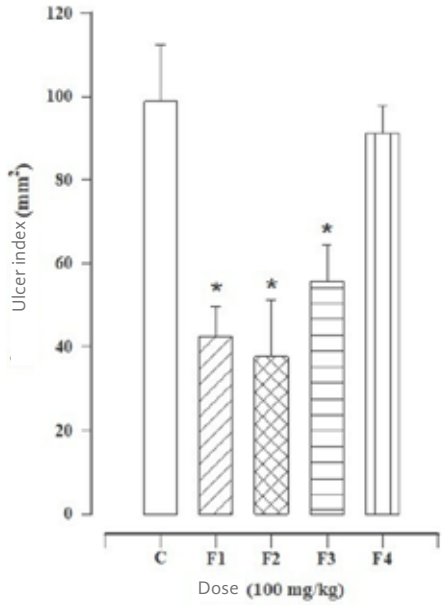
Extracts of hexane, dichloromethane, and methanol from *Hamelia patens* induced a gastroprotective effect against ethanol-induced lesions at the dose of 100 mg/kg (Figure 1 [A]). However, the hexane extract was inactive at lower doses (10 and 30 mg/kg), since there is no significant difference when compared to the vehicle control group. In contrast, dichloromethane and methanol extracts were active at those doses (10 and 30 mg/kg). It should be noted that the effect of these two active extracts is not dose-dependent (Figure 1 [B and C]). In the biodirected study, it was decided to fractionate the dichloromethane extract, since a significant difference between the two was found when comparing it with the methanolic extract at the dose of 10 mg/kg.



Note: Each bar represents the E.E.M.± average. (n = 7) *p < 0.05 compared to their respective control. Kruskal-Wallis test followed by Dunn's multiple comparison test.

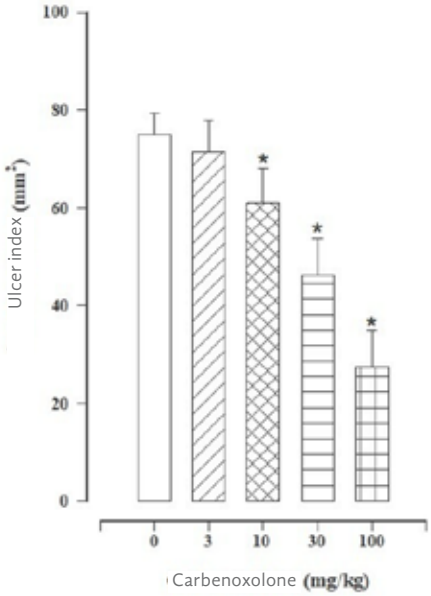
Figure 1. (A, B, and C). Gastroprotective effect of hexane extract (A), dichloromethane (B), and methanol (C) on ethanol-induced gastric lesions in Wistar rats

In the evaluation of the fractions obtained from the dichloromethane extract (Figure 2, 100 mg/kg) it was found that three of them, F1, F2, and F3, were active; and only F4 was inactive. When making a thin layer chromatography of the active fractions, some similar Rf (0.6) were observed between them. Regarding carbenoxolone, it was protected from gastric damage from the 10 mg/kg dose and had a dose-dependent effect (Figure 3). When comparing the ulcer index of the reference drug with that obtained by fractions F1 and F2, no statistical difference was found, indicating that they exert the same protection at the dose of 100 mg/kg.



Note. C=control, F1=hexane/ethyl acetate 9:1, F2=hexane/ethyl acetate 8:2, F3= hexane/ethyl acetate 5:5 and F4= 100% ethyl acetate. Each bar represents the average E.E.M.± (n = 7) *p < 0.05 compared to their respective control. Kruskal-Wallis test followed by Dunn's multiple comparison test.

Figure 2. Gastroprotective effect of dichloromethane extract fractionation on ethanol-induced gastric lesions in Wistar rats



Note. Each bar represents the average E.E.M.± (n = 7) *p < 0.05 compared to their respective control. Kruskal-Wallis test followed by Dunn's multiple comparison test.

Figure 3. Gastroprotective effect of carbenoxolone on ethanol-induced gastric lesions in Wistar rats

DISCUSSION

The results obtained showed that the *Hamelia* patens plant exerts gastroprotective activity, which supports its therapeutic use to treat gastric ulcers in traditional medicine in our country. Additionally, it is worth mentioning that previous studies of *Hamelia* patens have shown antinociceptive and anti-inflammatory activity (Noor et al., 2020). This combination of activities would give *Hamelia* patens an advantage because this would help reduce the doses of NSAIDs in those patients who consume them for a long time and thus reduce the risk of peptic ulcer caused by this type of drug (Dunlap & Patterson, 2019). On the other hand, throughout the biodirected study, it was evident that the plant contains more than one active compound with different physicochemical properties since the activity was found in the three extracts evaluated (hexane, dichloromethane, and methanol). However, the hexane extract only exerted activity at the dose of 100 mg/kg, which can be for two reasons: that said extract has very little of the active constituent (s), or that said compounds are poorly active. In contrast, the gastroprotective effect achieved with the 10 mg/kg dose of the dichloromethane extract differs significantly from the methanolic extract at the same dose, indicating that, in the dichloromethane extract, the compound(s) responsible for said activity is more potent or in greater quantity. Additionally,

from the fractionation of the dichloromethane extract three fractions were active and their thin layer chromatographies showed compounds with similar Rf, which suggests that fractions 1, 2, and 3 probably contain the same compound, in addition to others. Phytochemical studies of the plant *Hamelia* patens have reported that it contains a flavanone glycoside, rosmarinic acid, and various alkaloids such as pteropodine, isopteropodine, rumberine, palmirina, maruquina, alkaloid A, tetrahydroalstonine, aricina, hamelina, uncarina, especiofilina, and ephedrine (Jiménez-Suárez et al., 2016). Considering that gastroprotective activity has been reported for some types of flavonoids and alkaloids, it is pending to continue the study of this plant to identify the active gastroprotective constituents and determine their mechanism of action. Interestingly, the protective effect of active fractions F1 and F2 was similar to the reference drug carbenoxolone at the same dose, suggesting that purification of these fractions is likely to yield more active compounds than carbenoxolone.

CONCLUSION

The *Hamelia patens* plant protects Wistar rats from gastric damage caused by ethanol and contains more than one active compound.

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Study of Antimicrobial Potential Of Verbena litoralis Organic Extracts

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— Abstract—

Verbena litoralis is a plant used in traditional medicine in Mexico by the multicultural population and is effective in relieving cold symptoms, stomach aches, fever, and diarrhea, among others. Scientific reports of its pharmacological potential are limited, so in this study, the antimicrobial potential of extracts from *V. litoralis* on pathogenic strains responsible for gastrointestinal infections was determined. The crude organic extracts were prepared by sonication and the bacterial growth inhibition effect was performed using the disk diffusion method and the minimum inhibitory concentrations of the extracts were obtained through plate microdilution. Phytochemical analysis was also done by Thin Layer Chromatography (TLC) and visible light spectrophotometry. The methanolic leaf extract and the ethanolic and ketonic extracts of the stem from *V. litolaris* showed a positive effect of inhibition of growth in all the strains evaluated, *E. coli* was the strain with the highest sensitivity to the components of the ethanolic stem extract with a minimum inhibitory concentration (MIC) of 5 mg/mL. The methanolic extract leaf from *V. litolaris* presented the highest concentration of phenylpropanoids with 11.75 + 0.03 µg Eq rutin/mL. This is the first report of the presence of coumarins, anthrones, and anthraquinones in *V. litoralis*, and with our results, we contribute to validating their use as an alternative to inhibit the growth of the evaluated strains.

Keywords:

Antibacterial, Verbena litolaris, phytochemicals, gastrointestinal infections.

Gastrointestinal ailments are among the first reasons for medical consultation, and their low level of care has resulted in it currently being considered one of the leading causes of death not only in Mexico but also worldwide. Gastrointestinal symptoms due to acute infections are the most frequent and can occur at any time of the year, but the risk of suffering from these diseases increases in the hot season (Hernández Cortez et al., 2011).

Regarding the monitoring of infections caused by bacteria, the global health sector faces an increase in the number of cases that require treatment and medical surveillance in order to avoid complications and reduce the use of antibiotics that eventually lose effectiveness (World Health Organization [WHO], 2020). Of the enterobacteria monitored by the WHO, those that have shown the highest degree of resistance to various generations of antibiotics in recent years are *Escherichia coli, Klebsiella pneumoniae*, and *Salmonella* spp. Within the list of critical priority are *Pseudomonas aeruginosa* and Enterobacterial resistant to carbapenems; in the list of elevated and medium are *Salmonella* spp and *Shigella* spp, resistant to fluoroquinolones, respectively (WHO, 2021).

Traditional knowledge and healing practices developed by rural communities around the world represent an important alternative in health care, on par with their importance, in some cases, to Western medicine. The use of medicinal and aromatic plants is of vital importance for the preservation of the health of people around the world, especially in developing countries. Traditional Mexican medicine dates from pre-Hispanic times in primary health care (Campos et al., 2018). The process of making herbal medicines produces various responses in the metabolism of those who consume them because they contain multiple molecules that act as active ingredients; therefore, they must comply with pharmacopoeial and quality control specifications (Gallegos-Zurita, 2016).

The *Verbena litoralis* plant (Schoch CL et al., 2020) is native to Mexico and is distributed in several states such as Sonora, Sinaloa, Chihuahua, Tamaulipas, Durango, San Luís Potosí, Nuevo León, Guanajuato, Querétaro, Hidalgo, Nayarit, Jalisco, Colima, Michoacán, Mexico City, Michoacán, Morelos, Puebla, Veracruz, Guerrero, Oaxaca, Tabasco and Chiapas (Rzedowski & Rzedowski, 2002, as cited in CONABIO, 2010), where it is also known as verbena fina or yakan k 'ulub wamal (tzotzil), yaxal nich jomol (tzeltal) (Digital Library of Traditional Mexican Medicine, 2009).

The *V. litoralis* is used to cure stomach pain, vomiting, cough (CONABIO, 2010), fever (Willmann et al., 2000, as cited in CONABIO, 2010) and for biliary colic; the latter is recommended to be prepared in an infusion with the leaves (Digital Library of Traditional Mexican Medicine, 2009). Chemical or pharmacological studies that validate its therapeutic appli-

cation are scarce (Digital Library of Traditional Mexican Medicine, 2009), it has been reported to have antioxidant, contraceptive (Braga et al., 2012), hepatoprotective (Vestena et al., 2019), and anti-inflammatory activity, and it has been suggested that these are due to the presence of phenolic compounds (Lima et al., 2020), or to terpenes that have been identified in other Verbena species. Therefore, it is important to expand the information on the phytochemical composition of *V. litoralis* and check its ability to treat bacterial infections. Therefore, the objective of this study was to determine the antibacterial effect of organic extracts of *Verbena litoralis* on *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus*, and *Salmonella typhimurium* strains, in addition to phytochemical screening.

2. MATERIALS AND METHODS

2.1. Vegetal material

20 complete plants were collected from several randomly distributed individuals of *Verbena litoralis*, in the city of Comitán de Domínguez, Chiapas, in August 2022, the geographical coordinates being 16°15' N and 92° 08' W, and with an altitude of 1,600 masl.

2.2. Microorganisms

The strains evaluated were *Salmonella typhimurium* ATCC 14028 (donated by the Center for Research and Assistance in Technology and Design of the State of Jalisco, Southeast Subsite), *Escherichia coli*, ATCC 25922 (donated by the State Public Health Laboratory of the state of Chiapas), *Pseudomonas aeruginosa* and *Staphylococcus aureus* (donated by the laboratory of the Faculty of Medicine of the Universidad Autónoma de México).

2.3. Experimental design

A completely random design was made, the plant sample was divided into stem and leaves, and three solvents of different polarity were used: ethanol, methanol, and acetone, from which six extracts were obtained that when including the positive control (antibiotic) and the negative controls (solvents), 10 treatments were evaluated in triplicate with a total of 30 experimental units for each microorganism, the response variables being: the inhibition halos and the inhibitory effect.

2.4. Preparation of organic extracts

The dried and pulverized plant samples were weighed and the corresponding solvent according to the experimental design was added to each in a ratio of 1:10 (m/v). The six mixtures were sonicated for 2.5 hours at 20°C in a 40 Hertz VEBOR sonicator model: JPS-20ª. At the end of that time, each extract was vacuum filtered and centrifuged at 3500 rpm for 15 min; the supernatants were concentrated under reduced pressure (16 inHg) at 40°C on a HEIDOLPH rotary evaporator and the liquid recovered from each crude extract was deposited in amber bottles, which were kept under refrigeration for later use (Kuete et al., 2006).

2.5. Antibacterial activity by impregnated discs

For the antimicrobial evaluation, the diffusion method on agar with impregnated discs was used, based on the Kirby-Bauer method with an inoculum concentration of 1 x 10^8 UCF mL^{-1} distributed using an elbow rod on the surface of the Mueller Hinton agar Petri dishes. Subsequently, Whatman No. 5 sterile filter paper discs were placed, and impregnated with 15 µL of the crude extracts (Pandey, 2019), as a negative control the solvent of the extract was used, and as a positive control 30 µg mL^{-1} of chloramphenicol per disc (Vaghasiya & Chanda, 2007; Pandey, 2019). Each experiment was performed in triplicate. The boxes were incubated for 48 h at 37°C, the inhibition halo was measured and the relative inhibitory effect was determined, based on the positive control, by the formula:

$$\%\ Inhibitory\ effect\ (\%\ EI) = \left(\frac{mean\ inhibition\ halo\ diameter}{positive\ control\ inhibition\ halo\ diameter}\right) x\ 100$$

2.6. Determination of the Minimum Inhibitory Concentration

For those microorganisms that showed greater susceptibility to crude extracts, their minimum inhibitory concentration (MIC) was determined by the broth microdilution method, using sterile 96-well flat-bottomed microplates (Canche, 2019). The incubation of the microplates was at 37°C for 24 h. All experiments were done in triplicate.

2.7. Phytochemical analysis

It was performed qualitatively by Thin Layer Chromatography (TLC), using chloroform-acetone-acetic acid (9:1:0.2) as the mobile phase (Wagner et al., 1996). Quantitative analysis of phenolic compounds was performed by visible light spectrophotometry using the colorimetric methods: aluminum chloride

for flavones and flavonols (Chang et al., 2002), 2-Aminoethoxydiphenyl borate for total flavonoids (Robertson & Hall, 1989), and Folin Ciocalteau for total phenols (Singleton et al., 1999), using a Hach Dr 5000 spectrophotometer.

2.8. Statistical Analysis

The data obtained were analyzed using a one-way analysis of variance (ANOVA), and the comparison of means was performed by Tukey's test ($P<0.05$). A statistical analysis was carried out using Statgraphics software Centurion XIX® (Statgraphics Technologies, Inc., Madrid, Spain).

3. RESULTS AND DISCUSSION

Six crude *V litoralis extracts were obtained* with which the antibacterial effect on the pathogenic strains *S. aureus, P. aeruginosa, S. typhimurium*, and *E. coli* (which cause gastrointestinal diseases) was analyzed, the values obtained from inhibition halos as well as inhibitory effect, showed that only three extracts had a positive effect of inhibiting bacterial growth, and the statistical analysis indicated that there was a significant difference concerning the sensitivity of the strains with the extracts with halos between 6.17 to 9.9 mm (Figure 1), being the methanolic leaf extract with which we obtained 40.5 and 42.4% of inhibitory effect on *E. coli* and *S. aureus* as shown in Table 1. Bacterial growth was disrupted within 24 hours, where the lowest MIC (5 mg/mL) was determined to be with the ethanolic stem extract for all microorganisms tested.

The reported evidence of the use of *V. litoralis* in traditional herbal medicine, as well as the differences in the antibacterial effect of the extracts in this study led to phytochemical studies to relate this effect to the interaction of the compounds present. The qualitative analysis of leaf and stem extracts (Table 2) revealed the presence of the three main groups of secondary metabolites: alkaloids, saponins, flavonoids, coumarins, anthrones and anthraquinones, being abundant, mainly, in the methanolic and ethanolic extracts, which suggests that the positive inhibition effect may be due to the interaction of high polarity molecules, mainly by the hydroxyl groups presented by phenolic compounds, of which the presence of phenolic acids such as chlorogenic acid, caffeic acid, p-coumaric acid, vanillic acid and ferulic acid as well as flavonoids such as luteolin and apigenin has been reported (Lima et al., 2020), other metabolites with biological activity that have been identified for *V. officinalis*, a species belonging to the same genus, are: limonene, 1,8-cineole, ar-curcumene, epoxycaryophyllene, spatulenol, citral, geraniol, and verbenene of lipophilic nature, which correspond to monoterpenes and sesquiterpenes, which together with artemitin, sorbifolin, pedalitin, nepetin, and 7-O-β-D-glucopyranosyl-apigenin are considered

responsible for their biological properties (Deepak et al., 2000; Zhang et al., 2000). The high content of phenolic compounds of the *V. litoralis* also stands out in the crude extracts, mainly flavonoids with 11.75 + 0.03 µg Eq Routine/mL for methanolic leaf extract (Table 3).

The richness and content of secondary metabolites in these extracts may explain their effect on the growth of microorganisms. In this regard, Rodríguez-Pava et al. (2017) mention that metabolites such as alkaloids, flavonoids, tannins, and other compounds of a phenolic nature are responsible for antimicrobial activities in higher plants. For their part, Díaz-Solares et al. (2017) indicated that the pharmacological properties of plant extracts are attributed to the high content of phenolic compounds, which, in turn, are related to antioxidant and antimicrobial activities.

The antimicrobial activity of phenolic compounds, as mentioned by Aguilar-Mendez et al. (2020), involves the reaction of phenols with cell membrane proteins or sulfhydryl groups of proteins, which causes bacterial death by precipitation of membrane proteins and inhibition of some enzymes. The effect of flavan-3-ols has been shown to suggest that these classes of flavonols inhibit nucleic acid synthesis through the inhibition of topoisomerase or dihydrofolate reductase (Gradišar et al., 2007; Navarro-Martínez et al., 2005). Ikigai et al., (1993) used liposomes as models of bacterial membranes to test the activity of (-)-epigallocatechin-3-gallate (EGCG) on them and found that this catechin caused the leakage of small molecules from the intraliposomal space. The EGCG exhibited activity against *E. coli*, this was described by Nakayama, et al. (2013). EGCG was found to interact with the porin protein of the outer membrane of *E. coli*, thus inhibiting the main function of porin, namely the transport of small hydrophilic molecules such as glucose, which eventually leads to the inhibition of *E. coli growth*. Phosphatidic acid is the universal intermediate in the synthesis of membrane glycerophospholipids (Machinandiarena et al., 2020) in bacteria this synthesis is carried out by a complex of multiple individual enzymes known as fatty acid synthase II (FAS II) (Machinandiarena et al., 2020; Zhang & Rock, 2004). Being an attractive target for antibiotic development, several studies showed that various flavonoids exhibit inhibitory action on some of these enzymes in fatty acid synthetase.

CONCLUSION

Polar crude extracts of *V. litoralis leaves and stems* are a source of phenolic, terpenic, and alkaloid compounds, with the ability to inhibit the growth of bacteria such as *E. coli, P. aeruginosa, S. aureus*, and *S. typhimurium*, which lends validity to the empirical use of infusions to treat the symptoms of a gastrointestinal infection. However, other studies are required to define whether the antibacterial activity is due to a particular molecule or is a synergistic action of the metabolites present, as well as to test their cytotoxic effect.

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ANNEX 1

Table 1

Antimicrobial activity of the crude extracts of Justicia spicigera on the strains of "Staphylococcus aureus, Pseudomonas aeruginosa, Salmonella typhimurium, and Escherichia coli"

Crude extracts	S. aureus		P. aeruginosa		S. typhimurium		E. coli		CMI mg/mL
	HI mm	EI %	HI mm	EI %	HI mm	EI %	HI mm	EI %	
MH	8.87 a	42.4 a	6.67 b	25.0 b	6.67 a	32.6 a	9.67 a	40.5 a	50
ET	7.67 b	36.6 b	9.90 a	37.1 a	8.00 a	39.1 a	9.02 a	37.7 a	5
AT	6.33 bc	30.2 bc	6.17 b	23.2 b	7.51 a	36.7 a	6.42 b	26.9 b	18.33
CL	20.94		26.65		20.42		23.9		

Note. Average values followed by at least one letter are not significantly different between extracts for each strain studied at P ≤ 0.05 (Tukey's Test). M: Methanol, A: Acetone, H: Leaf, T: Stem. CL: chloramphenicol. HI: Halo of inhibition; EI: Inhibitory effect; CMI: Minimum inhibitory concentration.

Table 2

Phytochemical characterization of crude extracts of "Verbena litoralis" by thin-layer chromatography

Crude extracts	Alkaloid	Saponins	Flavonoids	Cumarin	Anthrone	Anthraquinone
MH	+	+	+++	++	+	++
MT	++	++	++	++	+	++
AH	-	-	++	-	-	+
AT	-	++	+	+	+	++
EH	+++	++	+	+	-	-
ET	+++	+++	+++	+	+	++

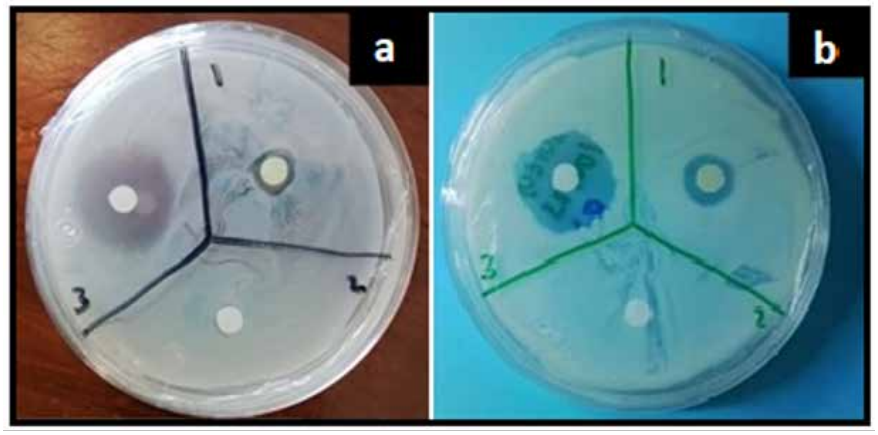
Note. M: Methanol, A: Acetone, E: Ethanol, H: Leaf, T: Stem. Abundant (+++), moderate (++), slight (+), and null (-) presence according to Kamatenesi-Mugisha et al., (2013).

Table 3

Quantification of phenolic compounds in crude extracts of "Verbena litoralis"

Crude extracts	Flavones and flavonols µg Eq quercetin/mL	Total flavonoids µg Eq rutina/mL	Total phenols µg Eq ác. gálico/mL
MH	2.63 + 0.01 b	11.75 + 0.03 a	9.20 + 0.02 a
ET	0.53 + 0.02 c	0.53 + 0.01 c	1.80 + 0.02 b
AT	4.88 + 0.07 a	2.05 + 0.01 b	1.46 + 0.01 c

Note. Mean values followed by at least one same letter are not significantly different between extracts at P ≤ 0.05 (Tukey's test). M: Methanol, A: Acetone, E: Ethanol, H: Leaf, T: Stem.



Note. a) ethanolic extract of the stem, b) methanolic extract of the leaf. 1) extracts, 2) negative control (solvent), 3) positive control (antibiotic)

Figure 1. Growth inhibition halos of Saureus in the presence of organic extracts of V. litoralis

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Analysis of the basic strategic crops of Mexico through the Food Self-Sufficiency Index, 2011-2020

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— Abstract—

The objective of this study is to calculate the Food Self-Sufficiency Index (FSI) for a set of nine of the basic strategic crops indicated by the Ministry of Agriculture and Rural Development of the Government of Mexico, the selected ones being rice, oats, cocoa, coffee, beans, apples, soybeans, sorghum, and wheat, for the period 2011-2020. The FSI helps to measure the state and evolution of the national capacity to satisfy its internal supply of a certain good. Low FSI values indicate that the supply of said product is highly dependent on the conditions prevailing in its international markets. For the Mexican case, the lowest FSI values were found in soybeans, rice, and oats. The products that showed the most favorable conditions were coffee, beans, apples, and sorghum.

Keywords:

Food; sufficiency; staple crops; imports; exports.

Food self-sufficiency is achieved when the food needs of the population are met through local production. Among other factors, this depends on the activities to promote the production of a given set of goods, the availability of inputs (seeds, fertilizers, fuels, and machinery), and the action of public policies, in particular those related to competition and trade. In such a scenario, food self-sufficiency implies not only increasing local production but also decreasing dependence on food imports and procuring exports, hoping that these will bring fresh resources that will help energize the Mexican countryside (Cruz et al., 2021).

On the other hand, the name of basic and strategic crops comes from the Rural Development Law of the year 2000. This classification obeys a set of characteristics such as the number of people employed in them, their relevance to the national economy, their ecological importance, their implications for maintaining health, public safety, and their participation in the diet of Mexicans. In addition, the law included as strategic activities the production, supply, and industrialization of eggs, milk, beef, pork, poultry, and fish (CEDRSSA, 2019).

The basic and strategic nature of these crops gives them a series of legal protections and makes them subjects of specific promotion activities for their cultivation, supply, and transformation. Therefore, it includes giving preference in its commercialization to national production, facilitating producers of these goods access to financing, ensuring that these goods are affordable for all Mexicans, and providing these activities with a priority in the negotiation of international trade agreements (CEDRSSA, 2019).

According to the Ministry of Agriculture and Rural Development (SADER), rice, oats, cocoa, coffee, sugar cane, beans, white and yellow corn, apple, oilseed rape, safflower, sunflower, soybean, sorghum, and wheat are considered basic strategic crops (SADER, 2017).

Despite the relative legal advantages expressed, the current situation of several of these crops is extremely complicated, and national self-sufficiency in their supply is subject to what happens to them in international markets. Proof of this is the recent setbacks experienced in the production of several of these goods in recent years.

If the period from 2011 to 2020 is taken into consideration, it can be seen that the production of at least four of the strategic staple crops in Mexico decreased. Cocoa decreased by 30%, coffee by 26%, sorghum by 32%, and wheat by 18% (FAO, 2022). This casts doubt on whether the aforementioned preferential measures have translated into improvements in self-sufficiency or food sovereignty.

This work, with descriptive aspirations, aims to measure the Food Self-Sufficiency Index (FSI) for a set of nine Mexican strategic staple crops, for the period from 2011 to 2020. The selection of these nine crops and the

study period was based on the availability of information in the databases of the Food and Agriculture Organization of the United Nations (FAO). The crops chosen were rice, oats, cocoa, coffee, beans, apples, soybeans, sorghum, and wheat. The aim is to demonstrate the descriptive hypothesis that indicates that in most of these crops, Mexico is not self-sufficient and is dependent on imports. Below is a review of the literature on the subject, followed by the presentation of the method used and the results found and then closing with the conclusions of the study.

1. LITERATURE REVIEW

Food self-sufficiency is linked to the concept of food security. Food security is defined as the access of the population to sufficient, safe, and nutritious food, which allows a diet that promotes health and pleases the preferences of individuals; its basic dimensions are availability, accessibility, use, and stability. The availability dimension refers to the existing quantities of food, whether these come from national production (i.e. self-sufficiency) or imports (Pérez, 2020).

The access dimension refers to the capacities of the population to acquire the products required for their meals; the use refers to combining food, access to drinking water, health, and medical care to ensure well-being and public health; and finally, the stability dimension implies the absence of serious risks that compromise access to food (Pérez, 2020).

Therefore, self-sufficiency plays a fundamental role in the food strategies of nations, not only for production and supply, but also to generate favorable conditions of access, use, and stability. These conditions are not guaranteed in many products for the Mexican case, which has generated numerous investigations on the subject. Table 1 contains some recent research on this topic.

Table 1
Review of recent literature on food self-sufficiency in Mexico

Espinosa y Zubirán (2022)	Using trade data, it is confirmed that grain marketing led by developed countries weakened traditional agriculture in peripheral countries. In the case of Mexico, this led to the growth of grain imports and the adoption of the non-traditional agro-export model.
Borja y García (2022)	The effect of subsidized fertilizers on Mexican bean productivity and food self-sufficiency was evaluated, finding a positive correlation between these elements.
Cruz *et al*. (2021)	An adaptation of the FSI is used to assess self-sufficiency in rice and wheat in Mexico, finding that PROCAMPO supports have an effective impact on the productivity of these crops.
Rivera *et al*. (2021)	Using data on food imports and exports from Mexico, it is concluded that Mexico is highly dependent on food from abroad, largely due to an unequal distribution of subsidies and financing, which have mainly favored large producers.
Torres y Rojas (2020)	The authors calculate a series of self-sufficiency indices to conclude that more than half of Mexico's population is in some degree of food insecurity.
Pérez (2020)	Using indicators of food self-sufficiency, it was found that this is positively related to the value of agricultural production and distribution infrastructure, while it is negatively affected by inflation and unemployment.
Cotler *et al*. (2020)	The influence of erosion and soil degradation on the lack of food self-sufficiency was confirmed, especially in the states of Guerrero, Michoacán, Guanajuato, and the State of Mexico.
Martínez (2016)	The FSI is calculated for the case of Mexican amaranth, finding that it is a positive alternative to achieving food security.
Soria *et al*. (2015)	It is concluded that the main cause of the lack of food self-sufficiency lies in the way international markets operate. The research closes with a proposal for co-participatory production and consumption focused on the marginalized rural population.
Rivera *et al*. (2014)	A food self-sufficiency index is calculated for the cases of corn, beans, and wheat in Mexico from 2006 to 2012, a six-year period, finding in all three cases high rates of import growth and decreases in the areas sown and harvested.

Note. Own elaboration based on the cited sources.

As can be seen, there are commonalities in these investigations; for example, the calculation of indexes to measure self-sufficiency, the use of trade statistics to diagnose the phenomenon, and concern about Mexican performance in cereal production.

This is a complex issue related to population, climate, and market factors, as well as the influence of public policies. An example of this is the programs aimed at reducing hunger in Mexico, which have been aid-oriented, rather than aimed at solving the problems of the productive apparatus (Soria et al., 2015).

Other problems of the sector, derived from policy decisions, can be identified with the adoption of the agro-export paradigm. This model obeys

the idea of the existence of central consuming countries and peripheral producing countries; in this way, the peripheral countries produce to export and meet the needs of the central countries, this being a necessary condition for their growth. In this paradigm, the responsibility for production and growth is transferred to the private sector; the government, for its part, assumes a role of facilitating these activities, favoring economically efficient branches, that is, those linked to international markets. In practice, the adoption of this model implied the neglect of the internal market and its needs, as well as the traditional social mechanisms of income redistribution (Acosta, 2006).

For the adoption of this model, between 1983 and 1989, multiple public companies dedicated to the agricultural sector were sold, liquidated, or transferred (Soria et al., 2015), which worsened unfair trade practices, accentuated the lack of subsidies to compensate for the support granted to producers in other countries and affected the availability of resources for agricultural financing and research (Schwentesius & Gómez, 1999).

Therefore, it is worth adding the low priority that cereals and other foods received in the negotiations of the North American Free Trade Agreement (NAFTA). NAFTA led to the deepening of neoliberalism in Mexico, which was expected to boost economic growth as a result of the increase in the production of export goods and the arrival of greater Foreign Direct Investment (FDI). However, the effects of NAFTA on the Mexican countryside were mixed and the dynamism of Mexico's agricultural production decreased in the years after NAFTA as a result of trade opening and the lack of protection of large sectors as trade barriers gradually fell (Escalante & González, 2018).

Regarding exports, it benefited as a result of the entry into force of NAFTA. However, this occurred with little socio-productive inclusion, since it is estimated that only 6% of producers in Mexico can export. The scheme adopted favored the production and export of the fruit and vegetable sector, to the detriment of grain producers, of which Mexico became a net importer (Escalante & González, 2018).

Other frequent concerns around the topic relate to the economic and political implications of food. There is a dynamic of hegemony and domination determined by the great economic powers that have transformed food into instruments for the protection of geopolitical interests. This has increased the subordination and food dependence of developing countries, to the detriment of marginalized productive units in international markets (Espinosa & Zubirán, 2022).

Another external sector issue related to food self-sufficiency is the provision of subsidies. These play a decisive role for agriculture to fulfill its function of providing food and raw materials at low cost and are funda-

mental for competition in international markets. High subsidies help central economies increase their exportable production, when this occurs, these countries can force the reduction of prices, causing a competitive disadvantage in underdeveloped countries, and privileging the consumption of imported goods (Rivera et al., 2021).

Additionally, there has been a significant reduction in agricultural land in Mexico (understood as the sum of arable land plus land used for grazing divided by the number of inhabitants), from the 1960s to the present day. While this indicator was 2.52 hectares (ha) in 1961, by 2018, it had decreased to only 0.85 ha (Ruiz, 2021).

This reduction in cultivable areas joins other problems such as those related to low technification and the limited availability of irrigation, which impact the productivity of the Mexican countryside. In 2018, the average yield in tons per hectare (TPH) for cereals in Mexico was 3.8 TPH, this same indicator was higher in countries such as Chile (7.1 TPH), Uruguay (5 TPH), Peru (4.5 TPH), Brazil (4.8 TPH), Colombia (4.5 TPH), and Paraguay (4.2 TPH) (Ruiz, 2021).

2. MATERIALS AND METHODS. THE FOOD SELF-SUFFICIENCY INDEX (FSI)

The FSI indicates to what extent the reference country is self-sufficient in the production of a given good, that is, to what extent it can satisfy its national consumption without the need for international trade (Ireta et al., 2015).

The FSI is determined by formula 1:

$$FSI = \frac{National\ Production}{National\ Production + Imports - Exports} * 100 \quad [1]$$

The result of the FSI is expressed as a percentage; the higher FSI values indicate greater self-sufficiency and denote the existence of favorable conditions for competitiveness, that is, they indicate to what extent the country can dedicate part of its local production to trade without compromising its consumption. In addition, the low values of the FSI imply that the supply of the product may be compromised by changes in international markets, such as sudden increases in prices, logistical problems, international conflicts, and sudden drops in production; that is, these are products on which the country is vulnerable and dependent (Ireta et al., 2015).

3. RESULTS

Table 2 shows the FSI calculation for the case of Mexican rice. As can be seen, despite the increase in domestic rice production, this in turn corresponded to an increase in imports. Rice exports were only significant in 2017 and 2018. The FSI value of this good remained between 15 and 23%, which indicates that the supply of this good with national production does not cover even a quarter of what is necessary.

Table 2
FSI calculation for rice in Mexico

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	115 698	666 830	1843	15 %
2012	119 251	604 361	1589	17 %
2013	119 911	673 877	1682	15 %
2014	154 850	657 165	1859	19 %
2015	157 424	640 812	2024	20 %
2016	169 447	671 533	9066	20 %
2017	177 133	868 592	88 360	19 %
2018	189 270	737 156	108 770	23 %
2019	163 560	972 795	10 275	15 %
2020	196 990	764 986	7553	21 %

Note. Own elaboration with data from FAO (2022).

On the other hand, oats show a behavior similar to that of rice, but in a less drastic way. Despite the sustained increase in the quantity produced, this is matched by an increase in imports and, throughout the period, there were no significant exports of this good. Therefore, as can be seen in Table 3, the percentage of national oat consumption that can be solved with national production was between 30 and 57%.

Table 3
FSI Calculation for oats in Mexico

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	50 582	115 374	21	30 %
2012	84 404	147 735	4	36 %
2013	91 049	110 972	19	45 %
2014	93 021	70 587	13	57 %
2015	84 789	92 668	76	48 %
2016	71 152	123 652	22	37 %
2017	72 092	132 099	36	35 %
2018	99 305	161 872	66	38 %
2019	100 672	151 619	59	40 %

Note. Own elaboration with data from FAO (2022).

With cocoa, the situation seems even more complex. During the study period, domestic production contracted by 30%, while imports increased significantly until 2019. If we compare cocoa imports from Mexico in 2011 with those made in 2019, we can detect that they were 2.4 times higher. The only year with low cocoa imports was 2020, a situation probably related to the pandemic. Likewise, exports of the goods were insignificant in most of the years considered. On the other hand, as can be seen in Table 4, the FSI value was between 38 and 89%.

Table 4
FSI Calculation for cocoa in Mexico

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	42 175	18 922	238	69 %
2012	38 825	13 590	277	74 %
2013	33 284	22 953	2246	62 %
2014	26 969	28 659	210	49 %
2015	28 007	23 521	134	54 %
2016	26 863	38 293	169	41 %
2017	27 287	41 322	1032	40 %
2018	28 399	38 547	476	43 %
2019	28 452	46 607	115	38 %
2020	29 429	3711	26	89 %

Note. Own elaboration with data from FAO (2022).

Another case that draws attention is that of Mexican coffee, which, despite having contracted its production during the study period by 26%, it also had exports considerably higher than imports, as shown in Table 5. In other words, it is a crop in which Mexico shows food self-sufficiency and solvency to supply international markets.

Table 5
FSI calculation for coffee in Mexico

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	237 056	11 635	112 452	174 %
2012	246 121	5895	160 771	270 %
2013	231 596	8153	140 090	232 %
2014	214 667	31 114	102 447	150 %
2015	188 934	48 027	91 998	130 %
2016	151 714	65 669	79 916	110 %
2017	153 777	31 232	112 988	214 %
2018	158 308	22 700	113 354	234 %
2019	165 712	39 771	97 986	154 %
2020	175 555	25 193	100 767	176 %

Note. Own elaboration with data from FAO (2022).

Mexican beans also appear to perform well. It was a crop that steadily increased its production during the period and with relatively high FSI values, as shown in Table 6, which were in a range between 83 and 99%.

Table 6
Cálculo del IAA para el frijol en el caso de México

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	567 779	104 897	37 593	89 %
2012	1 080 857	235 687	16 879	83 %
2013	1 294 634	134 494	32 908	93 %
2014	1 273 957	82 206	65 051	99 %
2015	969 146	88 543	36 800	95 %
2016	1 088 767	163 791	32 892	89 %
2017	1 183 868	151 215	74 343	94 %
2018	1 196 156	166 030	51 196	91 %
2019	879 404	123 491	43 823	92 %
2020	1 056 071	143 529	48 059	92 %

Note. Own elaboration with data from FAO (2022).

As far as apples are concerned, Table 7 shows that this crop increased its increased and exports were lower, it retained adequate FSI values in a range between 61 and 77%.

Table 7
FSI Calculation for apples in Mexico

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	630 533	198 481	613	76 %
2012	375 045	235 893	261	61 %
2013	858 608	274 978	269	76 %
2014	716 865	235 502	305	75%
2015	750 325	306 402	313	71 %
2016	716 931	212 678	1656	77 %
2017	714 149	280 930	910	72 %
2018	659 692	278 859	683	70 %
2019	761 483	252 224	606	75 %
2020	714 203	247 522	414	74 %

Note. Own elaboration with data from FAO (2022).

Of the products selected, the one that shows the greatest vulnerability is soybeans. Imports of this crop far exceed national production and have even been up to twenty times higher. On the other hand, Mexican exports of this good were minimal during the study period and, as can be seen in Table 8, its values in the FSI were between 5 and 11%.

Table 8
Fsi calculation for la soybeans in Mexico

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	205 234	3 340 376	85	6 %
2012	247 500	3 477 274	74	7 %
2013	239 248	3 612 685	265	6 %
2014	387 366	3 891 859	353	9 %
2015	341 088	3 890 229	227	8 %
2016	509 114	4 038 864	80	11 %
2017	432 927	4 341 346	528	9 %
2018	324 011	5 175 784	111	6 %
2019	232 680	4 851 030	1253	5 %
2020	246 019	3 900 201	601	6 %

Note. Own elaboration with data from FAO (2022).

Regarding sorghum, it showed strengths in its domestic production, which was higher than imports during the entire period studied. This contributed to the FSI values of this culture being between 73 and 99%, as shown in Table 9.

Table 9
FSI calculation for sorghum in Mexico

Year	Production in tons	Imports in tons	Exports in tons	FSI
2011	6 429 311	2 380 276	297	73 %
2012	6 969 502	1 726 232	386	80 %
2013	6 308 146	1 206 062	5 977	84 %
2014	8 394 057	72 702	7 249	99 %
2015	5 195 389	235 911	1 761	96 %
2016	5 005 837	645 966	653	89 %
2017	4 853 110	427 730	300	92 %
2018	4 531 097	220 378	2 427	95 %
2019	4 352 947	743 650	221	85 %

Note. Own elaboration with data from FAO (2022).

In the case of wheat, it can be identified that its imports were higher than national production during the entire period. The FSI values for this crop were between 42 and 55%, as shown in Table 10, which implies that Mexico is largely dependent on wheat imports to pay for its domestic consumption.

Table 10
FSI calculation for wheat in Mexico

Año	Producción en toneladas	Importaciones en toneladas	Exportaciones en toneladas	IAA
2011	3 627 511	4 047 832	835 908	53 %
2012	3 274 337	4 641 718	612 499	45 %
2013	3 357 307	4 166 753	732 745	49 %
2014	3 669 814	4 503 452	1 263 699	53 %
2015	3 710 706	4 182 851	909 195	53 %
2016	3 862 914	4 683 805	1 517 088	55 %
2017	3 503 521	4 900 848	490 031	44 %
2018	2 943 445	4 920 401	838 956	42 %
2019	3 244 062	4 804 838	736 296	44 %
2020	2 986 689	3 726 125	255 638	46 %

Note. Own elaboration with data from FAO (2022).

4. DISCUSSION

Calculating the FSI for the products mentioned in this study, as shown in Table 11, with data for 1990, that is, for a period before the intensification of trade opening in the mid-nineties, can put the results found in perspective.

Table 11
FSI calculation of the selected products. Data in tons for 1990

Product	Production	Imports	Exports	FSI
Rice	394 388	18 114	25	96 %
Oats	120 671	3931	16	97 %
Cocoa	44 045	3 495	10	93 %
Coffee	440 000	719	190 570	176 %
Beans	1 287 364	330 471	210	80 %
Apple	456 538	4 456	115	99 %
Soybeans	575 366	897 021	74	39 %
Sorghum	5 978 159	2 861 640	4410	68%
Wheat	3 930 934	338 771	2297	92 %

Note. Own calculation with data from FAO (2022).

As can be seen, the severe changes in the FSI occurred mainly in grains such as rice, oats, soybeans, and wheat. Even the FSI increased in some products, compared to 1990 and 2020, such as beans or sorghum.

Other studies that may be useful in contrasting the results of this research include the following:

Ayala et al. (2011) used the FSI to assess the performance of the Mexican agricultural sector, finding that, between 1993 and 2009, food self-sufficiency (calculated for this sector as a whole) went from being close to 100% to approaching only 88%, this in turn was strongly correlated with the increase in trade opening and the deficit in the agri-food trade balance, phenomena that occurred during the same period.

On the other hand, Ireta et al. (2015) found a relationship between the fall in the FSI and the increase in rice imports made by Mexico, which indicates a sustained loss in competitiveness in the trade of this product and the lack of national production to satisfy the supply.

Favila and Herrera (2023) measured the FSI for Mexican rice during the 2010-2018 period, using data from the Agri-Food and Fisheries Information System (SIAP); the resulting FSI values showed to be very similar to those obtained in this research, with only small variations of between 1 and 2%.

Another index that shares the sense of the FSI is the Cereal Import Dependency Coefficient, which is published by the FAO (2022). This coeffi-

cient is calculated over three-year periods and estimates the percentage that imports represent in the apparent consumption of grains. In the case of Mexico, for the 2014-2016 period, this indicator reached a value of 29.8%; for the 2017-2019 period, a value of 37%; and for the 2018-2020 period, a value of 39%; which reflects Mexico's dependence on grain imports and its growing trend.

The results obtained are consistent with what was pronounced in the study by Velázquez et al. (2020), who pointed out that Mexico lost its international competitiveness in grains since the mid-1990s. However, it maintained (or even increased) its competitiveness in those products benefiting from the agro-export paradigm (particularly in some fruits and vegetables).

This is consistent with the Baer and Sadowski (2019)'s work, who pointed out that, since the 1990s, countries assumed one of three possible positions in terms of their food self-sufficiency: a) countries that, due to their availability of capital and natural resources, can aspire to self-sufficiency and export; b) countries whose capital allows them to guarantee their food supply with imports; and c) countries whose food supply is compromised by economic and natural factors. It should be noted that dependence on imports may not necessarily be negative, as long as it allows economic efficiency and food in countries with economic and technological lags, or scarcity of natural resources. In this case, Mexico shows characteristics of group b, at least in those crops that are not oriented toward international markets.

CONCLUSIONS

The designation of basic strategic crops was rightly intended to encourage the production of certain goods to guarantee their supply. However, in practice, this was not enough to offset the effects of open borders, unfair competition, and falling trade barriers. These and other situations increased the intensity of competition and reduced the profitability of producing these crops in Mexico, thus increasing Mexican dependence on food imports.

The FSI is a tool that allows us to measure the extent to which a country is self-sufficient to pay for its consumption of a certain good. For the case of strategic commodities in Mexico, the FSI reveals important contrasts.

The products that showed the highest FSI values, that is, greater self-sufficiency and less dependence on imports, were coffee, beans, and sorghum. These products showed greater than 80% self-sufficiency for most of the period studied. Of these, coffee is the one that shows the most favorable conditions, that is, it shows the ability to supply the domestic market and export significant quantities consistently over time.

The most lagged products were soybeans and rice with self-sufficiency levels below 25% during the study period. Of these, soybean is the crop that

shows the greatest dependence on imports and the lowest FSI values. The rest of the products studied show a moderate and changing dependence on imports over time, although some of them show worrying conditions in which domestic production falls and imports grow, such as cocoa and wheat.

Future lines of research can address these cases in detail, highlighting the incentives and subsidies that exist in the production of each of these crops, and reflecting on how international competition has compromised their viability in national production and their ability to supply the consumption of Mexicans.

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Nature tourism and space production. Case study in an Indigenous Community in the Highlands Region of Chiapas

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— Abstract—

This article analyzes the production of the tourist space in the Río Arcotete community of the municipality of San Cristóbal de Las Casas, Chiapas. The process by which the federal and state governments of Chiapas have created the conditions for an indigenous community that suffers from an agricultural crisis and with accentuated pluriactivity to become involved in tourist services is shown. Under the conditions imposed by the tourism market, the indigenous have appropriated this productive activity, which has generated a dynamic of intra-community changes that strengthen their income, but on the condition of an increasing dependence on tourism. The challenge that the native population now faces is to comply with the circumstances that the market establishes, which weakens it and generates a slow maturation of the tourist destination. The research is qualitative based on primary sources and fieldwork.

Keywords:

Governmentality; tourist space; nature tourism; community organization; Río Arcotete; Chiapas.

There are studies on rural areas of Chiapas that highlight the dynamics of changes and transformations among farmers and indigenous people with the implementation of tourism projects (Sánchez, 2011; Oseguera, 2014). An important aspect they point out is the implementation of tourism policy in the rural sector, which has not had the desired effects due to short-term factors that make it impossible for it to mature in the long term (Sánchez, 2011; Oseguera, 2014). The gap between tourism policy and farmer projects generates slow economic development. This fails to best benefit the tourism-receiving population and mitigate conditions of poverty and lagging (Villafuerte, 2015).

Although Chiapas has a high biodiversity in natural resources that justifies its natural tourism potential, it has not managed to consolidate a market for quality services in this sector. The challenges to overcome are the endogenous weaknesses that persist in the local tourist services market. Chiapas being one of the poorest states in Mexico, fails to overcome the endemic difficulties of the rural sector such as poverty, marginalization, lack of public services, and road infrastructure.

According to the 2010 census figures (INEGI, 2011), the rural population reached 2,460,645 inhabitants, who lived in localities of less than 2500 inhabitants which, if expanded to less than 5000 residents, would be 60% of Chiapas. In 2015, the total population in Chiapas was 5,217,908, that is, 4.4% of the national population. In 2020, the total population is 5,543,828 with 20,951 rural localities and 206 urban localities (INEGI. Population and Housing Census 2020) 51% correspond to rural localities; and 49% to urban ones. In other words, more than half of the inhabitants live in rural areas, therefore, their socioeconomic vulnerability is aggravated. Finally, in 2018, 76.4% of the residents of the entity lived in poverty, which is equivalent to 4,174,600 people (CONEVAL, 2020). In general terms, 94.0% have a situation of poverty and vulnerability due to a lack of income (CONEVAL, 2020). These elements contribute to a scenario of critical poverty in Chiapas. These figures also show an X-ray that does not contribute to a positive reconfiguration of solid projects in the rural sector. On the contrary, problems accumulate that hardly contribute to the consolidation of programs in the medium term.

The difficulties faced by the peasants and indigenous people of Chiapas when inserting themselves into the tourism services market drastically place them in a reality that they cannot overcome: lack of capital, lack of road infrastructure, problems in the generation of social capital, in the agency capacity for tourism and, above all, the accompaniment of the government in the construction processes of tourist destinations in their territories. In the study presented here, in the Río Arcotete community of the municipality of San Cristóbal de Las Casas, Chiapas, the creation of the tourist space is the result of the intervention of the state government and important actors,

such as entrepreneurs and civil society. This mediation disrupted the living conditions of the indigenous people and the way they inhabit their space. However, the participation of the community was of vital importance for the realization of the project.

The importance of the analysis in this study lies in understanding how the tourist space in Río Arcotete was created and the factors that contributed to it. To explain this problem, we rely on the theoretical reflection of Michel Foucault (2004) on governmentality, as well as the notion of construction of space by Henri Lefebvre (2013). Both proposals contribute to the contemporary discussion of tourism in the new/old rural context of Chiapas. In this sense, nature tourism in Río Arcotete is considered a government technology that not only generates territorial changes but also normalizes practices among subjects and a social imagination towards environmental conservation. In addition, this economic activity contributes in the long term to productive pluriactivity among the population.

As for the structure of this article, eight sections are presented through which the analysis of governmentality and the construction of the tourist space stand out based on the justification of "nature" as a commodity. Subsequently, it refers to the research method used and the central theme of the research about the relationship of the Río Arcotete community with the State and the factors that contributed to the creation of a space of tourist value. Finally, it reflects on the importance of the process, and the participation of local actors and the government to generate a nature tourism destination in the indigenous territory, which brought with it new living conditions in the community.

Governmentality and the construction of the tourist space

Governmentality stands as a category that defines two important aspects. First, government projects, whose purpose is to normalize practices between subjects and technologies to maintain a real production regime (Foucault, 2004). Second, it produces a social and spatial order. This order refers to the notion of space as multidimensional integrality, as a social space that involves the various processes and elements of social relations (Lefebvre, 2013). Therefore, the construction of space stimulates power relations, since they have in it a vehicle for the naturalization of the process of domination. The space is no stranger to the underlying contradictions that the very nature of the dispute generates in the definition, use, and control between the actors involved. For Lefebvre (2013), "(social) space is a (social) product" of the social relations that take place in it through a historical process.

The relationship between government technologies, understood as procedures through which power relations are articulated in certain societies,

and the construction of space, derives from the consideration that social space is a transformed space, real, and of social practices. A society that generates practices constantly produces space from a temporal and historical dimension (Lefebvre, 2013). In this process, the role of agents and actors leads to territorial reconfiguration of other global and local transformations, placing and positioning, at the same time, agents and phases on a time scale of medium or long historical duration (Braudel, 1974). For Milton Santos (2000), space is a relational reality. It is the indissoluble set of systems of objects and actions in which the landscape, the territorial configuration, and the territorial division of labor converge. These elements depend on the ability to sustain local and global processes according to their own functionality and dialectics. Space is a part of the social totality that encompasses the economic and ideological-cultural aspects. It involves coexisting relationships, bonds, and relationships and interactions that lead to the construction, transformation, perception, and representation of reality.

Faced with the construction of space, subjectivity (of the actor/agent) is constituted from the technique and practices that the subject applies to himself. This mechanism of subjective control causes subjects to naturalize a regime of truth production as a field of possibilities for individual freedoms.

In this context, the State is an actor that acts as a leader of different objectives to produce and govern subjects in spaces built under a "regime of truth". Therefore, it adds the birth of homogenizing discourses (as government devices) that violently reconfigure the natural and social space and inaugurate a new economic geography, which in cases such as the one analyzed becomes a tourist geography. The latter not only depends on the State, but also on other actors (companies) to facilitate the opening of new investment spaces (capital), processes, and the creation of new natures for the leisure market. In terms of Michel Foucault (2004), this articulation configures a society mediated by the production of specific regimes of "truth". In this way, the State creates space and political conditions for internal or external agents to act freely, as long as it coincides with economic interests or political power.

It is important to point out that government is not the direct imposition of the norm or the law, but is the customary achievement of the agreement of wills between rulers and ruled (Foucault, 2004). Therefore, the construction of a tourist space obeys a regime that establishes the bases, rules, and relationships of the game where the actions of free agents take place, as well as the provision of ideological apparatuses so that a goal is achieved. In general, the objective is the normalization and naturalization of the populations from the control devices, which allows to produce in advanced societies, what David Harvey (2001) has called "capital spaces".

This process becomes the sphere of practices and discourses for the productive sectors in produced spaces. In addition, it generates a process of coordination of actors, social groups, and institutions to achieve collectively defined goals in fragmented environments characterized by uncertainty (Ruano de la Fuente, 2002). Local experiences have resulted in the use of its natural resources, such as goods, but with the nuance of a new socio-territorial reality that emerges with the production of the contemporary tourist space, as shown below.

METHODOLOGY

This research is qualitatively based on a broad review of the written literature on the issues raised, fieldwork in the study communities in July 2018 and from February to October 2019 in which passive, moderate, and active participation was applied (Vallés, 1997) and 15 semi-structured interviews with different relevant actors in the processes studied. To have a more precise picture, interviews were conducted with businessmen and employees of the tourism sector, journalists, academics from local educational institutions, officials of the Ministry of Tourism of Chiapas, tourist guides, and tourists, both national and foreign. Likewise, snowball sampling was applied in 2018 and 2019. stays. This method made it possible to engage with the main local and regional actors of both San Cristóbal de Las Casas and the Río Arcotete community. In this way, positive results were achieved by having a wealth of empirical data to highlight the tourism timeline in San Cristóbal de Las Casas, and Chiapas, in general. However, it is important to note that the information obtained was triangulated with other sources, such as reports and statistical data generated by official institutions such as the National Institute of Statistics and Geography (INEGI) and the Ministry of Tourism (SECTUR) in order to have a correct comparison in the data obtained.

Geographical location of the study site

The Río Arcotete ejido is located in the municipality of San Cristóbal de Las Casas, Chiapas (Figure 1). It is located 4 kilometers northwest of the city's urban layout (Montoya & Hernández, 2013). According to the farmers, it is argued that the ejido was founded by 45 people from other communities surrounding the municipality such as El Aguaje, Agua de Pajarito, Carmen Arcotete, Las Ollas, and Yut-osil II. The latter two correspond to the municipality of San Juan Chamula (Fieldwork, 2019). Many indigenous people were expelled or displaced for having opposed the religious beliefs and "traditional" policies in their communities. Particularly, in Chamula thousands of indigenous people were expelled due to religious and agrarian

problems (Cortéz & Velasco, 2012), and the nearest point of refuge and settlement for the displaced population was San Cristóbal de Las Casas.

Note. Picture taken from Google Earth.

Figure 1. Geographical location of Río Arcotete

The foundation of the ejido Río Arcotete took place on privately owned land. The tension experienced in the early nineties of the twentieth century by the armed conflict of the EZLN brought a demand for the appropriation of land by organized groups. The community joined this claim and the indigenous people decided to manage the creation of the ejido. This group settled on the outskirts of San Cristóbal de Las Casas, and it had the objective of obtaining land and wanted to reach an agreement with the owners of the inhabited properties. Faced with the widespread problems in the Altos de Chiapas region, due to expulsions, migrations, and illegal appropriation of land, the federal government decided to buy land and give it to organized groups. In Río Arcotete, after many efforts, they achieved this benefit. Consequently, the owners of encroached lands were paid and the indigenous people made way to legalize their new space. In 2001 the ejido Río Arcotete[1] was founded with 300 hectares of land (RAN, 2013). The purchase was financed by the federal government through the Rural Credit Bank of the Isthmus. The total population was 120 families that after already established were dedicated to the milpa, sheep grazing, planting vegetables, extracting wood for firewood or domestic use, and the production of charcoal and ornamental plants.

1 The Arcotete owes its name to the French soldier Jean Francoise D' Arcotete, who died in the place for "the love of a young woman from San Cristóbal" in colonial times, according to the legend that is very present in San Cristóbal de Las Casas (González, 2022).

The role of the government in the construction of tourist spaces

Since the 80s in Mexico, the neoliberal policy accentuated inequalities and led to the dismantling of government apparatuses that helped to encourage farmers in their agricultural work. This policy consisted of leaving to the market the determination of the prices of agricultural goods and the fixing of agricultural subsidies and supports based on productivity[2] (Huerta, 2003). The deep agricultural crisis, the trade deficit, public and private indebtedness, the decrease in public spending, and the privatization of public companies, among other aspects, generated more poverty in the majority of the population (Gil-Méndez, 2015). The bulk of these settlers were now in the rural sector, making living conditions more difficult.

At the regional level, the agony of the farmer sector became more chronic. In Chiapas, changes in agricultural policy triggered transformations in lifestyles that would affect the displacement of thousands of farmers towards the poles of economic development. In this way, a crisis in the agricultural sector and a deficit in production were accentuated (Villafuerte Solís, 2015). The fall in grain prices and the dismantling of institutions that guaranteed subsidies to the rural sector led to a relative orphanhood of farmers.

Coincidentally, the change in the economic model (from welfare to neoliberal) promotes nature[3] tourism as a device for economic development, environmental conservation, and poverty alleviation (Sandoval, 2006). Nature tourism is proposed as a project that generates long-term economic changes. In addition, it is considered a tourist modality that proposes a closer interrelation with nature, concerned with the conservation of the natural and social resources of the area in which the tourist activity is carried out (Miroglio, 2017). Due to the national conjunctures, Chiapas consolidated nature tourism in the rural sector, proposing it as a component of economic and territorial development.

The State was the piece to create a tourist geography and a leisure market in Chiapas. The construction of tourist spaces was in the logic of generating a spatiality of tourism as a component of the vitality of the farmer economy. This generated the implementation of economic mechanisms that contributed to a market economy where tourism would be the most relevant productive

2 In Mexico, subsidies to farmers and smallholders are not set according to productivity, but are oriented towards direct support (per hectare) regardless of the level of productivity. One example was the Programme of Direct Support to the Countryside (PROCAMPO) in the 2012-2018 six-year term.

3 Internationally, the discourse favors the adoption of green tourism as a balance between social, economic and ecological tourism as opposed to conventional mass tourism. Tourism takes on various adjectives, but it continues to be the industry that now seeks market segments in natural reservoirs and tourist attraction enclaves. The sustainability claim favored its appropriation in the political, business, and academic sectors.

component. It was no wonder that, on a national scale, in the first decade of the 21st century, the annual value of the formal market for tourism activities linked to nature exceeded 750 million pesos. The expenditure of international tourists represented 64.2% of the total, that is, 486 million pesos, while the expenditure of national tourists was 35.8% that is, 271 million pesos (SECTUR, 2006). This escalation of capital forced a restructuring of the planning scheme in the government bodies responsible for promoting tourist destinations.

The government's participation was expressed in the common objective of the market: to normalize the practice of nature tourism among Chiapas farmers.[4] Many of the experiences that were born since the 1990s were of rural microenterprises focused on ecotourism. In each case, government agencies such as the Ministry of Tourism (SECTUR), the Ministry of Environment and Natural Resources (SEMARNAT), the Ministry of Economy (SE), the Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food (SAGARPA), the Ministry of Social Development (SEDESOL), the National Commission for the Development of Indigenous Peoples (CDI), the National Commission of Natural Protected Areas (CONANP), the National Fund for the Promotion of Tourism (FONATUR), the Tourism Promotion Council of Mexico (CPTM), and the National Forestry Commission (CONAFOR) have been key to the promotion[5] of nature tourism projects, which was concretized with proposals for investment and development of tourism infrastructure. In addition, the strengthening of the "nature" component was a symptom of the new economic order that the tourism market was imposing. The consumer market of "the indigenous", "the cultural" and "the natural" was joined in the 90s by the implementation of nature tourism in Mexico. Likewise, environmental conservation and sustainable development at the international and national levels were two categories that forced change in public policy.

4 The data indicate that after the year 2000, an outstanding turnaround was registered in the traditional centers with the highest tourist attendance. For example, Tuxtla Gutierrez with 1,780,040 tourists; Tapachula with 788,268; San Cristobal de Las Casas with 1,394,363; Palenque with 1,019,621; Comitan with 459,267; and Chiapa de Corzo with 426,293. In this way, the state received around 7,722,289 visitors, which represents a greater influx compared to the same year in 2018 (6,620,042) (Ministry of Tourism, 2019). The accumulated economic revenue in 2019 was $23,908,000.00, increasing compared to 2018 ($21,607,000.00). The cumulative average hotel occupancy was 42%, higher than in 2018 (41%) (Ministry of Tourism, 2019). For their part, ecotourism centers in 2016, according to the Ministry of Tourism, reached 90 throughout the state, of which 55 offered services (López, Mazariegos & Milla, 2016). These data represent the importance of the globality of tourism and its practical consequences in the territories of Chiapas.

5 In 2006, a total of 1,239 enterprises and projects offering nature-based tourism services were registered in Mexico. 70% were operating enterprises and 30% were initiatives under development. 74% were community or social, mainly comprising rural or indigenous groups, and 26% were private. By 2016 these were reduced to 1,186 offering nature tourism (SEMARNAT, 2022). This economic change had an impact on new territorialities and also demonstrated the importance of the state in creating the conditions for the promotion of nature tourism.

Due to the social, economic, and political situations that had been dragging on since the 90s in the farmer and indigenous sector, the government of Chiapas promoted a strategy of socio-productive transformation, consisting of promoting business proposals focused on trade and sale of services, to diversify income among the rural sector. The crisis, in part due to the poor performance of the Chiapas economy coupled with a poor distribution of income, justified and forced these changes. For example, between 1990 and 2000, 74.5% of the population earned less than a minimum wage, a situation that reflected the conditions of poverty experienced by the majority of Chiapas residents (Villafuerte Solís, 2015). This scenario led to government-driven projects being adopted without major problems.

In the official discourse, tourism activity was now presented as an economic option to correct the conditions of poverty and marginalization in Chiapas (Mendiguchía, 2005). However, the structural conditions of poverty and marginalization of the farmer population paradoxically prevented the development of the projects. However, the route had already been promoted for several decades. The history of investment in tourism dates back to 1988 with the so-called "road modernization". The implementation of 11 583 kilometers, of which 6.3% were dirt, 69.9% coated, and 23.8% pavement, led the Bank of Internal Commerce to invest in tourist centers, entertainment centers, shops, and supplies in general (Vázquez, 2019). The function of the federal and state governments was to "facilitate" the construction of tourist spaces to give economic value to the regions of Chiapas.

The conjuncture condition and the "zapatour"

In the 90s, political changes in Chiapas forced the implementation of economic support programs for the agriculture sector. The birth of the Ejército Zapatista de Liberación Nacional (EZLN) political movement, in several indigenous regions with serious problems of material poverty, questioned the structures of the Mexican State (Solís & Aguilar, 2021). The EZLN, which coincides with the entry into force of the North American Free Trade Agreement (NAFTA), marked an obligatory route to carry out socio-economic development projects by the federal and state governments.

This situation in which Chiapas was identified only by the armed conflict was taken advantage of by the State government. In the late 90s and early 2000s, it was sold to Chiapas as a nature destination. The objective was to minimize the negative image of a "poor and abandoned" Chiapas, as the EZLN had disseminated it. The arrival of a type of politicized tourist (Coronado, 2008) who was interested in observing marginalization and poverty, paradoxically led to market conditions in tourism consumption: lodging, transport, and food.

After the so-called "zapatour", which consisted of people visiting Chiapas to get to know the Zapatistas for everything that was divulged about the indigenous peoples in rebellion, the State government took advantage of that image of the native groups to promote the natural resources and culture of Chiapas. In this way, "the indigenous" and "the cultural" were used by tourism companies and the state government as a commodity to offer in the tourism market. The objective was to promote an image of Chiapas as a natural destination under the protection of "the ancestral" peasant and indigenous peoples. Through a whole marketing campaign, rural spaces, which only figured in the imaginary and anthropological "rescue" literature as static societies without changes in historical depth (Trench, 2005), were reconfigured towards nature tourism and cultural tourism.

According to the government of Chiapas, the modernization of tourism in the region would come through the promotion of the cultural and artistic beauty of the native peoples. The new tourism geography would give way to local tourism projects and initiatives in the peasant and indigenous sectors. Many of them would obtain resources from the federal and state governments and would give way to new social, family, business, community, or individual microenterprises. This is how new tourist centers were born in several regions of the state such as the Tojolabal Comiteca Plateau: Causas Verde, UNINAJAB, Gallo Giro, Mam Tziscao; in Soconusco: Mariposas Alas de agua, Barra de Zacapulco, La Palma, Volcán del Tacaná, La Ruta del Café in the Aargavia, Liquidámbar, Hamburg and La Casa Grande estates in Unión Juárez; in the Isthmus-coast: El Castaño, Mapastepec, Cabeza de Toro and Madresal in Tonalá; in the Altos Tsotsil-Tseltal region: El Corralito, Oxchuc, Rancho Nuevo, Las Grutas del Mamut in the Agua de Pajarito community, El Arcotete and the Arcotete community in San Cristóbal de Las Casas; and the Zoque valleys: Sima de las Cotorras in Ocozocoautla.

Overall, in just three decades the tourist geography of Chiapas made qualitative leaps in the development of tourist spaces in the peasant and indigenous sectors. The case analyzed in this research, Río Arcotete of the municipality of San Cristóbal de Las Casas, Chiapas, is located in this context of changes and transformations. With the coverage of the government and other important actors, it will develop as a primary tourism destination, as we will see later.

The construction of the tourist space in Río Arcotete

The Río Arcotete ejido was born in 2001 and consolidated as a nature tourism project in 2008. It is located in an area whose existing natural resources are the limestone arch that is crossed by the Fogótico River, a pine-oak forest, a tributary of water, and caves that - according to the inhabitants of the area

- have a long tradition in the cult of "spirits" (Fieldwork, June 2019). These resources are considered potential assets for a sector of tourists seeking recreation and aesthetic contemplation of nature. Although the tourism proposal is proposed as a local and collective initiative that was born by the indigenous people of Río Arcotete (Picado, 2014; Montoya & Hernández, 2013), what was observed in dialogue with the inhabitants is that the context of social and economic vulnerability due to the crisis of the countryside and its subsistence conditions forced the search for new productive options in early 2000 among these options, tourism.

The above was important, in the regional scenario, the crisis in the countryside that had been dragging on for decades also affected the indigenous people. With the change in agricultural policy, the lack of subsidy for agrochemicals and the little support they had from the government sharpened their living conditions. The changes that had originated forced them to look for other economic activities since the yield they obtained from their lands covered the basics of their food needs. There was no surplus to market, as they point out:

> When we came to live on this side and when we legalized these portions of land, we already had problems working the land. The government didn't support us in getting fertilizer or grains or buying. The little we produced was used to eat, nothing else. Yes, there was support from other things, but not for the land or the purchase of animals, because they told us they would help us, but they never did. We were forced to look for work [...] we heard that the new government would support the creation of tourist centers and as we had some acquaintances, over the years we managed to start working in tourism, although many colleagues were not convinced, but it was achieved after several years of work (Pedro Gómez, personal communication, February 2018).

This response is evidence of the lack of support and monitoring by government institutions in the agricultural sector. Consequently, indigenous people sought income in other productive activities.

Public policies were given: the regime had been promoting the development of tourist destinations. The state government needed to justify its intervention and help strengthen the Pueblos Mágicos Program since San Cristóbal de Las Casas had acquired this distinction and Río Arcotete belonged to this municipality. In addition, peasant and indigenous discontent, which began in the 90s with the armed uprising of the EZLN, provided an environment for some businessmen, alongside the indigenous people, to express their interest in opening spaces for the business of nature tourism. Another important aspect was that the natives of Río Arcotete managed to create a tourist center.

90% of the indigenous people interviewed in Río Arcotete recall that the production of goods for self-consumption failed to meet their needs. In fact, due to the lack of subsidy for the field and the low yield of corn cultivation - scarce 600 kilos a year - many of them had to work in other productive activities. A fraction of the population of Río Arcotete migrated to the city of San Cristóbal de Las Casas in search of income and another to cheap labor receiving centers such as Cancún, Distrito Federal, and Puerto Vallarta. Those who stayed in their place of residence worked in the fire-wood trade selling roastery chickens or worked for the foreign population that liked to use fireplaces in San Cristóbal de Las Casas (Juan Hernández, personal communication, 2021).

Under the conditions they experienced, it was not difficult for this sector of the population to adapt socially to tourism. 80% of the indigenous people interviewed did not hesitate to affirm that one of the objectives of promoting tourism in their territory was the search for income and well-being in their families (Juan Hernández, personal communication, 2021). Other activities that are now dedicated to nature are the planting of beans, potatoes, and chilacayotes and then selling them in the José Castillo Tielemans market in San Cristóbal de Las Casas.

An important factor that influenced the creation of the tourist space was the increase in the flow of tourists in the city of San Cristóbal de Las Casas. First, because of the curiosity to meet the indigenous peoples who were "protagonists of the armed movement"[6]; and second, because of the result of the national and international dissemination of this city as a Pueblo Mágico (SECTUR, 2014). The latter resulted in the celebration of the Miss Universe 2007 contest, the Festival of Cultures 2009, Nuestra Belleza Mexico, and the International Adventure Tourism Festival, the most important national and international events. These programs fostered an interest in local entrepreneurship (hoteliers, restaurateurs, tour operators) and favored an agreement with the indigenous people to rethink a tourist destination in the Río Arcotete community.

The Río Arcotete community is located 4 kilometers from the city of San Cristóbal de Las Casas. The proximity between it and this city generated a tourist route. In addition, the beauty of the place has been the pretext for the rest of the social class that likes leisure (professionals, doctors, teachers, and microentrepreneurs) (Hernández, personal communication, 2020). The investment in this tourism project was made by the state government, and

6 This has been mythologised, because in reality, of the 18 indigenous municipalities in the Altos region, a fraction in the town of San Andrés Larraínzar participated in the armed movement. However, this discourse is used only for tourism purposes.

the business sector helped to promote it. The Jovel Valley Basin Committee made up of members of civil societies, has also participated in reforestation and biodiversity conservation programs in territories of indigenous populations. These actions have created expectations for a new nature resort in the peri-urban area of San Cristóbal de Las Casas. From being a "vacant" land, but private and usable only for agriculture, in a few years, it became a space for tourists. This has been the path towards the normalization of tourism in the indigenous context of Río Arcotete.

The influx of tourists to San Cristóbal de Las Casas[7] changed the appearance of the city. This phenomenon brought with it the increase in establishments for lodging, restaurants, bars, and shops, as well as the conditioning of the Historic Center (Hernández & Fenner, 2018). These circumstances were taken advantage of by organized businessmen made up of hoteliers and tourism service providers under the Arcotete Ecotourism Board, who requested the creation of an ecotourism park in the Río Arcotete community. This project raised an investment of 15,000,000 MXN for infrastructure. The inhabitants of the ejido accepted the proposal and contributed to generating the conditions and financing for such construction in their territory (RealEstate, Market & Lifestyle, 2010).

The alliance between indigenous people and local entrepreneurs yielded good results. Proof of this is that in 2014, the National Commission for the Development of Indigenous Peoples (CDI) and the Ministry of Tourism (SECTUR) allocated 27,000,000 MXN for training and promotion of ecotourism in indigenous communities. This was as part of the Alternative Tourism Program in Indigenous Zones (PTAZI) (Ministry of Tourism, 2014). This social policy of the federal and state governments to invest in vulnerable populations led to the creation of the Arcotete Tourist Center, whose contribution was 596,024 MXN. The executor was the Ministry of Social Development (SEDESOL) of the federal government. With this amount, walkers, palapas, rustic staircases, and bathrooms were built. This stage began as a new tourist destination in the peri-urban area of San Cristóbal de Las Casas. In the short term, other institutions such as the National Commission for the Development of Indian Peoples -formerly called CDI- were convened to contribute 1,407,917.55 MXN (Montoya & Hernández, 2013). This amount would be used to strengthen the tourist infrastructure with parking, zip lines, cabins, horses, rappels, and more.

The creation of this space required the ejidatarios to cede 23 hectares exclusively for tourism demand. On the other hand, the state and

7 This came about in the following years out of curiosity about the colonial city of San Cristóbal de Las Casas, Chiapas, the insurrection Ejército Zapatista de Liberación Nacional (EZLN) and the political, religious, and territorial disputes in the region.

municipal governments were responsible for creating market conditions. That is promotion, dissemination, route, and accompaniment in training and tourism training through a network of institutions. Since the founding of the Arcotete Ecotourism Center, indigenous people have had around 20 courses, workshops, and training in customer service, restaurant service, gastronomy, culture, and tourism guides, among other skills (Pérez, personal communication, June 2021). An advance in this tourism company was the formalization of the Indigenous Cooperative Society by 120 members who own the tourist center. This was done for administrative, legal, and operational purposes before the government bodies. Until this stage, the federal government enhanced the conditions for the creation of a new destination, as the Arcotete tourist center was considered. In the interviews conducted, 80% of the partners reiterated that the federal and state governments supported them in creating their ecotourism center, as can be seen in the following quote:

> The entrepreneurs and the government's support is not denied, they have also trained us in many things. Since we were founded, people have come from universities, research centers, students, tourists, and professors. Therefore, tourism support is not denied, although there hasn't been any more support for the crops. Now, according to the Secretary of Tourism of the city council, they told us they were going to train us if we wanted, to handle computers and for young people to get into tourism, but we have not decided in the assembly (Hernández, personal communication, June 2020).

The above shows the significant progress they have had as a microenterprise and the tourist influx in the community, for which the institutions seek to know the experience of the indigenous people.

From farmers to sellers and consumers

Pluriactivity is a trait today. So far, 90% of the inhabitants of the Río Arcotete community are engaged in various productive activities. However, subsistence agriculture, particularly milpa, and vegetables, as well as ovinoculture and livestock farming are less developed. Rio Arcotete residents have quickly transitioned from agricultural to commercial and service work. The traditional form of family organization, conceived as a structure where members cooperate in the domestic economy, has been disrupted. This is how some members of the family do not cooperate, others migrate and no longer contribute financially. However, those who stay -which is the new labor composition of the families of the community- are forced to help others (women, children, young people, and the elderly) for the domestic economy. Now everyone works at the ecotourism center. This is part of the changes in the rural landscape.

On the other hand, in 2018, around 18,000 tourists arrived in the aforementioned community, and with it an economic spill that encouraged the collective work of the indigenous population of Río Arcotete. The entrance to the tourist park has a cost of 10.00 MXN, which, in real terms, generates approximately 180,000.00 MXN of annual gross income. Added to this are the services offered in tours to the caves (10.00 MXN), boat ride (20.00 MXN), horseback riding (30.00 MXN), zip line (100.00MXN), abseiling (150.00 MXN), and camping (25.00 MXN), among others, which causes tourism income to increase (Field Notes, September 21, 2021). The income, subtracting the operating costs, returns them and excites them to devote themselves to tourism. Therefore, the peasants are assumed as tourist servers. In addition to having standardized these practices, they see themselves as guides for visitors (Artemio Girón, personal communication, June 2019). However, tourism has gained ground by slowly displacing other productive activities.

The Río Arcotete Ecotourism Center is currently a place of recreation for San Cristóbal de Las Casas families and tourists. With the incorporation of tourism activity in the community, conditions have improved in basic public infrastructure services such as roads, electricity, and drinking water. The transition from the productive agricultural model to the tertiary sector gives a new functionality to the territory and, in turn, determines new uses of the land. The use of space for specialized activities such as tourism has led to advances in infrastructure, investment, and changes in domestic structure. One of the latter is the consumption of goods that they did not have before, such as junk food, alcoholic beverages, and cars. So, the people of Río Arcotete went from agricultural workers to consumers and self-employed.

In the speech, the population of this community accepts the challenge of seeing themselves as entrepreneurs of nature tourism, although in the end, their practices do not help, as deforestation continues. Some farmers are engaged in cutting down trees to obtain firewood that is sold in San Cristóbal de Las Casas. This is contradictory: on the one hand, nature tourism is promoted; and on the other, it is destroyed. Meanwhile, the ominous silence of the official authorities causes the image of environmental conservation and tourism in the hands of indigenous people to continue to be created. For them, the most important thing is the "generation of employment and self-employment", despite the tree felling and the damage it causes to the environment.

The role of the Assembly in conflict mediation

In general, it is assumed among indigenous people that tourism is an extremely important activity that has required agreements, consensus, and dissent. Even though there is a collaborative work, based on legitimate

economic interests among the inhabitants, conflicts have been generated. However, they settle, because collectively they want to improve their living conditions and certain patterns to harmonize work in tourism.

The type of organization that the community has had for decades requires the Community Assembly as the axis that regulates social behavior and contributes to resolving tensions among the inhabitants. This has resulted in organizational, administrative, and participation benefits, not only functional but also effective for tourism activity. This has also helped the assembly to achieve a better articulation with economic and political actors interested in tourism. Thus, the interrelationship between community and external actors articulates a balanced working dynamic. Although there are displays of autonomy in decision-making, as there are alliances, negotiations, and appropriations in the territory about tourism that takes place in the indigenous territory. The assembly, then, has a preponderant role in mediating conflicts and helping the tourism project to move forward, despite the absence of actors who at one stage were involved, and who over the years have withdrawn.

FINAL THOUGHTS

The process experienced by the farmers of Rio Arcotete speaks of a consensual social restructuring based on nature tourism. This transformation explains the depth of the crisis in the farming sector in Chiapas and its repercussions in all rural areas. The imprint of state governmentality in creating market conditions and new tourist spaces that normalize behavior in the long term is also evident. Undoubtedly, Río Arcotete stands as a transformed, real, and practical social space. It is a produced area where power relations are generated, as it defines the use, control, and exploitation of natural resources. Indigenous people now reconfigure their labor dynamics territorially, by global and local times. Tourism has placed them in a dynamic work schedule where they are forced to make social, family, and work-related adjustments. Thus, a new territorial division of labor is generated. This process has sustained the people of Rio Arcotete for several years. However, it has been functional for their economic interests and lifestyles in the community.

The production regime created by tourism has led farmers to subjectively assume the importance of this activity and gradually normalize environmental conservation while relying on the state for income through government programs.

The normalization of tourism in the Río Arcotete community is gradually acquiring the character of a social and economic fact. The transition from a primary to a tertiary production model points to an important fact: the strategy

of planning the tourist space by local and external actors whose interests are economic. The change from a rural space for milpa to one for recreation and tourist visits, speaks of a market logic and the government's support to sustain it. However, the activity itself brings other problems among the inhabitants, such as the need for infrastructure, agency skills, and capital development. Consequently, more social energy and new socio-productive strategies for work are required. These components are nuanced and the state fails to be the real expression of the desired economic development among the subjects.

The rural territory sets limits to the accumulation of capital, as the conditions for the expanded reproduction of the capital they derive from tourism are not yet in place. Farmers are in a slow stage of economic progress, and despite being pluriactive, there are historical conditions that weigh on them. For example, in the general scenario of Chiapas, the structural condition of poverty (74.7 %) and extreme poverty (46.7 %) (Levy et al., 2016) prevents the coexistence of positive conditions to overcome inequality and, therefore, the social conflicts generated by precarious employment, in the countryside and services.

Tourism and environmental policy, as a technology of government (Foucault, 2009), operated in the Río Arcotete community to minimize the political and social situation experienced in the 1990s. With tourism as a life project, patterns of normalization of this activity and a socio-organizational dynamic within the rural territory are instrumentalized. These changes reinforce the idea that projects 'from above' are effective - at least in discourse - although on the condition that they have limits and contradictions 'from below' since the *habit* generates resistance to social change. At least in Rio Arcotete, this verticality of public policy has been positive, as economic interest forced different sectors to negotiate and compromise.

The diversity of leadership that emerges in the community, whether through individual or collective experiences, generates ideas, actions, and political relations. It also gives rise to power relations and various forms of exercising control over natural resources and tourism activity. In this situation, the government appears as the creator of space and plays a central role, because capital alone does not produce space, but the government is needed, through economic policy echoes the needs of capital.

The indigenous territory in Arcotete is the expression of the dominance of a regime of truth, just as Foucault suggests, it is the historical dispersion of discourses that are created as a function of power, in this case, the discourses that oscillate in the tourist market, as cost-benefit criteria are prioritized and responsibility is awarded to the users (the indigenous people who have to protect the natural resources for tourism). Consequently, in the long term, the same criteria, truths, and logic that dominate the market

economy and competitiveness will be reproduced, a logic in which the criterion of conservation and economic development ends up being imposed.

These effects have been internalized in the population of Rio Arcotete. For example, from being landless farmers, they now take on the role of micro-entrepreneurs in nature tourism. This fact generates multiple identities that are constructed in the fragmentation of discourses in favor of subsistence alternatives, but under a common history: the rural. However, the paradox is that they are constructed as subjects and objects of agrarian and environmental public policies and recreate an internal and external reality where tourism is seen as an economic development activity. In this imagination, the idea of 'the indigenous and cultural' is sold as intangible goods appreciated by the tourist market. The farmers of Rio Arcotete are subjects forced to negotiate, but subordinate to the local businessmen who reinforce the tourism routes. As subjects/products of the market and the state, they do not achieve economic autonomy, as they remain a society dependent on external financing. There is no economic self-management as a tourism project. They therefore maintain a relational tension that forces them to construct semantic fields in order to reinterpret their social and economic world and thus to negotiate. This is why farmers strengthen their institutions (the assembly and the rules) in order to act, think, and feel according to the context.

Río Arcotete is an example of governmentality violently reconfiguring indigenous territory, generating new territorial divisions of labor, social relations, and institutional arrangements that are slowly internalized. Although indigenous people enjoy a positive social construction by government institutions, they have not been able to fully adapt to the radical changes in their lifestyles. From the government's point of view, voluntary participation is important and may or may not be effective. Indigenous people are often seen as lacking the political power to effectively demand the full backing of the government and their impoverished situation gives them no real choice. The crises have left them in a state of helplessness and they are now left with the option of accepting and distributing their time in various productive activities, to earn various incomes to subsist.

The political use of tourism is the palliative to poverty that has been dragging on for decades. This discourse is internalized with all the social and cultural complexity among farmers and is generalized day by day by the implementation of environmental conservation standardization programs. The result is that in the community there is community tourism where all the indigenous people are integrated into the project. In the last decade, the boom in nature tourism permeated the territory, in such a way that economic changes were brought about by the influx of tourists. This

experience made up for the few benefits obtained from other activities such as agriculture or the sale of their labor force.

In general, the type of tourism developed by the inhabitants of Río Arcotete has a long way to go before it can be consolidated. Indigenous people continue to depend on the government through its economic and social development programs. This endogenous weakness obstructs local capacities and prevents the development of nature tourism, as there is no economic self-management.

From a market point of view, despite possessing the potential to build a nature tourism destination and an underpinning corpus of individual and collective rules, policies, and regulations, the people of Rio Arcotete are unable to move beyond the problem of reorganization to raise capital to invest in infrastructure and generate agency to be self-managing. These issues prevent them from advancing and consolidating their offer as an ecotourism center and not depending on other actors such as local entrepreneurs, who are, in many cases, the direct beneficiaries of the sale of tourism services.

However, the indigenous people have adapted to the rules of the tourism services market. Day to day they experience how to do business in their territory, deal with the kind of government that almost abandons them, and face other difficulties. They now rely on other local and regional actors to drive the process of creating demand for these new tourism spaces. As a result, the process of economic autonomy is still underway. The challenge is to emerge from the apparent prosperity that tourism could bring and to balance its productive pluriactivity.

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Evaluation of the polyol/diisocyanate molar ratio in the physicochemical properties of biopolyurethane produced from poultry fat

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— Abstract—

Conventional polyurethanes are the most demanded plastics in the world, they are manufactured from petroleum derivatives which is a non-renewable resource and contributes to environmental pollution. However, biopolyurethanes are produced from renewable sources, such as vegetable oils or plant-derived sugars, which help reduce dependence on fossil fuels and decrease the carbon footprint. The synthesis of biopolyurethanes makes it possible to adjust the properties of the final materials to suit different applications such as the automotive industry, construction, furniture manufacturing, and textile industry. They can vary in terms of strength, elasticity, stiffness, and load capacity. These characteristics depend on the chemical structure and concentration of the polyol and diisocyanate with which they are produced.

This paper describes the synthesis of polyurethanes using polyol from poultry fat and isophorone diisocyanate and the effect of the polyol/isocyanate (OH/NCO) ratio on the physicochemical properties of polyurethanes obtained. In the infrared spectra (FTIR) was observed the presence of the band 3350 cm^{-1} corresponding to the -NH bond and the absence of stretching of the isocyanate group (NCO) to 2270 cm^{-1}, indicating that all isocyanate groups reacted during polymerization. Polyurethanes generated with molar ratios polyol/isocyanate (OH/NCO) 1: 3, 1: 4, and 1: 5 were evaluated, observing that the higher the molar ratio increases the rigidity and compressive strength of biopolyurethane, probably due to the greater formation of crosslinks.

Keywords:

Bioplastics; waste; stiffness; compression.

Polyurethanes are versatile polymeric materials that, from the synthesis developed by Bayer et al. in 1937, have been used to generate products with different characteristics such as resins, coatings, flexible and rigid foams, elastomers, and adhesives. Among these applications, rigid and flexible foams have been mainly used in the transportation, construction, packaging, and furniture industries. Polyurethanes are polymers that are generally produced by polyaddition reactions between polyols and isocyanates, which, depending on their structures, will be the physical-mechanical properties of the polyurethane obtained (Shen, et al. 2019). For example, Kasprzyk and Datta (2019) observed that the concentration of isocyanate groups in the prepolymer affects the degree of phase separation of the hard segment that can be correlated with the chemical structure and mechanical-dynamic properties of the polyurethane. Moreover, Zieglowski et al. (2019) researched the reactivity of Kraft lignin modified with different commercial isocyanates in the reaction with conventional polyols, identifying that the morphology, modulus of elasticity, and density are different in all the polyurethanes obtained. Daneshvar et al. (2019) prepared adhesive polyurethanes using poly 4,4'-diphenyl methane diisocyanate and toluene diisocyanate (TDI) in different NCO/OH and sawdust polyol ratios, observing that by increasing the NCO/OH ratio to 1.7, the shear force increased.

As can be seen, different efforts have been made to develop biopolyurethanes using polyols or isocyanates of biological origin. The synthesis of polyols from vegetable oils such as sunflower, fig, soybean, castor, palm, olive, flaxseed, grape seed, corn, jatropha, and rice bran oil are mainly described (Ang et al., 2014; Calvo-Correas et al., 2015; Fu et al., 2019; Ismail et al., 2011; Narine et al., 2007; Purwanto, 2010; Rosnah et al., 2016; Shen et al., 2019; Valero et al., 2008). However, these oils, since they are edible, generate controversy regarding their use for industrial purposes. Poultry fat has been used as a raw material for the production of biodiesel, biolubricants, and polyols (Galeano & Guapacha, 2011; Rojas & Girón, 2011, Ramírez et al., 2023). This project proposes the use of polyol of poultry origin for the production of biopolyurethanes and its study on the effect of the OH/NCO molar ratio on their physicochemical properties.

METHODOLOGY

Synthesis of polyol from poultry fat

Poultry fat was extracted, purified, and characterized as described by Hernández-Cruz et al. (2015). The methodology described by Ramírez, et al. (2023) was used to obtain the polyol. wherein the poultry fat was epoxidized by adding acetic acid and hydrogen peroxide in stoichiometric relation

to the number of moles of double bonds present in the oil. To determine the number of moles of the double bonds of poultry fat, the iodine value was used according to the following formula (equation 1):

$$(1) \quad mol(=) = IY/(2\ x\ Mi\ x\ 100)\ \ x\ P$$

Where:

mol (=) mol of the double bonds present in the oil
IY= 63.09 I_2/100g.
Mi= molecular weight of iodine in grams.
P = weight of sample in grams.

Subsequently, according to the calculations obtained, the sample was placed in a 3-neck flask, acetic acid (CH_3COOH) was added, and as a catalyst H_2SO_4. The reaction was kept under constant stirring (350 rpm) in an oil bath at a temperature below 30°C, then at this same temperature H_2O_2 was added dropwise over 30 minutes; once added, the temperature was increased and maintained for 6 h. After the reaction time, 5% v/v sodium bicarbonate was added, stirred and the contents of the flask were placed in a separatory funnel to perform washes by adding 10% $NaHCO_3$ twice, then water, and finally 5% $NaHCO_3$ until neutrality was reached, which was measured with a model potentiometer Session 3 (HACH, Colorado, USA) with a model pH electrode 51935-00 (HACH, Colorado, USA). Finally, 20% w/w anhydrous Na_2SO_4 was added to the organic phase to remove any remaining traces of water from the washes (Salimon et al., 2014).

To characterize the synthesized polyol, an IR spectroscopy was performed using an IR Nicolet™ spectrophotometer (Thermo Scientific, Massachusetts, USA) in the range of 650-4000 cm-1 with a resolution of 4 cm-1 and 16 scans (Jayavani et al., 2017). The structure of the polyol was confirmed by 13C nuclear magnetic resonance (NMR) using a model DD2 (Agilent, California, USA) of 500 MHz. Experiments were performed at 25°C and deuterated chloroform as solvent. After dissolving 5 mg of the sample, approximately 1 mL of the solution was transferred to a 5 mm NMR tube. The sample tube was inserted into the magnet and allowed to reach thermal equilibrium for 10 minutes before the experiment.

The acid number was performed according to the official AOCs Te 1a-64 method (2009). For the determination of the hydroxyl number of the polyol, the methodology described by Zhang et al., (2015) was used. 1 g of sample was placed in a 50 mL flask, 10 mL of tetrahydrofuran (THF) was added, and the contents were mixed with the aid of a magnetic stirrer; to this solution, 10 mL of catalyst solution (1 g of pyridine in 100 mL THF) was added followed by 5 mL of acetylating solution (5 mL of acetic anhydrous in 50

mL THF) and stirred for 10 min at 25°C, then 10 mL of hydrolysis solution (20 mL of water in 80 mL THF) was added and the stirring continued for 30 min. This solution was titrated potentiometrically with the standard 1 N ethanolic KOH solution, using the potentiometer model Session 3 (HACH, Colorado, USA), with a pH electrode model 51935-00 (HACH, Colorado, USA) until the first pH change was observed. Calculation of the hydroxyl number was obtained by equation 2:

$$OHN = \frac{(V2 - V1 * N * 56.11)}{m} + AN \quad (2)$$

Where:

OHN is the hydroxyl number value
V_2 is the volume of KOH spent during blank titration
V_1 is the volume of KOH spent during sample titration
N is the normality of the KOH standard solution
m is the weight of the sample, g.
AN is the acid value of the sample.

Obtaining polyurethanes

Polyurethanes (PUs) were obtained according to the methodology described by Zhang et al., (2014) with modifications. The synthesized polyol was mixed with isophorone diisocyanate (IPDI) in OH:NCO molar ratios of 1:3, 1:4, and 1:5, using ethyl methyl ketone (EMC) as solvent (5mL). The components were brought to 70°C and mixed continuously for 30 min. Subsequently, the mixture was poured into 8 cm x 4.5 cm (length x width) silicone molds, which were dried for about 14 days. Finally, the PU sheets were cut into specific dimensions for mechanical testing.

The polyurethanes obtained were characterized by Fourier transform infrared spectroscopy according to the methodology described above.

Compression properties were evaluated according to the methodology described by Acuña et al. (2021), using an EZ-SX model texturometer (Shimadzu, Maryland, USA) following the ASTM D1621 standard with a sample size of 5 cm x 5 cm x 3 cm and a speed of 3 mm/min.

RESULTS AND DISCUSSION

The polyol synthesized under the conditions described had an acid value of 12.63 mg KOH/g (Table 1), a value higher than that observed in the poultry fat used as raw material. This increase in acid number checks for the presence of acidic hydrogens, i.e. hydroxyl groups (OH) in the reaction product corresponding to the polyol.

On the other hand, the quantification of the hydroxyl number (OHN) for the polyol was 70 mg KOH/g, a value close to the prediction of the model described by Ramírez (2023), which was 78 mg KOH/g. Comparing the hydroxyl number values with other investigations that produce polyols from vegetable fats, the hydroxyl number values obtained in this study are lower (Table 1).

Table 1

Acid index and hydroxyl number of the polyol from chicken fat and polyols from vegetable oils (Shen et al. 2019).

Sample	Acidity index (mg KOH/g)	Hydroxyl number (mg KOH/g)
Raw matter (chicken fat)	0.89	-
Chicken Fat Polyol	12.63	70
Soybean Oil Polyol	-	150.4
Flaxseed Oil Polyol	-	190.8
Olive Oil Polyol	-	190
Grapeseed Oil Polyol	-	270
Rice Bran Oil Polyol	-	232

This difference in results may be due to three factors; firstly because the vegetable oils used for this purpose have higher percentages of polyunsaturated fatty acids in their triglycerides (Table 2); therefore, there is a greater likelihood that these double bonds generate a greater number of hydroxyl groups (Marcano Serrano, 2008). A second factor is that, in the reaction, some hydroxyl groups formed in the triglyceride were nucleophilically added to a nearby epoxide group, forming an ether group. On the other hand, the side reactions associated with ring opening caused by the components present in the reaction mixture such as acetic acid, protons, acetic peracid, or hydrogen peroxide, generate non-hydroxylated compounds or with fewer hydroxyl groups, which would generate less quantification (Rangarajan, 1995).

Table 2

Percentage of polyunsaturated fatty acids from chicken fat and different vegetable oils (Marcano Serrano, 2008)

Sample	Linoleic acid (%)	Linoleic acid (%)
Chicken fat (this study)	17.834	1.180
Soybean oil	53	8
Linseed Oil	16	52
Olive oil	6.3	0.3
Palm Oil	52.1	7
Rapeseed oil	14.5	11

To study the structure of the polyol, functional groups present were identified by ATR-FTIR (Figure 1). The bands observed in the polyol of this work are similar to those observed by Ionescu et al. (2011), who prepared polyester polyols by esterification from castor oil and petrochemical polyesters (adipic acid and diethylene glycol).

The band at 3432.30 cm^{-1} is assigned to hydroxyl groups, while the bands at 2922.63 cm-1 and 2853.90 cm^{-1} are assigned to symmetrical stretching in the C-H phase. The sharp intense band at 1739.90 cm^{-1} is characteristic of the ester carbonyl, the band at 1460.27 cm^{-1} is assigned to asymmetric C-H bending, and the bands at 1097.56 cm^{-1} and 1159.31 cm^{-1} to symmetric and asymmetric C-O-C stretching.

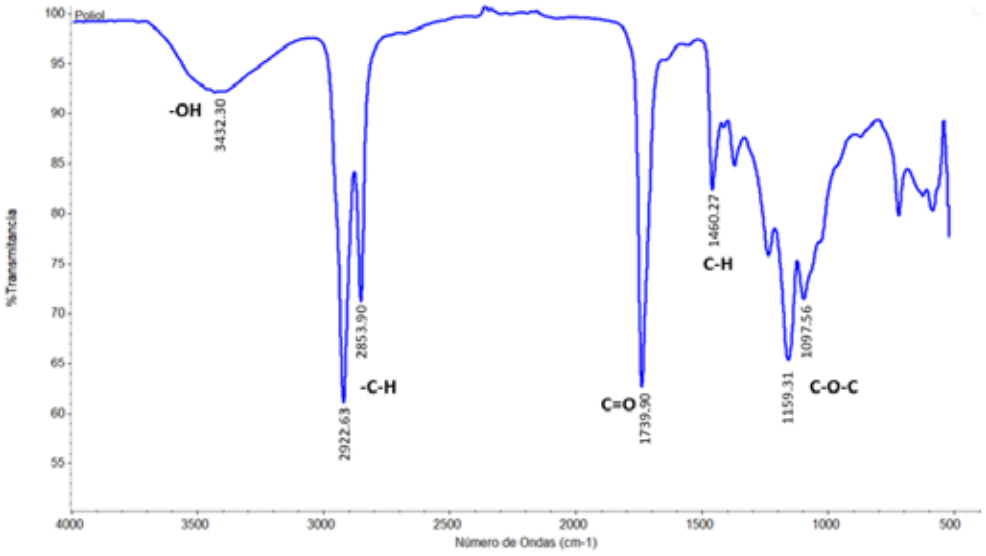

Figure 1. Polyol FTIR spectrum from chicken fat

On the other hand, when evaluating the FTIR spectra (Figure 2) of the synthesized polyurethanes, it is observed that (OH/NCO molar ratio 1:3, 1:4, and 1:5) the 2270 cm^{-1} signal band is not present, associated with the stretching vibration of the N=C=O group of the IPDI, indicating that all the isocyanate groups reacted during the polymerization with the polyols. Also observed in the PU spectra is a band centered at 3350.63 cm^{-1}, 3351.95 cm^{-1}, and 3341.13 cm^{-1} respectively, which was attributed to N-H stretching of the urethane group, this becomes more intense as the isocyanate content in the material increases, due to increased formation of urethane groups. In addition, two bands could be observed in the region of amide II assigned to the stretching vibration of C-N together with the vibration in the plane of the N-H bond, present in the product of molar ratio 1:3 at 1644.74 cm^{-1} and 1552.68 cm^{-1}; in that of molar ratio 1:4 at 1643.27 cm^{-1} and 1554.00 cm^{-1} and for the ratio 1:5 at 1640.79 cm^{-1} and 1552.89 cm^{-1}. This band also becomes more intense with the increase in isocyanate content due to the greater participation of urethane groups.

The bands could be seen at 1734 cm^{-1} attributed to the stretching of the carbonyl of the ester groups (C=O). These results indicate that the IPDI reacted completely with the polyol's hydroxyls and produced polyurethane (Chen et al., 2021; Dai et al., 2020; Mathew et al., 2017).

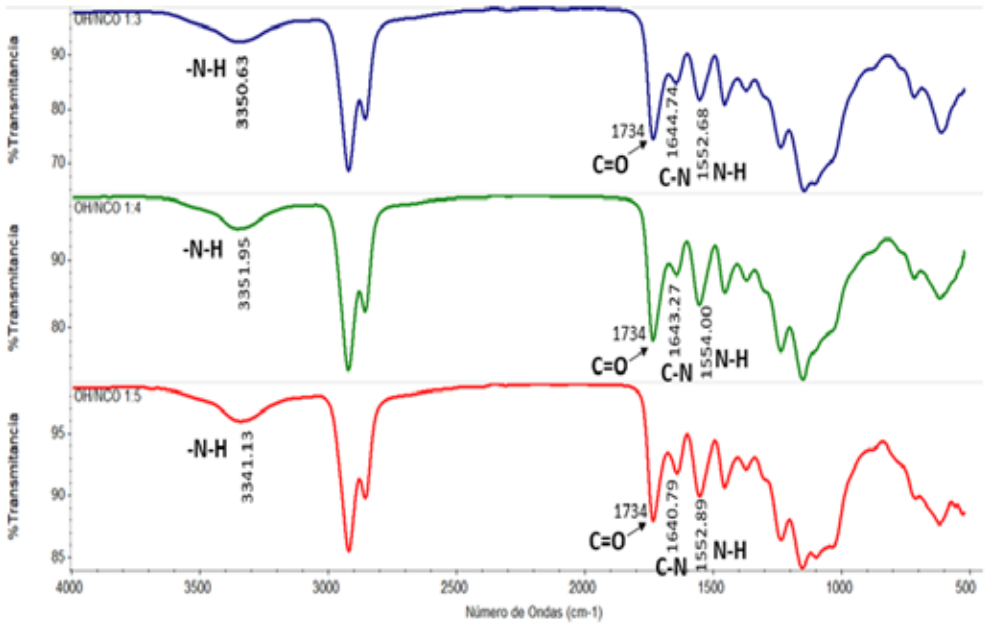

Figure 2. FTIR spectrum of the polyurethanes obtained at different molar ratios of the OH/NCO groups

The high reactivity of the isocyanate group with the active hydrogen compounds can be explained by the following resonance structures (Figure 3):

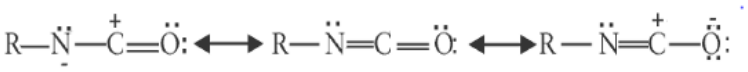

Figure 3. Canonical structures generated by the resonance effect of the isocyanate group

The electron density is highest on the oxygen atom, while the carbon atom has the lowest electron density, making the carbon atom positively charged and the oxygen or nitrogen negatively charged depending on the canonical structure.

The reaction of isocyanates with active hydrogen (OH) compounds is an addition to the carbon-nitrogen double bond (Figure 4). This reaction takes place as follows: the nucleophilic center of the active hydrogen compounds, i.e. the oxygen atom of the hydroxyl groups or the nitrogen atoms in the case of amines, nucleophilically attacks the electrophilic carbon atom, and hydrogen is added to the nitrogen atom of the -NCO groups. Electron-removing groups increase the reactivity of -NCO groups and, on the other hand, electron-donating groups decrease the reactivity towards active hydrogen compounds (Ionescu, 2016).

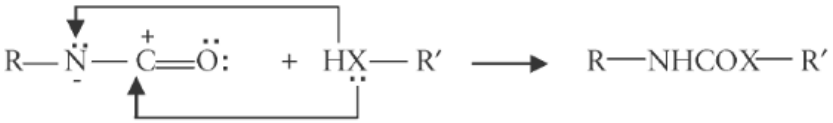

Figure 4. Reaction mechanism of the isocyanate group with active hydrogen compounds

To evaluate the effect of the OH/NCO molar ratio on the formulation of the polyurethanes, the mechanical compression test was carried out.

Of the three samples generated, the PU sample with a molar ratio of 1:3 (OH/NCO) did not meet the requirements for the compression method, because the material obtained was a material that hydrated easily, which made it unmanageable, preventing quantification, while the polyurethanes prepared from the 1:4 and 1:5 OH/NCO molar ratios were solid foams and therefore it was possible to perform the determination. Nguyen Dang et al (2016) mention that the higher the OH/NCO ratio, the greater the increase in hard segments, generating more crosslinking in PU polymerization.

Figures 5 and 6 show the graphs of the force exerted in Newton (N) and the displacement of the material (mm), a parameter described as stiffness, which is a quantitative measure of the opposition to elastic deformation due to force or stress. The material obtained with the ratio 1:4 (OH/NCO) had a displacement of 15.478 mm applying stress of 400.753 N, so the resulting stiffness was 25.89 N/mm, while for the polyurethane obtained with a ratio 1:5 (OH/NCO), applying the same stress, displaced 9.652 mm so the stiffness

was 41.52 N/mm. This indicates that at a lower 1:4 (OH/NCO) ratio, the stiffness was lower, compared to the PU with a 1:5 (OH/NCO) ratio. This result may be because, in PU 1:5, there is a greater amount of isocyanate groups that generate greater cross-linking with the polyol, which generates greater resistance to deformation compared to the PU obtained with the 1:4 ratio.

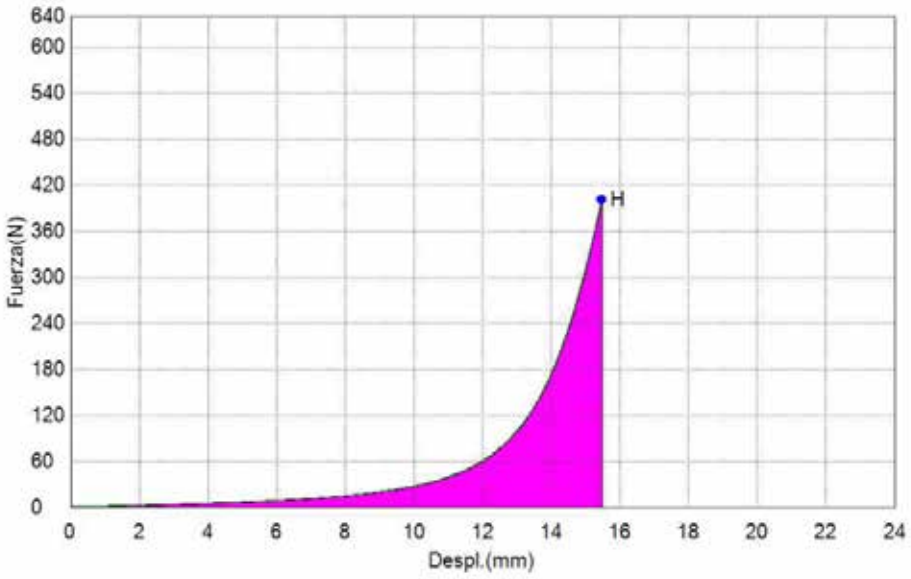

Figure 5. Stiffness of polyurethane generated with molar ratio 1:4 (OH/NCO)

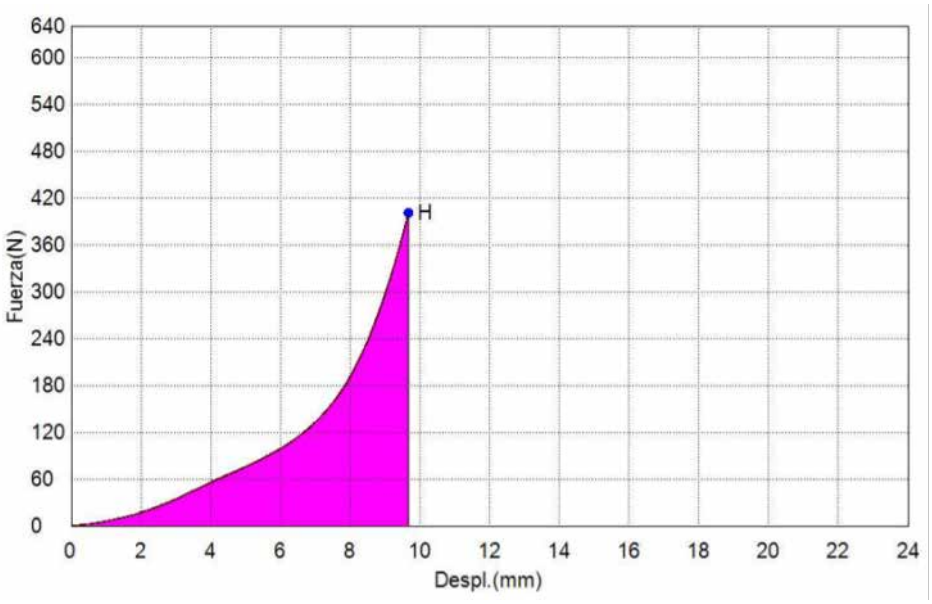

Figure 6. Stiffness of polyurethane generated with molar ratio 1:5 (OH/NCO)

This same behavior is observed in the quantification of the compressive strength, with a higher value being observed for the material generated with the ratio 1:5 (0.4152±0.003 MPa) about that obtained with the ratio 1:4 (0.2589±0.001 MPa).

The compressive strength of chicken fat polyurethanes was compared with the research of Acuña et al., (2020) (Table 3), who prepared rigid polyurethane foams based on castor oil with flame retardant properties and high insulation capacity. They prepared PU from castor oil polyol (BIO1), PU from castor oil with surfactants and foaming agents (BIO2), and PU from castor oil with surfactants and flame retardant properties (BIO2/EG).

BIO1 foam obtained low compressive strength because it had a porous structure and large cells, which favored the fragility of the cell walls. By modifying the polyol with a surfactant, the compressive strength increased because the viscosity increased by the interaction of the higher number of OH groups of the biobased polyol with the isocyanate groups, improving the network structure, generating more closed cells and increasing the crosslinking density.

When the flame retardant agent is added, the compressive strength decreases, causing poor interfacial adhesion, and damaging cell walls and foam integrity. For this reason, the compression values obtained in this work are higher than bio-based polyurethanes with additives, confirming the presence of a homogeneous mixture in the polymerization.

Table 3

Compressive strength of PU from chicken fat, castor oil, and fossil origin

Sample	Compressive strength (MPa)
PU1:4 from chicken fat (This work)	0.2589±0.001
PU1:5 from chicken fat (This work)	0.4152±0.003
BIO1 from castor oil (Acuña, 2020)	0.071
BIO2 from castor oil (Acuña, 2020)	0.146
BIO2/EG from castor oil (Acuña, 2020)	0.112
PU foam to petroleum base (Li et al., 2015)	0.137 – 0.310

Comparing the compressive strength values with those of polyurethane foams generated from petroleum, it is observed that PU 1:4 and those obtained with castor oil are within the range obtained for petroleum-based PU; while PU 1:5 is higher, demonstrating that it is possible to obtain polyurethane foams from chicken fat polyols with properties similar to those of petroleum-based foam.

The scaling up of the polyurethane production process from poultry fat reveals the search for sustainable and environmentally friendly materials.

However, the feasibility of this process for commercial exploitation depends on several key factors that must be carefully considered such as the quantity and quality of poultry fat, the investment for process optimization, the evaluation of the costs associated with production, the analysis of the market to compete in price and quality with conventional polyurethanes, and the evaluation of the environmental impact on their production.

CONCLUSIONS

The chicken fat polyols generated by epoxidation and *in situ* hydrolysis were appropriate for the formulation of biopolyurethanes since the number of hydroxyl numbers of the polyol and the molar ratio of NCO used favored the polymerization of the PU synthesis, therefore, the FTIR spectra indicated the formation of the PU, which indicated that the hydroxyl groups had reacted with the NCO group forming the hydrogen bonds.

The OH/NCO molar ratio is of utmost importance for the synthesis of PU, since its mechanical properties depend on it, the higher the hydroxyl value, the more flexible products will be generated, and the higher the NCO value, the less ductile and more rigid products will be generated.

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A C A D E M I C S
P A P E R S

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Innovative Entrepreneurial Initiatives Promoted at a Public University of Ciudad Juárez

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— Abstract—

Entrepreneurship has taken an upswing from several years ago through nowadays due to its importance for economic development in geographical regions. Thus, higher education is a proper period to impulse entrepreneurial spirit in students. The objective of this article is to acknowledge the entrepreneurship contest organized by Universidad Autónoma de Ciudad Juarez. The applied methods were observation and research about how this contest is conducted and who participates in it. Results show that there is great entrepreneurial activity by the university's students and that the performed projects have creativity and innovation.

Keywords:

Entrepreneurship; Innovation; Education; Universities; Ciudad Juarez.

Entrepreneurship is an important part of community development because it represents social and economic development. The creation of self-employment initiatives is a necessary and indispensable source to assist the well-being of society (Segura-Baron et al., 2019). Currently, the issue of entrepreneurship has taken off in Latin American countries, and different countries have expressed interest as a possible solution to the shortage of job offers, which has led to a high growth rate (Canales et al., 2017). This is because entrepreneurship represents an opportunity for regional economic growth due to the investment capital and the production of goods and services resulting from this process (Vargas & Uttermann, 2020).

According to Barba-Bayas and Viteri-Ojeda (2016) in recent years entrepreneurship has taken on importance, both in academic research and teaching. Therefore, universities have increased their entrepreneurship courses, increasing the student's chances of developing successful business initiatives. In this way, educational institutions implement strategies for the development of entrepreneurship skills, which allow students to undertake successful businesses by taking advantage of the opportunities in their environment (Castro, 2016). Among the main elements for the development of entrepreneurship projects, the motivation of the entrepreneur, the identification of a market idea, the existence of resources, and the skills and abilities acquired should be mentioned, which leads to the idea of the need for entrepreneurship education (Hidalgo, 2014).

Because education is a transcendental factor in social changes, entrepreneurship must be considered as a transversal attitude in various aspects, such as cultural, political, and business, which emphasizes the work of the entrepreneur as a creator of wealth and work for his community (Rodríguez, 2007).

Globalization and the need to adapt to these circumstances, in addition to continuous innovation, are some of the aspects that higher education institutions have considered for entrepreneurship. According to Valdivia-Velasco et al. (2019), in Mexico, private universities, due to their commercial nature, were pioneers in the development of entrepreneurship skills in their students, unlike public universities.

2. LITERATURE REVIEW

2.1. Entrepreneurship

The entrepreneur is a pioneer, a different character due to his/her abilities to take risks, take advantage of crises, introduce new technology, and create opportunities for innovation (Canales et al., 2017). Other researchers in economic theory deduce that entrepreneurship comes from the word *entrepreneur* and refers to adventurers, due to the role it plays in this activity,

such as product development, taking risks, seeking financing, being creative, and finding opportunities (Jiménez-Silva et al., 2019.) In this way, these people identified their characteristics when they undertook the construction of large works. This concept is associated then with the concept of the company, identified as that particular economic activity, on the production of a good or service and its equivalent in money (García-García, 2015).

For Farayibi (2015), entrepreneurship is an opportunity to create new products and services, being an important process for economic growth. It is also necessary to consider entrepreneurship as a set of skills that a person possesses to manage, organize, innovate, and take risks (Vargas & Uttermann, 2020). However, Torres-Vázquez et al. (2020) say that entrepreneurship should be considered to begin at home since there is a great influence of the environment in which it takes place, strengthening those skills for entrepreneurship.

Currently, entrepreneurs who become competent move quickly creating strategic advantages over their competitors in the economy, creating opportunities for their companies to become innovative and better face those external pressures that arise, leaving their routines and comfort zones to become creative problem solvers and thus solidify their entrepreneurial spirit along the way (Alvarado et al., 2021). Likewise, there is the influence of society where entrepreneurs see various needs reflected that, to satisfy them promptly, provoke the innovative management of business ideas. From this, the concept of entrepreneurship emerges that "alludes to communities in which the population can generate innovative initiatives and projects in different spaces of action and to flexibly adapt to changes in an increasingly uncertain world" (Kantis, 2017, p. 121).

Jones et al. (2014) highlight certain qualities of entrepreneurs with the development of the company, which begin with the ability to recognize opportunities to develop the idea of the company, followed by the organizational aspects of the resources, and add that for the permanence of the business, aspects such as motivation, financing, and commitment must be considered. Canales et al. (2017) state that:

> [...] the project begins with the identification and validation of a company idea, which subsequently needs to organize material and human factors; however, having resources and an innovative concept does not ensure the permanence of the business in the market, because it depends to a large extent on the motivation and commitment of the entrepreneur, coupled with the availability of financing and a healthy environment for business development. (p.5).

This is because the development of a business involves different factors of the entrepreneur's environment, they are related to their family, education,

and culture since they provide skills, experience, and knowledge. Therefore, entrepreneurship must be considered as an ability to structure projects to improve the quality of life of both the entrepreneur and his community (Rodríguez, 2007).

According to Canales et al. (2017), entrepreneurship can be considered in three phases:

a) The *initial*, which is, on the one hand, the conception of the idea and can influence the individual from a positive perspective that includes the desire for realization; and on the other, a negative visualization that seeks entrepreneurship to face unemployment, frustration, and the need to survive.
b) The *intermediate* includes the factors that make a person a potential entrepreneur, such as personal relationships and the family, cultural, social, and educational environment.
c) The *last* one contemplates the actions and obtaining resources to develop the project.

Regarding the personal goals that cause individuals to become entrepreneurs, several can be considered; one of the most important is motivation, which can develop over time. Being surrounded by positive attitudes is one of the most important factors in the entrepreneurship process. "Motivation will be the engine that promotes the development of entrepreneurship since it will define why we give our effort and that of others" (Yépez et al., 2019, p. 28). Marulanda et al. (2014) point out other factors that should be considered: originality, moderate risk aversion, acceptance of responsibilities, perseverance, self-confidence, desire to learn, and long-term goal planning. One more important aspect, pointed out by Canales et al. (2017), is the motivation to undertake; a preponderant reason is income, economic independence, and personal satisfaction. Suarez et al. (2020) state in this regard: "Among the reasons for undertaking there is a predominance of those that acquire an intrinsic character, which has to do with self-actualization and personal-professional improvement and growth" (p. 181).

The entrepreneur will then show a satisfactory performance through the aforementioned motivators, which will be what will drive him to continue in the face of any obstacle; they will help him to carry out the activities so that, methodologically, he achieves the expected objective, in addition to putting his essence in the whole process, which will help him, even more, to be successful. "The attitudes that young people have about themselves are an important factor because they will determine their expectations, motivations, decision-making and, ultimately, their behavior" (Santos et al., 2015, p. 130).

2.2. The University and Entrepreneurship

Awareness of the importance of entrepreneurship is a task that must be addressed daily. In universities, it is a priority to highlight the fact that new companies promote the economic growth of a territory, due to the creation of new jobs and the increase in income from the payment of taxes, the increase in exports, and an increase in productivity, (Pérez & Solíz, 2020). "Entrepreneurship is an important vehicle for the growth and economic development of countries and young people are the ones who usually lead it" (Kantis, 2017, p.120).

For their part, Vargas and Uttermann (2020) point out the importance of education to boost the entrepreneurial spirit in young people to develop new entrepreneurs and, with it, boost economic growth and job creation. In turn, Aboobaker and Renjini (2020) allude that business education has a significant relationship with the development of positive attitudes for students to undertake. Likewise, Vélez et al. (2020) point out that business education helps the development of competencies, skills, attitudes, and values of the entrepreneurial spirit.

Berbetti (2015) reports that the lack of knowledge of the markets in which it is intended to venture, the insufficiency of training actions without permanent accompaniment and advice after the process has begun, coupled with budgetary restrictions and the difficulties in maintaining the financing required at the beginning of the experiences, appear as the factors that frequently hinder achievements and lead to the low survival of the ventures.

Today, society is more competitive and requires more entrepreneurs. Therefore, universities are essential for the training of professionals with cognitive skills who develop capacities for the implementation of innovative and sustainable ventures (Jiménez et al., 2019). García et al. (2018) argue that "business support and training services are essential in the creation of companies, however, the lack of access to such services leads the entrepreneur to imitate other people's ideas" (p. 92).

Knowledge is a fundamental part of entrepreneurship because it helps the transformation of ideas into products or services and these are promoted in a local, national, or international market (Pérez & Solíz, 2020). In addition, entrepreneurship involves processes and activities that are carried out to discover, define, and take advantage of the opportunities that generate wealth with the creation of innovative companies (Zahra et al., 2009). Meanwhile, Bravo et al. (2021) refer to entrepreneurship from a cognitive approach, because it understands intentions and perceptions. According to this approach, everything that is done involves a mental process that requires motivation, perception, and attitude.

For Osorio and Pereira (2011), a good educational practice for entrepreneurship is one that develops students' skills, attributes, and attitudes, not just an understanding of the principles, practices, and strategies of business. That is, learning must accompany the entrepreneur to observe their behavior through the environment. Therefore, the relationship between entrepreneurship and the University is preponderant, due to the causality of the application of this knowledge. That is, to the extent that knowledge is put into practice, it is how universities concretize their work in the social and economic development of communities (Segura-Barón et al., 2019).

In university education, the student's cognitive abilities must be strengthened to recognize opportunities. Therefore, according to Jiménez et al. (2019), those cognitive activities that should be given greater attention in the study of entrepreneurship are the identification and recognition of opportunities since these are the preamble of the entrepreneurship process.

In education, it is a priority to develop skills, which must be understood as knowledge within a given context, which implies the development of skills, capacities, and knowledge, to make use of them in the environment where they are developed (Rodríguez, 2007). For their part, Valdivia-Velasco et al. (2019) believe that entrepreneurial skills can be learned, so universities play an important role in teaching these characteristics and developing the entrepreneurial spirit.

Therefore, universities tend to promote projects or events where entrepreneurship skills are developed in young students. Torres (2015) mentions that "Young people are more likely to be entrepreneurs than non-young people because socio-cultural and psychological factors of self-confidence, reference models and social stigma to failure seem to affect young individuals less" (p. 138).

The university stage is one of the most important, it is the emergence of all the plans of young people, especially entrepreneurship, being the university a training body that guides young people to a better future, and not only to find a well-paid job, but to be their own boss and obtain their own income through a business idea (Espejo & Espíndola, 2015).

2.3. Entrepreneurship and economic and social development

The opening of new companies involves characteristics aimed at taking advantage of the creativity and opportunities of the environment. The creation of companies seeks to boost employment, innovation, and growth (Fuentelsaz & González, 2015). Therefore, entrepreneurship is a process that takes place within a particular environment and is carried out by people with motivations and skills. According to Díaz (2017), this process takes place in three stages:

a) The *first* is the conception of the potential entrepreneur, the search for opportunities and ideas.
b) The *second* is that of the nascent entrepreneur with a business in training, to become a manager of his new business.
c) The *third* consolidates the figure of the established entrepreneur.

To carry out successful ventures, it is desirable to have different skills, composed of personal, organizational, and technological aspects. These conform to attitudes, vision, values, resources, knowledge, skills, abilities, and experiences. The formulation of these competencies occurs in conjunction with intellectual and human capital, and they help entrepreneurship to have a greater probability of success (Pérez & Solíz, 2020).

Due to the above, entrepreneurs who meet the real needs of the population profitably will be the ones most likely to thrive in the future. Therefore, entrepreneurship must be understood as a process of discovery, creation, and exploitation of opportunities, to offer products and services to obtain an economic benefit (Chirinos et al., 2018). In addition, entrepreneurship contains processes and activities to discover, define, and take advantage of opportunities to improve social wealth through the creation of companies (Zahra et al., 2009).

Marulanda and Morales (2016) point out that there are several factors for the creation of a company, the most important being the aspirations of the entrepreneur, his skills (knowing how), the resources he has, and the environment, which is the environment where he is going to develop. Although there are other factors for the company to have sustainability such as the market, size of the company, competition, level of growth, cost, and indebtedness (Sepúlveda & Gutiérrez, 2016).

In turn, entrepreneurship is related to innovation, so entrepreneurs must develop strategies and attitudes of risk, creativity, self-confidence, and vision. With the above and the needs of the environment, we seek to produce new things, under the premise of profitability and sustainability (Castro, 2016). For this reason, Barba-Bayas and Viteri-Ojeda (2016) point out that there are people who are born with an entrepreneurial capacity, since from an early age they demonstrate an ability to innovate and take risks.

As noted by Vernanza et al. (2020), currently undertaking an innovative project is very likely to succeed, many entrepreneurs develop ventures with broad competitive advantages offered by technology. Therefore, innovation and entrepreneurship are related. That is, entrepreneurs see technology as a tool to be more competitive and achieve sustainability.

Díaz-Casero et al. (2013) point out that it is important to consider the region where entrepreneurship is to be implemented, as an important factor for the success of the company; because, in developed economies, it is more

viable to execute an entrepreneurship project and that it is successful, and on the contrary, in countries with emerging economies, viability is reduced. Likewise, Vargas and Uttermann (2020) affirm that in countries with strong economies, entrepreneurship is carried out relatively easily and entrepreneurs are considered visionary people, unlike in developing countries where entrepreneurship is very few and only carried out of necessity. Mendoza et al. (2020) point out that in developing countries, entrepreneurship is not carried out of conviction but out of necessity, due to the difficulties it represents, such as low levels of innovation, lack of money, scarce market, and the price/cost ratio.

3. METHODOLOGICAL ASPECTS

The Autonomous University of Ciudad Juárez has an instance called the Office of Business Development, which works with teachers who are part of the Transversal Academy of Entrepreneurship, with the task of implementing a contest called EMPRENDIZATE-UACJ, which takes place every semester. The purpose of this event is to promote the entrepreneurial culture within the students and to distinguish the innovative ideas and business projects that are worked on in different classes of the institution. This competition aims to promote the development of companies in the region. The participating projects are characterized by innovation, creativity, and sustainability. This event promotes the environment for students, entrepreneurs, and businessmen to coexist and exchange experiences as in the evaluation of a project, in the feedback on the weaknesses and strengths of each project. In addition, this meeting is held through a call addressed to all undergraduate students of the Universidad Autónoma de Ciudad Juárez, through the registration of their project within one of the three categories, as shown in Table 1.

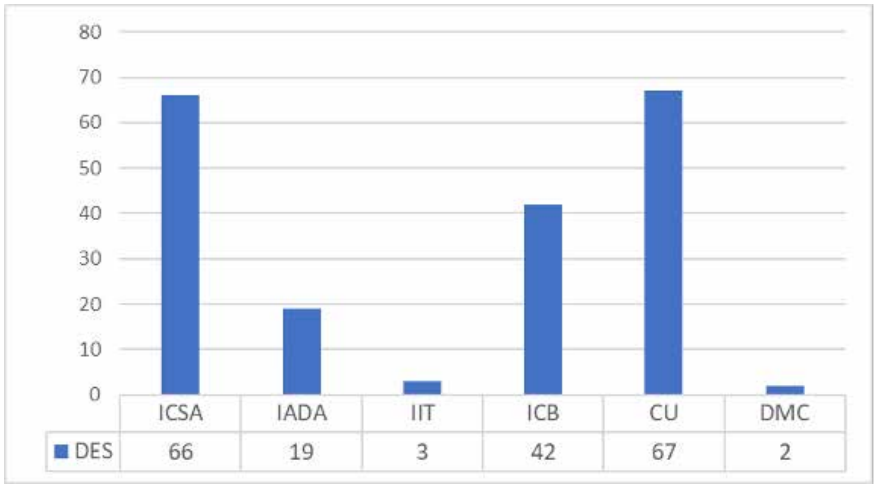
Table 1
Project Categories

Category	Description
Traditional	These are projects whose objective is the marketing and distribution of a product or service.
Technological	This type of project is the creation, modification, or adaptation of a tangible product thanks to the use of technology.
Social	These are projects whose business model aims to improve, solve, or eliminate social problems or needs.
Artistic	This category aims to develop projects with tendencies to encourage, promote, develop, disseminate, and value artistic and cultural projects.

Note: Own elaboration.

In 2021, due to COVID-19, a virtual edition of EMPRENDÍZATE-UACJ was held. Through a call, students are invited to participate every semester. First, through teachers with the recognition of innovative ideas and business models developed by their students. When the call is launched, projects are submitted and those with greater innovation and relevance are selected. Projects may participate within one of the four categories mentioned in Table 1.

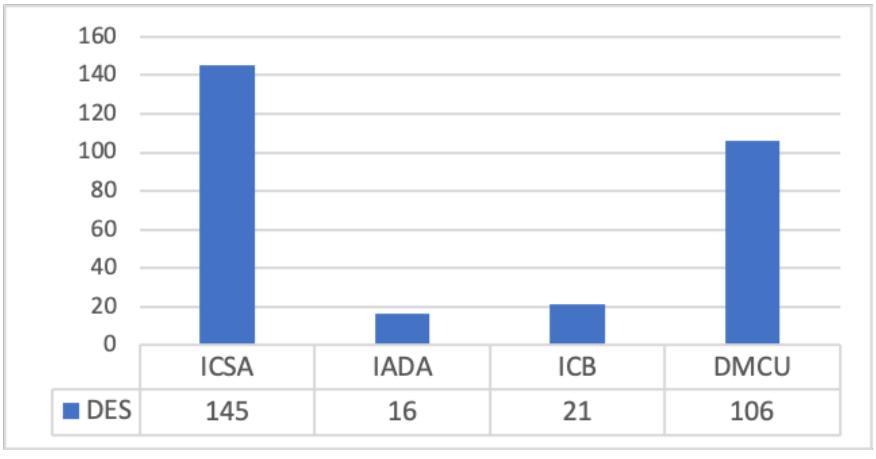
A total of 197 students participated in the 2021-1 semester (January-June) (see Figure 1).



Note. Own elaboration.

Figure 1. Student Participation, Semester 2021-1

A total of 288 students participated in the 2021-2 semester (August-December), as shown in Figure 2.



Note. Own elaboration.

Figure 2. Student Participation, Semester 2021-2

4. DISCUSSION OF RESULTS

By the number of students who registered their projects for the competitions of both semesters, there is a great interest on their part to generate and develop a viable business, in addition to the influence of the embedded inertia of society, where these young university entrepreneurs see the possibilities projected, from a tangible perspective, to meet their various needs, provoking and encouraging the management of their business ideas. From this arises the concept of entrepreneurial society which "refers to communities in which the population can generate innovative initiatives and projects in different spaces of action and adapt flexibly to changes in an increasingly uncertain world" (Kantis, 2017, p. 121).

The numbers of university students interested in entering their projects to the competitions identify in them their entrepreneurial spirit, which can emerge and develop in an adequate environment that allows them to clearly see that it is the precise moment for the development of that idea and that, with the appropriate monitoring and accompaniment, all their objectives can be carried out. This corroborates what Canales et al. (2017, p. 5) explain:

> [...] the project begins with the identification and validation of a company idea, which subsequently needs to organize material and human factors; however, having resources and an innovative concept does not ensure the permanence of the business in the market, because it depends to a large extent on the motivation and commitment of the entrepreneur, coupled with the availability of financing and a healthy environment for business development.

Throughout the development of these competitions, it has been possible to identify those factors that influence the desire for entrepreneurship of these young university students, among which it stands out that their project is developed in an environment of support and advice that, even though the current circumstances in the city may make it difficult, has all the opportunities to strengthen the business; to this must be paid another factor identified, which is the good attitude on the part of young entrepreneurial university students, which makes it the perfect mixture to have the expected growth and progress.

If these young university students are clear about the scope of how far they could go, they will develop the right motivation to create and generate a strong business, and that all their work and effort made during the time invested is worth it.

5. CONCLUSIONS

One of the most important issues that are addressed about entrepreneurship is the economic development that triggers in the regions, through the sources of employment that it generates. However, for entrepreneurs to generate these sources of employment, their project must first be profitable and sustainable. Therefore, universities play an important role in the development of young entrepreneurs who can create these companies.

One of the priority issues is that universities should focus on transmitting the different types of entrepreneurship and the differences between entrepreneurship out of necessity or enthusiasm. Entrepreneurship that is developed by necessity is focused on a self-employment strategy and must have a base of understanding to guarantee the competitiveness and sustainability of the project. The second is developed based on attitudes, skills, and, above all, enthusiasm for entrepreneurship.

Another fundamental aspect of promoting entrepreneurship projects is that they are adequately monitored, that is, the proposed company is not only reflected on paper as a simple project. For this reason, entrepreneurship competitions, incubators, and business accelerators are vital for the development and sustainability of projects. As suggested by Barba-Bayas and Viteri-Ojeda (2016), a life project for entrepreneurial students is important so that they see themselves as future successful entrepreneurs and can overcome the phrase "you can't".

On the other hand, in the different entrepreneurship projects developed by university students, creativity and innovation can be observed and applied to the solution of various problems faced by the different entities. On the contrary, there is a shortage of publications by academics about entrepreneurship in Mexico, which opens a window of opportunity for future research.

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Improving Energy Storage Conditions through Supercapacitor Banks: A Bibliographical Review

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— Abstract—

This literature review work presents the compilation of various studies in which the topics of energy storage systems, supercapacitors (SCs), supercapacitor banks, and switching matrices, which are considered elementary for the future of electrical systems, stand out. The storage systems allow a backup when the power supply lines fail or are not efficient enough, and have different classifications, which change depending on the types and needs of the systems. In addition to this, supercapacitors, types, and applications are described in general, as well as the characteristics that position them as a better storage option than batteries, to lay the foundations for the development of supercapacitor banks and switching matrices; the former help to enhance the characteristics of supercapacitors through different electrical arrangements, while the latter are a proposal to control the changes of supercapacitor banks in the search for control of electrical parameters.

Keywords:

Supercapacitors; energy storage systems; biomass; switching matrix; supercapacitors bank.

The electrical industry has evolved exponentially in recent decades, automating most processes and seeking to reduce environmental impact, providing greater control in industrial processes by developing energy backup systems. Energy storage systems have become novel topics of research to produce and supply electricity when there are periods of disconnection from conventional networks or to improve the response of the system. It is important to highlight that in energy storage we find two general classifications: direct means such as batteries, and indirect means including Supercapacitors and conventional capacitors. These systems are distinguished by the control of parameters such as energy and power density, efficiencies in the charge and discharge cycles of energy, and the life cycles of storage systems (Reveles, 2013).

According to research by Reveles (2013), not all storage devices are efficient for all types of systems since "the fundamental parameters that we have to consider are how much energy it can store and how fast it can deliver that energy" (Reveles, 2013, p. 29).

The high demand for electrical energy storage systems has become one of the main goals in science and engineering, seeking to obtain increasingly efficient and environmentally friendly storage systems. In recent decades, the most widely used storage system has been batteries. However, their environmental impact is very high and does not provide sufficient efficiency to the systems because their charge and discharge cycles are lower compared to other devices and, in addition, they do not deliver the power characteristics that are needed in most cases.

Attributed to the above, much more efficient alternatives began to be analyzed, such as the use of capacitors and the subsequent development of SCs.

The first are devices formed by two conductors and separated by a dielectric solution with acidic pH; while the second consists of two porous electrodes impregnated in an electrolyte and insulated from electrical contact by a separating paper; they store energy by the principle of electrochemical double layer formed at the electrode/electrolyte interface, of which we will focus the review. SCs are classified into three types: electrochemical double layer (EDLC), pseudocapacitors (Ps), and hybrids (Olán et al., 2021).

It is essential to highlight that since it contains characteristics similar to batteries, in terms of energy management, it has been necessary to develop arrangements that help improve the electrical parameters in the systems. At the same time, the development of Supercapacitors that use biomass as components has been studied to take advantage of the waste of certain products such as coconut, coffee, cocoa, bamboo, and rice, thus proposing innovative storage strategies with a reduced environmental impact in consideration of commercial ones.

The objective of this literature review document is to present the development of new technologies and improvements for energy storage, as well as their environmental impact compared to conventional batteries, documenting information about supercapacitors based on the studies of other authors embodied in articles and theses.

ENERGY STORAGE SYSTEMS

Energy storage systems are characterized by the amount of energy they store, the maximum power they supply, and the response times of charge/discharge processes related to their operation, as shown in Table 1. Based on these parameters, we can talk about large-scale storage systems, distribution systems, and power systems (Díaz, 2016).

Table 1

Classification and general characteristics of storage systems according to the amount of energy they store

Types of Energy Storage Systems	Characteristics
Large-scale storage systems	They can store energies between 10 and 8000 MWh and supply powers between 10 and 1000 MW with discharge times between 1 and 8 hours.
Distribution systems	The energy and power values range between 50 to 8000 kWh and 100 to 2000 kW respectively, reducing the discharge times by half concerning the previous ones.
Power Systems	Characterized by energy values ranging from 0.03 to 17 kWh, powers from 0.1 to 2 MW, and discharge times from 1 to 30 seconds.

Note. Díaz, 2016.

These types of systems can also be classified according to the type of energy they store as shown in Table 2.

Table 2

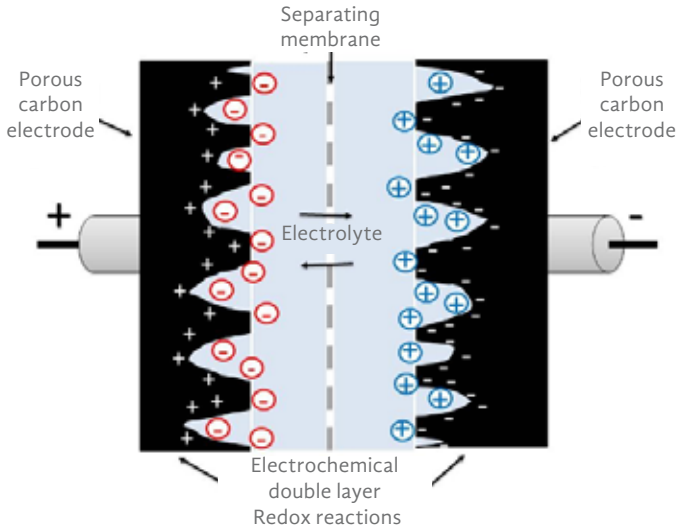
Distributed storage systems, according to the type of energy they protect

Types of Storage Systems	Características de los sistemas
Indirect electric power	- In the form of mechanical energy, such as hydraulic pumping systems (PHES), compressed air systems (CAEs), and flywheels. - In the form of chemical energy, as in the case of batteries (Mírez, 2012).
Direct electric power	- Like superconducting coils (SMES) and supercapacitors (Olán, 2020).

Note. It is important to know the storage medium to establish the most optimal one to be applied according to the energy supply needs of the system.

Supercapacitors

Supercapacitors are energy storage devices that have become a focus of attention for science because they show greater efficiency in supplying electrical energy and providing power to various systems, based on electrostatic forces (Olán et al., 2021). These devices contain two electrodes immersed in an electrolyte separated by a semipermeable material in the search to reduce the presence of short circuits without affecting the transfer of ions from the electrolyte medium (Figure 1). When a potential difference is applied to them, a charge density difference is created between their plates and the ions migrate towards the surface of the electrodes, adsorbing in the interfacial region. However, it is important to mention that these devices require electrodes made with materials of high specific area so that the capacity to accumulate charge increases, in addition to a porous structure that provides greater surface area and facilitates the conditions of displacement of the ions in the electrolyte (Olán, 2020).



Note. (Olán, 2020, p.20).

Figure 1. Representation of the internal behavior of a supercapacitor

These devices are formed mostly commercially of activated carbon that acts as electrodes, which are polarized and separated by a permeable ion that separates the electrodes in the search to avoid the presence of short circuits between the plates; it also contains an electrolytic solution forming a charge distribution along the contact surface between the carbon and the electrolyte (Muñoz, 2020).

One detail to consider regarding SCs as storage systems is that the extraction of energy in these devices is more demanding compared to batteries; this

is because when SCs have delivered only 75% of their energy, their voltage has already decreased to 50%. Although SC has a higher power density, longer life cycle, and higher discharge/charge efficiency than a battery, faster charging time, wider operating temperature window, and lower internal resistance, due to their low power density, they report a maximum energy utilization efficiency of only 75% (Reveles-Miranda et al., 2017).

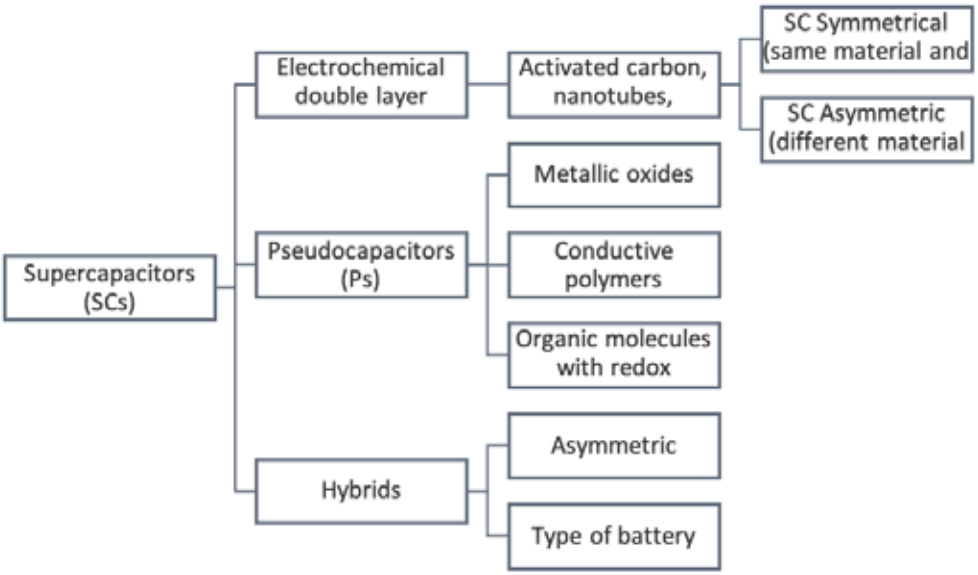
According to various studies shown in Table 3, the material of the active electrode in the processed electrode is the main factor influencing the performance of the SC. Three types of active electrode materials for SCs have been examined.

Table 3
Active electrode materials for SCs

Type of electrode	Characteristics
Activated carbons (AC)	• They show a larger surface area but lower electrical conductivity, leading to the use of conductive additives and AC in the processed electrodes. • Lower cost materials. • They can be derived from agricultural products and waste (cocoa, coconut, coffee, rice, and bamboo).
Carbon nanotube (CNT)	• It shows a high electrical conductivity but a moderate surface area due to the cylindrical shape they have. • High-cost material.
Reduced graphene oxide (rGO)	• They show a high electrical conductivity but a moderate surface area due to the restacking of the graphene layers. • High-cost material.

Note. In this table, a slight comparison is made of the general characteristics of materials used as active electrodes for SCs (Olán et al., 2021).

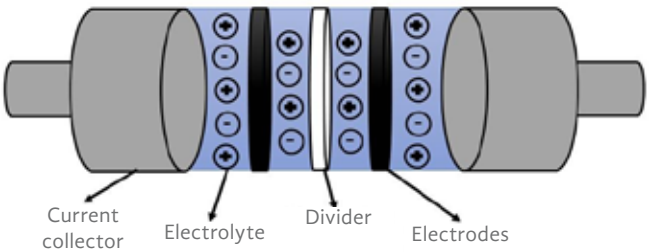
In the study of supercapacitors, classifications have been established according to the electrode used, operating principle, and design. However, the most widely accepted are three: electrochemical double-layer supercapacitors (EDLCs), pseudocapacitors (Ps), and hybrid supercapacitors. As mentioned in Figure 2.



Note. SCs are classified in this way to be able to make the appropriate choice according to the needs of the systems to be supplied (Olán, 2020).

Figure 2. Classification of supercapacitors

"Electrical double layer electrochemical supercapacitors." (Segura & Remigio, 2016) Double-layer SCs store charge mostly through the double interfacial charge effect. In this sense, this type of SC seeks to have a surface area as high as possible to capture a large amount of ions at the electrode-electrolyte interface. Generally, the larger the surface area of the electrode, the greater its capacity to accumulate charge. However, this surface must be electrochemically accessible to ions (Delgado, 2018). Although EDLCs are considered electrochemical devices, there are no chemical reactions, as they are involved in the energy storage mechanism. The energy storage mechanism is a physical phenomenon and is highly reversible. Figure 3 shows the schematic of a double-layer electrochemical supercapacitor (Segura & Remigio, 2016).



Note. The life cycle of SCs is long compared to batteries, this is due to the physical movement of the ions, which regulate the charge and discharge rates (Olán, 2020).

Figure 3. Electrochemical double-layer supercapacitor schematic

"For their part, SCs that store energy electrochemically are called pseudocapacitors, because they perform reversible oxidation-reduction or redox reaction on the electrode surface." (Segura and Remigio, 2016). Most of them are built with metal oxide electrodes such as ruthenium oxide (iridium oxide, nickel oxide, or conductive polymers are also used); they have low efficiency and very low cell voltages due to the use of aqueous electrolytes, besides being costly at the production level due to their internal composition (Romero, 2009).

Another relevant classification is that of hybrid SCs, also called asymmetrical, defined as devices that combine pseudocapacitors with double-layer capabilities, using asymmetrical electrodes. That is, in an electrode, charge separation occurs due to double-layer formation only (Yuan et al., 2012).

Table 4 shows the specific characteristics of all SCs that differentiate them from other storage devices regardless of their classification.

Table 4

General characteristics of SC to differentiate them from other storage devices

General characteristics	Description
Energy storage (energy density)	SCs can achieve an energy density of magnitude greater than that obtained by conventional batteries.
High power density	The amount of power that a device is capable of delivering/receiving per unit volume, in the case of SCs is proposed to average 10kW/kg.
Equivalent Series Low Resistance (ESR)	Compared to batteries, the internal resistance of EDLCs is much lower, allowing them to operate at very high currents with high energy efficiency.
Very fast loading and unloading	They can handle high currents, and with almost equal efficiency, both in charging and discharging.
Shelf life	According to supercapacitor manufacturers, the lifetime of supercapacitors can be estimated at 1 million charge/discharge cycles, while that of lithium-ion batteries is about 1000 cycles.
Voltage per cell	Typically EDLCs have a maximum voltage per cell of about 2.7V. Supercapacitors can work over the entire voltage range up to their maximum voltage. In addition, they can be fully unloaded without suffering any degradation, improving safety in storage.
Ease of determining charge status	The charge and discharge are practically linear, and therefore, the state of charge (SOC) is obtained directly through the measurement of the voltage at a certain moment.
Wide operating temperature range	Typically, manufacturers establish a working range of between -40 and 65°C in both loading and unloading. This range is much higher than that of lithium batteries, especially at low temperatures (according to manufacturers' data, -20 to 60°C in discharge and 0 to 45°C in charge approximately).

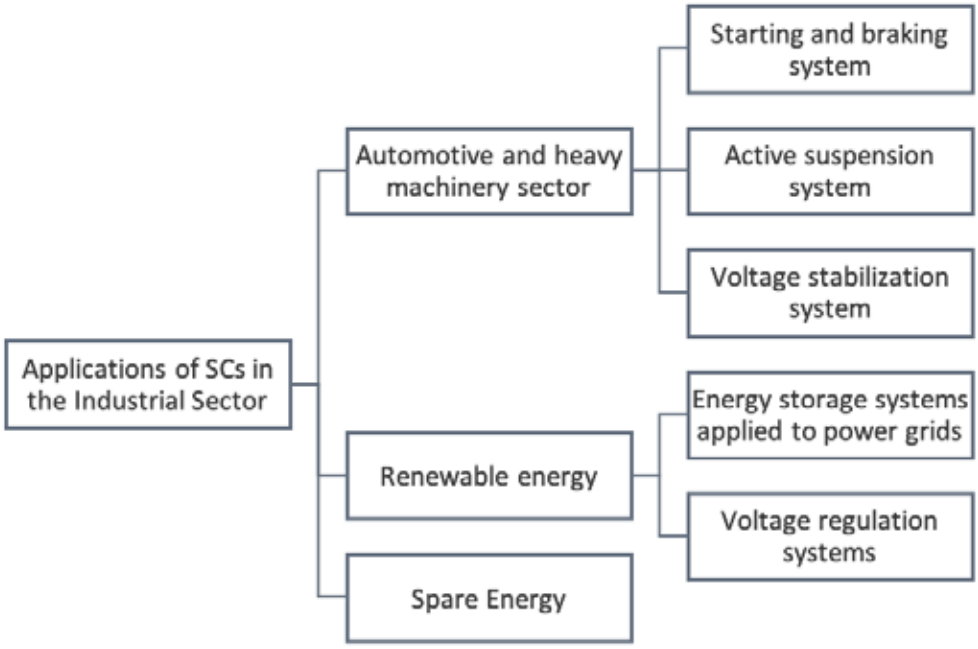
Note: These characteristics are what make a difference between direct storage devices such as batteries, and indirect storage devices such as SCs (Pradas, 2013).

"SC can be used to complete the electric power capacity of batteries in numerous applications. They can be used to store energy and provide power demand peaks in power electronic systems " (Reveles-Miranda et al., 2017).

Due to the energy advantages such as availability to handle the high voltage, current, and temperature values; short charge/discharge cycles, and optimal maintenance availability in a simple way. In addition to all the above and as a practical representation of the aforementioned qualities, the following are the most widespread applications of supercapacitors:

- Development of converters integrating supercapacitors applying the principles of power electronics for the aforementioned purpose.
- Development of systems that allow having an energy back-up integrating the use of supercapacitors.
- Development of a system that allows improving charging autonomy with the integration of supercapacitors to improve the charging times of the aforementioned system (Méndez et al., 2020).

Figure 4 shows applications of SCs in the industrial sector, in which the use of this type of storage system is more efficient (Technologies, 2020).

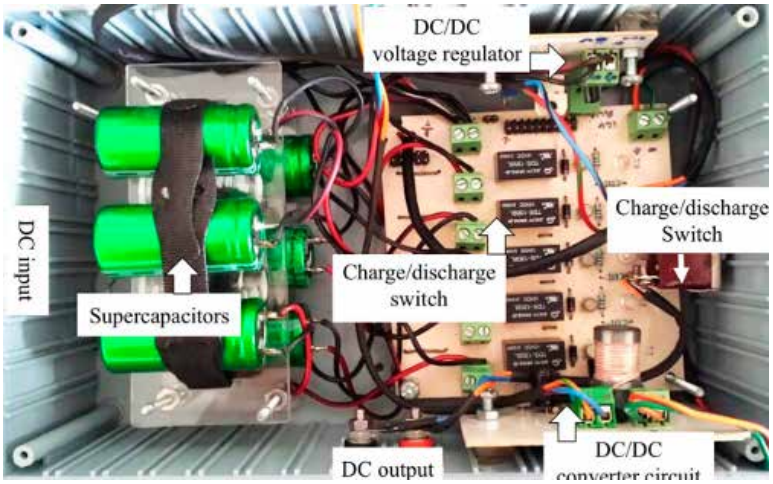


Note. (Technologies, 2020).

Figure 4. Applications of SCs in the industry

Supercapacitor Bank

A capacitor bank is an electrical equipment with a metal structure that contains two or more identical capacitors and is grouped fixedly (Figure 5). However, this type of system makes use of various arrangements with which we can enhance various electrical parameters depending on the specifications of the SCs we are using (Domínguez, 2012).



Note. Supercapacitor Bank carried out the study of arrangements applied in a Supercapacitor Bank to enhance electrical parameters (Reveles-Miranda et al., 2017).

They are used to correct the power factor (the ratio of the active power to the apparent power) of a commercial or industrial environment that uses several electric motors and transformers. This first point is important since in the industry, if the power factor is not corrected, there may be a penalty and a negative effect on the operation of the systems, as shown in Table 5 in detail: characteristics, types of capacitors, and which are the most used of the same (García, 2022).

Table 5

Comparative description of the operation of capacitor banks

Characteristics of capacitor banks		
Having control of the power factor helps the efficiency of energy consumption and the operation of some systems (Arredondo-Ferrer et al., 2022).	It stabilizes and adapts the voltage when a deficiency in electrical current levels occurs (Rayon, 2018).	Improves voltage profile, long service life, and cheaper capacitor bank maintenance (Garcia, 2022).

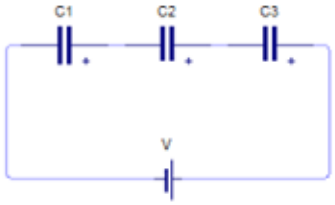
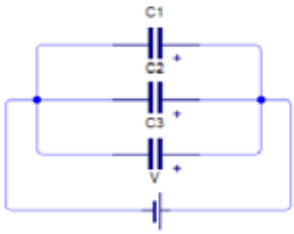
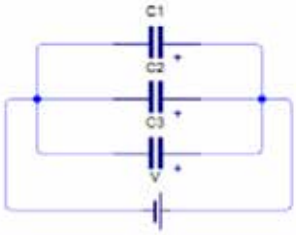
Table 6
Classification and characteristics of capacitors for the realization of a capacitor bank balancing network connection

Types of capacitors	Characteristics	Authors
Ceramic capacitors	It is one of the most used and well-known capacitors in the field of electronics and electricity. It features a dielectric made of different types of ceramics. The dielectric constant of these devices is usually higher than average.	(Vilela *et al.*, 2017).
Electrolytic capacitors	In its interior, there is an electrolyte that functions as a cathode and anode, having the outstanding characteristic of receiving very large currents. They can explode if they have polarity and are not connected correctly.	(García, 2022).
Air capacitors	It is composed of parallel conductive plates and uses air as a dielectric. They are used when there is a lower consumption of electrical energy.	(Fornaro *et al.*, 2012).
Mica capacitors	Capacitors are more resistant since their dielectric is made of mica; this material has the characteristic of low energy loss, and the use of this type of capacitor is more efficient when there are high voltages.	(Vilela *et al.*, 2017).
Aluminum capacitors	This capacitor is often used in the capacitor bank. It is made of aluminum and boric acid-based electrolyte and is also used for audio systems.	(Méndez *et al.*, 2020).
Paper capacitors	The dielectric is made of kerosene paper, Bakelite, or some other material that prevents humidity. Two paper plates are used in conjunction with aluminum.	(Vilela *et al.*, 2017).

Depending on requirements, series, parallel, or mixed connections can be made. The series connection of a supercapacitor is made by connecting a set of the negative part to the positive part of a capacitor. When a higher rated voltage is required from a supercapacitor it is necessary to make a series connection since the total voltage is the sum of each of the supercapacitors and the current is equal in each. A disadvantage of using the series connection is that the capacitance decreases (Table 7a). In turn, when applying a parallel connection, the capacitance of each supercapacitor is added (Table 7b); the voltage is equal to that of a single supercapacitor, and the current is summed (Tippens et al., 2007). Finally, it should be considered that to make a supercapacitor arrangement for an application with higher voltage demand and at the same time maintain its capacitance (Table 7c), it is necessary to make a mixed connection, that is, to connect capacitors both in series and in parallel (Escribano, 2020).

Table 7

Comparison of array types to enhance the electrical parameters of SCs

Comparación de los arreglos de las conexiones de los SC´s	
a) Series	
b) Paralelo	
c) Mixto	

Nota. (Tippens *et al.*, 2007)

Switching matrix

A switching matrix is a circuit that involves having all the levels of a supercapacitor bank (SCB) and controlling the changes between the levels of the bank to take advantage of the characteristics of the SCs (Table 8).

Table 8
Comparison of switching matrix applications in different storage systems

Authors	Year	Objective	Results
Freddy Chan, Jorge Aguilar, Víctor Sánchez, Emmanuel Torres and Marlos Alpuche	2019	"Switching matrix applied to a photovoltaic system (SFVI) to reconfigure both photovoltaic modules, inverters, and connected loads under certain operating conditions, generation, and electrical energy consumption."	Experimental evaluation of the performance under different generation conditions and for different types of loads connected to the grid is developed. The system has reconfiguration capabilities for various situations, such as inverter failures, phase overloads, line unbalances, consumption increases, short circuits, etc. The system is capable of adapting to various operating conditions (Ramiro et al., 2019).
María Guadalupe Reveles-Miranda, Manuel Israel Flota-Bañuelos, Freddy Chan-Puc, and Daniella Pacheco-Catalán	2017	Basic Switching Cell (BSC) that allows reconnection of the SCs to increase the storage bank power delivery time to a constant voltage level within a set interval to ensure uniform power draw from each SC with deep charge/discharge cycles.	By implementing the switching matrix, the average energy extracted was increased to 98.87%. The discharge patterns show that the proposed reconfigurations increase the discharge time in all cases. (Reveles-Miranda et al., 2017b).
Pietro Romano, Roberto Candela, Marzia Cardinale, Vincenzo Li Vigni, Domenico Musso, Eleonora Riva Sanseverino	2013	"Reconfiguration system that enhances the power extracted by a photovoltaic generator under non-uniform solar irradiance conditions using a flexible switch array topology to maximize the power generated in real time under various mismatch conditions."	The fully reconfigurable dynamic electrical system (DES) for photovoltaic generators allowed satisfactory power gain both in the case of non-uniform irradiance and in the case of fixed obstacles (Romano et al., 2013).

CONCLUSION

In today's industry, the development of new energy storage technologies has been considered of vital importance due to the increasing automation of production systems since these types of systems require that the devices are properly electrically powered, and in turn, deliver the necessary electrical characteristics to ensure that the process is carried out correctly, such as power, charge/discharge times, and amperage. SCs represent an alternative solution for energy storage because they are more stable devices compared to conventional batteries, and thanks to several studies have been proposed configurations that allow them to conserve electrical parameters such as voltage, power, amperage, and better conditions in the charge/discharge cycles; in addition to this, the activated carbon that composes the electrodes of the SC's can be made of biomass (coconut, cocoa, bamboo, coffee, and rice), which would represent an environmentally friendly alternative with

a longer life cycle compared to commercial ones. Among the improvements proposed with the use of SCs, we find the development of supercapacitor banks, defined as a series of SCs connected by electrical arrangements (series, parallel or mixed) that allow improving the voltage and amperage parameters, stabilizing the systems, to enhance the electrical parameters. However, these banks require control according to their applications; from which the switching matrices are presented, these have the particularity of allowing to change the parameters delivered according to the needs of the system that is being fed; this is a topic that is under research development and proposes revolutionary changes for the electrical industry.

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