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CIRCULAR ECONOMY IN THE HANDLING OF COFFEE HONEY WATER: CASE OF A COFFEE COOPERATIVE

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ABSTRACT

The activity of coffee production, specifically that which is carried out by small producers, generates liquid waste, called honey water, which without treatment contaminates soils and waters, before which, it was proposed to develop a technological protocol for the treatment of honey water from the wet process of coffee through the use of organic polymers and from this, use the treated water for the irrigation of coffee plantations and the solid residue that comes out to elaborate food of fish. It was found that the treatment with organic polymers achieved a reduction of 80% of the levels and/or the absence of the indicator in 11 of 15 physicochemical and microbiological indicators analyzed. Likewise, the implementation of a drip irrigation module with the treated water, using 2 LPH drippers was validated, and the solid residues or sludge obtained from the honey water treatment performed well as a by-product for the production of fish feed.

Keywords: waste, coffee, water treatment, irrigation, fish

INTRODUCCIÓN

Coffee in Peru has been for several years the first agricultural export product (Zegarra, 2019) being surpassed in recent years by other non-traditional agricultural export products such as grapes and blueberries (SUNAT, 2021). The cultivation of coffee takes on great importance in small-scale agriculture, with productive units of between three and five hectares, thus housing around 2 million people who cultivate some 350 thousand hectares. (JNC, 2020). This panorama

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and together with the work on several fronts has made small farmers organize themselves into Associations and Cooperatives of coffee growers to face the challenges of the international market, with around 110 exporting organizations to 2021, (JNC, 2022) being the Northern Coffee Region, mainly the provinces of Jaén and San Ignacio, the most prolific coffee zone in the development of organizations (Diaz & Carmen, 2017; JNC, 2022; Torres Avila et al., 2022), this added to the fact that Cajamarca is located in the tenth position (of a total of 24, excluding Lima and Callao) of importance in Peru in terms of Gross Domestic Product (IPE, 2020).

The production of coffee is focused on marketing abroad in the tariff "unroasted coffee, without decaffeination" (dry parchment) (BCRP, 2021; MIDAGRI, 2021), For this, post-harvest processing is carried out mainly under a wet processing system. (Diaz & Carmen, 2017) which is mostly done in an artisanal way by small producers. The progress of the coffee sector in post-harvest management, and mainly productive practices, have allowed Peru to be the world's main supplier of organic coffee with around 1 million quintals per year exported in this type of coffee. (JNC, 2020), In addition, various production areas, mainly the northern coffee axis, have been improving and increasing their volumes in terms of specialty coffees (organoleptic quality). (CPCC, 2021), that exceed 90 points on the SCAA scale (SCAA, 2015), which is evidenced by the prizes obtained, the participation of Peru in international competitions and the auction of specialty coffees at very honorable prices of up to US$100 per pound (ACE, 2021).

However, the progress shown in the previous paragraph still maintains a technological gap in terms of solving various problems analyzed within coffee producers or farms. (Dilas J., 2013), mainly in problems not directly linked to productivity, as is the case of waste treatment such as coffee pulp (Arteaga-Cuba et al., 2021) and the treatment of honey water, given its significant content of contaminants for water, air and soil (Zambrano-Franco & Izaza-Hinestroza, 1998).

In this framework, the Cooperativa Agraria Valles del Café, which associates small coffee growers in the district of Chirinos in the Cajamarca region, Peru (see figure 1) with the support of researchers from the Universidad Nacional Agraria La Molina, and the financing of the PROINNOVATE program, among October 2020 to May 2022, they executed a technological development project that sought to develop a technological protocol for the treatment of honey water from the wet processing of coffee through the use of organic polymers and from there, use the treated water for the irrigation of coffee plantations and the outgoing solid residue as fish feed. This project is based on a Circular Economy application approach, which is part of global policies (Braun & Toth, 2021), having as a challenge not only to reduce the negative effect of the waste generated but also to seek reusability and obtaining by-products to contribute to the sustainability of this crop. (Nikolaou et al., 2021). Next, the results of the project and its final application comments are presented as a summary.

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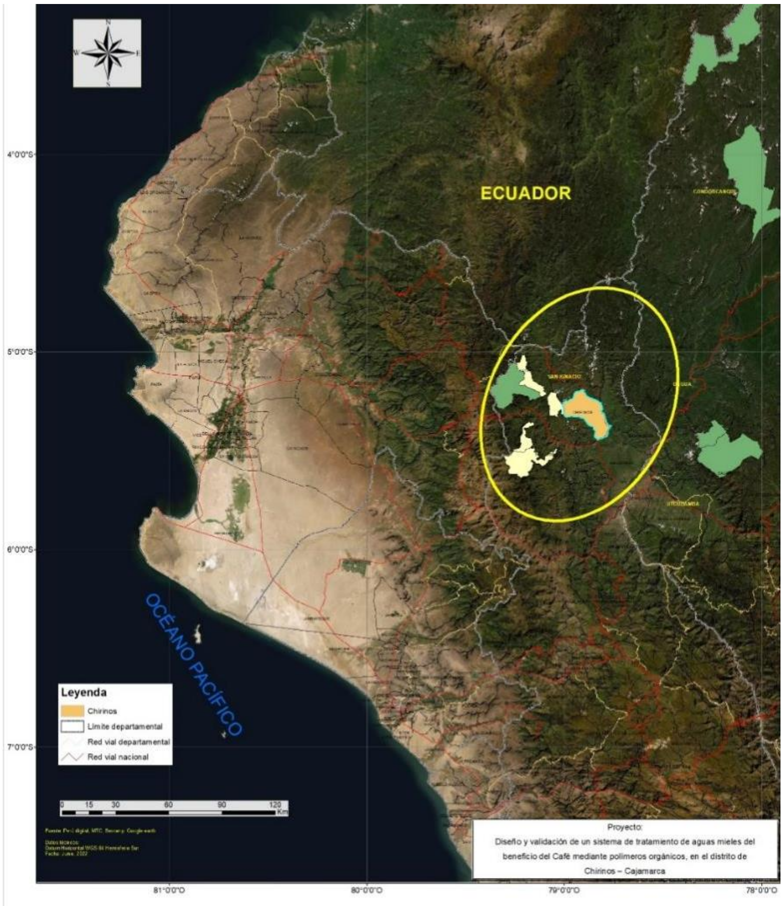

Figure 1: Location of the project in Chirinos, Cajamarca, Peru

DEVELOPING

Ecological treatment of honey water from the wet processing of coffee

With the execution of the project, the treatment of honey water was carried out with the use of natural organic polymers in three wet benefit mini-plants of coffee producers of the Cooperativa Agraria Valles del Café. These technologies have already been the subject of research and development, mainly in the treatment of wastewater and its reuse. (Alemayehu et al., 2021; Reyes-Prado et al., 2022).

Two organic polymers obtained on the market were used, one of them with a cationic charge (+) from chitosan (polymer B) and another with an anionic charge (-) from caramelose or CMC (polymer C). These polymers were applied as a polymer broth in a mixture of both polymers, one after the other, as it has had better responses in other investigations. (Wang et al., 1977).

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In the laboratory tests and in the mini-plants, the values and/or concentration of the levels of the following physicochemical indicators were measured: pH, temperature, electrical conductivity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), content of oils and fats, total solids in suspension TSS, dissolved oxygen, content of nitrates and total phosphorus. Likewise, a microbiological analysis related to the determination of the quality of the water at the microbiological level was carried out. (Ramírez et al., 2021; Rodríguez et al., 2018): Mesophilic aerobic count, yeast count, lactic acid bacteria count, total coliform enumeration and enumeration of *Escherichia coli*.

Table 1: Average results of laboratory analysis for physicochemical and microbiological indicators of honey water from coffee after polymer treatment

Indicator	Measure unit	Honey water result without treatment	Average result treated honey water-laboratory	Average result honey water treated-Pilot	Average % reduction achieved (pilot)
Conductivity (*)	µS/cm	3612.67	2523.33	2750.00	30.15
pH (**)	(value)	3.44	3.43	3.59	Does not apply
Temperature (**)	°C	19.87	21.00	19.87	Does not apply
Oils and fats (*)	mg/l	2223.53	13.93	11.73	99.37
Total Suspended Solids (*)	mg total suspended solids/l	20216.67	966.67	632.33	95.22
Dissolved oxygen (**)	mgDO/l	2.03	0.27	0.20	86.89
Biochemical Oxygen Demand -DBO$_5$ (*)	mg/l	50278.67	20015.00	24385.00	60.19
Chemical oxygen demand -DQO (*)	mg O_2/l	103260.67	50087.33	46062.30	51.49
Total phosphorus (*)	mg P/l	163036.67	25054.67	7110.00	84.63
Nitrate (*)	mg NO_3-/l	22961.33	786.51	5575.33	96.57
Mesophilic aerobic count (**)	UFC/ml	16×10^7	22×10^4	-	99.86
Yeast count (**)	UFC/ml	24×10^5	29×10^4	-	87.92
Lactic acid bacteria count (**)	UFC/ml	48×10^6	10×10^4	-	99.79
Total coliform enumeration (**)	NMP/ml	< 3	< 1.8	-	Absence
Enumeration of *Escherichia coli* (**)	NMP/ml	< 3	< 1.8	-	Absence

(*) Result obtained corresponds to an accredited test method. (**) Result obtained does not correspond to accredited test method

The results of table 1 show that in 11 of 15 indicators, as a result of the treatment carried out, a reduction of more than 80% of the levels analyzed has been achieved and/or the indicator is absent. Likewise, several indicators such as temperature, dissolved oxygen and Escherichia coli have achieved a reduction below the Maximum Permissible Limits established in the Peruvian environmental regulations regarding water for irrigation level three (Decreto Supremo N° 004-2017-MINAM, 2017).

Implementation of irrigation technology with treated water from coffee honey water

The treated water, with the treatment of natural organic polymers, was used as water for irrigation of the coffee farm, implementing a drip irrigation system, with a 1 m^3 water storage tank, with which 2 systems were tested: one with filter and one without filter, for each of them 5 types of emitters: 1) drip irrigation tape of 2 LPH (liters per hour), 2) irrigation hose with 4 LPH dripper, 3) hose with irrigation 6 LPH, irrigation hose with 2.3 LPH dripper and 4 mm microtube. These treatments were done in a homemade pilot module. Weekly measurements were made for a period of 2 months, parallel to the polymeric treatment, finding that the 2 LPH drippers turned out to be the most stable against clogging and efficiency in the use of water.

After the pilot, a validation of the technology was carried out in three coffee plots belonging to the Cooperativa Agraria Valles del Café, for the installation of the system on the farm, hydraulic studies were carried out for each case. In all cases, the irrigation system turned out to be functional, validating the results obtained in the pilot tests.

Figure 2: Left: Pilot test module for the drip irrigation system. Center: 1 m3 tank for storage of irrigation water. Right: Irrigation system installed in final field

In this way, it has been possible to validate the use of residual water that can even give the farmer the possibility of doing fertigation without going against a sustainable production of the coffee plantation. (Chauhan & Kumar, 2020)and furthermore without resulting in pressure

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towards clean water in times of freshwater scarcity from climate change (Younas et al., 2020). In addition, due to the treatment received by these waters, the health of people and the health of the soil itself would not be endangered, as is usually the case with the use of wastewater from other use schemes. (Owusu et al., 2012).

Use of solid by-product from coffee honey water treatment

The project under study, seeking the greatest benefit under a circular economy approach (Nikolaou et al., 2021), With the use of all feasible material to use, it had the challenge of reusing the solid surplus (sludge) that was obtained from the polymeric treatment of the coffee honey water as a by-product to be used for the elaboration of fish food, given its content of biomass, carbohydrates and sugars, being positively used in the manufacture of animal feed(Pinto et al., 2014; Yaakob et al., 2019).

To this end, a survey-type consultation was carried out with fish farmers in the direct area of influence of the project (Chirinos district and surroundings), where it was found that 69% buy food for fish in their fattening stage and 30% buy food for the growth stage, likewise, 50% would agree to buy a food that contains a by-product of coffee honey water. These results showed the latent opportunity for the elaboration and sale of fish food as proposed by the project.

Based on what is indicated, following some national experiences in the Amazonian fishing CITE (CITE-Pesquero-Amazónico, 2020) and following the recommendations for its formulation (FAO, 2022), A formulation was proposed to obtain fish feed in pellets, using as one of its base by-products the sludge recovered from the honey water treatment, as shown in table 2.

Table 1: Imputs used for the preparation of pelleted fish feed

Nº	Input	%	Quantity (g)
1	Ground corn	32%	796
2	Wheat flour	9%	225
3	soy cake	47%	1.165
4	Fish flour	7%	176
5	Soy oil	4%	100
6	Coffee honey water by-product (recovered sludge)	1%	25
7	fungus inhibitor	1%	13
Total		**100%**	**2500**

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Once the elaboration procedure has been followed, following the recommendations for the preparation (FAO, 2022), the pellets with an average size of 4 mm were obtained, the food was tested in fattening tilapia weighing 50-200g, which were found at a density of 320 fish distributed in a fiberglass pond that stored 9.82 m^3 of water, where a good acceptance by the fish for the elaborated food was verified.

FINAL COMMENTS

The use of natural polymers from organic sources, due to the results shown, are potential for the treatment of honey water from the wet processing of coffee, therefore, they are a highly viable alternative for use in organic coffee production. To improve the results found in terms of treatment efficiency, complementary research can be carried out to add some physical treatment techniques such as oxygenation (Álvarez et al., 2011) or others such as the application of lime that allows to bring the pH to neutral and have better results (Devi, 2010).

The results regarding the use of treated water for technified irrigation, and even more so the use of sludge recovered from the treatment of honey water as an input in the production of fish feed, show the potential left by the technology that has been tested, for the implementation of modules for the ecological benefit of coffee under a circular economy approach, where the waste generated is as little as possible and additional income is obtained for the coffee producer.

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REFERENCES

[1] ACE. (2021). *COE Auction Results*. https://allianceforcoffeeexcellence.org/competition-auction-results/

[2] Alemayehu, Y. A., Asfaw, S. L., & Terfie, T. A. (2021). Reusing Coffee Processing Wastewater and Human Urine as a Nutrient Source: Effect on Cabbage Cultivation. *Waste and Biomass Valorization*, *12*(11), 6165–6175. https://doi.org/10.1007/s12649-021-01451-9

[3] Álvarez, J., Smeltekop, H., & Loza-murguia, M. (2011). Evaluation of a treatment system wastewater prebeneficiado of coffee (Coffea arabica) implemented in the community

Carmen Pampa province of Nor Yungas of La Paz Department. *Journal of the Selva Andina Research Society*, *2*(1), 34–42.

[4] Arteaga-Cuba, M. N., Dilas-Jiménez, J. O., Díaz, N., Miranda, O. C., García, J. E., & Vassallo, C. (2021). Isolation and identification of a native microbial consortium for the coffee pulp degradation above 2000 masl. *Coffee Science*, *16*, e161810. https://doi.org/10.25186/.v16i.1810

[5] BCRP. (2021). *Exportaciones de productos tradicionales - valores FOB (millones US$) - Agrícolas - Café*. https://estadisticas.bcrp.gob.pe/estadisticas/series/mensuales/resultados/PN01511BM/html/2018-1/2018-1

[6] Braun, A., & Toth, R. (2021). Circular economy: national and global policy. *Clean Technologies and Environmental Policy*, *23*(2), 299. https://doi.org/10.1007/s10098-020-01987-9

[7] Chauhan, J. S., & Kumar, S. (2020). Wastewater ferti-irrigation: an eco-technology for sustainable agriculture. *Sustainable Water Resources Management*, *6*(3), 1–11. https://doi.org/10.1007/s40899-020-00389-5

[8] CITE-Pesquero-Amazónico. (2020). *Elaboración de dietas balanceadas para peces amazónicos*. CITE Pesquero Amazónico. https://www.youtube.com/watch?v=rx7NhLoilG4&ab_channel=CITEpesqueroAmazónicoPucallpa

[9] CPCC. (2021). *Datos actualizados sobre café en Perú*. https://camcafeperu.com.pe/ES/cafe-datos.php

[10] Devi, R. (2010). Innovative technology of COD and BOD reduction from coffee processing wastewater using Avocado Seed Carbon (ASC). *Water, Air, and Soil Pollution*, *207*(1–4), 299–306. https://doi.org/10.1007/s11270-009-0137-2

[11] Diaz, C., & Carmen, M. (2017). *Linea de base del café en el Perú*. file:///C:/Users/Usuario/Downloads/Libro cafe_PNUD_PE.pdf

[12] Dilas J., J. O. (2013). *Identificación de oportunidades de innovación tecnológicas en la producción del café en la región Cajamarca* [Universidad Peruana Cayetano Heredia]. http://repositorio.upch.edu.pe/handle/upch/1315

[13] FAO. (2022). *Tilapia-Formulación y preparación/producción de alimentos*. https://www.fao.org/fishery/affris/perfiles-de-las-especies/nile-tilapia/formulacion-y-preparacion-produccion-de-alimentos/es/

[14] IPE. (2020). *Indice de Competitividad Regional 2020*. https://incoreperu.pe/portal/index.php/ediciones-anteriores/item/14-incore-edicion-2020

[15] JNC. (2020). *El café de perú*. https://juntadelcafe.org.pe/el-cafe-de-peru/

ISSN: 2455-6939

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[16] JNC. (2022). *Café: Exportaciones por empresa-enero diciembre 2021*. https://juntadelcafe.org.pe/wp-content/uploads/2022/03/Exportación-de-Café-Enero-Diciembre-Por-Empresa2021.pdf

[17] MIDAGRI. (2021). *Siscex comercio exterior para el agro-Reporte de capítulos y subpartidas*. http://sistemas.minagri.gob.pe/siscex/

[18] Decreto Supremo N° 004-2017-MINAM, (2017). https://www.minam.gob.pe/wp-content/uploads/2017/06/DS-004-2017-MINAM.pdf

[19] Nikolaou, I. E., Jones, N., & Stefanakis, A. (2021). Correction to: Circular Economy and Sustainability: the Past, the Present and the Future Directions. *Circular Economy and Sustainability*, *1*(2), 783–783. https://doi.org/10.1007/s43615-021-00054-9

[20] Owusu, V., Bakang, J. E. A., Abaidoo, R. C., & Kinane, M. L. (2012). Perception on untreated wastewater irrigation for vegetable production in Ghana. *Environment, Development and Sustainability*, *14*(1), 135–150. https://doi.org/10.1007/s10668-011-9312-x

[21] Pinto, R., Medina, J., Medina, F., Guevara, F., Gómez, H., Ley, A., & Carmona, J. (2014). Sustitución de melaza por mucílago de café (Coffea arabica L.) en bloques nutricionales para rumiantes. *Archivos de Zootecnia*, *63*(241), 65–71. https://doi.org/https://dx.doi.org/10.4321/S0004-05922014000100007

[22] Ramírez, L. E. C., Rubiano, C. C. P., Arias, H. P., & Galindo, D. H. (2021). Determination of the microbiological quality of the Toca-Boyacá River, downstream Tuaneca and the center sectors. *Revista Lasallista de Investigacion*, *18*(1), 192–202. https://doi.org/10.22507/rli.v18n1a12

[23] Reyes-Prado, M. A., Ramírez-Pereda, B., Ramírez, K., Gonzáles Huitrón, V., Rodríguez-Mata, A. E., Uriarte Aceves, P. M., & Amabilis-Sosa, L. (2022). Recuperación de nutrientes y degradación de materia orgánica de agua residual agrícola por medio de un sistema uv/h2O2 optimizado. *Revista Internacional de Contaminación Ambiental*, *38*, 235–248. https://doi.org/https://doi.org/10.20937/RICA.54236

[24] Rodríguez, S. C., Asmundis, C. L., Ayala, M. T., & Arzú, O. R. (2018). Presencia de indicadores microbiológicos en agua para consumo humano en San Cosme (Corrientes, Argentina). *Revista Veterinaria*, *29*(1), 9. https://doi.org/10.30972/vet.2912779

[25] SUNAT. (2021). *Información aduanera-Exportaciones*. http://www.sunat.gob.pe/estadisticasestudios/exportaciones.html

[26] Torres Avila, A., Aguilar Avila, J., Martinez Gonzáles, E. G., Aguilar Gallegos, N., Santoyo Cortés, V. H., & Solleiro Rebolledo, J. L. (2022). *Análisis de sistemas de innovación en cadenas agroalimentarias*. Univfersidad Autónoma de Chapingo. https://www.researchgate.net/publication/361650659_Analisis_de_sistemas_de_innovacion_en_cadenas_agroalimentarias

ISSN: 2455-6939

Volume: 08, Issue: 04 "July-August 2022"

[27] Wang, L. K., Wang, M. H., & Kao, J. F. (1977). Application and determination of organic polymers. *Water, Air, and Soil Pollution*, *9*(3), 337–348. https://doi.org/10.1007/BF00280682

[28] Yaakob, M. A., Mohamed, R. M. S. R., Al-Gheethi, A., Tiey, A., & Kassim, A. H. M. (2019). Optimising of Scenedesmus sp. biomass production in chicken slaughterhouse wastewater using response surface methodology and potential utilisation as fish feeds. *Environmental Science and Pollution Research*, *26*(12), 12089–12108. https://doi.org/10.1007/s11356-019-04633-0

[29] Younas, S., Rizvi, H., Ali, S., & Abbas, F. (2020). Irrigation of Zea mays with UASB-treated textile wastewater; effect on early irrigation of Zea mays with UASB-treated textile wastewater; effect on early growth and physiology. *Environmental Science and Pollution Research*, *27*(13), 15305–15324. https://doi.org/10.1007/s11356-020-07948-5

[30] Zambrano-Franco, D. A., & Izaza-Hinestroza, J. D. (1998). Demanda química de oxígeno y nitrógeno total, de los subproductos del proceso tradicional de beneficio húmedo del café. *Cenicafé*, *49*(4), 279–289. https://doi.org/10.15332/dt.inv.2020.01508

[31] Zegarra, E. (2019). *Auge agroexportador en el Perú: Un análisis de sobrevivencia de productos y empresas*.

