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Journal of Environmental Sciences and Natural Resources

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Presentation of content

In the first article we present, *The role of tillage systems on the presence of heavy metals in corn grains*, by PONCE-LIRA Brenda, AGUILAR-ARTEAGA, Karina and DIAZ-BATALLA, Luis, with adscription in the Universidad Politécnica de Francisco I. Madero, as next article we present, *Characterization and analysis of the mango supply chain in San Cristóbal de la Impact of climate change on Melipona beecheii and socioeconomic assessment of meliponiculture in the mexican southeast*, by VÁZQUEZ-ELORZA, Ariel, RAMOS-DÍAZ, Ana Luisa and ANDRADE-GUTIERREZ, Rosalba, with adscription in the Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco A. C., as next article we present, *Sustainable impact on the use of dairy products residues*, by BLEN, Erick, HUESCA, Laura, VARGAS, Julio and CRUZ, Elena, with adscription in the Instituto Tecnológico Superior de Martínez de la Torre and Universidad de San Carlos de Guatemala, as last article we present, *Analysis of correlations in the growth of biogranules from synthetic wastewater of industrial origin*, by MIRANDA-FLORES, German, SANCHEZ-SANCHEZ, Celina and MORENO-RODRIGUEZ, Ernestina, with adscription in the Universidad de las Américas Puebla.

Content

Article **Journal of Environmental Sciences and Natural Resources**
December 2022, Vol.8 No.22 1-7

The role of tillage systems on the presence of heavy metals in corn grains

El papel de los sistemas de labranza sobre la presencia de metales pesados en granos de maíz

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Abstract

The contamination of heavy metal influences in different environmental as it is in soil, water and plant, as has been presented in the region of the Mezquital Valley, state of Hidalgo, where for more than 100 years it has been used the wastewater from the metropolitan area of Mexico City (ZMCM) for agricultural purposes; where the uptake of heavy metals by plants is usually the first step for entry into the food chain as a result of conventional agriculture. The present research work was aimed to evaluate the concentration of lead, cadmium and chromium in corn grain produced in the Mezquital Valley, by the different tillage systems and residue management with the aim of identifying the best system of agricultural production. Using an experimental design of randomized blocks with two replications and a test of means (Tukey, p>0.05), it becomes an invitation to producers in the region to change the traditional system applied by implement a rotation of corn with oats, in zero tillage with stubble on the surface (MA, CL, D); still this treatment is the ideal to ensure minimal concentrations of heavy metals in the grain of corn.

Mezquital valley, Pollution, Conventional

Resumen

La contaminación de metales pesados influye en diferentes ambientes como lo es en suelo, agua y planta, como se ha presentado en la región del Valle del Mezquital, estado de Hidalgo, en donde desde hace más de 100 años se ha utilizado el agua residual que proviene de la zona metropolitana de la Ciudad de México (ZMCM) con fines agrícolas; en donde la absorción de metales pesados por las plantas es generalmente el primer paso para la entrada de éstos en la cadena alimentaria como resultado de una agricultura convencional. El presente trabajo de investigación tuvo como objetivo evaluar la concentración de plomo, cadmio y cromo en grano de maíz producido en el Valle del Mezquital, mediante diferentes sistemas de labranza y manejo de residuos con la finalidad de identificar el mejor sistema de producción agrícola. Mediante un diseño experimental de bloques al azar con dos replicas y una prueba de medias (Tukey, p>0.05), se hace una invitación a productores de la región a cambiar el sistema tradicional que aplican por implementar una rotación maíz con avena, en cero labranzas con rastrojo sobre la superficie (MA, CL, D); siendo este tratamiento el ideal para asegurar mínimas concentraciones de metales pesados en el grano de maíz.

Valle del Mezquital, Contaminación, Convencional

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Introduction

Conventional agriculture is an environment that has been developed by farmers around the world over the years, leaving many consequences for the different applications given to the soil (subsoiling, harrowing, fallowing), as well as the irrational use of pesticides and fertilisers exposing their productions to the absorption of heavy metals by crops by leaving trace metals in the soil (Ramirez Haberkon, 2022), generally being the first step for the entry of these residues into the food chain as a result of conventional agriculture and excessive use of untreated wastewater for agricultural irrigation as cited by Grabach *et al*., in 2001.

The Mezquital Valley is located within the boundaries of the state of Hidalgo. It is located at the top of the Mexican plateau, 60 km from Mexico City, with an altitude between 1,700 m and 2,100 m above sea level. It has 27 municipalities where most of the inhabitants are dedicated to livestock production and mainly to agricultural activities.

Currently, agricultural activities are being developed in diverse crops such as alfalfa, corn, wheat, oats, beans, tomatoes, chillies and beets, where the production of corn grain stands out, with the Mezquital Valley being one of the first places at a national level. It is worth mentioning that all agricultural activities are based on a conventional or traditional system which consists of implementing a series of agricultural machinery such as subsoiling, with which producers ensure the decompaction of their plots, followed by fallowing and harrowing, whose main objective is to invert the soil horizons to leave a pulverised soil.

It is relevant to mention one of the problems afflicting the Valle del Mezquital Hidalgo, which has been the use of sewage water for agricultural irrigation for more than 100 years. Several studies in the Mezquital Valley have shown that the wastewater problem is very serious, due to the presence of heavy metals (Zn, Cr, Cd, Hg, Pb and As) in plants and soil, which means that these metals directly affect human beings who feed on the various vegetables and cereals produced in the region (Cayetano & Siebe, 2012; Grabach *et al*., 2001; Vázquez-Alarcón *et al*., 2005).

In addition to the above, the purpose of this research is to evaluate the concentration of cadmium, lead and chromium in maize grain produced in the Mezquital Valley, using different tillage and residue management systems in order to identify the best agricultural production system.

Theoretical Framework

According to the General Directorate of Environmental Health, acute exposure to cadmium can cause death in humans as it is attributed to induce prostate and lung cancer, among others, such is the case of a study carried out in Lima Peru, in the urban community of Chiquitanta, in which the concentration of cadmium present in water for human consumption was determined, where average concentrations of cadmium were found to be 0. 00417 mg-L^{-1} which indicates having exceeded the permissible limits of 0.003 mg^{-1} established by the World Health Organisation and the Peruvian Regulation on the Quality of Water for Human Consumption (Gonzales Poveda & Osorio Fernández, 2014); results that indicate a latent risk of chronic intoxication or a serious health problem for the population.

On the other hand, lead in its different forms can enter the body by inhalation and ingestion. It enters the circulatory system through the lungs and digestive tract and is excreted via the urinary tract and faeces. The manifestation of the symptoms of poisoning is known as plumbism or saturnism. The maximum permissible limit for Pb in blood is 10 µg/dL (Infantas, 2005). Above this value, it interferes with cognitive functions, as shown in Figure 1.

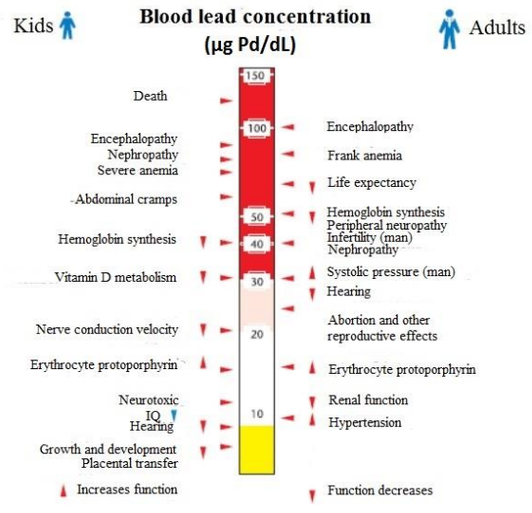

Figure 1 Plumbism and clinical manifestations
Source: Infantas, 2005

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Finally, chromium (VI) is a highly toxic element for humans and is classified by the IARC (International Agency for Research on Cancer) in group I (proven carcinogen in humans) since in occupational exposure it produces cancer in the respiratory system (Barrón, 2016; Téllez, Roxs, & Gaitán, 2004). Humans and animals are exposed to Cr by inhalation (air, tobacco smoke), through the skin or by ingestion (agricultural products, water). Occupations at risk include: mining and crushing, wood preservation, welding, cement manufacturing, paint industry, leather industry, photographic industry, electroplating industry, metal workers and stainless steel production (Cuberos, Rodriguez, & Prieto, 2009).

Methodology

Random sampling of ears, in plots within the Valle del Mezquital area

The maize cobs were sampled in the Valle del Mezquital area in the municipality of Francisco I. Madero Hidalgo, within the facilities of the Universidad Politécnica Francisco I. Madero.

Subsequently, the physical location of the aforementioned treatments was determined, located at the MasAgro experimental platform, at 20°13'46.9 "N 99°05'21.23 "W, at an altitude of 2300 m above sea level.

A random sampling was carried out in which an experimental lot was represented, containing 8 furrows. Three quadrants of 1.5 m wide and 3 m long are drawn, preferably in the central furrows (furrow numbers 4, 5 and 6); this practice is carried out in each experimental lot and then all the ears within each quadrant are cut and a sub-sample of approximately 200 grams is taken from each treatment.

Prepare and select the maize grain sample to be evaluated

The preparation of our maize grain sample must be in optimal conditions to be able to carry out further studies. The conditions that the sample must have are: completely dry and totally crushed grains until they reach a flour consistency.

Carry out an acid digestion for the extraction of lead, cadmium and chromium

Acid digestion is the traditional method used in the preparation of various types of samples in order to completely transfer the analytes in solution so that they can be analysed in liquid form by analytical techniques (Antoci, 2012; Mendoza, Parra, Almao, & Rodríguez, 2014).

0.1g of ground maize from each treatment was weighed in 10 ml of nitric acid at 150°C for 20 minutes.

Analysis of lead, cadmium and chromium concentration using an emission spectrophotometer with plasma source

For the analysis of heavy metals, a standard addition method was carried out on the digested samples. 200 µl of lead, chromium and cadmium standards were added to the real samples for subsequent reading.

The samples were measured by Inductively Coupled Plasma (ICP) on a Perkin-Elmer, (USA) Model 8300. The wavelength used was 228.802 nm for Cd, λ= 267.716 nm for Cr and 220.353 nm for Pb, which allows a detection range of 0-10µg/L of each element. Data were analysed by Tukey significance of treatments ($p>0.05$).

Results

Mexico is the fifth largest producer of Cd in the world, and it is generally found associated with Zn with ratios that vary in the range of 200:1 to 400:1. Cadmium is a heavy metal considered to be one of the most toxic elements released into the environment, together with mercury and lead (Grabach et al., 2001). It is widely distributed in nature associated with different minerals, and man has also contributed to its distribution and dispersion since the beginning of mining and metallurgical activity.

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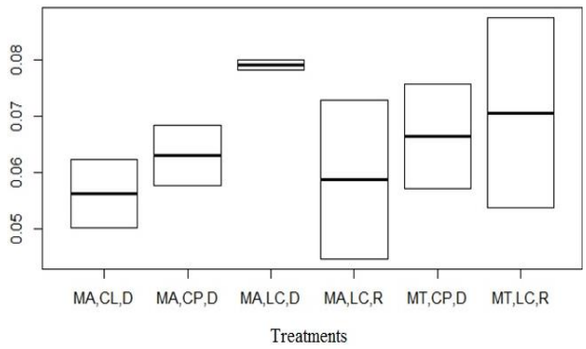
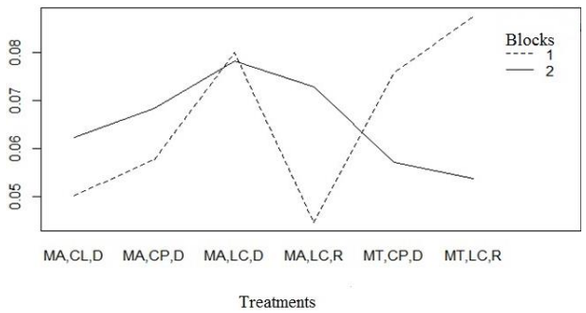


Graphic 1 Cadmium concentrations in maize grains under different tillage systems

Abbreviations: M is maize, A is oats, T is wheat, LC is conventional tillage, CP is narrow permanent beds, CL is zero tillage, R is removed stubble and D is with stubble.

Although no significant difference between treatments is reported (Tukey, p>0.05), the MA, CL, D batch shows the lowest concentration (0. 05633027 µg/ Kg of Cd^{2+}) this is an advantage because the producer will not only save resources in machinery (subsoil, harrow and plough), but also his production will have less or almost no concentration of the metal and the soil will maintain its texture and structure, improving the latter with the presence of organic matter, due to the presence of organic matter on the surface of the treatment, to also support the absorption of these pollutants in the agricultural system (Munive Cerrón *et al*., 2018).

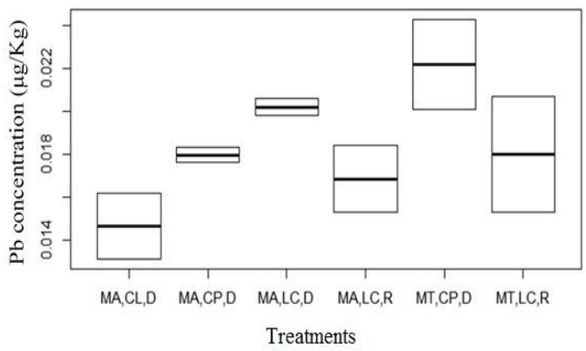
It should be noted that statistically it is accepted that there is no significant Tukey difference (p>0.05) between treatments, however the MA,LC,D batch presents the highest concentration (0.07910347 µg/ Kg of Cd2+) of all the treatments evaluated, however, this is considered a disadvantage for the producer because most implement conventional tillage which increases the investment due to the use of different agricultural machinery, as well as increasing the contamination of the raw material by this metal. It should be noted that previous studies carried out by the previous author have attributed the presence of heavy metals to the excessive use of agrochemicals.



Graphic 2 Comparison of blocks in the evaluation of cadmium in maize grains under different tillage systems

In the comparison of the two replicates there is no homogeneity in all the treatments, the most stable treatment was MA, LC, D, in which there is no great difference. Block one of this treatment presented an average concentration of 0.08001869 µg/Kg of Cd^{2+} and for replicate two 0.07818825 µg/Kg of Cd^{2+}, which leaves a minimum difference between the two replicates of 0.00183044 µg/Kg of Cd^{2+}. The least homogeneous treatment was MT, LC, R where there was a variation of 0.03374394 µg/Kg Cd^{2+} between the two blocks.

Similarly, lead is a heavy metal that occurs naturally in the earth's crust and has been distributed in the environment. There are organic and inorganic lead compounds, which are released into the air during the combustion of carbon and oil. Lead can enter the body by three routes: respiratory, digestive and dermal or cutaneous and cause harmful effects on human health at the cellular level, without even being perceived in the short term (Téllez-Rojo *et al*., 2021).



Graphic 3 Lead concentrations in maize grains under different tillage systems
Abbreviations: M is maize, A is oats, T is wheat, LC is conventional tillage, CP is narrow permanent beds, CL is zero tillage, R is removed stubble and D is with stubble

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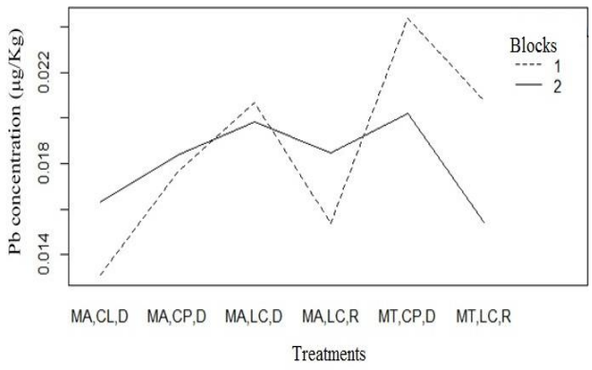
The treatments evaluated do not report significant differences (Tukey, p>0.05), however, numerically, the treatment with permanent beds (MT, CP, D) reported the highest accumulation of lead (0.022 µg/Kg of Pb^{2+}), this treatment also reported the third highest concentration of cadmium (0.066 µg/Kg of Pb^{2+}). In addition, it is believed that the structure of the planting beds, together with the lack of soil movement and flood irrigation in the study area, generates an accumulation of metals, favouring their absorption by the plant structure. Another of the treatments with the highest bioaccumulation of lead is MA, LC, D, which reported (0.020 µg/Kg of Pb^{2+}); it should be noted that previous studies have related the use of organic compounds such as vermicompost or fodder for the absorption of heavy metals (Munive Cerrón *et al*., 2018; Sanchez Tarrillo & Vilcas Guerrero, 2021). It is important to note that the treatment with the lowest concentration of lead (0.014 µg/ Kg of Pb^{2+}) was the one with zero tillage and where stubble was left on the surface (MA, CL, D); likewise, this treatment was reported to have the lowest concentration of Cd (0. 056 µg/ Kg of Cd^{2+}), i.e., it stands out because in this experimental lot the soil is not removed at all, so the producer does not invest in the rental of agricultural machinery and benefits the soil and the ecosystem in general, likewise, it ensures the lowest bioaccumulation of metals in the maize grain produced, contrary to what was reported by Mendoza-Escalona *et al*., 2021 where the content of Co, Cu, Ni, Cd and Zn was higher in the no-tillage system.

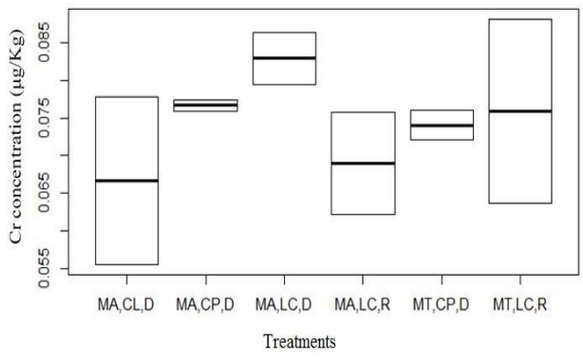


Graphic 4 Block comparison in the evaluation of lead in maize grains under different tillage systems
Abbreviations: M is maize, A is oats, T is wheat, LC is conventional tillage, CP is narrow permanent beds, CL is zero tillage, R is removed stubble and D is with stubble

In the comparison of the two lead blocks, a variation between them is evident, it should be noted that the most homogeneous treatments have been those in which rotation with oats has been carried out mainly with the presence of stubble. The most heterogeneous treatments were those in which a rotation with wheat was carried out in the absence of stubble. This shows the stability in nature with respect to the presence and absence of organic matter in the soil. In other words, the data in which the cover crop was considered have been more reliable.

On the other hand, chromium is a chemical element characterised as a hard, brittle, steel-grey, highly corrosion-resistant transition metal.

Its mechanical properties, including hardness and tensile strength, determine the usability of the substance. It has a relatively low forging and coiling capacity, however, when absolutely free of oxygen, hydrogen, carbon and nitrogen, it is very ductile and can be forged and machined (Montoya, Casas, & Wandurraga, 2010; Téllez *et al*., 2004).



Graphic 5 Chromium concentrations in maize kernels under different tillage systems
Abbreviations: M is maize, A is oats, T is wheat, LC is conventional tillage, CP is narrow permanent beds, CL is zero tillage, R is stubble removed and D is with stubble

Of the six treatments evaluated, statistically it is accepted that there is no significant difference between them, but numerically the MA, LC, D reports a higher concentration of chromium (0.0820.012 µg/Kg Cr^{2+}). It is relevant to note that this treatment also obtained the first place in the highest concentration of cadmium (0.079 µg/Kg of Cd^{2+}) and the second place in the highest concentration of lead (0.020 µg/Kg of Pb^{2+}).

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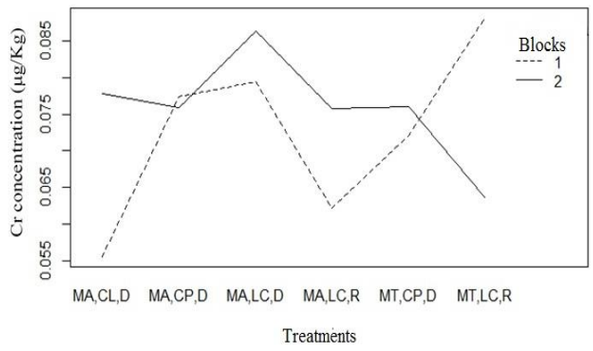
The results show that this treatment is one of the least recommended due to the fact that the highest concentrations of cadmium, lead and chromium were obtained. It is important to note that the conventional treatment promotes the excessive death of microorganisms derived from the continuous movement of the soil, including earthworms (Eisenia foetida), this macrobiota being a natural organism to reduce the concentrations of chromium in the soil (Barbaran Cruz, 2017).

It is important to mention that the treatment with the lowest chromium concentration is MA, CL, D, (0.066 µg/Kg of Cr^{2+}), this treatment reports the first place in the lowest concentration of both cadmium and lead (0.056 µg/ Kg and 0.014 µg/ Kg respectively). Therefore, this treatment would be considered the best for mitigating the uptake of these metals.



Graphic 6 Block comparison in the evaluation of chromium in maize grains under different tillage systems
Abbreviations: M is maize, A is oats, T is wheat, LC is conventional tillage, CP is narrow permanent beds, CL is zero tillage, R is stubble removed and D is with stubble

In the comparison of the two blocks of each treatment there was no homogenisation. These results may be due to various soil and climatic factors, since these are open field experimental treatments where these variables are not controlled.

Conclusions

It is important to highlight that during the development of this research project, strict methodologies and evaluations based on official Mexican standards were used. In addition, the results obtained are shown to be quite reliable, which were discussed objectively and sensibly in order to determine which treatment is the most appropriate to recommend the production of corn grain in the Mezquital Valley area with lower cadmium, lead and chromium concentrations.

The treatment considered as the most appropriate for the production system in the Mezquital Valley is MA, CL, D, which represents multiple benefits to the ecosystem, the economy and the production system in general. This research suggests raising awareness of the cultural practices currently used by producers in the region. With the above, a cordial call is made to ensure the proper management of both organic and inorganic waste and thus reduce pollution in soil, water and air, to make a comprehensive and sustainable use of resources for the benefit of all and future generations.

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Impact of climate change on *Melipona beecheii* and socioeconomic assessment of meliponiculture in the mexican southeast

Impacto del cambio climático en Melipona beecheii y evaluación socioeconómica de la meliponicultura en el sureste mexicano

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Abstract

The present study aimed to show the impact of climate change on Melipona bees in the Yucatan Peninsula and the socioeconomic situation of Melipona honey producers. Meliponiculture is a very important activity for some Mayans in the Yucatan Peninsula. However, the production of Melipona honey and its territorial distribution has decreased in recent decades, compared to the last century. Fieldwork was carried out in the east of the state of Yucatan to assess honey production activities and the socioeconomic situation of the population that depends on them. Data from Worldclim was used to generate distribution models for Melipona bees as well as scenarios of the impact of climate change on these species in the next seven decades. The scenarios that assume the continued presence of Melipona bees in the next seven decades show disappointing results in the face of climate change. It is necessary to implement effective public policies that help promote the well-being of both Melipona bees and the population that depends on them.

Melipona bee, Honey producers, Socioeconomic situation, Yucatan

Resumen

El presente estudio tuvo como objetivo mostrar el impacto del cambio climático en las abejas meliponas de la Península de Yucatán y la situación socioeconómica de los productores de miel melipona. La meliponicultura es una actividad muy importante para algunos mayas de la Península de Yucatán. Sin embargo, la producción de miel de Melipona y su distribución territorial ha disminuido en las últimas décadas, en comparación con el siglo pasado. Se realizó un trabajo de campo en el oriente del estado de Yucatán para evaluar las actividades de producción de miel y la situación socioeconómica de la población que depende de ellas. Se utilizaron datos de Worldclim para generar modelos de distribución de las abejas Melipona, así como escenarios del impacto del cambio climático sobre estas especies en las próximas siete décadas. Los escenarios que asumen la continuidad de las abejas Meliponas en las próximas siete décadas muestran resultados decepcionantes ante el cambio climático. Es necesario aplicar políticas públicas eficaces que ayuden a promover el bienestar tanto de las abejas Melipona como de la población que depende de ellas.

Abeja melipona, Productores de miel, Situación socioeconómica, Yucatán

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Introduction

Meliponiculture has been a traditional activity in the Yucatan Peninsula, especially for rural Mayan producers who have for generations produced honey and related products from the Melipona beecheii Bennett bee (Villanueva-Gutiérrez & Collí-Ucán, 1996). Labougle & Zozaya (1986), Apud Correa-Benítez & Guzmán-Novoa (2011), point out that "Mesoamerican cultures managed to cultivate various species of the Melipona and Trigona genera, [...] particularly the Melipona beecheii Bennett species, which is still used in Yucatan and which in the Mayan language is called Xuna`an-Kab, Kolel`Kab or Po`ol-Kab".

Indeed, "native bees are primary and essential pollinators of the flowers of most wild and agricultural plants that require a pollinator" (Cane & Tepedino, 2001, p. 1) and it is constantly evolving and adapting (Oliveira et al., 2022; Eleutério et al., 2022). It is worth noting that, by enhancing pollination processes, stingless bees play an important role in the "environmental health" of their ecosystems (González-Acereto, 2012). For rural families, meliponiculture represents a secondary economic alternative that generates income, promotes ecotourism, and facilitates the preservation of ancestral knowledge.

Meliponiculture is currently facing daily threats from internal and external factors, such as climate change, environmental pollution, the lack of marketing channels and services, together with a devaluation of the consumption of Melipona honey due to a lack of information and culture about its ancestral value and the processes required for its production (personal communication with key actors during fieldwork) (May-Itzá et al., 2022). There are also negative externalities affecting the sector. For example, the indiscriminate use of deforestation in the Yucatan Peninsula, and the increasing environmental contamination with glyphosates. Furthermore, the demand for environmental services has consequences that affect the environment of the region, greatly impacting the agricultural, livestock, beekeeping, and aquaculture systems in the region.

Climate change is and will be an external factor that will have a direct and indirect impact on the production processes of honey and the conservation of Melipona bees. There is evidence that the consequences of climate change on beekeeping have also been observed in other parts of Latin America. Maia-Silva et al., (2020) conducted a one-year study on honey and pollen from five colonies of M. subnitida. During this period, the colonies fed on native trees, shrubs and herbaceous species, which shows the importance of all plant strata for the bees' diet. However, from 2012 to 2016 the plants on which these bees feed was ravaged by drought in the Brazilian Tropical Dry Forest.

It is considered that the time of year (collection period) is an important variable that greatly influences the physicochemical characteristics of honey according to the bee species (Sant'ana et al., 2020; Real-Luna et al., 2022). Richard et al. (2019) point out that "climate change can modulate the environmental stimuli that trigger polyphenisms and/or some epigenetic marks, thus modifying in the short and long term the discrete phenotypic proportions within populations", including bees.

For many years, Melipona bees have been highly valued in the Mayan culture. According to the (Instituto Nacional de Ecología A.C. (s/f.): "In America, before the arrival of the Spaniards in the fifteenth century, the different species of the genus Apis did not exist. However, the cultures established in the area interacted with stingless bees, also called meliponas. For more than a thousand years, ancient Mesoamerican cultures traded and used as tribute the honey and wax produced by these bees."

In the last two decades, there have been significant changes in the production structure of beekeeping, mainly in the case of native bees of the Yucatan peninsula, as a consequence of the negative effects of various climatological events that have hit mainly the rural areas of the region. Sánchez (2019, p. 119) point out that the "impact of climate change on meliponiculture and beekeeping has affected this species". A year with less-than-ideal environmental conditions (flowering, weather, rain, etc.) can lead to having a single harvest instead of the usual two.

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Unfortunately, there is currently no accessible or transparent official census on the location of meliponiculture units in the Yucatan Peninsula. Ideally, each federal entity would generate a database to identify the economic activity of its population, which would help improve the decision-making process of public policymakers. In this case, the closest thing we had access to is the National Survey of Household Income and Expenses of the Instituto Nacional de Geografía y Estadística (ENIGH-INEGI, 2020).

However, there are some efforts by state governments in this regard. For example, the (Gobierno del Estado de Yucatán (2018, p. 1) stated in 2018 that it had started a state inventory of meliponiculture. It indicated that it had 70% progress on it and had recorded “2,949 hives of 87 producers, 40 women and 47 men, from 24 municipalities”. Based on this information, it can be assumed that, in 2018, there would have been around 4,213 hives of 124 producers, 57 women and 67 men (own interpolation). However, the number of productive hives can increase or decrease because of changing climatic conditions.

Primary sources (ENIGH-INEGI, 2020) were used to assess the importance of meliponiculture production in the Yucatan Peninsula. Available statistics show that among families with beekeeping activities, it is women who work on honey production. But even in these cases, the oldest male is usually recognized as the household head, "according to current stereotypes" (Instituto de las Mujeres, 2010, p. 52).

In the Yucatan Peninsula, women traditionally play a preponderant role in the cultivation of apis or Melipona bees, which can contravene patriarchal stereotypes about home management. "What is the problem? It is the very concept on which “patriarcl cultural patterns” are rooted. The use of the term "headship" is absolutely violent because it allows relationships within the home to become hierarchical. From the devaluation of domestic work to the impossibility for women to become "heads", except in the absence of men, this is all implicated in the concept of "Head of the Household"(Navarro-Ochoa, 2010, p. 126).

We find the value of the Melipona bee and its associated products in both tangible and intangible elements of Mayan society. For example, honey was used by Mayan priests to cure diseases of the eyes, ears, and skin, as well as for other therapeutic purposes in the community (Sánchez, 2019). Melipona honey is part of the culture and traditions of Mayan society. Today, the production of Melipona honey is mainly done within the territory of the Yucatan Peninsula and is then marketed to other parts of the country. Expanding the concept of valorization involves integrating a complexity of factors and dimensions associated with local realities and development processes (Champredonde & Gonzalez-Cosiorovski, 2016).

Methods

Within the framework of the CONACYT-CIATEJ Project "Microbiological and organoleptic revaluation and differentiation of Melipona beecheii honey and its contribution to the development of indigenous communities", different municipalities in the east of the State of Yucatan were visited on April 25-30 to evaluate the cultural aspects of the management of Melipona bees and the social, economic, and environmental benefits of honey production for Mayan indigenous families.

We conducted fourteen interviews with Melipona producers. It should be noted that it is currently very complex to identify them because there is no official register of producers. Non-random, snowball sampling was used to select participants. The sample is considered representative given its characteristics, which are described in the results section. The agricultural section of the National Household Income and Expenditure Survey (ENIGH-INEGI, 2020) was used as a primary source to segment the population working on the production of honey in the Yucatan Peninsula and assess the relevant socioeconomic indicators.

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The emergence of new statistical techniques and tools for geographic analysis has made it easier to develop predictive models of species and habitat distribution. This allows us to study climate change and its repercussions on bee species. The present study includes a prospective analysis of the effects of climate change on southeastern Mexico for the next seven decades. It seeks to contextualize the main challenges that lie ahead for the beekeeping sector and thereby highlight the main direct and indirect effects that can harm the population that works on the production of Melipona honey. Guisan et al. (2013) point out that, "Species distribution models (SDMs), commonly known as ecological niche models, ENMs, among other names; [...] are currently the main tools used to derive spatially explicit predictions of environmental suitability for species" as studied by Franklin (2010), Elith & Leathwick (2009), and Guisan & Thuiller (2005).

The prospective climate change model was developed in the statistical software R® with the Wallace model, using the shiny software package. An analysis of the spatial biodiversity of the bee Melipona beecheii Bennett was generated for the Yucatan Peninsula. Information from the Global Biodiversity Information Facility (GBIF, 2022) was used to identify the main territories and localities with a presence of this bee species. This allowed to stratify the localities surrounding those in which the presence of Melipona bees had been identified. The information on the socioeconomic characteristics of the local population was complemented by considering the presence of Melipona bees.

Once the geographical positions of Melipona bees were found, a radius of 5 kilometers was established around them to focus the research and improve the database by adding relational points corresponding to the states of Campeche, Quintana Roo and Yucatan and reducing the effect of spatial sampling bias. WorldClim agro-climatological databases corresponding to 2.5 minutes of arc ≈ 5 km were also obtained (Hijmans et al., 2005). "Bioclimatic variables are derived from the monthly values of temperature and precipitation to generate biologically more significant variables" (Worldclim, 2022) to use them for spatial analysis.

The following variables were selected:

BIO1 = Average annual temperature.

BIO2 = Midday range (monthly average (maximum temperature – minimum temperature)).

BIO3 = Isothermality (BIO2/BIO7) (×100).

BIO4 = Temperature seasonality (standard deviation ×100).

BIO5 = Maximum temperature of the warmest month.

BIO6 = Minimum temperature of the coldest month.

BIO10 = Average temperature of the warmest quarter.

BIO11 = Average temperature of the coldest quarter.

BIO12 = Annual rainfall.

BIO13 = Precipitation of the wettest month.

BIO14 = Precipitation of the driest month.

BIO15 = Precipitation seasonality (Coefficient of variation).

BIO16 = Wettest quarter rainfall.

BIO17 = Driest quarter rainfall.

The research was geographically focused by drawing a minimized area (minimum convex polygon) around the localities of occurrence of the bee. Non-spatial partitions were then made and the locations with presence of Melipona bees were randomly assigned. The aim was to reduce to a minimum any sampling bias. Besides, the model was not used to analyze transfer over time (Shcheglovitova & Anderson, 2013; Pearson *et al*., 2007). The Maxent module of the Wallace package of R® was used to build the distribution model (niche) of the species under study. This allowed us to identify "test" and "training" localities in the model of the scenarios of spatial presence and absence of bees over a period of time. We established a baseline with 61 points with presence of Melipona bees based on GBIF information. Of this total, 30 points were used for model training and 31 for testing.

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The Maxent model was used with the transformation of the logistic scale (Phillips et al., 2017) whose assumption is that the prevalence of the species is equal to 0.5 (Merow et al., 2013). The Wallace software package calculates the output of this model based on the values of the predictor variables for each cell and plots the prediction on the map.

Following the method used by Dorji et al. (2020, p. 4), the sequential models were selected according to 10th percentile training presence test omission (hereafter, 'percentile OR') and "balance training omission, predicted area and threshold values test omission" (hereafter "balance OR"). Percentile OR was chosen (Radosavljevic & Anderson, 2014); Galante et al., 2018) over the " minimum training presence test omission" (Shcheglovitova & Anderson, 2013); because the latter is more sensitive to extreme localities and over-predicts when there are many calibration locations (Radosavljevic & Anderson, 2014). Balance OR was used to assess the usefulness of a new threshold rule and its OR in selecting the optimal model. Different sequential combinations of the two OR, A UCTEST and AUCDIFF were used to formulate four sequential approaches.

The model was used to estimate future scenarios of the effect of climate change on Melipona bees for the next seven decades (Franklin, 2010; Ficetola et al., 2007). The climate change model used to create the scenarios was NorESM1-M. The following component models were used: CAM-OSLO to represent the environment; CLM to represent the land; CICE to represent sea ice; MICOM-HAMOCC to represent the ocean.

Results

The population that works in the production of Melipona honey has an age range between 19 and 71 years. In meliponiculturist households, 77.8% of the people dedicated to this activity correspond to the female gender. Most Melipona honey-producing units are run by women.

In most of the producer units that were surveyed, the volume of annual production fluctuated between 0.300 kg and 45 kg since the production of honey is usually a secondary economic activity, even though it supports other types of economic activities such as ecotourism, restaurants, and rural medicinal stores. The production of Melipona honey serves thus as a regional economic generator. It should be pointed out that an increase in the number of people dedicated to meliponiculture does not necessarily mean an increase in production due to the reduced economies of scale in this activity. For example, six people from one household produce 20 kg in the town of Tahmek, while in the town of Kantunil in Quintana Roo one person produces 45 kg.

Rural families dedicated to the production of Melipona honey reported having positive medicinal benefits from the use of the product; 89.4% of the population said they had made savings in medicines by substituting them for Melipona honey. The majority of the interviewed population uses Melipona honey for eye care and cataract cleaning, among other uses, as shown in Figure 1.

Figure 1 Use of the honey of the bee Melipona beecheii Bennett among producing families

The ecosystem of activities and products of Melipona bees also generates tourism activities, in which 28.6% of the participants are men and 71.4% are women. Half of the people interviewed said they perform ancestral rituals of gratitude for the production of honey. On average, 2.71 people work directly in each Melipona producing unit, with a minimum of 1 and a maximum of 6 people. Of the producers who sell Melipona honey in the markets, 35.7% indicated that they have significant savings in the consumption of honey derivatives, which substitute market products.

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Most of the producing families could consume the honey themselves but have greater incentives to sell this product in the market and thus obtain additional income.

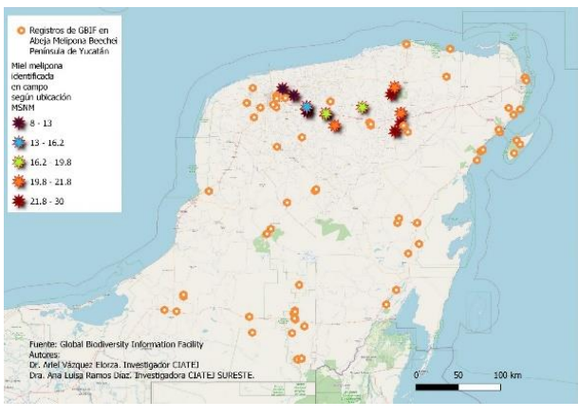

Figure 2 Presence of the Melipona beecheii Bennett bee in the Yucatan Peninsula
Source: Own elaboration based on information from Global Biodiversity Information Facility (GBIF, 2022) and fieldwork

The production and presence of the Melipona bee can be explained by multiple environmental, ecological, social, and economic factors. To contextualize the effects of climate change on this economic and cultural activity, the results yielded by the Maxent model are presented below. The scenarios generated extend to the year 2070 and make it possible to estimate the effect of climate change on the presence of the species according to the level of generated greenhouse gas (GHG) emissions. Figure 3 shows the model configuration and the different combinations of characteristics of Melipona bees.

Figure 3a shows the current distribution of the Melipona beecheii Bennett bees in Latin America. Figure 3 b shows the territorial presence of the bee in the Yucatan Peninsula. The model was evaluated using receiver operating characteristic analysis of the threshold-independent area under the curve (AUC), threshold-dependent minimal training presence (mtp), and 10th percentile (p10) training presence according to the Representative Concentration Trajectories (RCP). The results of the calculation of the territory with minimal training presence and an RCP2.6 are shown in Figure 3c. RCP4.5 is shown in Figure 3e; RCP6.0 in Figure 3g and RCP8.5 in Figure 3i.

The latter (RCP8.5) would mean an absolute loss of the presence of *Melipon*a bees in the Yucatan Peninsula since it tends to enlarge too much the non-presence areas in the distribution of bees, especially in the cases in which the data comes from the 10th percentile model. According to the results of the present study, the best option is to use the 10th percentile training presence, which considers the probability that 10% of the training presence records are skipped, especially the outliers. These results indicate that the continued presence of Melipona bees in the Yucatan Peninsula is largely uncertain.

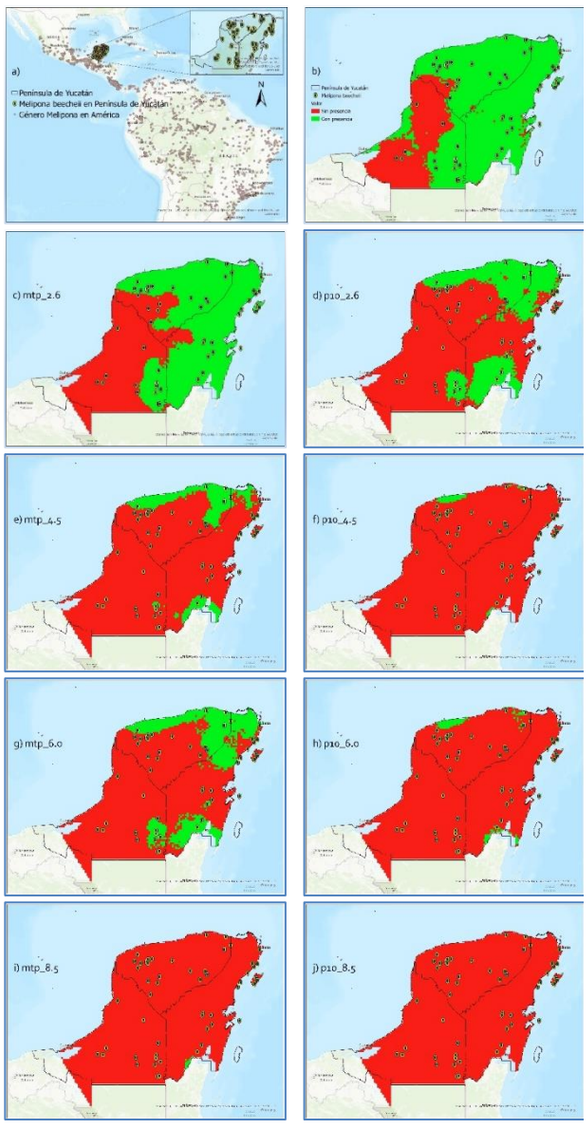

Figure 3 Scenarios of the loss of the presence of the bee Melipona beecheii Bennett in the south and southeast of Mexico and the Caribbean

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Conclusions and discussion

The production of Melipona honey is strongly linked to Mayan traditions and culture in the Yucatan Peninsula, including ceremonial activities that have lasted through several centuries. It also represents an important source of honey, honey-derivatives, and wax. It has significant medicinal and healing properties that are used by the producing Mayan families. The positive externalities are not limited to the production of Melipona honey since this activity represents a regional alternative for the promotion and development of rural community tourism. However, much remains to be done to increase the value of Melipona throughout Mexico. The social and economic benefits of the production of Melipona honey include both its intangible value for its contributions to family union, gastronomy, and health, as well as its tangible value in the generation of additional income for families, substitution of medicine products, creation of community jobs, empowerment of women and cultural production and transmission.

In the majority of producer households, this activity symbolizes a bond of family union and cohesion between the members of the household. In most cases, it is the women who attend and direct this activity, creating sources of employment. The whole family usually participates in it, including children, youth and the elderly. It is necessary to promote a revaluation of the importance of the production of Melipona honey among consumers so that the price paid for the product and the consumption of it incorporates the efforts and natural and cultural resources used in it. Moreover, the production of Melipona greatly benefits the pollination of important crops and vegetation in the region.

The results of prospective models regarding the absence or presence of the Melipona bee in the Yucatan Peninsula show significant risks of presence in the next seven decades.

This assumes that greenhouse gas emissions will increase, leading to higher temperatures, climate change, and pollution, coupled with an over-exploitation of natural resources. This reality makes the presence of the Melipona bee in the Yucatan Peninsula very uncertain. Public policy decision-makers should take this information into account and start designing strategies to promote the growth and competitiveness of the sector.

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Sustainable impact on the use of dairy products residues

Impacto sustentable en el aprovechamiento de residuos de productos lácteos

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Abstract

This article makes a proposal for the use of whey residues in the production of dairy products such as cheese. Currently, this type of waste does not generate benefits beyond its sale to the pig breeding industry for the fattens them, obtaining a price of no more than $ 0.03 MXN; This project proposes a use giving added value, attending to a food crisis problem with product innovation, as well as avoiding discarding said serum contaminating the water.

Whey, Added value, Food crisis, Innovation, Contamination

Resumen

El presente artículo, realiza una propuesta para el aprovechamiento de los residuos de suero de leche en la producción de productos lácteos como el queso, actualmente ese tipo de desecho no genera beneficios más allá de su venta a la industria de cría de ganado porcino para la engorda de los mismos, obteniendo un precio de no mayor a los $ 0.03 MXN; este proyecto plantea un aprovechamiento dándole valor agregado, atendiendo a un problema de crisis alimentaria con innovación de productos, así como también el evitar desechar dicho suero contaminando el agua.

Suero de leche, Valor agregado, Crisis alimentaria, Innovación, Contaminación

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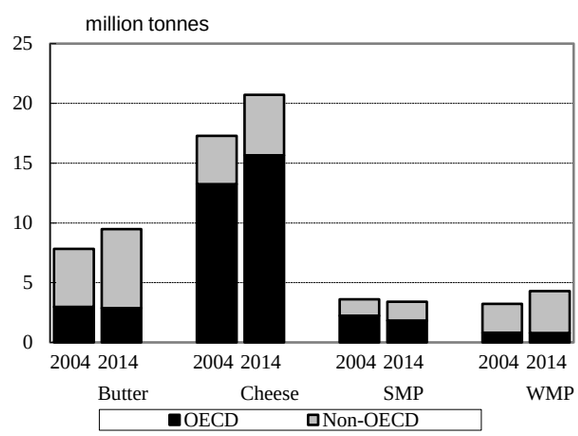
Introduction

In recent years, the global food industry has suffered inflationary effects due to a decrease in supply and an increase in demand, as well as the growing global energy crisis. The power to generate derivative products, at a low cost, which could at a given moment be the spearhead for the transformation of the food industry and a potential source of employment in countries with a food crisis.

In Latin America, especially in Mexico, where this document is focused, there are countless food options not exploited by the industry, as well as alternative energy options or other unexploited waste.

The particular case to be dealt with in this research focuses on the maximum exploitation of all derivatives of the dairy industry, which in Mexico is one of the industries with the greatest weight in the agricultural sector and which, given the country's food habits, represents the number one option, especially cattle farming. Jalisco, Coahuila and Durango are the first places respectively in milk production for different uses, either as a primary product or with added value. In addition, Mexico has the thirteenth place in milk production worldwide (INEGI 2016).

The state of Veracruz ranks first in cattle production with 261, 581 tons of meat, however, in terms of milk production Veracruz ranks fifth (5th) nationally, however, the exploitation of this industry in terms of food is still poor, this we can perceive in the daily lives of families in this particular state that live obtaining maximum income of $ 8.32 USD per day (average exchange rate in May - 2016).



Graphic 1 Prospects for consumption of dairy products
Source: OECD and FAO Secretariats
Statlink: http://dx.doi.org/10.1787/181214162651

Graphic 1 shows the outlook for 2014, the latest study presented by the OECD (Organisation for Economic Co-operation and Development) and the FAO (Food and Agriculture Organisation of the United Nations), which speaks of a strong potential market in terms of consumption, suggesting an expansion of the supply of dairy products as well as a broadening of product lines.

Therefore the search for value-added alternatives to this problem on the food side, as global food production is in crisis, and on the other side in the creation and use of the wealth of primary industries such as the cattle industry in this case, in its dairy production, represent a potential solution to both problems.

Similarly, this probable increase in the production levels of the dairy industry brings with it two important problems to solve: on the one hand, the improvement of the production process, especially for those who still use traditional methods, without this implying an increase in the cost of production; and on the other hand, we must take into account that a greater production of cheese implies a greater generation of whey as industrial waste, which causes high levels of water pollution.

Added value and circular economy (industrial symbiosis)

Our industrialisation and food processing systems suffer from leaks of valuable materials because they are based on a linear processing system based on the hypothesis of abundance, availability, ease of obtaining resources and cheap disposal of the waste generated in these processes. In other words, the current food processing model is based on the sequence of: take - manufacture - consume and dispose, in addition to generating additional and unnecessary costs that limit growth and contribute to the generation of emissions (1).

One of the main challenges is the implementation of a coordinated system for the handling of leftovers from one process as input for another, in pursuit of achieving that fundamental component of the circular economy that improves resource efficiency and in particular provides openness, competitiveness and flexibility. (2)

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Moreover, the transition to a circular economy requires changes in all value chains, from product design to the conversion of waste into an asset to new forms of consumer behaviour. (2)

It is estimated that improving resource efficiency along value chains could reduce material input requirements by 17-24% by 2030. (3)

Several authors mention various alternatives for the use of whey from the dairy industry, including all those that make use of its biotechnological and food properties. Some examples of these applications are protein powders, various types of flavoured beverages, edible coatings for products, bioplastics and biofuels. Zandona (9) mentions whey-derived protein powders, biogas and protein-based functional beverages as the most popular options for whey processing today. However, there are a number of challenges for the implementation of these options to be achieved efficiently and on a large scale. In the case of biogas production, the main difficulty reported by Tesfaw, Oner and Assefa (10) is the high costs of the reactors needed for effective conversion of feedstock to products, as well as the need for stringent control systems.

In general, the variety of possible routes in terms of industrial symbiosis is very wide. Liu et al. (11) and Das (15) mention the possibility of generating ethanol from whey, which leads to the need for more specific reactors whose technology increases installation and operating costs. Zandona (9) reports a list of the different microorganisms with which bioethanol can be synthesised from different serum variants and sources. On the other hand, Chen (12) mentions the possibility of synthesising bioplastics from the use of whey, at the expense of considerable investments for the installation of equipment and the treatment of raw materials. The degradation of raw materials must also be considered as a critical point for decision making in the development of new products, as mentioned by Barukcic (13). The author and his collaborators report that a large part of the limitations for the production of food and other value-added consumer goods is due to the chemical and physical processes necessary for the upgrading of raw materials, mainly the protein content (13).

Novel technologies such as blending of whey with by-products from the wine industry using supercritical carbon dioxide technology are also considered (14). Lactic acid production by microbial means has also been reported by Idler et al (16) and Liu et al (17) and more novel technologies detailed by Juturu (18), mentioning the possibilities, limitations and benefits obtained by these biological processes. Also several authors such as Guimaraes (21), Feng (22) and Basiak (23), propose the use of whey wastes as raw materials in the formulation of coatings and edible surfaces that can be applied to food and nutritional products.

However, it is necessary to emphasise that one of the primary objectives of both industrial symbiosis and cleaner production and circular economy schemes is the use of resources to avoid pollution and the inherent environmental impacts (19). Therefore, it is necessary to stepwise investigate all possibilities that result in lower environmental, social and economic costs (20). In this case, the aforementioned options become technologically feasible but economically and environmentally very difficult to achieve. In Latin America, and specifically in Mexico, many of the initiatives for the reduction of pollutants and the generation of clean production alternatives do not have the commercial, business and social openness to be easily accepted. For this reason, a preliminary case study is proposed that involves the creation of a product derived from whey in which the economic implications and demands are far less than the benefits. Furthermore, it allows for the opening of new practical and technological routes in the utilisation of waste. This case will be presented in the next section of the article.

Case study: flavoured cottage cheese

Currently, in the Vega de Alatorre region, an estimated 3 tonnes of cheese are produced daily (mainly fresh cheese and string cheese, also known as Oaxaca cheese), of which 300 litres of whey are wasted daily. Only 10 to 15% is used to produce butter or cottage cheese, as they are unaware of the economic benefits of giving added value to this waste. In addition to the opportunity cost of wasting 300 litres of whey, the problem is that this whey is discharged into rivers, streams or other sources of drinking water, which significantly contaminates the water, causing very serious pollution problems.

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Due to this and the lack of use of this type of waste, a small cheese producer in the region of Vega de Alatorre, in the state of Veracruz, Mexico, was taken as a reference to not only produce cottage cheese from the waste in the traditional way, but also to give added value to this product by flavouring it.

Cost of cheese production				
Materials				
Concept	Unit	Cost ($)	Quantity	Amount ($)
Milk	Litre	9.00	7	63.00
Coagulant additive	Litre	265.00	0.002	0.53
Labour				
Cheese maker	Journey	250.00	0.00025	0.06
Indirect costs			10%	6.36
Total production cost per cheese				69.95
Selling price				70.00
Profit margin				0.05
Whey residue	Litre	0.30	8	2.40

Table 1 Current Cost of Cheese Production
Source: Own elaboration

Table 1 shows the total cost of production for a 1 kg cheese, in addition to the waste in terms of litres of whey generated. In other words, analysing the unit price for a 1 kg cheese, the company invests $ 56.53, adding $ 5.66 in expenses associated with production and labour, which due to the fact that it has a unit sales price of $ 75.00 pesos, leaves a profit margin per unit of only 16.9%. 9%; it is important to point out that for the production of 1 cheese, an average of between 7 and 10 litres of milk is required, of which at the end of the production process, 8 and 6 litres become waste whey, which has a waste price of $ 2.4

It is important to point out that these 8 litres are generally dumped into the public sewage system, generating contamination and resulting in $ 2.40 for each cheese produced that is dumped into the sewage system. It is important to note that the value of $ 0.30 that is attributed to the waste whey is due to the fact that this is the price paid by some pig producers who use the whey as a supplement for fattening their pigs.

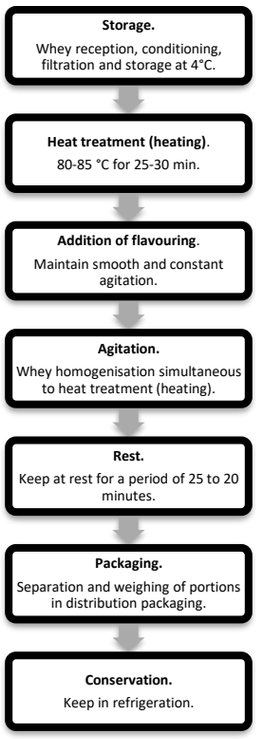

Figure 1 General manufacturing process.
Source: Own elaboration

Cottage cheese is a dairy product that can be obtained from whey, which represents the aqueous phase that is separated from the miscelar phase during the cheese-making process, and is also considered one of the main leftovers of the dairy industry.

The production of flavoured cottage cheese requires heating the whey to a temperature of 80 - 85° C, in order to induce enzymatic coagulation with an ideal pH of 6.60 (16ºD). The proper handling of these two critical control points allows the flavouring process to be carried out homogeneously, The product itself (unflavoured cottage cheese) does not have a very wide market, however, similar products such as flavoured cream cheese have been successfully industrialised by large transnational companies such as KRAFT; However, this other product has a high production cost compared to cottage cheese, as the latter uses whey, which in many cases is a waste product.

In order to produce one kilogram of cottage cheese, an estimated 150 litres of whey is required, which goes through a flavouring process, as described below, which results in our product. As a result of this flavouring process, a new waste is generated (whey 2nd process), which results in terms of costs as shown in the table below.

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Concept	Unit	Cost ($)	Quantity	Amount ($)
Whey residue	Litre	0.30	150	45.00
Sauce	Litre	6.00	0.25	1.50
Labour				
Cheese maker	Journey	171.43	0	0.06
Indirect costs			10%	4.66
Total cost of cottage cheese production (Kg)				49.72
Selling price				75.00
Profit margin				25.28

Table 2 Cost of Production of new product
Source: Own elaboration

As can be seen in Table 2, taking waste whey as raw material at a cost of $ 0.30, the production cost of 1 kg of cottage cheese is $ 45.50, when its market price with the added value of being flavoured is $ 75.00, leaving a profit margin of $ 25.28, i.e. 50.84%.

The yield per kilo of flavoured cottage cheese is 40% per kilo, exceeding the yield of 22.2% that cheese leaves per kilo, we are talking about a superior use of dairy production, as this multiplied by the number of tonnes produced daily, we are talking about litres of whey that are not used due to a lack of market.

Taking into account that the opportunity cost of not using this waste would be a very high loss, since the sale of whey as waste is only 30 ctvs. of Mexican peso per litre, which some pig farmers use for the fattening process.

It is worth mentioning that even after the flavouring process of the cottage cheese, there is still a surplus of 100 litres per kilogram.

Conclusion

The case study that is the subject of this document is currently in the process of opening up a local market, which, although still small, due to the fact that the area of influence of the market is only regional (6 neighbouring municipalities), has allowed a great use to be made of the waste whey by flavouring the cottage cheese.

It is important to emphasise that the production of whey is currently limited due to various factors, mainly the drop in milk production in the region, as a result of the drought that has hit the central-northern part of the state of Veracruz; in addition, SMEs alone may lack a reliable source of information and specialised advice that would allow them to move towards the implementation of circular economy solutions.

For its part, the financial system often does not offer investments for efficiency improvements or innovative management models, which are seen as more risky and complex. Traditional consumption habits can also hinder the development of new products.

These barriers, coupled with dissent from the paradigm that the reconversion of cheese industry waste cannot be used for human consumption, do not allow for clear and uniform signals of transition to a circular economy.

Monthly sales of cottage cheese, before being flavoured, were the equivalent of 30 kilograms per month, with a selling price of $ 60.00 (MXN); after one month of local marketing, it increased by 40 kilograms at a selling price of $ 75. 00 (MXN), this increase in both volume and price is significant, as the fact that the flavoured cottage cheese has been presented has represented a broadening of its commercial spectrum, as it not only has as clients retailers who generally sell with a 100% profit margin in relation to the cost obtained from the producer, but also managed to expand retail sales to the service area (restaurants), as the flavoured cottage cheese is representing a complement for these businesses.

This progress, although very small, reinforces the business project as it is a product with relative success in the market, with little investment and with a captive market, which serves as an incentive to obtain federal resources from the Ministry of Economy (SECOM), the Ministry of Social Development (SEDESOL) and other Mexican government agencies, thus proving that small enterprises with a well-founded sustainability plan represent a successful business model that, at a given moment, can become a spearhead for the development of a powerful industrial symbiosis, generating economy of scale and ultimately a potential increase in the country's Gross Domestic Product.

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Analysis of correlations in the growth of biogranules from synthetic wastewater of industrial origin

Análisis de correlaciones en el crecimiento de biogránulos a partir de aguas residuales sintéticas de origen industrial

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Abstract

Pearson correlation is a statistical method used to identify dependence of variables in a system. This paper proposed this correlation method to analyze the relations between variables in a biogranulation process using a synthetic wastewater. These later was prepared assuming an industrial textile origin. The analysis was divided in aerobic, anaerobic and combinate cycles. Results obtained indicated Pearson correlation identified a relation in pH variable between dissolved oxygen and conductivity in aerobic cycle. Conversely, relations with conductivity between density are found in anaerobic cycles. Evaluating total data (in both cycles) relation pH variable between conductivity and mixing were found as a strong correlation in the system. Finally, the importance of identify relationship between variables it is important to monitoring those variables that might affect the system in each formation cycle of biogranulation. For example, in the aerobic cycle the desnitrification is crucial to decomposed until nitrates (N-NO2) and nitrites (N-NO3), or in the anaerobic cycle the reduction to nitrogen gas (N2).

Correlation, Statistical, Dependence, Synthetic, Wastewater

Resumen

La correlación de Pearson es un método estadístico empleado para identificar dependencias entre variables. Este artículo propone emplear esta correlación para analizar las relaciones entre variables en un proceso de biogranulación usando agua sintética residual. Esta última fue preparada asumiendo un origen industrial textil. El análisis fue dividido en los ciclos aerobio, anaerobio y combinados. Los resultados obtenidos indican una relación del pH con respecto a las variables de oxígeno disuelto y conductividad en el ciclo aerobio. Mientras que, en el ciclo anaerobio se encontraron relaciones entre la conductividad y la densidad. En la evaluación de los datos totales (para ambos ciclos) la relación entre el pH y las variables de conductividad y mezclado mostraron una alta correlación en el sistema. Finalmente, la importancia de identificar relaciones entre las variables es importante para monitorear aquellas variables que pudieran afectar el sistema en cada uno de los ciclos de formación de los biogranulos. Por ejemplo, en los ciclos aerobios el proceso de desnitrificación es crucial para la descomposición hasta nitratos (N-NO2) y nitritos (N-NO3), o en el ciclo anaerobio la reducción a nitrógeno gas (N2).

Correlación, Estadística, Dependencia, Sintética, Agua residual

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Introduction

An important concern worldwide is the contamination of rivers, water aquifers and underground rivers. In this topic, Wastewater treatment plants (WWTPs) are the main resource to treat domestic wastewater, agricultural wastewater, or industrial wastewater. Domestic wastewater is divided into two categories, i.e. black water (discharge from toilets that contains high organic, nitrogen & phosphorus content) and grey water (all the other wastewater except the toilet, & contains low organic persistent compounds) (Wulan et al., 2022). The most common pollutants coming from agricultural activities are high loads of oxygen-demanding organic compounds, associated nutrients (particularly nitrogen & phosphorus) and a variety of organic xenobiotic substances applied to cultures, soils or used in livestock, such as pesticides and pharmaceuticals (Dordio & Carvalho, 2013). In the case of industrial wastewater usually contains organic pollutants, heavy metals, and non-disintegrating materials (Abdelbasir & Shalan, 2019). The sectors that produces pollutants are iron-steel; textiles and paper; petrochemicals-refineries; non-ferrous metals; microelectronics; and mining (Hanchang, 2009).

By 2050, global water demand will increase by 20-30% due to increased industrial and domestic water use (WWAP (UNESCO World Water Assessment Programme), 2019). Through scientific including a reasonable treatment and reclamation, wastewater can be transformed into safe reclaimed water, which can not only reduce environmental pollution, also effectively increase water resources, realize the safe and efficient use of alternative water resources (Liao et al., 2021).

Movement and wastewater treatment systems are important energy consumers around 3%-4% of total U.S. electricity consumption employed (Us, 2008; Galbraith, 2011; Goldstein & Smith, 2002). The operational modifications could lead in some instabilities and hence an increase in energy consumption. As a result, the need for research to focus on improve the operational conditions during the operational processes is so important.

Some biological wastewater treatment processes (BWWTPs) are employed in conventional WWTPs depending on microorganisms available in the system (Meng et al., 2020). Aerobic Granular Sludge (AGS) technology becomes a very competitive method to activated sludge system. Its main advantages include: high energy efficiency, low investment costs, improved sludge settling (Arrojo et al., 2004; Czarnota et al., 2018; Lee et al., 2010; Ni et al., 2009; Othman et al., 2013; Su & Yu, 2005). The use of biogranule in BWWTPs imply their formation, growth and stability of dense and irregular clusters.

Aerobic granular sludge have been applied for treatment for high strength organic wastewater (Moy et al., 2002), degrade phenol (Adav et al., 2007a; Chou et al., 2004; Jiang et al., 2002), remove toxic organic compounds (Xie, 2003), also can degrade pyridine (by products of coal gasification) (Adav et al. id., 2007b). Aerobic granules played a promising role in adsorption of toxic chemicals (Adav et al., 2008), just for mention the highly toxic heavy metals had been removed with sludge granules by biosorption (Wei et. al., 2018; Pagliaccia, et. al., 2022).

There are many factors that can affect the capacity of WWTPs to remove pollutants or micropollutants. The main drawbacks of aerobic granules implementation are the loss of stability, granule break-up, and filament overgrowth (Adav et al., loc. cit.; Liu & Liu , 2006; Su & Yu, loc. cit.). Overcoming the obstacles, during the granule formation is important to identify the most favorable operation conditions (physical & chemical parameters) for granule stability, and increased removal of nitrogen, phosphorus, heavy metals, or particle matter, just for mention some conditions.

Some investigations demonstrate the Pearson correlation is used to identify linear and nonlinear relationship between random variables such as wastewater treatment rate, reclaimed water use rate, phosphate accumulation, eco-efficiency factors, community structure , abiotic parameters, sewage temperature, power consumption, volumetric flow rate and other pollutant parameters (Günther et al., 2012; Hu et al., 2019; Liao et al., 2021; Rashid & Liu, 2020).

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In this regard, the aim from this study is demonstrate that some variables are correlated. Therefore, physic-chemical parameters such as pH, conductivity, temperature, dissolved oxygen, and density were correlated during biogranulation in aerobic and anaerobic cycle times.

Methodology

A. Sludge source

A sample of sludge were obtained from the wastewater treatment plant at Universidad de las Americas Puebla, Mexico. The sample was obtained before the conventional aeration process. The collected sample was settled for 5 min to remove excess water to obtain the residual sludge that will be inoculated in the bioreactor.

B. Synthetic wastewater

The concentrations of the effluent from the textile industry were simulated considering only the spinning and weaving process. The synthetic wastewater was prepared using component listed in Table 1. It´s important to mention that colorants and dyes were omitted in the synthetic wastewater.

Component	Formula	Dosed sewage	Unit
Sodium acetate	CH_3COONa	1.5	g/L
Phenol	C_6H_6O	0.20	
Magnesium sulphate	$MgSO_4$	5	
Calcium chloride	$CaCl_2$	2	
Iron(III) chloride	$FeCl_3$	110	mg/L
Copper sulphate	$CuSO_4$	50	
Potassium chloride	KCl	100	
Aluminum chloride	$AlCl_3$	90	
Zinc sulfate hepta-hydrate	$ZnSO_4.7H_2O$	120	

Table 1 Composition of synthetic substrate
Source: (Muda et al., 2010)

C. Bioreactor conditions

A Photo-Sequential Bach Reactor (SBR) model 2F-5000 (Figure 1) was used to analyze the formation, and growing in biogranulation process. The samples were composed in a 2:1 ratio, that is, 2 L of synthetic substrate per 1 L of suspended solids (SS). The SBR was kept at 25°C±1°C using temperature control SEV FC10, and was shaken at 50 rpm with an F2-5000 magnetic stirrer. The air system was controlled with a pump Model BD-15 at 1 L/min.

According to feast famine approach, in the biogranules formation were considered cycles of initial feeding followed by 96 h aerobic cycle (AC) and 72 h anaerobic cycle (ANC) without food for twelve cycles over a period of 12±1 day (Sun, et al., 2019),. Samples were taken at the end of each cycle and observed under a light microscope with a 4× objective lens (Nikon Eclipse E200) to verify biogranule formation, growth, and stability. A multiparametric equipment Thermo Scientific Orion was used to monitor the pH, temperature, conductivity. The density was estimated using a weight mass pycnometer method. Also, the dissolved oxygen (DO) was measured with a dissolved oxygen equipment model YSI Pro2030.

Figure 1 Photo-Sequential Bach Reactor (SBR) used in experimental biogranulation process

D. Pearson correlation analysis

The Pearson correlation coefficient (PCC) that refers to a measure of the linear and nonlinear relationship between two random variables defines as (Zou et. al., 2003)

$$r_{xy} = \frac{E[xy]}{\sigma_x \sigma_y} = \frac{\sum(x_i - \bar{x})\ \sum(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2}\sqrt{\sum(y_i - \bar{y})^2}} \quad (1)$$

Where:

$\bar{x} = \frac{1}{n}\sum_{i=1}^{N} x_i$, is the mean of x

$\bar{y} = \frac{1}{n}\sum_{i=1}^{N} y_i$, is the mean of y

r_{xy}, is the correlation coefficient

$E[xy]$, is the cross correlation between x and y

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The correlation coefficient varies between -1 and +1. The value "-1" corresponds to a negative correlation between variables. Meanwhile the value "+1" corresponds to a positive correlation. See Table 2 for details and interpretation.

Correlation coefficient value	Direction and Strength of Correlation
-1.0	Perfectly negative (negatively correlated)
-0.8	Strongly negative
-0.5	Moderately negative
-0.2	Weakly negative
0.0	Uncorrelated (No association)
+0.2	Weakly positive
+0.5	Moderately positive
+0.8	Strongly positive
+1	Perfectly positive correlated (positively correlated)

Table 2 Interpretation of correlation coefficient
Source: (Zou et. al., 2003)

During operational conditions of WWTPS are common nonnormal data, due to the complex behavior of the system involve. Due to non-normal distributions, some variables were normalized before implement Pearson correlation analysis. In this study, the analysis was carried out to identify the relation between variables during the cycles of formation (AC & ANC), growth and stability of biogranules using Minitab® 21.2. Two main cycles were proposed, in the AC occurs the Nitrogen (*N*) ammoniacal oxidation ($N\text{-}NH_4^+$) until nitrates ($N\text{-}NO_2$) and nitrites ($N\text{-}NO_3$). In the ANC, denitrifying bacteria reduce nitrites and nitrates to *N* gas (N_2). Pearson correlation coefficients were computed using the total transformed data and for each AC and ANC. Figure 2 shows the schematic diagram to estimate the Pearson correlations in the SBR at different cycles. The data analyzed were divided in three group:

- Aerobic cycle (AC), cycle of 4 days
- Anaerobic cycles (ANC), cycle of 3 days
- Both cycles (AC & ANC), total data

Some models were obtained to predict main variables that dominate the system behaviors in each group of data.

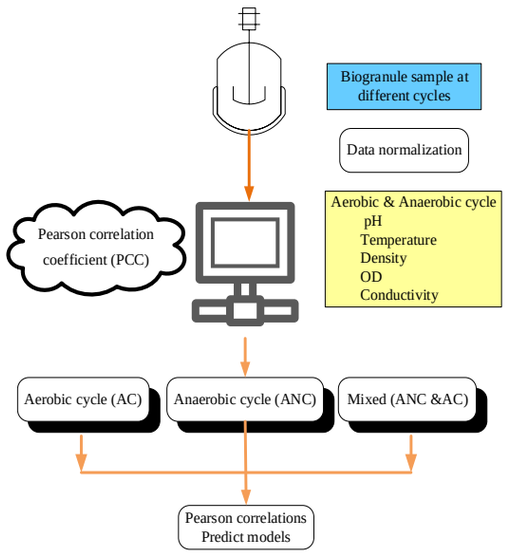


Figure 2 Schematic procedure to estimate the Pearson correlations in the SBR at different cycles

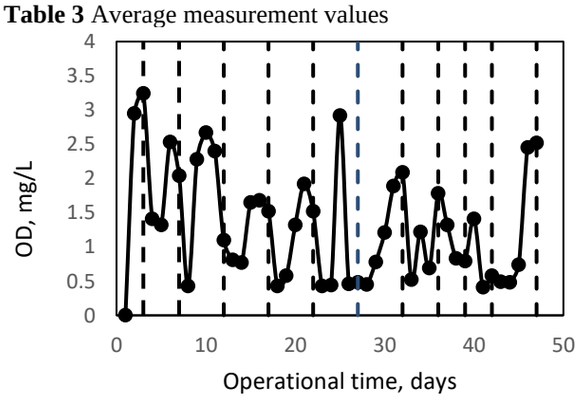
Results and discussion

A. Both cycles (AC & ANC)

Considering total data monitored, Graphic 1 shows variable´s fluctuations where discontinues line represents a new cycle (aerobic or anaerobic). In average the OD was 1.35 mg/L, with a 0.41 mg/L as minimum value and a 3.24 mg/L as maximum value.

Condition	Average value
pH	8.25
T, °C	24.63
OD, mg/L	1.35
Cond, mS/cm	5.76
Rpm	54.48
ρ, g/cm^3	0.98

Table 3 Average measurement values



Graphic 1 Variations of the OD in the SBR

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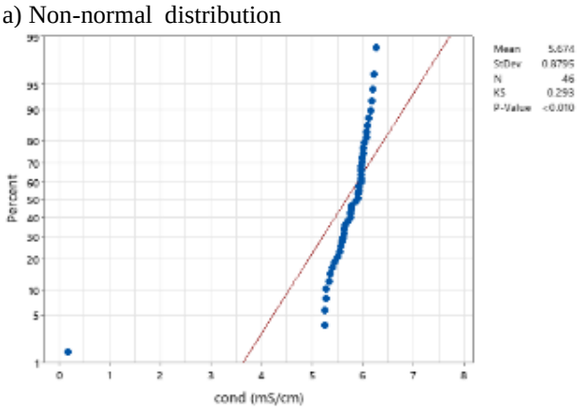
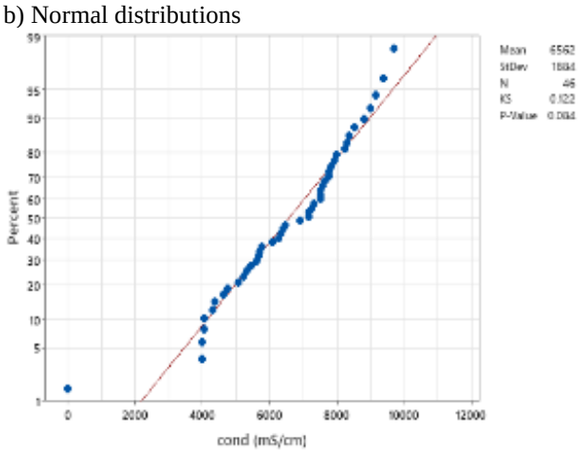
Due to non-normal distributions of data, a normalization analysis was done using Box Cox transformation approach (λ=0.5). Variables like temperature, mixing, and conductivity were normalized before implement Pearson correlation analysis. For example, conductivity of the system using normalized Box Cox method is shown in Graphic 2 (a) original data distributions (p value of 0.004) and (b) after normalized data (p value < 0.070).

a) Non-normal distribution

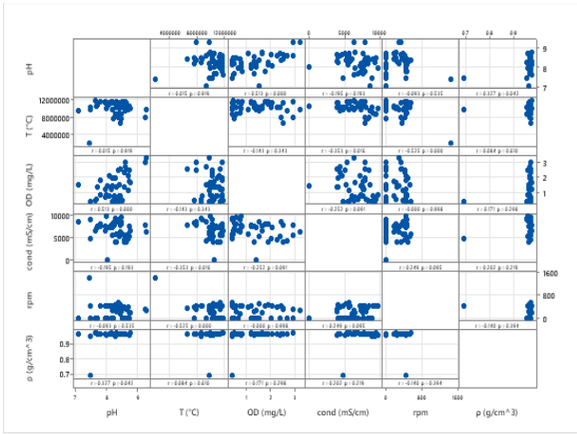


b) Normal distributions



Graphic 2 Normalization of conductivity data in the SBR

Correlations analysis of all data indicate some clusters identifed in the matrix plot (see Graphic 3) that are related with their Pearson coefficient and represented the relations between variables.



Graphic 3 Matrix plot of variable system AC & ANC.

Correlation models were estimated using the highest positive or negatives *Pearson* value in the matrix plot. Conversely no higher correlation was obtained, only two correlations were found as moderate positive and moderate negative correlations. It was found a positive correlation between pH and OD. Yin et al., (2016) demonstrated that the combined effects of DO and pH affects the nitrogen removal rate, where oxygen-consuming bacteria (nitrifiers) were implicitly inhibited by the low pH and less oxygen consumption.

Meanwhile, the temperature as a dependent variable were related with conductivity and mixing as independent variables. These variables are related with water distribution in the wet mass, can give a measure of the uniformity of liquid distribution and also a measure of the change of packing density of the damp mass during the massing stage of the granulation process (Spring, 1983). The correlations models are shown in Table 4 where it can be seen the correlation coefficient (R^2) value.

Correlation	Model	R^2(%)
Moderate positive	$pH = 7.904 + 0.269\ OD$	26.33
Moderate negative	$T = 11.9x10^6 - 224\ Cond - 37952\ Mix$	13.44

Table 4 Model correlation for both cycles (AC &ANC)

Where: pH, hydrogen potential; OD, Oxygen dissolved [mg/L]; T, Temperature [°C]; Cond, Conductivity [mS/cm]; Mix, Mixing [rpm].

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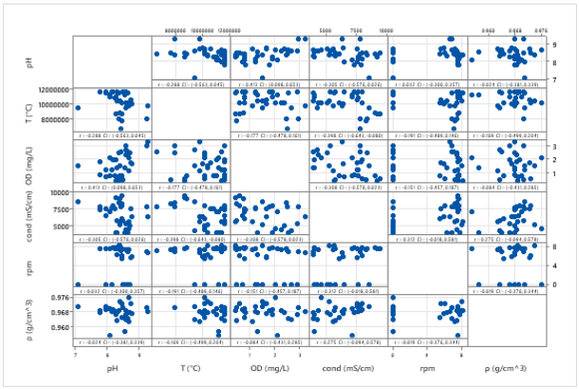
B. Aerobic cycle (AC)

During AC cycle a degradation phase in the SBR was done followed by an aerobic starvation phase with no substrate feeding. Many factors can be related with the performance in the aerobic cycle where is desired the characteristics like good granulation, excellent settling time, regular and smooth compactness, or strong microbial structure, and high biomass retention. Pearson correlation analysis were done to identify relationship between variables of the system.



Graphic 4 Matrix plot of variable system AC

The results indicated four models that presents the highest *Pearson* value. Graphic 4 shows the matrix correlation for AC where some clusters are identified. Table 5 shows the models obtained where the higher correlation was pH (as dependent variable) versus OD and conductivity (as independent variable). In AC, the negative correlation between temperature and conductivity indicates the relation of packing density during granulation process The later, is have reported as deterioration of the settling properties due to overgrowth of filamentous microbial structures at higher mesophilic temperatures Liu & Liu, loc. cit.

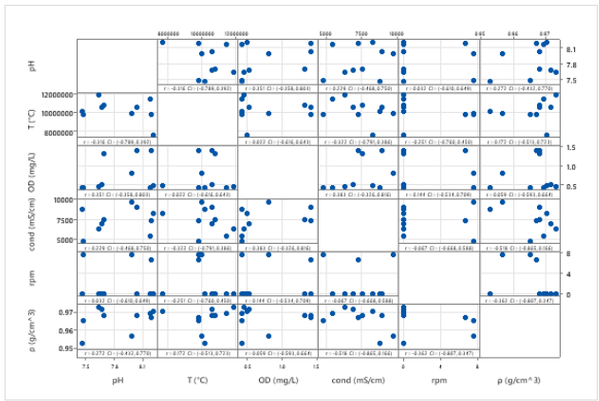
Correlation	Model	R^2(%)
Moderately negative with *OD* Moderately positive with respect to *Cond*	$pH = 8.447 + 0.1652\ OD - 4.4\ x10^{-5}\ Cond$	20.55
Moderately negative	$T = 12.424361x10^{6} - 329\ Cond$	15.88
Moderately negative	$OD = 2.553 - 0.000159\ Cond$	9.47
Moderately positive	$Cond = 5727 - 158.5\ rpm$	9.75

Table 5 Model correlation for AC

Where: pH, hydrogen potential; OD, Oxygen dissolved [mg/L]; T, Temperature [°C]; Cond, Conductivity [mS/cm]; Mix, Mixing [rpm]

C. Anaerobic cycle (ANC)

Removal of organic carbon, nitrogen and phosphorus simultaneously in sequential batch reactors combined the aerobic with anaerobic cycle adding anoxic stage (Callado & Foresti, 2001). As can be seen in Table 6, the highest correlation was found between conductivity (dependent variable) versus density (independent variable). The granule formation is related with biomass density, shape, or packing, between others. The biomass density of aerobic granules is related with a higher settling velocity and result from the dense microbial structure (Tay et al., 2001).



Graphic 5 Matrix plot of variable system ANC

Correlation	Model	R^2 (%)
High Moderately positive	$Cond = 128693 - 5022\ Dens$	26.80
Moderately negative	$T = 11.988949x10^{6} - 235\ Cond$	10.34
Moderately positive	$OD = -0.012 + 0.000106\ Cond$	14.63
Moderately positive	$pH = 8.516 - 0.243\ OD$	22.80
Moderately negative	$rpm = 191 - 7.80\ Dens$	13.07

Table 6 Model correlation for ANC

Where: pH, hydrogen potential; OD, Oxygen dissolved [mg/L]; T, Temperature [°C]; Cond, Conductivity [mS/cm]; Mix, Mixing [rpm]; Dens, density [g/cm^3]

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Conlusions

The results indicated that in AC, ANC or both cycles are some variables correlated significantly. In AC and ANC, were found that OD and pH shows a moderate positive correlation. These relations could also have influence operational factors-values (OD, temperature, aeration) or biogranule characteristic (settling times, microbial community, mass density, high biomass retention). This study provides a basis to find the variables that could enhance aerobic, or anaerobic properties during granulation process.

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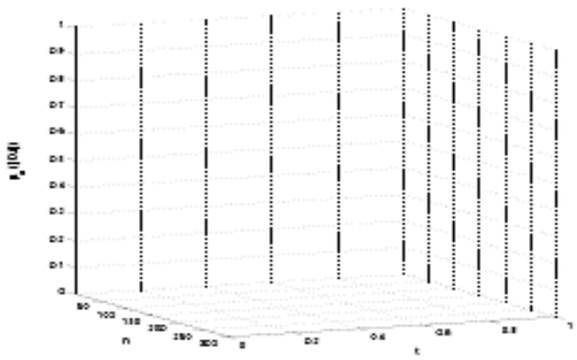

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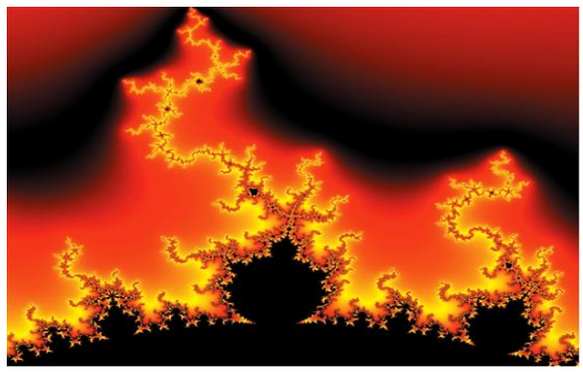

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