Cooperative Action in Recycling and Reuse of Olive Mill Waste for Food and Agriculture Production

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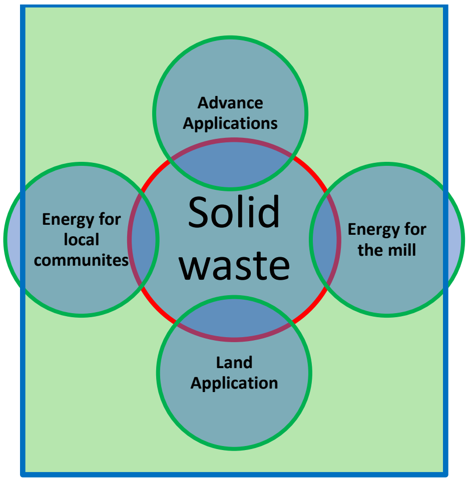

A. Project Idea

With 95% of the world's olive trees, the Mediterranean region produces 98% of olive oil in the world, generating huge solid and wastewater quantities which pose heavy environmental and economic loads. The slurry mass contains pulp residues of the fruit, including a large amount of organic materials of about 4% oil. About 0.35- 0.45 kg of solid olive cake can be generated from the milling of a kg of olive fruit. The waste discharge from this industry has a significant impact on the ecosystem and causes contamination of soil and water resources, and air pollution. This material, if stored for a long time under natural conditions, it begins to decompose quickly and generates undesirable odor. In addition to the health and environmental impacts, the owners of the mills pay high costs for waste transfer and disposal. Also, the mills owners are subjected to high penalties in case of any violation of the environmental regulations in this field. For these reasons, the management of olive mill waste appears the main challenge of the mill owners and the environmentalists, especially in the southern countries. Due to the high environmental impact of this waste, much research have been conducted to treat and reuse it without achieving comprehensive solutions. Water and food are the most important needs for life survival. So providing of both products to the consumers has the highest priority and is the main challenge for the global economy. The dramatic increase in the world population accompanied by industrialization and urbanization resulted in a sharp increase in water and food demand, while the available sources are decreased year by year. The agricultural sector consumes a high quantity of water reaching more than 70% in some countries.

This proposal aims to interchange experiences, and technologies between the three parties in order to achieve better management of this waste through a comprehensive process depends on the reuse and recycling approach for food production. Liquid and solid waste from the olive mill will be reused and recycled to improve soil fertility, enhance food production, and to reduce the cost of food production.

Liquid wastes from olive mills will be collected and characterized, then treated by simple low cost natural materials. The treated wastewater will be used for olive trees and other crops irrigation within the farm vicinity. Solid materials will be subjected to anaerobic digestion process to produce fertilizer as soil amendment and nutrients for crops, while the produced biogas will be reused for heating within the plant.

By following this approach, it is possible to reduce the impact of this industry on the environment, conserve the natural resources, save the ecosystem, and self-sustain of the olive industry. This will help the industry in reducing the cost of waste management, recycling and reuse of waste for food production. From an economic point of view, this approach eliminates the waste disposal cost, produces new water sources, gives new products, reduces the energy bill, prevents environmental penalties, and increases food production. Our proposal lies in the core of PGTF call which covers: Food and Agriculture Production, Research and Development, Transfer of Technology in Food and Agriculture, Development and Exploitation of New and Renewable Sources of Energy, and Exchange of information and experiences in the field of technology.

B. Objectives:

The project aims to achieve the following objectives:

- Identify the technologies used in olive milling.
- Determine the OMWW management applied practice.
- Investigate the applicability of OMWW for biogas production.
- Investigate the applicability of OMWW for reuse in the irrigation of crops.

C. Activities

- Preparing the country report for Jordan, Tunis, and Egypt concerning OMWW management.
- Five workshops for experts and stakeholders.
- Two research concerning the reuse of liquid waste of OMWW for irrigation of crops (bean, Barely).
- Two research concerning biogas production from OMWW.
- Preparing management strategy and guidelines for OMW.

D. Main Results

- Stakeholders confirmed that OMWW has resulted in a significant environmental issue, for which many parties are responsible for identifying a remedy.
- The country report revealed there is a shortage of data in this area.
- Lack of cooperation and transparency between partners hindered effective management of this problem.
- OM sector needs support to improve the environment inside the plant as well as waste management.

- During the initial stage of managing OMWW, it's important to identify clear responsibilities for each party.
- A national plan is required for the management of OMWW.
- Participants gained a solid understanding of OMWW management practices.
- Participants shared their recommendations for OMWW management.
- Participants shared their experiences and knowledge about OMWW management.
- The owners of OM outline the key challenges they face in OMWW management.
- The Plants (bean) irrigated with varied percentages of fermented OMWW significantly produced more pods per plant, ranging from 2.3 to 12.7% more than the control ($p \leq 0.05$) with the highest results obtained when irrigated with 4% OMWW.
- The results of irrigation with fermented OMWW at different percentages showed a significant effect on total chlorophyll content in the early growth stages. The irrigation with fermented OMWW 19% scored the highest total chlorophyll content (9.2) followed by 8., 6, and 1.3% underwater treatments of : T1, T2, T3, and T4 respectively.
- Treatment of OMWW with different types of filters can reduce the contamination significantly, and the generated water after treatment can be reused.
- Treated OMW using most filter media types used in this research improved the germination percentage and seedling growth, as compared to untreated OMW, especially effluent generated from clay loam and loamy sand soil filters.
- The treatment of OMWW is useful in reducing the impact of OMWW on the germination of barley.
- The highest germination percentage was recorded after irrigation with tap water (96.7%) compared to 66,7%, 25%, 23%, 18%, 16%, 8.4%, 6.7%, 5% after irrigation with OMW that was filtered with clay loam , rubber, loamy sand, rubber+ zeolite , pomace, fruit peel, zeolite and coal, respectively.
- The germination speed index was noticed for seeds irrigated by tap water (22.44%) compared to 12.46%, 7.65%, 5.25%, 5%, 4.95%, 3.5%, 3%, 2.71% clay loam soil, rubber, loamy sand soil, pomace, rubber + zeolite, fruit peel, zeolite and coal filter, respectively.
- The generated gas generated from OMW+ CM increased gradually during the first week and decreased after 15 days.
- The generation rate of gas reached the optimum value of 9652ml in the 15th day.

- Regarding the methane rate, it was 22, 41, 56 % after 10, 20 and 30 days respectively.
- Gas production rate was 7.02 l/d for OMW+ CM.
- The methane production rate was 3.7 l/d for OMW+ CM.
- The generation rate of gas form OMW with chicken manure reached the optimum value of 47005ml in the 8th day.
- Regarding the methane rate, it was 22, 41, 56 % after 10, 20 and 30 days respectively for OMW with chicken manure.
- Gas production rate was 41.7 l/d for OMW with chicken manure.
- Methane production rate was 23.5 l/d for OMW with chicken manure.
- The removal effectiveness of TS and VS. with nanoparticle impact (IONP) was found to be IONP25 > IONP30 > control > IONP20 > IONP35 > IONP40> and IONP15, respectively.
- The dose of 25INOPs provided the optimum COD, color, and turbidity removal reaching 85%, 73%, and 80% respectively.

E. Recommendations

- Develop a national strategy for OMWW management.
- Encourage and strengthen cooperation among partners.
- Capacity building is essential for all stakeholders in this area.
- Building capacity is essential for all organizations operating in this industry.
- OM owner should be supported to improve the internal environment and management of OMWW.
- Switching to new technologies mainly a two-phase continuous centrifugation system.
- Understanding the importance of reusing waste for land applications and energy generation.
- Encourage OMWW reuse and application research.
- Encourage the olive milling byproducts industry.
- Improving the current landfills to minimize their impacts on the groundwater and the environment.
- Motivate mill owners to reuse waste for land applications and energy generation.
- Monitoring illegal waste disposal and enforcing strict penalties.
- Development of legislation and regulations for OMWW management.

- Segregating of OMWW generation from each production line.
- Resue of OMWW from washing process for direct irrigation.

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Abbreviation

- ASTM: American Society of Testing Materials
- BOD: Biological Oxygen Demand
- CAS: Chemical Abstracts Service
- COD: Chemical Oxygen Demand
- CM: Cow manure.
- EA : Environmental Assessment
- EHU: Environmental Health Unit
- EIA: Environmental Impact Assessment
- EPA: Environmental Protection Agency
- F. Coli: Fecal Coliform HVAC Heating, ventilation and cooling
- ISCO: Instrumentation Specialists Company
- ISIC: International Standard Industrial Classification of all Economic Activities
- MSDS: Material Safety Data Sheet NEPA National Environment and Planning Agency
- NEPIS: National Environmental Publications Information System NMP Nutrient Management Plan
- NRCA: Natural Resources Conservation Authority
- NTIS: National Technical Information Service
- NWC: National Water Commission ix P&L Permits and Licenses
- OM: olive mill
- OMW: olive mill waste.
- OMWW: olive mill wastewater.
- STP: Sewage Treatment Plant
- TDS: Total Dissolved Solids
- TSS: Total Suspended Solids
- WA: Water Authority

Chapter One

Experiences and Technology Transfer

A. Objectives:

This section's primary goal is the technology transfer across all partners (Jordan, Tunisia, Egypt). The specific goals are as follows:

- Experience and technology exchange between partners (Jordan, Tunis, Egypt)
- Enhance public awareness for better waste management.
- Determine the OMWW management applied practice.
- Identify the OMWW management's SWOT (strengths, weaknesses, opportunities, and threats) areas.

F. Activities:

- Preparing OMWW Country reports (Jordan, Tunis, and Egypt).
- Meetings and discussions between partners.
- Develop Strategy for OMWW.
- Design brochures for OMWW management.

Jordan Country Report

Management of Olive Waste in Jordan

1. Abstract

The olive industry in Jordan plays a crucial role in the country's economy, providing income for thousands of households and contributing to the global trade of olive oil. However, with an increase in olive production, the generation of significant amounts of olive mill waste (OMW) is also on the rise. This report provides an in-depth examination of the current state of OMW management in Jordan, including the types and methods of management for both liquid and solid waste, as well as the impact it has on the environment and economy. A SWOT analysis of OMW management in Jordan is also presented, providing insight into its strengths, weaknesses, opportunities, and threats. To address the challenges faced in managing OMW, the report offers sustainable solutions and recommendations to ensure the continued success and sustainability of the olive industry in Jordan. Effective OMW management is crucial for protecting the environment, public health, and the economic well-being of those in the industry.

2. Introduction

Jordan is well-known for its rich history, cultural heritage, and diverse landscapes. One of its most valuable resources is its olive tree plantations, which have been an integral part of the country's agricultural sector for centuries. In recent years, the increasing demand for olive oil has led to an increase in olive tree cultivation and the development of modern olive mills (Ayoub et al., 2014). There are 130 olive mills are in operating in the country, which service the 130,000 hectares of olive groves and produce approximately 200,000 cubic meters of olive mill wastewater (OMW) each year. (MoA, 2012).

The utilization of treated wastewater for agricultural irrigation is being seen as a potential solution to the shortage of freshwater resources in some countries. There are numerous types of effluent that are suitable for reuse, including olive mill wastewater (Ben Rouina et al., 2006), municipal waste (Shdiefat et al., 2009), and effluent from textile and steel industries (Al-Absi et al., 2009). These have all been studied for their potential in supporting agriculture and crop production.

The olive oil extraction industry plays a significant role in Mediterranean countries and results in a large amount of waste from the process. Olive mill wastewater (OMW) is a byproduct of olive oil extraction and is produced through either pressure or centrifugation systems. The typical extraction process produces three different phases of products – an oily phase, a solid residue, and an aqueous phase, which when combined with washing water forms OMW. The amount of OMW produced varies depending on the extraction method, ranging from 0.5 to 1.5 m3 per ton of processed olives (Monteoliva-Sanchez et al., 1996). The annual production of OMW in the Mediterranean region is estimated to be over 30 million m3 (Ballesteros et al., 2001), creating a pressing issue of proper disposal.

The olive mill wastewater produced during the three-phase process is characterized by a very high biological and chemical oxygen demand (BOD and COD), with levels reaching as high as 100,000 and 220,000 mg/L respectively (Azbar et al., 2004). This waste contains high amounts of fats, oils and greases (FOGs) and a significant amount of polyphenols (several to 10 g per liter) (Azbar et al., 2004). The presence of phenols and fatty acids, both short- and long-chain, is thought to make the waste phytotoxic and antimicrobial (Isidori et al., 2005).

The high organic load and toxicity of OMW make it unsuitable for direct discharge into municipal sewage systems. Additionally, a major challenge in treating OMW is its seasonal nature, as it is only produced during a limited period of time (typically mid-October to mid-January). Currently, a significant amount of OMW in Jordan remains untreated, which poses a threat to the precious and limited water resources in the country.This report will provide an overview of the current status of olive tree cultivation, olive mill waste management practices, and the international efforts to address this issue in Jordan.

3. Olive trees in Jordan

Olive trees play a vital role in Jordan’s agricultural sector and cultural identity. The country is home to an estimated approximately 17 million olive trees in Jordan, covering approximately 130,000 hectares of land, making it one of the largest olive tree producing countries in the world (Al-zboon, 2020). Olive trees are predominantly grown in the western and central regions of Jordan, specifically in the governorates of Amman, Zarqa, Irbid, Balqa, and Ajloun (ILO, 2014).

The size of olive groves in Jordan ranges from small family-owned farms to large commercial plantations. Despite the diverse size and distribution of the olive trees, the industry has experienced significant growth in recent years, due to an increase in demand for olive oil both domestically and internationally. The majority of the country's olive production is centered around small-scale farmers who cultivate the trees for both oil and table olives. The annual volume of olives produced in Jordan varies depending on factors such as weather conditions, disease outbreaks, and market demand, but it is estimated that the country produces between 40,000 to 50,000 tons of olives each year (Qrunfleh, 2011).

The country is also known for its high-quality olive oil, with a large portion of the production being exported to international markets. Exports of Jordanian olive oil have been increasing in recent years, with the country exporting over 15,000 tons of olive oil in 2020.

4. Olive mills in Jordan

Jordan has 128 olive mills (ISSP-USAID ,2013)., there are two main types of olive mills: traditional and modern. Traditional olive mills are small-scale operations that use traditional methods of pressing and extracting olive oil, typically using stone presses. These mills are often family-owned and operated, and they serve the local communities in which they are located.

On the other hand, modern olive oil production facilities are large-scale operations that employ advanced technologies in the pressing and extraction process. These facilities are often equipped with high-tech centrifuge or continuous-flow systems, enabling them to produce olive oil at a more efficient and high-volume rate. In total, there are 272 fully automated production lines with a combined capacity of 378 tons per hour. The majority of these modern mills are found in Jordan's larger cities and cater to the nationwide demand. Of these mills, 70% are located in northern Jordan, while 22% are in the central region, and the remaining 8% are situated in the south (Ayoub, 2017).

In terms of distribution, both traditional and modern olive mills can be found throughout the country, with the majority located in the central and northern regions where the majority of olive tree plantations are found. However, the concentration of modern olive mills is higher in the larger cities, where they can more easily access transportation and distribution networks.

5. Uses and quantity of olives and olive oil in Jordan

Jordan is a significant producer of olives, with an estimated production of around 45,000 tons per year. The most common varieties of olives grown in Jordan are the Nabali, Carotina, Souri, and Grossa de Espagna, which are known for their high oil content and excellent flavor (El-Sheikh et al., 2004).

Olive oil is an even more important product in Jordan, with an estimated production of around 10,000 tons per year. The majority of the country's olive oil is produced in the northern regions, where the majority of olive groves are located. Olive oil is used in a wide range of products, from cooking oil to cosmetics and soaps.

There is a consensus that attaining high-quality olive oil requires the precise timing of harvesting fully ripe fruit. However, determining the ideal moment for harvest in the field can be challenging. Numerous studies in the Mediterranean region have demonstrated that the oil content significantly increases during the early stages of fruit ripening (Salvador, 2001). The quality of the oil improves along with its increased oil content, but begins to decline before the peak oil yield is reached (Rotondi et al., 2004). A deeper understanding of the morphological, physiological, and biochemical changes that occur during the ripening process can aid in enhancing the commercial and qualitative attributes of the fruit.

As olive fruit ripens, several metabolic processes occur leading to changes in the levels of various compounds. These changes are reflected in the quality rating, sensory attributes, oxidative stability, and/or nutritional value of the resulting product. Compounds such as polyphenols, tocopherols, chlorophyll pigments, carotenoids, and the fatty acid and sterol composition are involved in this process (Gasparini, 2001).

Olive oil holds a distinctive place among edible oils due to its tasty flavor, appealing taste, stability, and health advantages. These advantages are attributed to the presence of nutrients and other elements such as linoleic acid, vitamins, natural antioxidants, and other dietary essentials. Furthermore, the oil's high content of oleic acid helps to impede the buildup of fatty acids in arterial walls, thus reducing the risk of cardiovascular disease(Al-Maaitah et al., 2009).

6. Governmental Policies and Regulations

In Jordan, the management of olive waste is regulated by several government policies and regulations aimed at promoting environmentally sustainable practices and reducing the negative impacts of waste on public health and the environment. Some of the key policies and regulations related to olive waste management in Jordan include:

Solid Waste Management Law: This law, enacted in 2006, establishes the framework for managing solid waste in Jordan, including olive waste. The law requires waste producers to properly manage their waste and ensures the proper disposal of waste in an environmentally sound manner (Ministry of Environment 2017).

- Environmental Permitting System: This system requires all businesses and industries, including those producing olive waste, to obtain permits to operate in accordance with environmental regulations. This includes requirements for the proper disposal of olive waste (Ministry of Environment 2006).
- Biodegradable Waste Management Regulations: These regulations specify the requirements for the proper disposal of biodegradable waste, including olive waste. The regulations outline the requirements for composting and other forms of waste treatment to ensure that waste is managed in an environmentally responsible manner (Ministry of Environment 2006).
- Agricultural Waste Management Regulations: These regulations outline the requirements for the management of agricultural waste, including olive waste. The regulations require farmers to implement best practices for the management of olive waste, including composting, to minimize its impact on the environment (Ministry of Environment 2006).
- Industrial Waste Management Regulations: These regulations outline the requirements for the management of industrial waste, including waste from olive oil production. The regulations require olive oil producers to implement best practices for the management of waste generated during the production process to minimize its impact on the environment (Ministry of Environment 2006).

In addition to these regulations, the Jordanian government also provides incentives and support to businesses and individuals implementing sustainable waste management practices, including the proper management of olive waste. This includes financial support for waste treatment facilities and technical assistance for the implementation of waste management practices.

Overall, the government policies and regulations related to olive waste management in Jordan aim to promote environmentally sustainable practices and reduce the negative impacts of waste on public health and the environment. These policies and regulations encourage waste reduction, reuse, and recycling and ensure the proper disposal of waste in an environmentally responsible manner.

7. Methods of management for liquid and solid waste

The management of liquid and solid waste generated during the production of olives and olive oil is an important issue in Jordan. Is regulated by several government policies and regulations aimed at promoting environmentally sustainable practices and reducing the negative impacts of waste on public health and the environment.

In 2018, the production of olive oil resulted in over 120,000 m^3 of olive mill wastewater (OMW), also referred to as Zebar, and 33 thousand tons of olive cake (Department of Statistics, 2018, Ministry of Agriculture 2019). The composition of OMW varies depending on factors such as the climate, cultivation methods, and grinding techniques employed in the olive oil production. Olive oil is produced using various methods, including traditional pressing, two-phase, and three-phase decanting processes.

OMW in Jordan is characterized by elevated levels of phenolic content, chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and high concentrations of cations and anions, as well as a low pH value. The significant organic load, with chemical and biochemical oxygen demands that can reach up to 100-200 g/L, poses challenges in terms of effective management and meeting legal discharge thresholds(Al-Hmoud, 2020). Furthermore, the presence of toxic compounds within its composition makes conventional biological treatment methods ineffective.

Consequently, several methods have been proposed and developed to reduce the environmental impact of OMW. These methods are based on chemical, biological, and physical scientific aspects and have often used more than one form.

Physical methods for treating OMW include liquid extraction, filtration/non-filtration, flotation, adsorption, flocculation, coagulation, used alone or in combination with one another. For instance, Abu-Lafi et al. (2017) enriched phenolic compounds from OMW by using liquid-liquid extraction with ethyl acetate, which was found to be an effective solvent. The resulting extract contained mainly hydroxytyrosol and tyrosol, and had potential to act as a natural antioxidant and preservative for olive oil, as well as antibacterial, antifungal, and anti-yeast properties.

Sygouni et al. (2019) isolated phenolic compounds from OMW by liquid extraction with a 50% ethanol and 50% distilled water mixture, before passing it through a membrane filtration system consisting of ultrafiltration, nanofiltration, and reverse osmosis membranes in series. The final effluent in the permeate stream after the RO membrane was almost free from polyphenols, and had low carbohydrate and COD values. This method allowed for the simultaneous recovery of high amounts of phenolic substances and the cleaning of the two-phase OMW.

Gikas et al. (2018) found that hybrid natural systems, such as two open tanks with different flows and one constructed wetland, can be used efficiently and economically in treating OMW, resulting in high pollutant removals in the liquid phase. Ait-hmane et al. (2018) showed that multi-soil-layering ecotechnology is an efficient, low-cost method for treating OMW, with a high pollutant reduction rate under certain conditions.

Vuppala et al. (2019) conducted a study to optimize the coagulation and flocculation conditions for the treatment of olive mill wastewater (OMW). They investigated the effect of different pH levels and coagulant dosages on the system efficiency. The study found that a pH of 4.5 was the most efficient and selected this value for further optimization of coagulant dosage.

Two coagulants were used in the study: 400 mg/L of aluminum sulfate (Alum) and 100 mg/L of chitosan. The results showed that both coagulants achieved a 99% reduction of turbidity with 1 hour of sedimentation. However, the study found that the performance of alum was better than that of chitosan when the process was operated at pH values $\geq$ 4.0.The study further optimized the coagulant dosage of alum and chitosan ranging from 400 to 1,200 mg/L and 300 to 700 mg/L, respectively. The use of 800 mg/L of alum led to reductions of about 17%, 57%, and 63% in TOC, COD, and phenols. After biological oxidation treatment of the clarified water, further reductions of 82% in COD, 72% in TOC, and 99% in phenols levels were achieved. Overall, the study demonstrated the effectiveness of coagulation and flocculation in the treatment of OMW and highlighted the importance of optimizing the pH and coagulant dosage to achieve the best results.

Hydrothermal carbonization (HTC) has been investigated as a pre-treatment technology for converting waste into carbonaceous materials that can be used for various applications (Azzaz et al., 2020). Among the available chemical treatment methods, researchers have also focused on electrohydrolysis and electrocoagulation, photocatalytic membrane reactor utilization, and Fenton and Fenton-like processes. Studies have shown that HTC is an efficient and valuable method for the treatment of olive mill waste, with potential for producing energy-dense and mechanically stable biofuels from the resulting hydrocars (Volpe et al., 2018). In addition, the liquid fractions obtained from HTC have the potential to be used as liquid fertilizers, making HTC a greener alternative for the valorization of olive mill industry waste streams. Recent studies have investigated the use of HTC for the treatment of OMW, with promising results.

The study by Volpe et al. (2018) investigated the use of hydrothermal carbonization (HTC) for the treatment of olive waste stream mixture, obtained from a three phase-continuous centrifugation olive oil mill. The waste was subjected to HTC at different temperatures (180, 220, and 250°C) for a 3-hour residence time in a stainless steel electrically heated batch reactor. The resulting hydrochars were characterized, and it was found that as the HTC temperature increased, the carbonization and energy densification ratio of the hydrochars also increased, with a maximum energy densification ratio of 142% observed at 250°C. the study demonstrated that HTC is a promising and greener alternative for the valorization of olive mill industry waste streams.

The researchers in Ibrahimoglu et al. (2018) used plasma technology as a valorization technique to reduce pollution parameters in OMW and bring the water to discharge limits. The COD and BOD of the wastewater were reduced by 94.4% and 95.4%, respectively, and the dissolved oxygen content increased from 0.36 to 6.97 mg/L. Additionally, the plasma gas produced had a high H2 content (60-75% H_2, 4-10% CO_2, 1-2% CO, and 14-18% O_2) which can be used for other purposes. The treated water was found to be suitable for use in agricultural areas for irrigation, with an (Sodium Adsorption Ratio) SAR value of 1.14.

The study by Fraga et al. (2019) focused on the development of a new design of a photocatalytic membrane reactor for treating real OMW and enhancing the degradation of organic compounds. The reactor had a cuboid shape with a squared base and was made of polyethylene. The researchers used commercial high flux flat sheet silicon carbide membranes, and the surfaces were modified with TiO2 obtained by the sol-gel process, using Degussa P25 and silicon carbide nanoparticles. The photocatalytic activity of the membrane was demonstrated, achieving high removals of chemical oxygen demand (89%), total organic carbon (87%), and phenolic compounds (95%) with this system at 20 minutes of operation. However, the high particulate concentration in OMW caused cake formation on the membrane surface, preventing light from reaching the membrane's photocatalytic layer, leading to a reduction of the produced permeate quality. The researchers suggested solving this problem in a pilot/full-scale system through effective pre-treatment and applying previously proven strategies to minimize fouling, such as backwashing and back pulsing.

Integrated systems that combine different treatment methods in series have been studied extensively to achieve acceptable wastewaters that can be discharged into the environment. Amaral-Silva et al. (2016) used an integrated coagulation/flocculation and Fenton process to treat OMW. They found that coupling the coagulation stage with flocculation promoted greater removal efficiency than single coagulation for higher organic matter removal by gravitational settling. The highest COD removal was achieved when 0.1 g/L of 2045-SH flocculant was applied to wastewater previously treated with 1 g/L of P19 coagulant, leading to 82% elimination and 84% abatement of total polyphenolic content (TPh). Further combination with the Fenton process resulted in larger COD and TPh content abatement (90% and 92%, respectively) and enhanced biodegradability (0.52 compared to 0.05 of the raw OMW). The main parameters that can affect this system were studied, including operating pH, Fe^{2+} and H_2O_2 concentrations, and the ratio between them. The researchers observed an improvement in pollutant degradation with higher H_2O_2 levels and H_2O_2/Fe^{2+} ratio until a plateau was reached. Increasing iron load up to a certain level permitted better COD removal, after which higher iron concentration promoted an adverse effect on the performance rate, possibly due to Fe^{2+}induced radical scavenging. The treated stream TSS and TDS decreased by 95% and 69%, respectively.

Khani et al. (2020) demonstrated that combining electrocoagulation, catalytic ozonation, and biodegradation can effectively reduce the organic load and improve the biodegradability of OMW. By optimizing the electrocoagulation conditions to a current density of 5 mA/cm2 for 45 minutes, the treated wastewater was then introduced into a catalytic ozonation process (COP) reactor, which achieved 44% TOC and 56% COD removals after 90 minutes. Finally, the COP reactor effluent was fed into a biological reactor, resulting in an overall system efficiency of 98.4% and 97.2% for COD and TOC removal, respectively.

Malvis et al., (2019) proposed an integrated process for the treatment of real OMW that consisted of two stages: physico-chemical treatment (flocculation, photolysis, and microfiltration) and microalgal growth. The primary treatment stage achieved significant reduction of the OMW organic load, including 96.2% of COD, 80.3% of TOC, and 96.6% of total phenolic compounds (TPCs). The secondary treatment stage utilized the microalgae Chlorella pyrenoidosa in stirred batch tank reactors at different OMW concentrations in the culture medium. The optimal OMW concentration was found to be 50% (v/v), which resulted in the highest maximum specific growth rate (0.07 h^{-1}) and volumetric biomass production (1.25 mg/(L.h)). The final treated water was suitable for irrigation use, discharge to receiving waters, or reuse in the process itself, allowing for the closure of the process water cycle.

Utilizing Olive Mill Solid Residue (OMSR) as a bio-sorbent in wastewater treatment is a viable option. The efficacy of OMSR was investigated through various treatments (untreated; OMSR-U, treated with n-hexane; OMSR-H, and treated with water; OMSR-W) by measuring chemical oxygen demand and cation exchange capacity. Results from both tests confirmed that OMSR-W was the most effective treatment, which was further validated through batch uptake experiments of heavy metal ions(Hawari et al., 2009).

8. The Environmental and Economic Impact of Olive Waste

The environmental and economic impact of olive waste in Jordan can be significant, and it is important to implement proper waste management practices to minimize these impacts. Due to cost constraints, treatment plants are not available at the mills, resulting in the discharge of OMWWs into the environment. This discharge causes severe environmental problems such as water discoloration, pollution of surface and ground waters, soil surface, and foul odors. In Jordan alone, the processing of approximately 209,000 tons of olives in 2017 generated 175,000 m3 of OMWWs, including 3,069 tons of BOD5, 7,956 tons of COD, 149 tons of residual olive oil, 2.07 tons of phenols, 3,753 tons of total suspended solids, and 4.2 tons of phosphorus(Khdair et al., 2019). The high levels of organic matter, indicated by COD/BOD5 of 2.6, render OMWWs unsuitable for biological treatment, necessitating treatment before discharge into the environment or sewer system. To mitigate their environmental impact, cleaner production methods and appropriate waste management systems are necessary at mills. These could include the adoption of two-phase mills, which can reduce water usage to less than half of the amounts used in traditional and three-phase mills.

Due to the prevalence of olive mills and the importance of the olive oil industry in Jordan, Olive mill wastewater (OMW) is a common pollutant in the country. (AL-Eitan et al., 2021) investigate the effects of OMW and fertilizer on soil microbial populations. To accomplish this, the number of microbial colonies on plates treated with water, OMW, and fertilizer were counted and identified based on macroscopic and microscopic examination, as well as a range of biochemical tests. The results showed a significant increase in Bacillus (p-value of 0.011 in clay) and Yeast (p-values of 0.001 in clay and 0.037 in sand) populations after treatment with OMW. Conversely, Staphylococcus, Streptomyces (p-values of 0.034 in clay and 0.016 in sand), and Mold (p-value of 0.013 in sand) populations exhibited decreases. These findings are particularly important as most OMW in Jordan is disposed of in a way that exposes it to the soil. The study highlights the potential for OMW to be recycled and utilized as an antibacterial agent. Further studies using molecular PCR analysis should be conducted to accurately determine the species of each microorganism studied.

OMW is widely recognized as toxic to both plants and microorganisms, including soil microflora. The high salt content and relatively low pH of OMW can be phytotoxic to soil biological properties(Greco et al., 2006). This toxicity is largely due to the presence of monomeric phenols, which can cause severe phytotoxic effects on higher plants, particularly during germination and seedling development. Phenolic compounds can enhance seed dormancy, exacerbating the negative effects on plant growth(Krogmeier & Bremner, 1990).

Numerous studies have documented the harmful effects of OMW application on plants, especially when applied near the sowing period. For instance, Boz et al. found that adverse effects on wheat were limited to the early growth stages and were not observed in later production stages. Casa et al. reported that undiluted OMW completely inhibited the development of durum wheat seeds. El Hadrami et al. also observed significant reductions in seed germination in tomato, chickpea, maize, and durum wheat after the application of various concentrations of OMW or its phenolic extracts. Additionally, Quaratino et al. noted a reduction in maize seed development with increasing volumes of OMW in loamy sand soil, while Greco et al. observed a phenolic dose-dependent phytotoxic effect on the germination of tomato and English cress seeds.

Given these findings, OMW poses a significant environmental challenge when illegally dumped on lands or into the open environment without treatment. It is, therefore, necessary to develop effective and sustainable plans for managing OMW to minimize their negative environmental impact and to establish sustainable processes for recovering their valuable components for use in various crucial human and agricultural applications.

Although the chemical properties of OMW may lead to soil and water contamination, its use in agriculture as a soil amendment or fertilizer can be justified due to its high content of plant growth nutrients, including nitrogen (N), phosphorus (P), and potassium (K), as well as organic matter. These nutrients can help to address plant nutrient requirements, especially in arid environments and areas with poor soil fertility conditions (Mohawesh et al. 2014). Furthermore, the low pH of OMW resulting from the presence of organic acids can be beneficial for calcareous soils, which have a high pH, as is the case with many soils in Jordan. By using OMW as a soil amendment, agricultural soils can be enriched with nutrients, improve soil fertility, and support the productivity of rain-fed lands in arid environments. This approach has the potential to promote environmental sustainability while also providing benefits to agricultural production (Belqziz et al. 2016).

9. SWOT Analyses of Waste Management

A SWOT analysis can help to identify areas for improvement in waste management practices in the olive industry in Jordan and support the development of strategies to minimize the environmental and economic impact of waste.

The waste management sector has several strengths, including Strong government regulations and policies to support waste management, growing awareness and concern among the public and industry stakeholders about the need for proper waste management and Advances in technology and processes to support effective waste treatment and disposal is the most Strengths point. However, the sector also faces some challenges, such as Limited infrastructure and resources for waste management, particularly in rural areas, Lack of awareness and understanding among some producers and processors about proper waste management practices, Challenges in securing funding and investment for waste management infrastructure and services

The growing demand for sustainable and environmentally responsible products, including olive oil, presents opportunities for waste management in the olive industry in Jordan. The recycling and reuse of waste materials can help to reduce costs and increase efficiency, and there is potential for new technologies and processes to support more sustainable and cost-effective waste management practices. However, there are also threats to effective waste management in Jordan, including competition for resources and funding with other sectors such as energy and water management, resistance to change and innovation among some producers and processors, and uncertainty and changes in government regulations and policies related to waste management.

OMW is typically a seasonal occurrence, appearing only during a specific time of year from October to January or February. As a result, fresh OMW is only accessible during this period, placing additional stress on research teams. This reality motivates researchers to seek a viable storage method that preserves the freshness of OMW while minimizing the degradation of its valuable components(Al-qodah et al., 2022).

The majority of studies on olive mill wastewater (OMW) have been conducted in Mediterranean nations, with minimal to no collaboration among researchers across borders. This underscores the critical requirement for donors to offer funding for sizable collaborative projects that bring together experts from various countries, enabling them to attain more effective and meaningful outcomes(Al-qodah et al., 2022).

10. Sustainable Solutions

Several sustainable solutions can be implemented to manage the waste generated in the olive industry in Jordan. Recycling and reuse of waste materials, such as containers and packaging, can help to reduce waste(El-Abbassi et al., 2014). The process of anaerobic digestion uses microorganisms to break down organic waste and produce biogas which can be used to generate energy and heat(Gunay and Karadag,2015). Incineration involves burning waste at high temperatures to reduce its volume, but also produces emissions and ash that need to be managed appropriately. Composting is a process that breaks down organic waste into compost, which can be used in agriculture as a nutrient-rich soil amendment(Sarika et al., 2005). While landfilling is a process that involves burying waste in a designated area, it is not considered a sustainable solution as it can contribute to the depletion of natural resources and the release of greenhouse gases. Implementing these sustainable solutions can minimize the environmental and economic impact of waste in the olive industry, and support the development of a more sustainable and responsible industry.

Managing olive mill wastewater (OMW) can be challenging due to its properties, which can result in practical and financial difficulties. One option is to spread OMW into the soil as a regulated approach for effective management. (Mohawesh et al., 2019) explore the sustainable reuse of OMW through land application to enhance soil quality and wheat growth performance under rain-fed conditions. OMW was spread at various rates (20, 40, 60, 80, and 120 m3 ha^{-1}) at two sites, and soil physical and chemical properties were measured after OMW application and after harvest. Wheat growth performance and leaf nutrient content were also analyzed. The study found no negative impact of OMW application on soil properties or wheat growth at either location and for all OMW application doses. Moreover, the land spreading of OMW significantly improved wheat growth by increasing the biological yield (BYLD) (8.4 to 36.5%), grain yield (GYLD) (20.1 to 79.4%), and harvest index (HI) (4.2 to 60.2%). Based on the measured soil chemical parameters and wheat grain yield, the study suggests that an OMW application rate of 60 m3 ha−1 could significantly improve wheat growth without significant negative impact on soil properties. In conclusion, the study recommends using OMW as suggested for wheat, but long-term application assessment and local legislative adaptation are still necessary.

Many industrial wastes, including OMW, contain valuable components that can be recovered and reused as functional additives. Fortunately, modern separation technologies make it relatively inexpensive to extract these components. Among the available processes, extraction is a conventional and preferred method due to its simplicity(Galanakis, 2014). It involves transferring one or more immiscible liquid components to another liquid using an extractant. To achieve complete separation, several parameters must be optimized, including the nature of the solvent, the volumetric ratio of solvent, the pH of the OMW, and the number of extraction stages required.

Elkacmi et al., (2020) conducted a study on the detoxification of OMW using electrocoagulation (EC) in an external loop airlift reactor (ALR) powered by a photovoltaic solar system. This approach utilizes a renewable and sustainable energy source. The study involved using a continuous flow with two aluminum electrodes to examine the impact of various operating parameters, including initial pH, electrolysis time, current density (CD), and electrode axial position. The results indicated that after 40 minutes of treatment at 32.14 mA/cm2 CD, 5.6 initial pH, and electrodes positioned 35 cm from the bottom of the riser compartment, approximately 79% of COD, 95% of polyphenols, and 98% of dark color were removed. The electrical energy consumption and electrode consumption were 9.86 kWh/m3 and 0.1118 kg/m3, respectively. The findings suggest that coupling the electrocoagulation process with a photovoltaic solar system in a continuous airlift reactor is a cost-effective approach compared to other treatment processes.

Zagklis et al. (2013) carried out a study on sustainability and benchmarking of different methods for treating olive mill wastewater (OMWW). Their findings demonstrated that the processes which were most effective in reducing organics were electrolysis, membrane filtration, supercritical water oxidation, and Photo-Fenton. On the other hand, coagulation, anaerobic digestion, and lime processes had a lower environmental impact. Composting and membrane filtration were identified as the lowest-cost methods, with composting providing added-value through the production of composts, and membrane filtration generating phenolic compounds.

Several researchers have proposed the use of olive mill wastewater (OMWW) for agronomic purposes due to its high concentration of nutrients and its ability to mobilize soil ions (Kurtz et al.2015). However, negative consequences are associated with its high mineral salt content, low pH, and the presence of phenols, as noted by Belaqziz et al. (2016).

11. Challenges Face in the Management of Waste

The management of waste in the olive industry in Jordan faces several challenges that need to be addressed for a more sustainable and responsible approach. One of the major challenges is the competition for resources and funding with other essential sectors such as energy and water management. The resistance to change and innovation among some producers and processors can also hinder the implementation of new and more sustainable waste management practices. Uncertainty and changes in government regulations and policies related to waste management create difficulties for the industry to plan and execute effective waste management strategies. The lack of infrastructure and investment in waste management systems also presents a challenge. To overcome these challenges, innovative and creative solutions are needed, as well as collaboration between industry stakeholders and government agencies.

The separation of phenolic compounds from waste materials presents several challenges. However, surfactants have emerged as a potential solution to these challenges due to their cost-effectiveness, low energy consumption, and the fact that they do not require expensive equipment or organic solvents for their use in the separation of phenolic compounds from waste materials (Al Bawab et al., 2017).

12. Conclusion

Olives and olive oil play a crucial role in both Jordan’s economy and cultural heritage. The country is a significant producer of both, with an estimated 45,000 tons of olives and 10,000 tons of olive oil produced annually. These products have a wide range of uses, including food, cosmetics, and pharmaceuticals, and are a key source of export revenue for Jordan.

To ensure that the production of olives and olive oil has a minimal impact on public health and the environment, the government has established policies and regulations related to olive waste management. These policies encourage waste reduction, reuse, and recycling and ensure proper disposal of waste. The management of liquid waste generated during the production process is regulated by the government to ensure that waste is treated, transported, and disposed of in an environmentally responsible manner.

Effective waste management is crucial for the sustainability of the olive industry in Jordan, both for environmental and economic reasons. Proper waste management practices can protect the environment and public health, as well as reduce costs associated with waste management. Adopting sustainable solutions such as recycling and composting can minimize the environmental and economic impact of waste and support the development of a more sustainable and responsible industry. Implementing these solutions will help to enhance the competitiveness of the olive industry in the global market and support its continued growth.

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Tunis Country Report

Management of Olive Waste in TUNISIA

1- Abstract

Tunisia is the best-known southern Mediterranean country in the field of olive cultivation and the export of olive oil, after the European Union. Olive growing is the main agricultural activity in Tunisia and its socio-economic role is very important. The anchoring of this culture in Tunisian traditions, which favor the production and consumption of olive oil, means that the olive tree contributes to the formation of the income of 309,000 farmers.

However, olive oil extraction generates huge quantities of byproducts, including leaves, pomace residues, stones, and wastewater, which have severe environmental impacts mainly because of their phytotoxicity and great organic content. Therefore, it is of important to consider all potential pathways for a circular economy in the olive oil supply chain.

2- Introduction

Olive growing is the main activity for 60% of Tunisian farmers employed in the various links in the olive-growing sector (mechanization, pruning, picking, transport, crushing, storage, marketing, etc.), represents the direct or indirect source of money for more than one million people and generates 34 million working days per year, which is equivalent to more than 20% of employability in the agricultural sector.

The extraction of olive oil can be carried out by different extraction processes, the most applied ones are the conventional pressing process, the two-phase decanter process, and the three-phase decanter process. Three-phase decanters involve the addition of hot water to the process that dilutes water-soluble compounds and separates the paste into three parts: oil phase, solid waste (pomace and stones), and vegetation water. One of the drawbacks of this system is the production of a significant volume of wastewater with a negative impact on the environment compared to the conventional press (Torres &

Maestri, 2006)[1]. In 1990s, the two-phase decanter process was introduced as an environmentally friendly solution to reduce the level of oil mill waste (Dermeche et al., 2013)[2].

Despite the economic and dietetic benefits of olive oil, huge amounts of waste are generated either in the cultivation fields from pruning or in the olive mills during olive oil processing.

3- Olive trees in Tunisia

Tunisia is one of the founding member countries of the International Olives Council which was created in February 1956. It has 1,825,000 ha of surface area of olive trees, which represents the second largest olive area in the world and About a third of the country's cultivated area, with 16% of the global olive growth area and more than 80 million olive trees, 99% of them for extraction of oil. According to Ghedira[3], Tunisian olive trees are classified according to their age group: 18% of young plantations (1 to 20 years), 75% of planting in production (20 to 70 years) and 7% older plantations (more than 70 years). However, there are only 5% of the growth areas of olives cultivated on an irrigated system[4]. The national sector contributes significantly to rural exodus slowdown and revenue income due to its powerful industrial base. In fact, it includes more than 1750 oil mills, 15 refineries, 10 olive pomace oil extraction units, and more than 40 modern bottling plants[5]. The geographic distribution of olive trees in Tunisia is as follows: 30% in the North, 45% in the Center and 25% in the South. Although the south represents the lowest percentage, its production in olive oil is 55% against only 27% in the center and 18% in the North. In addition, the oil content of the olives produced in the south is slightly higher than in the other regions. However, the advantage of northern olive trees is explained by higher densities of olive trees per hectare. Indeed, Tunisia is the depositary of a rich varietal heritage. Despite this richness, only two varieties are omnipresent in arable lands, which are :

- The Chemlali cultivar which represents about 80% of the Tunisian production of olive oil and it is grown in the center and south of the Tunisia country, areas with low rainfall (<250 mm per year).

- The Che'toui cultivar is widespread in the north, whether in the plains or mountain areas. It covers 176,000 hectares and represents about 20% of the Tunisian olive oil production.

Other cultivars are present in Tunisia, they include Oueslati, Gerboui, Zalmati, Zarazi, Barouni, and Chemchali de Gafsa.

The capacity of the trituration increased from 8,000 t / day in 1986 to more than 40,000 t / day in recent years thanks to the modernization of factories but additional efforts remain to be made, because traditional oil factories still exist and represent approximately 35% of the upstream capacity.

Consequently, the first export agreements were concluded with the European Union during the 1980s. Since then, the European Union has represented the priority market for Tunisian olive oil with more than 80% of exports. Thus, in addition to classical destinations such as Italy and France, Spain and Portugal have become new European destinations.

The United States is also a classic market for Tunisia, since 52% of the olive oil consumed is of Tunisian origin.

In recent years, South America, Sub-Saharan Africa and North Africa, as well as the Middle East and the Gulf countries, Asia and Australia have also been conquered by oil from Tunisian olive. Currently, Tunisian olive oil is exported to the five continents. These exports are very often in bulk and, recently, exports of organic and bottled olive oil have increased. They now represent around 12 and 10% of exports, respectively[6].

4- Olive mills in Tunisia

Since oil represents only 20% of Olivier's ass, good management of by-products in the olive sector is necessary. Indeed, waste represents 80% and the extraction of olive oil is characterized by the generation of huge quantities of wastewater from pomace and olive. The olive cake varies according to the olive crushing system used. In fact, the resultant pomace of a discontinuous system and continuous three-phase system is dry pomace. Whereas, for the continuous two-phase system, it is wet pomace. Indeed, the management of these two types of pomace differs:

- For the dry pomace, the first step in treatment is the extraction of pomace oil which is sold for soap production, followed by drying to obtain the exhausted pomace which is sold as fuel; The second step is oil refining (that is to say neutralization, discoloration and deodorization) to extract refined olive oil.

- for the treatment of humid pomace, pulp and stone are removed; The pulp is used for the production of compost and the stone is sold in the form of fuel and animal feed.

Olive mill wastewater is the liquid effluents generated by the crushing of olives in order to obtain the oil[7].

In addition, it should be noted that the chemical composition of olive wastewater produced by a continuous two -phase system is extremely different from those produced by a discontinuous system or a continuous three -phase system. The wastewater of washing olives in the supply chain are almost the only liquid discharge produced, because during oil extraction, the production of olive wastewater is very low.

The olive mill wastewater is generally discharged into drainage basins throughout the Tunisian territory; the two main basins are in Sfax and El Kalaa, where they are dried by natural evaporation. However, evaporation in these basins is not satisfactory because of the formation of a thin film of oil on the surface of the basins, which hinders the phenomenon of evaporation[5]. For this reason, another more reliable solution has been applied in Tunisia, which is the direct application of this olive mill wastewater on soil.

5- The main uses and quantity of olives and olive oil in the country

Tunisian olive production is very fluctuating from one year to another, due to the phenomenon of the biological alternation of the olive tree and extremely uncertain climatic conditions. Production of olives for oil is estimated at around 706,500 tonnes per year, or 142,000 tons of oil.

The oil content of olives produced in the South is slightly higher than in other regions. The South therefore contributes 55% of total oil production, compared to 27% for the Center and 18% for the North.

The average orchard density is between 100 and 150 trees per hectare in irrigated fields. In orchards with high rainfall cultivated for the production of olive oil, the density is 40 trees per hectare. As for the olive trees producing table olives, the density of the orchard varies between 200 trees per hectare under irrigated conditions and 100 trees per hectare under dry cultivation.

As a general rule, there are 100 olive trees/ha in the North, 60 trees/ha in the Center and 20 trees/ha in the South. Currently, more than 2,000 ha of orchards are super-intensive and produce an average of 7 to 8 tons per ha.

Finally, Tunisia's average yields are generally considered below potential. They could indeed reach triple in the North and the Center and double in the South. The average yield (olive/ha) varies significantly depending on the region and rainfall. According to rough estimates, oil olive orchards give yields ranging from 600 kg/ha to 900 kg/ha, while the yield for table olives is 1,400 kg/ha.

Apart from the fact that cultivated areas are constantly expanding, great efforts have been made to modernize the sector, the aim in particular of highlighting the organoleptic properties specific to varieties of Tunisian origin, such as the Chétoui variety known for its great richness in polyphenols. Thanks to its abundant harvests which have competed with those of the main producing countries, Tunisia remains an important link in the entire olive-growing sphere.

The oil olive tree runs an industrial fabric made up of 1,707 oil mills with a theoretical olive crushing capacity of 43,680 t/8 hours per day, distributed geographically as follows: the North: 18% (Tunis, Manouba , Ariana, Ben Arous, Bizerte, Beja, Jendouba, Le Kef, Siliana, Zaghouan, Nabeul); the Sahel: 28% (Sousse, Monastir, Mahdia); the Sfax region: 33%; the Center and the South-West: 15% (Kairouan, Kasserine, Gafsa, Sidi Bouzid); and the South-East: 6% (Médnine, Gabès, Tataouine)[6].

6- Governmental policies and regulations related to olive waste management

Agriculture is one of the pillars of the Tunisian economy and olive cultivation is one of the main economic and agricultural sectors. Thus, development policies in the olive sector must establish a sustainable olive oil supply chain (OOSC), which aims to ensure economic profitability while preserving the natural environment and social well-being.

In Tunisian legislation, the disposal of olive waste in nature is prohibited in order to avoid environmental problems. According to decree No. 2000-2339 of October 10, 2000, this waste is considered hazardous waste and the Tunisian law No. 96-41 of June 10, 1996, in article 7 specifies that the operations of their elimination by incineration can only be carried out through approved establishments in accordance with the provisions of this law. In fact, vegetable water in Tunisia is generally stored in landfill sites to be eliminated by natural evaporation or recovered by spreading on cultivated soils or by composting. For landfill sites, and according to the Tunisian decree No. 2005 - 1991 of July 11, 2005, these are classified as being hazardous waste management projects that necessarily require an environmental impact study which must be drawn up by design offices or experts in the field. While the spreading of vegetable water on agricultural land was authorized from 2013 by the promulgation of decree No. 2013-1308 of February 26, 2013, setting the conditions and procedures for managing these wastes from oil and their use in agriculture[8].

7- Methods of management for olive liquid waste

The pressing of one ton of olives with modern production methods produces an average of 1.5 tons of vegetable water, although this varies with the different extraction processes: prior washing of the olives or not, moistening of the paste during pressing.

The storage and evaporation in collective ponds of discharges of margins (vegetable water) remains the most used solution in Tunisia. Currently, there are 150 vegetable water storage sites. Nearly half of the landfill sites are built individually on private land by the owners of the oil mills. The rest of the landfill sites are public sites/common landfills (Built by the governorates or city municipalities, the National Office for Sanitation or even private companies that transport and recover vegetable water).

The transport of the vegetable waters is ensured by tank trucks, of a variable capacity making it possible to evacuate the vegetable waters in the reception basin.

The adaptation of the capacity of evacuation and storage of vegetable waters to their level of production constitutes the central axis of this mechanism. As a result, this capacity is continuously extended through the creation of new basins.

8- Methods of management for solid waste

Olive pomace is the solid residue from the first pressure. They are formed of the pulp and olive nuclei. The weight of pomace represents about a third of the weight of crushed fresh olives. This waste contains on average 28.5% water, 41.5% shell, 21.5% pulp and 8.5% oil.

Because of this significant percentage of oil, pomace is often valued by the production of secondary oil. These oils are extracted using a solvent and can be made into soap.

New value chains for olive pomace have been created in Tunisia such as transformation into powder for energy production, production of new fuels replacing traditional biochar for heating and transport, etc.

9- The environmental and economic impact of olive waste in Tunisia

The olive mill wastewaters constitute a real environmental problem for the producing countries of the Mediterranean basin. In fact, the conventional mode of vegetable water management adopted in Tunisia and other Mediterranean countries, and which is essentially based on the storage of vegetable water and the elimination of these effluents through evapotranspiration no longer meets current environmental requirements, particularly in years of high production.

These effluents are very toxic because it contains a high polyphenol content, and it has a significant chemical oxygen demand (COD: 100 to 220 kg/m^3) and high total organic carbon (TOC). This is why they are considered hazardous waste.

An optimal recovery strategy should be adopted for these effluents in order to derive maximum economic benefit from them and minimize their impact on the environment. An environmentally sustainable and economically profitable vegetable water dump site must play a dual role: i) The storage of vegetable water in optimal conditions by respecting the specifications and by developing the reception sites; and ii) recovery of vegetable waters through the reuse of treated wastewater and generated sludge. Admittedly, storage is a buffer link in the management of vegetable waters, but parallel treatment and recovery actions must be undertaken.

10- SWOT analyses of waste management

Tunisia generally ranks among the world's six largest producers of olive oil, rising to fourth or third in the world when the harvest is good. Despite an upward trend, Tunisian production is characterized by high variability because yields are largely influenced by rainfall. For the country's production potential to be fully expressed, an increase and stabilization of yields would be necessary.

SWOT analysis stands for strengths, weaknesses, opportunities, and threats analysis. It is a tool utilized to assess several methods by analyzing internal and external factors to yield productive and effective strategies[9].

a- Strengths

S1: Existence of national strategy for olive mills waste management,

S2: Significant number of evaporation ponds sites,

S3: Emergence of start-up, e-commerce, artificial intelligence (IA), blockchain, and other new marketing tools in the olive oil sector to promote Tunisian products,

S4: Increased demand for organic products which have created new possibilities for Tunisian exports.

b- Weaknesses

W1: Need for large areas of landfill sites,

W2: Need for pretreatment processes before evaporation ponds

W3: High costs of operational and maintenance activities for olive mills waste transformation,

W4: Limitation of transformation activities of olive pomace,

W5: High cost of process installation for olive by-products valorization.

c- Opportunities

O1: The olive sector is supported by several governmental institutions,

O2: Many projects and programs aim to promote the presence of start-ups led by young people in the agriculture and agri-food sectors,

O3: Reuse of treated wastewater and sludge,

O4: Many job creation opportunities in this sector.

d- Threats

T1: The promotion of olive oil value chain aims to differentiate products in term of quality is generally related to personnel and individual initiative and not a national strategy, T2: Lack of human and financial resources,

T3: Public/farmers acceptance for installing landfills near their lands,

T4: Difficulty of implementing circular economy approaches because of the mindset.

11- Sustainable solutions

Apart from revenue from registration of oil mills and the costs of receiving vegetable water, other sources of revenue from other actions and recovery channels are possible, namely:

i) The extraction of oil for the manufacture of soap and cosmetic products: A layer of the oil always remains on the surface of the margins at the level of the drainage basins. This layer, which is often harmful for the evapotranspiration of vegetable water, is eliminated by the oil removers to be sold later to soap factories for their use in the manufacture of soap and cosmetic products based on olive oil.

ii) Extraction of the refined oil: An existing paste at the bottom of the piles of vegetable waters transported is passed to refining at the level of the refining units. The refined oil extracted is sold to canning units, in particular the fish cannery.

iii) Composting: The pulp remaining from the refining operation can potentially be used in the manufacture of compost.

iv) Sale of dry crust: The dry crust remaining at the bottom of the pond after the vegetable waters have dried can be sold to pottery kilns for use as fuel or sold to building constructors for use in making construction bricks.

v) Providing oil mills with means for transporting vegetable water: Some landfill sites provide oil mills with means for transporting vegetable water. This represents an additional source of revenue for landfill projects.

Several other possibilities for recovering vegetable waters were not considered by the landfill sites studied and can be envisaged, such as: spreading in agriculture[10], hydrothermal carbonization[11] and advanced oxidation processes[12].

12- Challenges face in management of olive waste in Tunis

In Tunisia, the management of vegetable water at landfill sites (including public sites) is essentially based on two components: the storage of vegetable waters and the elimination of these effluents through evapotranspiration. Currently, this management model has deeply undergone substantial changes, especially by private entrepreneurs. The question is no longer the storage of the margins downstream of the oil mills but an optimal recovery of the latter in order to derive the maximum economic profit for the landfill projects.

For a wastewater dump site to be environmentally sustainable and economically profitable, it must play a dual role:

i) The storage of vegetable water in optimal conditions while respecting the specifications and while fitting out the reception sites;

ii) The elimination of vegetable water through actions of elimination and valorization.

Admittedly, storage is a buffer link in the management of vegetable water, notwithstanding parallel processing and recovery actions must be undertaken. This, in order to guarantee the elimination of annual stocks over a period of less than nine months and at the same time to ensure better recovery and better economic profitability of landfill sites.

13- Conclusion

Despite the shortcomings and lack of infrastructure, landfill sites offer a range of ways to promote vegetable water and open up possibilities for new entrepreneurs who wish to invest in this area. Admittedly, vegetable water will only cease to represent an environmental nuisance in our country when it ceases to be considered as a by-product. Indeed, vegetable waters, which are toxic effluents, are widely valued and can be managed as a product in an integrated management sector. This approach can lead to a rational management of vegetable waters while deploying joint efforts to strengthen the participation of private entrepreneurs and encourage innovative ideas in this same context.

This highlights the importance of choosing the location of landfill sites before they are set up. This choice involves a very complex multi-criteria process since several criteria must be taken into consideration simultaneously. The criteria must allow a sustainable vision of the project on several dimensions including in particular: the economic dimension, the social dimension and the environmental dimens

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Egypt Country Report

Management of Olive Waste in Egypt

1. Olive trees in Egypt:

Egypt has a total area of one million square kilometers. The desert represents about 97 percent of the country's area. All of the population approximately, lives on 3 percent of the total area in both the Nile valley and in the Nile delta (Ghanem 2014).

Egypt's agriculture sector accounts for 14-15% of the country's gross domestic product (GDP) and provides about 30% of employment, and it is considered the main source of livelihood for more than 50% of Egyptians (IFAD, 2014).

Olive cultivation and processing are considered one of the main agricultural sectors in Egypt, where, olive cultivation and olive oil production as well as olive mill wastes in Egypt are additional income sources and support the population in rural areas (Abou-Zaid 2021).

Egypt is the world's second-largest producer of table olives after Spain and produced around 450,000 tons in 2018/19 of which around 100,000 tons were exported.

The Egyptian government highlighted progress on the expansion of Egypt's olive groves, which have grown from 5,000acres in the late 1970s to 108,000 by the millennium and now encompass 240,000acres.

2. Management of olive mill waste:

liquid wastewater:

The main treatment of the liquid wastewater of olive mill is the anaerobic digestion. Wastewater generated by olive oil processors each year represents a huge challenge for conventional wastewater treatment techniques. Dark liquid effluents are characterized by high concentrations of organic compounds, including organic acids, sugars, tannins, pectin, and phenolic substances that make them phytotoxic and inhibit bacterial activity. From an environmental point of view, this wastewater have a great negative impact on the ecosystem

functions and services.

During processing, olives are crushed and mixed with water in mills. The oil is separated out of this mixture, and the dirty water and solid residue are discarded. The mill wastewater is collected in underground septic tanks. Depending on the size of the tank and the amount of the wastewater used in the washing processes, these tanks is evacuated by sewage service cars. The wastewater is

then transported to the biogas treatment units. According to Abou-Taleb et al., (2018), the anaerobic treatment methods are known to be more suitable for the treatment of concentrated high saline waste for the following reasons: offer lower operating costs, produce energy (biogas) and less sludge with a better quality as compared to aerobic treatment. The remaining wastewater is dumped into a desert area.

3. Olive mill cake (Pomace):

The olive mill cake is obtained by mechanical extraction. This product contains residual oil and stones. Results indicated that up to 40 kg of cake is obtained from 100 kg of olives. Its characteristics depend on the process followed in the extraction of the oil and will differ according to whether pressure, centrifuging or selective filtration was used (Abou-Zaid (2005). In Egypt, olive cake is sun dried and can be used in either: Animal feeding, Composting (for production of organic fe1iilizers)

4. Animal Feed Production:

Fadel and EI-Ghonemy (2015) Seven fungal strains (non-mycotoxin producing) namely Trichoderma reesei F-418, T. harzianumF-416, T. virdie F- 520, T. koningii F-322, Aspergillus oryzae FK-923, A. fumigatus F-993, and A. awamori F-524 were cultured on olive pomace for 7 days at 36 C. The resultant substrate was subjected to further determination of chemical composition and Lignocellulolytic enzyme activities. A. oryzae FK-923,was the most promising strain, where crude protein increased from 9.5% (control sample) to 17.4% (fungal treated sample), while total polyphenols were reduced from 3.1% (control) to 0.92% (fungal treated sample) and fibers decreased from 33 to 22.2%. Also, the values of both neutral detergent fiber (NDF) and acid detergent fiber (ADF) were decreased. The addition of sugarcane molasses (at 2%) led to raise the crude protein to 18.9% and decline in both of phenols and fibers to 0.69 and 21.8%, respectively. Meanwhile, active dry yeast (Saccharomyces cerevisiae) addition by 1.5% to the growth medium increased the crude protein.

to 20.2% (w/ w), whereas phenols and fibers were reduced to 0.55 and 19.2%, respectively. These findings indicated that A. oryzae FK-923 could be an effective organism for the production of lignocellulolytic enzymes and in the same time improve the crude protein content and in vitro digestibility of olive pomace.

5. Composting:

Composting is a bio-chemical aerobic degradation process of organic waste materials. The microbial metabolic activities generate heat which leads to physicochemical changes of the organic matter into biomass, $CO2$ and hwnus-like end-products and, at the end of the process, produce a stable, hwnus-rich, complex mixture (Abu Khayer et al., 2013). It was found that the complex interactions between physical, chemical and biological processes that occur during composting. Factors such as temperature, pH, electrical conductivity (EC), moisture, bulk density, porosity, particle size, organic carbon (C), nitrogen (N) content, carbon to nitrogen ratio (C/N), and oxygen supply, have proved to be key elements to improve composting process, (Richard et al., 2002; Agnew and Leonard, 2003).

The composting of olive mill wastes has been shown to be a feasible method of producing mature, pathogen-free compost, ensuring maximum benefit for crop production, and so increase the economic benefit of the olive mill waste.

6. Conclusion:

Egypt is considered as the second producer of olive in the Mediterranean countries. Egypt characterized by suitable conditions to grow olive and consequence olive oil production. Olive oil production resulted in huge quantities of three wastes (olive leaves, olive mill cake and olive mill wastewater). So improving olive oil yield and quality as well as utilization olive mill wastes could play an important role in rural development in Egyptian

desserts through increasing income.

The post harvest of mill olives, leaf removal, olive washing, olive crushing, olive paste malaxation, olive oil extraction systems are mainly economically important factors while waste water recycling are important economical and environmental factors. olive mill wastes (olive leaves, olive mill cake or pomace and olive mill wastewater) could be another source of added value to olive oil production.

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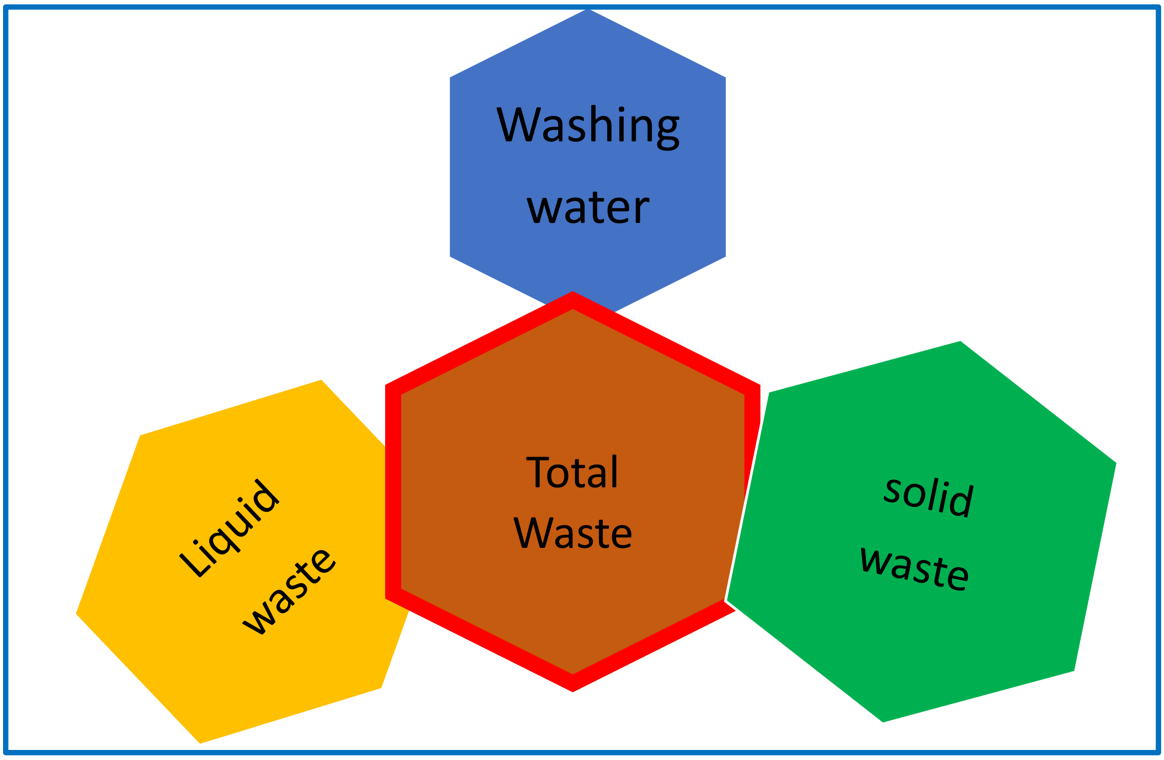
Development of OMWW Strategy.

A. Management Strategy

The proposed management strategy was set based on the country reports, experiments and the outcomes of workshops.

The strategy was divided into three sub-strategies:

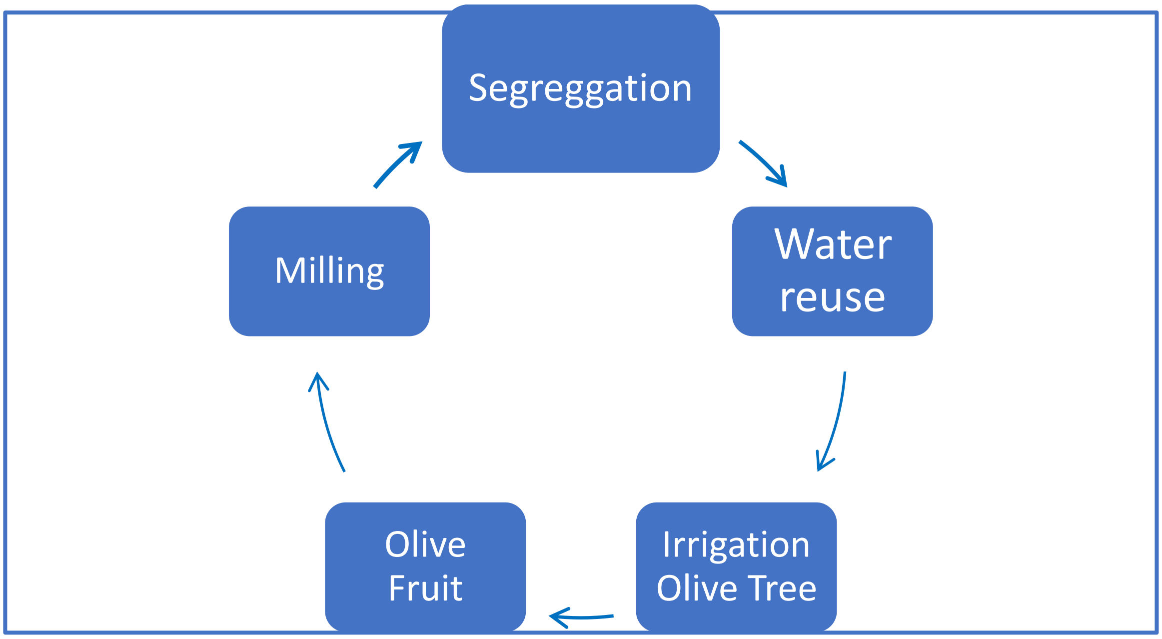
- Management of washing water
- Management of liquid waste
- Management of solid waste.
- Capacity building



B. Management of the washing water

This strategy was developed based on three pillars:

- Segregation of waste to collect the water used for fruit washing.
- Reuse of water for tree irrigation.
- Circular economy of washing water-trees-fruit-milling-water for washing.



C. Management of the liquid OMWW

This strategy was developed based on three principles:

- Segregation: washing water was removed, segregating liquid and solid waste, and collecting the liquid waste.
- Settling, Treatment /biogas,
- Reus or Disposal

Treatment, reuse, and disposal options have many advantages and disadvantages as shown in the table below.

Table 1-1: Advantages and Disadvantages of liquid waste management options

Option	Advantages	Disadvantages
Treatment	• Provide a Clean industry. • Eliminate the impact on the environment. • Good effluent quality suitable for reuse. • May produce valuable byproducts. • Reduce public health risk. • Environmentally friendly.	• High cost. • Odor and air pollution. • High installation and maintenance costs
Disposal	• lower cost for the plant. • Transfer the problem outside the plant.	• Environmental impacts on air, groundwater, surface water, soil,.. • High cost of transportation. • High cost of landfill capital and operational cost. • Large area needs.
Reuse	• Low cost of transportation. • Increase productivity. • Circular economy achievement.	• Impacts of toxic compounds(phenol). • Long-term impacts. • Acceptability.

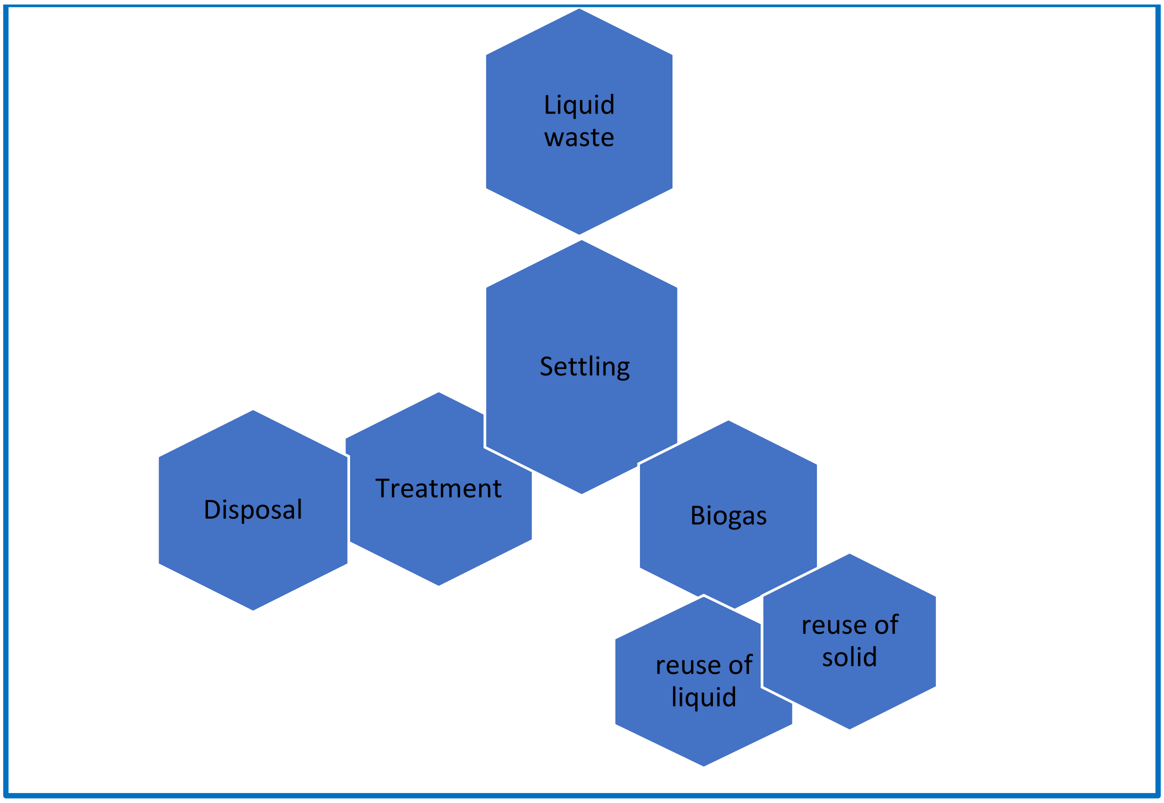


Fig.1-1 : Alternatives of Liquid waste management

D. Management of the Solid OM waste

This strategy was developed based on four opportunities:

- Reuse for energy production inside the plant.
- Reuse for energy production for the local community.
- Land application.
- Advanced Applications, by products, cosmetics, food, products, ..

The advantages and disadvantages of each option are shown in table below:

Table 1-2: Advantages and Disadvantages of solid waste management options

Option	Advantages	Disadvantages
Reuse energy inside the plant.	• No cost of transportation. • Reduce the cost of energy. • Circular economy achievement.	• Air pollution.
Reuse for energy production for local communities.	• low cost of transportation. • Low cost of energy. • Circular economy achievement.	• Air pollution. • Toxic compounds.
Land Application	• Low cost of transportation. • Increase productivity. • Circular economy achievement.	• Impacts of toxic compounds(phenol). • Long-term impacts. • Acceptability.
Advanced applications	• Low cost. • Rich with valuable materials. • Circular economy achievement.	• Lack of experience. • Need separation technology. • Marketing.

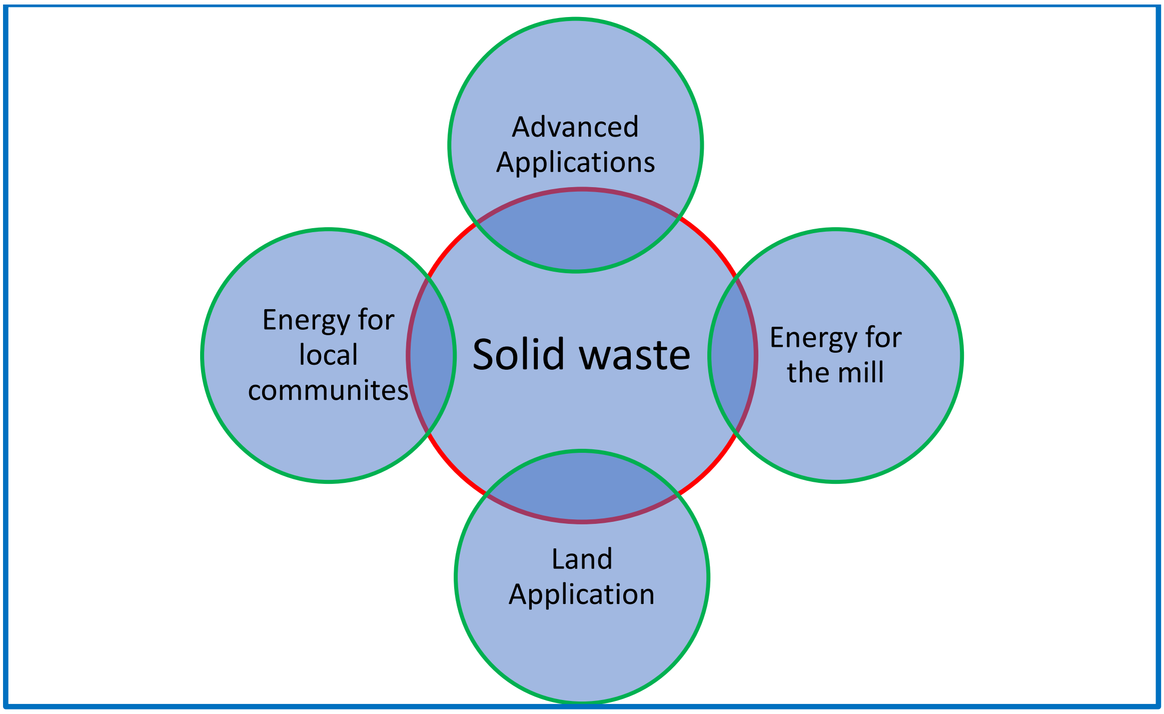


Fig.1-2 : Alternatives of solid waste management

E. Capacity Building in OMWW Sector:

Capacity building will be implemented in five areas:

- Technology transfer
- Legislations and regulations.
- Research.
- Transparency and cooperation.
- Training.

OMWW Management Brochure

1. General guidelines for OMWW management.

The proposed guideline was designed based on the following criteria:

- Cost of management
- Available technology.
- Acceptability.
- Durability.


ادارة و تثمين
المخلفات
الناتجة عن
عصر الزيتون
Project: INT/20/K18 Cooperative Action in Recycling and Reuse
of Olive Mill Waste for Food and Agriculture Production
1


ينتج عن استخراج زيت الزيتون كميات هائلة من المنتجات الثانوية ، بما في ذلك الأوراق ومخلفات الثفل والحجارة ومياه الصرف أثناء المعالجة
تعتبر هذه المنتجات الثانوية المختلفة مواد خام غير مكلفة تحتوي على جزيئات نشطة بيولوجيًا ، والتي لديها القدرة على تعزيز القيمة الاقتصادية للمغذيات والأغذية الوظيفية والمكملات الغذائية ومواد التعبئة والتغليف والمستحضرات الصيدلانية
المنتجات الثانوية
استخدامات عالية القيمة
استخدامات متوسطة القيمة
استخدامات منخفضة القيمة
الأدوية ومستحضرات التجميل
الطاقة الحيوية
الجزيئات الحيوية
الأعلاف الحيوانية
إنتاج الفطريات الصالحة للأكل
سماد
توليد الكهرباء
التدفئة الصناعية والمنزلية
صباغة مواد النسيج
إنتاج الماء
2

تثمين المياه الناتجة عن عصر الزيتون

على الرغم من الافتقار إلى البنية التحتية ، تقدم مواقع دفن النفايات مجموعة من الطرق لتثمين المياه الناتجة عن عصر الزيتون وفتح الإمكانيات أمام رواد الأعمال الجدد الذين يرغبون في الاستثمار في هذا المجال. في الواقع ، المياه الناتجة عن عصر الزيتون ، وهي عبارة عن نفايات سائلة سامة ، تحظى بتقدير كبير ويمكن استغلالها كمادة أولية في نطاق اقتصاد دائري مع بذل جهود مشتركة لتعزيز مشاركة رواد الأعمال من القطاع الخاص وتشجيع الأفكار المبتكرة في هذا السياق نفسه.

وهذا يسلط الضوء على أهمية اختيار مكان مواقع دفن النفايات قبل إنشائها. يتضمن هذا الاختيار العديد من المعايير في وقت واحد. يجب أن تسمح هذه المعايير برؤية مستدامة للمشروع على عدة أبعاد بما في ذلك :

البعد الاقتصادي
البعد الاجتماعي
البعد البيئي

3

Figure 1-3: Management guidelines brochure

Meeting and Discussions

Table below illustrates the meetings conducted throughout the project's activities:

Table 1-3: list of meetings

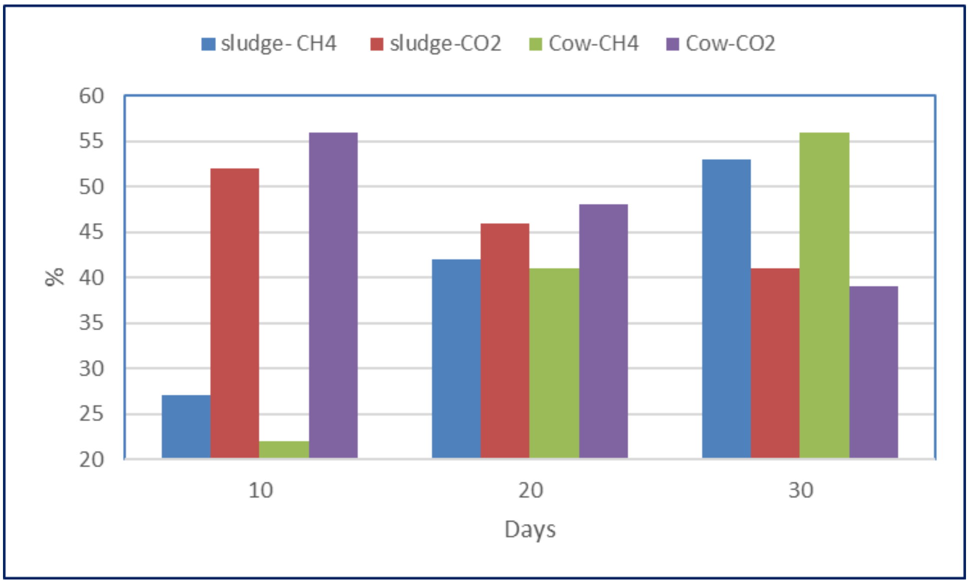
Date	Attendees	Agenda	Action
16/4/2021 (17:00-16:20)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi • Yaser Jaber	• Project objectives. • Responsibilities. • Roles.	• Each partner should review the proposal. • Each partner defines his schedule.
23/10/2021 (16:00-17:10)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi • Yaser Jaber	• Comments about the proposal. • Partners schedule.	• Starting with the country report.
21/3/2022 (16:00-17:40)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi • Yaser Jaber • Ayat Khaswaneh	• Review of country report.	• Each partner should revise his report.
17/9/2022 (18:00-18:40)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi	• planning of biogas experiment. • Planning for a	• Jordan's partner will provide the result of biogas. • Jordan's partner will

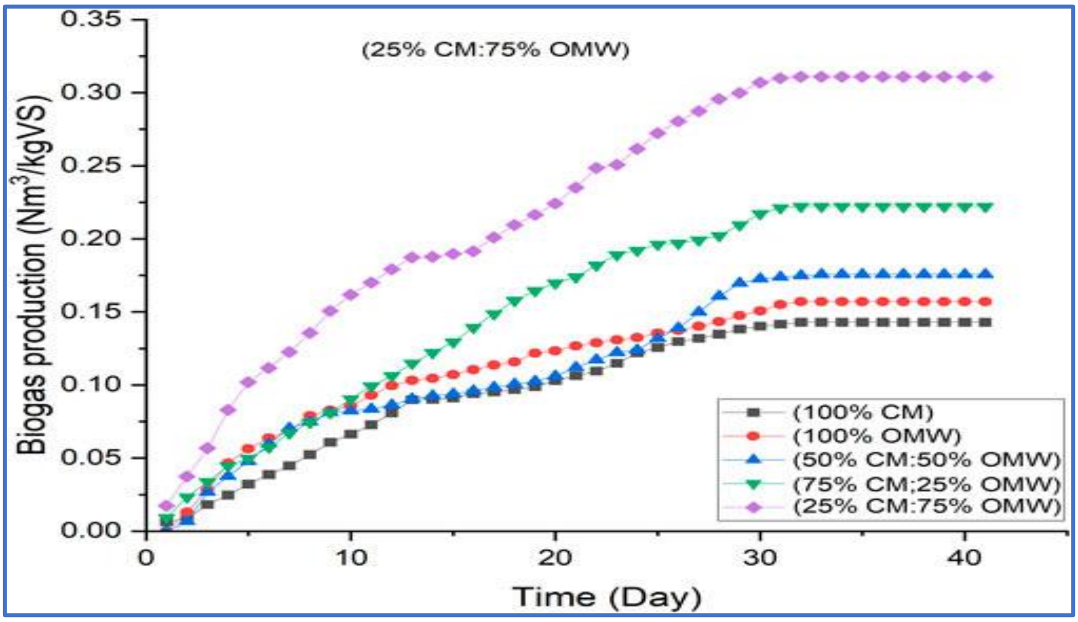
	• Yaser Jaber • Ayat Khaswaneh • Omar AlZoubi	workshop.	provide a detail of Workshop feedback.
17/1/2023 (17:00-18:20)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi • Yaser Jaber • Ayat Khaswaneh • Omar AlZoubi	• Results of biogas production. • Evaluation of the workshop conducted on 7/12/2022	• Preparation for OMWW reuse. • Preparing for a new workshop.
22/7/2023 (16:00-16:40)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi • Yaser Jaber • Ayat Khaswaneh. • Khalidah Rawasdah • Eng. Hanan Ali	• Comments about the OMWW experiment.	• Each partner should conduct one workshop. • Jordan's partner will provide results of OMWW reuse.
21/9/2023 (17:00-17:50)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi • Yaser Jaber • Ayat Khaswaneh. • Khalidah	• Jordan's partner provided a report about the workshop conducted on 23/8/2023. • Results of OMWW reuse	• Conducting workshops in Egypt and Tunisia.

	Rawasdah		
29/12/2023 (18:00-19:10)	• Kamel Alzboon • Rebhi Damsah • Shaima Farsi • Yaser Jaber • Ayat Khaswaneh. • Eng. Hanan Ali • Mohammad Nawaflah	• Tunisia's partner provided a report for their workshop. • The Egyptian partner provided a report for their workshop. • Jordan's partner provided a report for their training day. •	• Preparing the final report.

Chapter Two

Biogas production





A. Objectives:

This chapter aims to cover the following proposal goals:

- **Biogas production (Experiment 1)**

  The solid content in olive mill waste (pomace) was used for the production of biogas through anaerobic digestion. The best environmental conditions (temp, pH) for gas production were controlled based on our experience in this field.

- **Investigate the impact of Nanomaterials on Biogas Production from OMWW (Experiment 2).**

A. Working group:

- Kamel Al-Zboon
- Said Al Rabadi
- Moayyad Shawaqfah
- Rebhi Damseh
- Omar Al Zoubi

1. Abstract

In the first experiment, olive mill wastewater (OMWW) was mixed with two types of waste: cow manure (CM) and wastewater sludge (WW). The results revealed that the generated gas of OMWW+WW increased gradually during the first week and decreased after 15 days and reached the optimum value of 9652ml in the 15th day with accumulative amount of biogas production was 209646ml. The methane rate, it was 22, 41, 56 % after 10, 20 and 30 days respectively. The generation rate of gas from OMWW+CM reached the optimum value of 47005ml in the 8th day. The methane rate, it was 22, 41, 56 % after 10, 20, and 30 days respectively. The gas production rate was 41.7 l/d while the Methane production rate was 23.5 l/d.

The second experiment aims to investigate the impact of Fe nanoparticles (IONP) on biogas production from OMWW mixed with Chicken manure (CM). The results found that biogas production started from the first day of digestion and reached a stable condition after 30-32 days. The rate of gas production was higher in the first stage (up to 12 days) with a slope of 0.14- 0.086 Nm^3/kg Vs. ratio of CM: OMW has a significant impact on the rate of biogas production, where the ratio of 25:75 resulted in the optimum biogas production. The removal effectiveness of TS and VS. was found to be IONP25 > IONP30 > control > IONP20 > IONP35 > IONP40> and IONP15, respectively. The dose of 25INOPs provided the optimum COD, color, and turbidity removal reaching 85%, 73%, and 80% respectively.

2. Introduction

In previous centuries, fossil fuels have been the primary source of energy. The heavy use of traditional energy sources resulted in a significant depletion of these nonrenewable resources. Furthermore, the combustion of fossil fuel produces large amounts of emissions, which has caused many environmental disasters. Conventional Fossil fuel combustion is considered the major source of different greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). it is also responsible for the emissions of other air pollutants such as carbon monoxide (CO), sulphur dioxide (SO_2), oxides of nitrogen (NO_x), non-methane volatile organic compounds (NMVOCs), and particulate matter [Paul Jun et al., 2000].

The disadvantages of using conventional energy sources prompted the researchers to investigate new clean and renewable energy sources. Solar, wind, hydropower, and biomass are all potential renewable energy sources.

Renewable energy sources have many environmental, economic, security, and health advantages. the wide use of renewable energy sources in the last decades resulted in lower emissions, created new jobs in this industry, increased energy independence, afforded many types of energy, provided energy for remote areas, decreased the cost of energy shipping, and enhanced energy security.

Biogas is considered an example of a clean renewable source of energy. Biogas can be generated through simple anaerobic digestion of raw and waste materials such as animal manure, agricultural waste, sludge of municipal waste, wood pellets, and food waste.

Anaerobic digestion can be operated in two thermal phases: mesophilic(35-40°C) and thermophilic (55-60°C). The mesophilic range requires less heat to maintain the anaerobic process, so it is preferred over the thermophilic range. While the thermophilic process is difficult to keep under control, the high temperature of digestion accelerates the decomposition rate and enhances the generating rate of biogas which reduces pathogens in the digestate produced. The produced gas stream consists of many gases, mainly CH4, CO2 with minor constituents of H2S , siloxanes , and moisture. The produced gas can be used for heating, cooking, vehicle fuel and electricity generation [AD Centre, 2024].

In terms of equivalent energy production, Biogas production increased significantly from 0.29 exajoules in 2000 to 0.89 in 2010 and reached about 1.46 exajoules in 2020 [Statista, 2020].

Today, China has become the world leader in biogas production with more than 100,000 biogas plants covering the energy needs of more than 50 million households mostly in rural areas. In the USA, there are over 2,200 operational sites producing biogas plants of which 250 are anaerobic digesters on farms and 652 landfill sites. In contrast, it is estimated that biogas has the potential to generate 103 trillion KW of electricity annually equivalent to 117 million passenger vehicles [WBA, 2019].

Globally it is estimated that the available manure from living today's livestock (1.5 billion cattle, 1 billion pigs, 22 billion chickens, and 0.2 billion buffaloes) can generate 250 to 370 bcm of biomethane equivalent to 2,600 to 3,800 TWh, sufficient to provide the needs of 330-390 million people[WBA, 2019].

The First Research On Biogas:

Title: **Biogas Production through Co-Digestion of Olive Mill with Municipal Sewage Sludge and Cow Manure**

Available full paper: https://ph02.tci-thaijo.org/index.php/ennrj/article/view/245754/166547

Published: Environment and Natural Resources Journal 2022; 20(2): 137-147.

3. Methodology

3.1. Materials

The olive mill wastewater (OMW) sample was collected from a local three-phase olive mill in Irbid region during November 2021. A bout 200liter of OMW was collected in a plastic bottle, preserved, stored and analyzed according to the American standards for water and wastewater examination guidelines (APHA, 2017). The initial characteristics of waste were analyzed immediately once reaching the lab, while the remaining amount of sample was kept in an incubator at a constant temperature of ° C for further tests and uses. A sample of wastewater (WW) sludge with a volume of 50 liter was collected from anaerobic sludge digester in Shalalah wastewater treatment plant in Irbid region. About 50 liters of cow manure was collected from a local cow farm and was preserved, stored and analyzed similarly as the OMW sample.

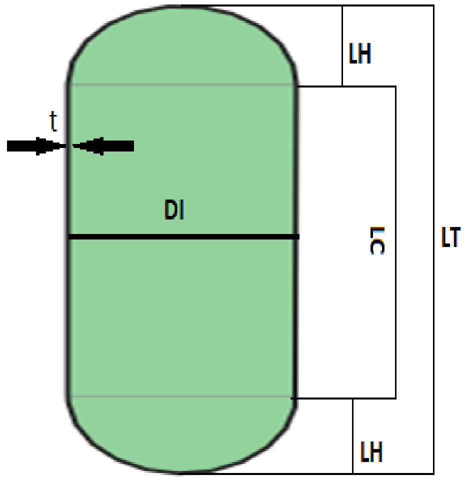
3.2. Design of the reactor

The reactor was designed in Al-Huson College with an internal volume of 100liter and consists of: reactor, gas cylinder, standby gas cylinder, pressure regulator to the point of use, pressure gauge, mixer, heat exchanger, pipes, safety valve, tank, gas holder, nonreturnable valve, cleaning port and sampling port. The general design parameters of the gas cylinder is shown in table below:

Table 2-1: parameters criteria

Parameter	**Symbol**	**Value**	
Inside depth of the head	LH	10 cm	

height of cylindrical	LC	19 cm
Total height of the vessel	LT	39 cm
Inside diameter	DI	20 cm
Thickness	T	2 mm



The digester is equipped with a water jacket and electrical heater to bring the water jacket to the appropriate operating temperature. In-turn the water jacket is insulated by rock wool to prevent the heat exchange with the surrounding environment. The stainless-steel digester is equipped with temperature, gauge pressure and level indicators for monitoring the predefined parameters under which the fermentation process is taken place.

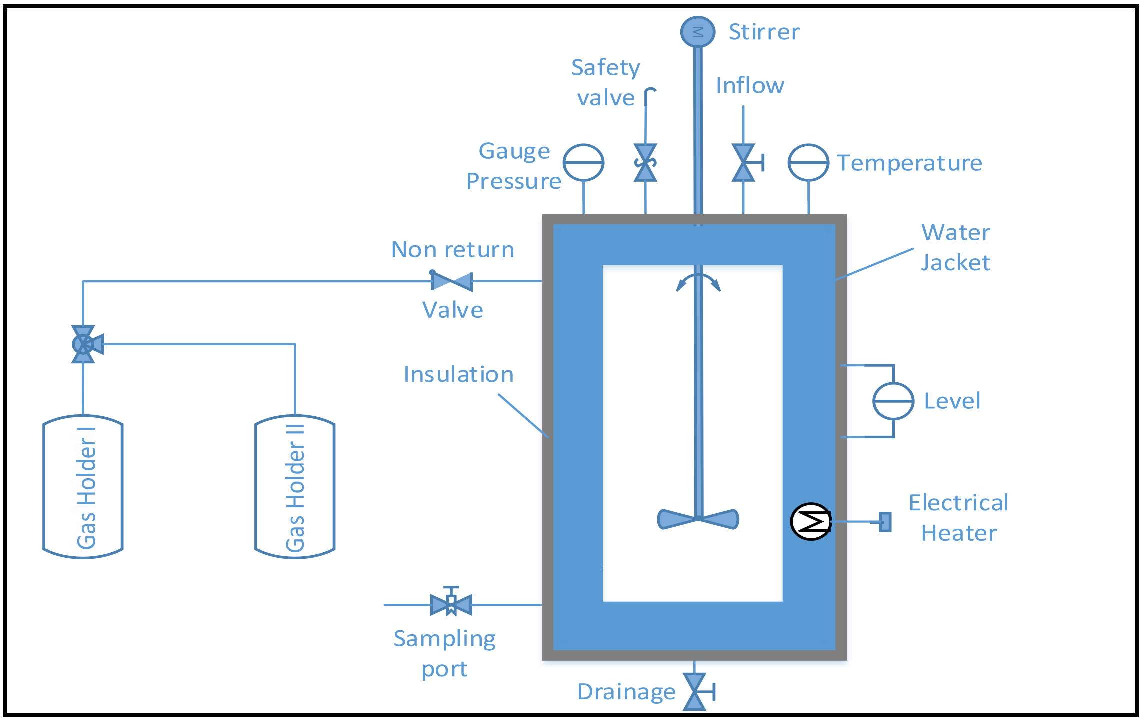


Fig. 2-1: Components of the system

Fig. 2-2: The Digester used.

3.3. Experiment setup.

The feed stock is introduced to the digestor through an inflow pipe and filled up to 70 % of the total volume with olive mill, about 20% was filled with sewage water or cow manure while the remaining was kept empty for adding pH control material. A tie-in is used as sampling port for monitoring the feed composition and pH readings. To avoid the build-up pressure, the fermenter is mounted with a safety valve. The digestion process is foreseen for a period of time of 30 days. The produced gas is directed through a non-return valve to gas holders. Gas holder are connected in series, when the first one is reached a default pressure of 1 bar gauge, then the produced gas is directed to the second gas holder.

Water jacket and the electrical heater helped in keeping the temperature in the optimum condition at 35° °C. The waste inside the digestor was subjected to mixing three times per day with a constant speed of 40 RPM. A daily sample of substrate was collected to monitor the characteristics of the substrate, mainly pH. pH was controlled by adding $CaCO_3$ to keep it in the optimum range (about 7). Usually, the anaerobic process may continue for more than 30days.

Characteristics of the waste

The initial sample of the wastes was categorized for: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand(COD), Total Suspended Solids (TSS), Total Nitrogen(TN) and Total Dissolved Solids (TDS).

4. Results and discussion

The general results can be summarized as illustrated below, while the full results can be shown in the scientific paper.

4.1. Results of OMW&WW

1. Gas pressure increased during the first week, then it decreased after the 15 days of digestion Figure .
2. PH for ranged from 7.4 to 7.56 and was affected strongly by CO_2 generation.
3. pH has a high impact on gas production through controlling phenol content and mesophilic microorganisms.
4. The generated gas of increased gradually during the first week and decreased after 15 days.
5. The generation rate of gas reached the optimum value of 9652ml in the 15^{th} day.

6. Insignificant change in the Gas generation rate after 18 days.
7. The accumulative amount of biogas production was 209646ml.
8. Regarding the methane rate, it was 22, 41, 56 % after 10, 20 and 30 days respectively.
9. Gas production rate was 7.02 l/d.
10. methane production rate was 3.7 l/d.

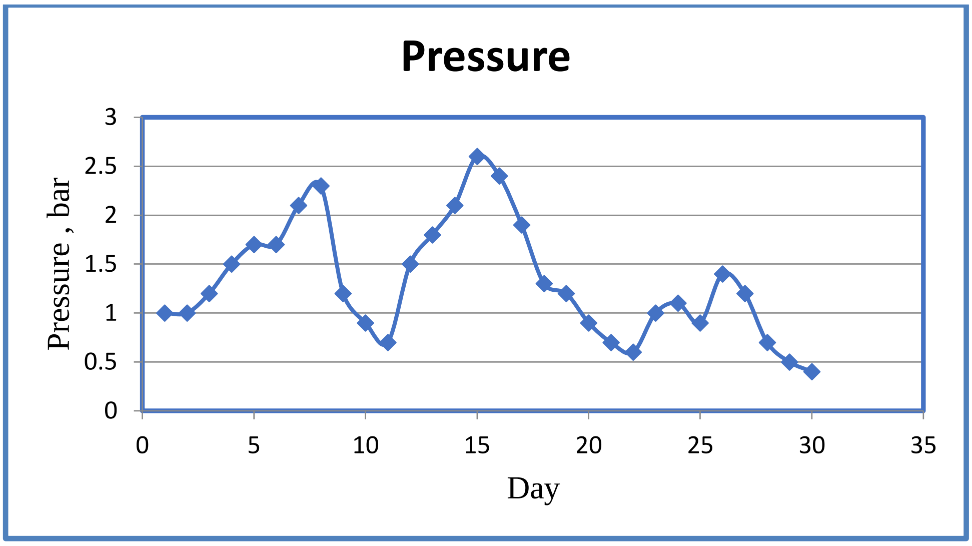


Fig. 2-3: Pressure development with time

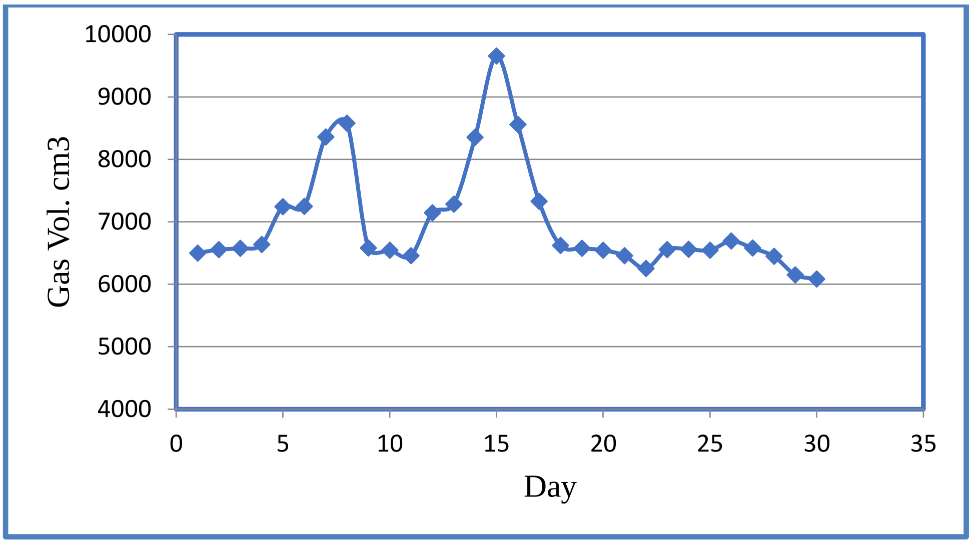


Fig. 2-4: Gas Volume development with time

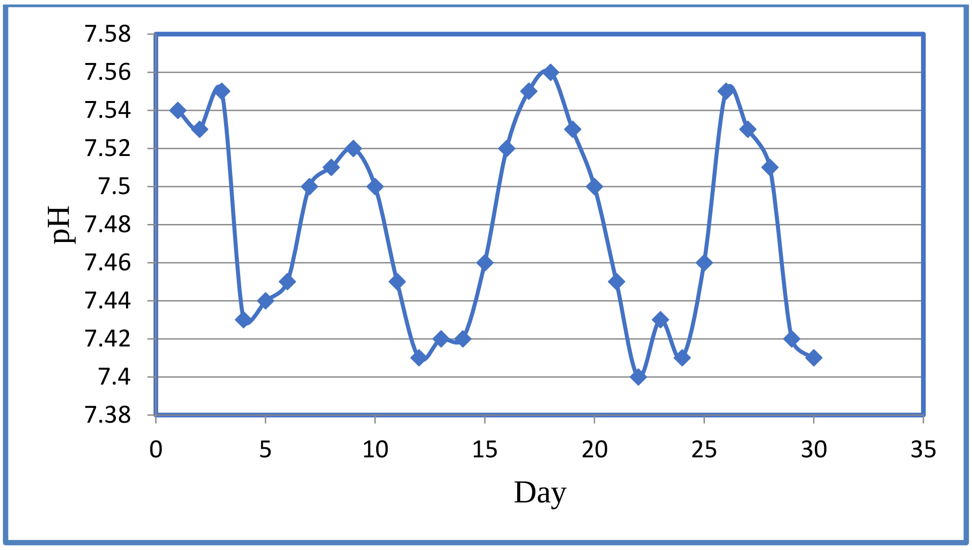


Fig. 2-5: pH variation with time for OMW&WW

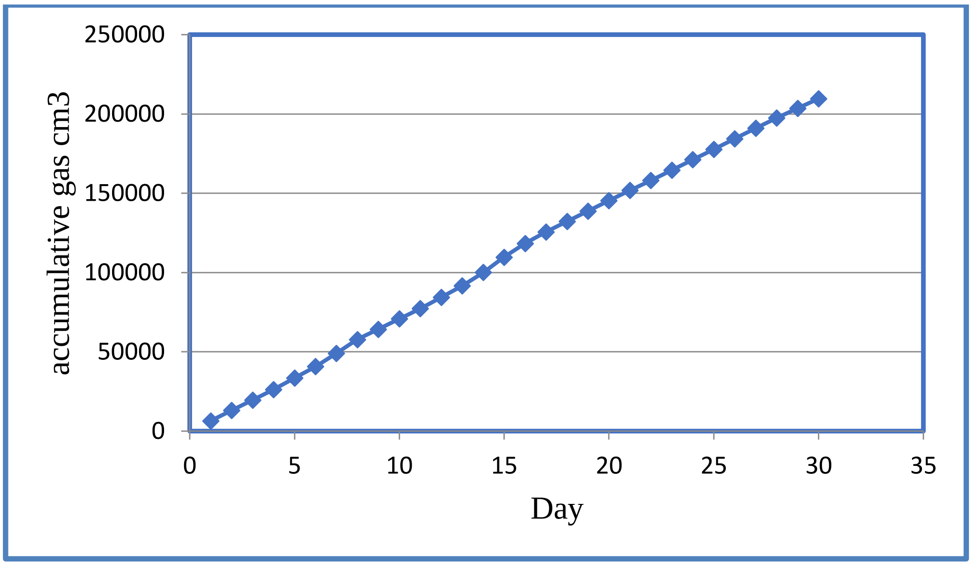


Fig. 2-6: Accumulated gas with time for OMW&WW

4.2. OMW&CM

1. PH ranged from 4.8 in the 8th day to 5.3 after 23 days.
2. Gas pressure increased between days 1-8, then it decreased and fluctuated as shown Figure .
3. The generated gas of increased gradually during the first 8 days and decreased after that with a slight increase during the days 22-24.

4. The generation rate of gas reached the optimum value of 47005ml in the 8th day.
5. Insignificant change in the Gas generation rate during the days 9-29.
6. The accumulative amount of biogas production was 126100ml after 30 days of digestion.
7. Regarding the methane rate, it was 22, 41, 56 % after 10, 20 and 30 days respectively.
8. Gas production rate was 41.7 l/d.
9. Methane production rate was 23.5 l/d.

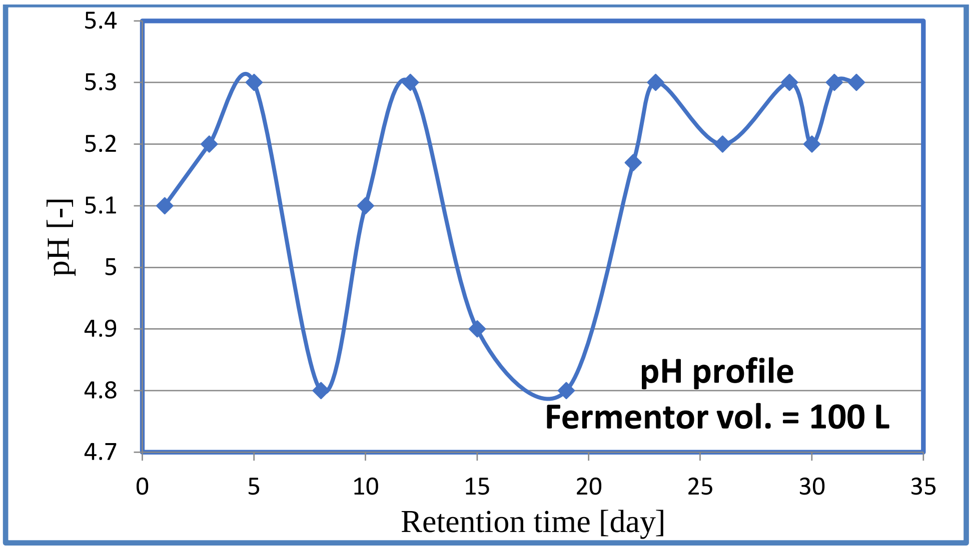


Fig. 2-7: pH variation with time for OMW&C

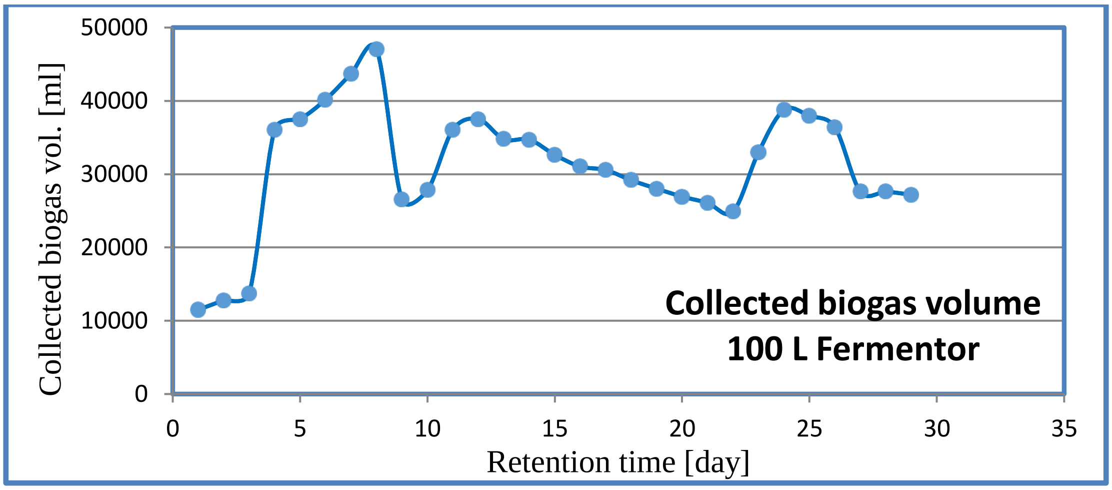


Fig. 2-8: Collected gas for OMW&CM

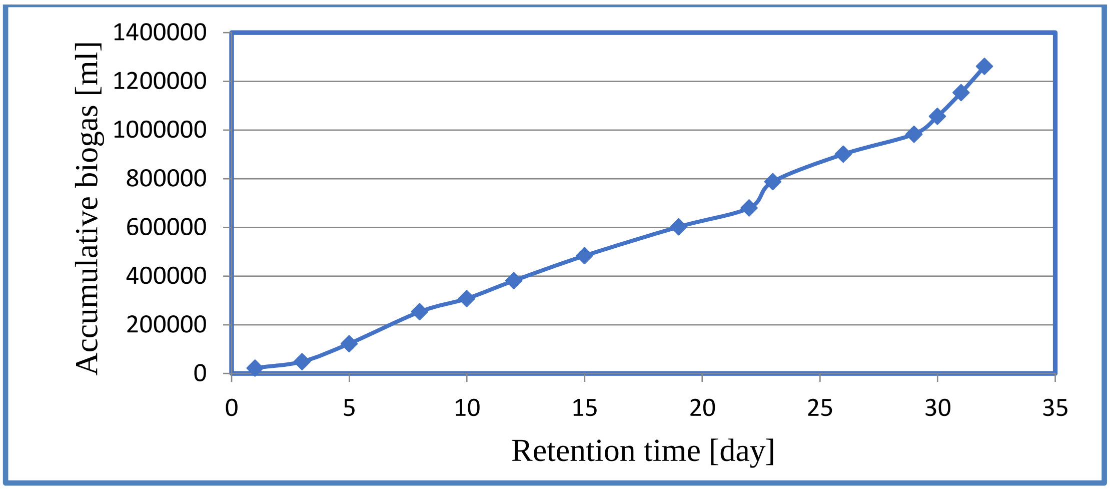


Fig. 2-9: Accumulated gas for OMW&CM

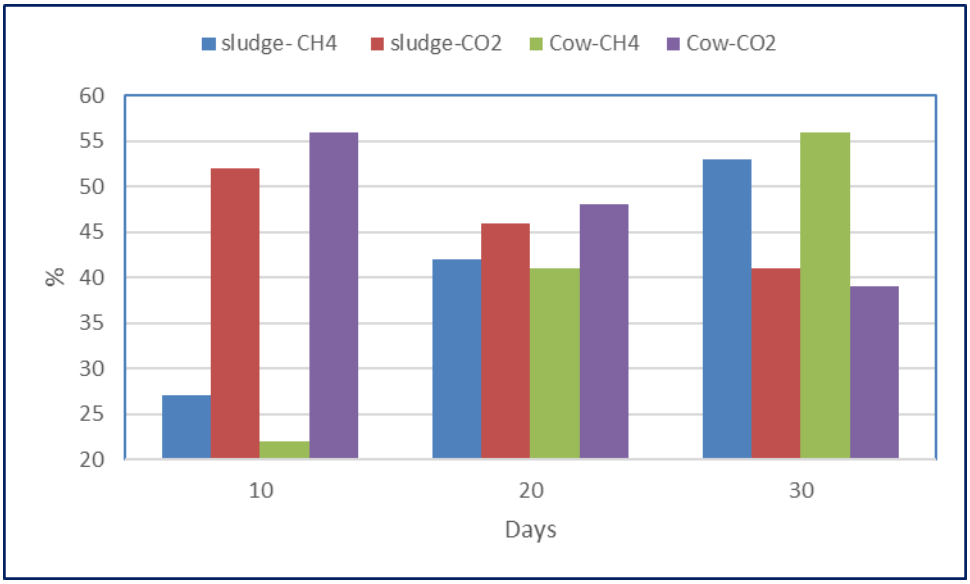


Fig. 2-10: Percentage of CH4

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The Second Experiment

Impact Of Nanomaterials on Biogas Production from OMWW

A. Working group

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- Khalideh Al Bkoor Alrawashdeh1
- Said Al Rabadi
- Eid Gul
- La'aly A. AL-Samrraie2
- Rabia Ali
- Jalal A. Al-Tabbal

Title: **Impact of Iron oxide nanoparticles on sustainable production of biogas through anaerobic co-digestion of chicken waste and wastewater.**

Available full paper: https://www.frontiersin.org/articles/10.3389/fceng.2022.974546/full

Published: **Frontier in Chemical Engineering**

2. Materials and Methods

2.1. Materials

Chicken manure (CM) was used to enhance the digestion process, and the sample with 5kg weight was collected from a local check farm. The olive mill waste water (OMW) sample was obtained from a local three-phase olive mill in Irbid area for the 2021 olive harvest season. The samples were collected, preserved, and analyzed according to the ASTM procedure (APHA, 2008) . Both CM and

OMW feedstocks were kept at 4°C until they were used. Both samples were analyzed for moisture content, volatile solides, percent of ash, fixed carbon, phenole content, chemical oxygen demand(COD), biochemical oxygen demand(BOD) and pH as shown in figure below.

Substrate	Moisture, U(%)	Total solide, TS (%)	Volatile solids, VS. (%)	Ash (%)	Fixed carbone (%)	pH	Phenols (mgl^{-1})	TCOD (gl^{-1})	BOD5 (gl^{-1})
CM	76.80 ± 0.22	23.20 ± 1.04	4.36 ± 0.41	0.04 ± 1.0	0 ± 0.55	6.13 ± 0.26	4.61 ± 0.79	8.56 ± 0.64	7.8 ± 0.81
OMW	93.65 ± 1.51	6.35 ± 1.91	2.50 ± 1.73	0.39 ± 1.08	18.79 ± 1.03	4.72 ± 0.47	6.7 ± 1.13	55.2 ± 2.18	9.47 ± 0.03
Inoculum	98.56 ± 0.52	1.44 ± 0.23	0.43 ± 0.02	0.50 ± 0.31	0.51	6.53 ± 1.05	3.02 ± 0.41	17.23 ± 3.73	2.71 ± 3.59

The first test aimed to determine the optimum ratio of CM/OMW that provides the optimum amount of methane gas. During digestion process, the mixed sample of OMW and CM with different ratios were immersed in a bath to control the temperate for mesophilic condition and the system was run for the required detention time (about 40 days) and ran at an HRT of 40 days.

The second test aimed to determine tests were conducted with magnetite IONP concentrations of 15, 20, 25, 30, 35, 40 mg IONPs/g VS. BMP tests were conducted with magnetite IONP concentrations of 15, 20, 25, 30, 35, 40 mg IONPs/g VS. e the impact of iron nanoparticles on the digestion process and gas production. The iron particle was prepared through a chemical approach by dissolving two moles of FeCl3.6H2O (ferric-molecular weight 270.33) and one mole of FeCl3.4H2O (ferrous-molecular weight 198.81) into 100 ml of deoxygenated water separately. Fe nanoparticles (IONPs) were loaded to the experiments with rates of 15, 20, 25, 30, 35, and 40 mg IONPs/g VS.

2.2. Tests methods

All tests have been conducted according to the standard methods for the examination of water and wastewater as illustrated in table below (APHA, 2017). The Fe concentration was measured by using atomic absorption spectroscopy with flame atomization (AAS-FA) using a Perkin Elmer analyzer 400 spectrometer (CT, Norwalk, United States). A carbon analyzer (LECO CR-412, United States) was used to determine total carbon (C) in substrates.

Table 2-2: Considered parameters in the expermint

Parameter	Container	preservation	Max.	Method

Organic carbon	P,G	Cool at 4^{o}C; HCl to	28	High-Temperature
Volatile organic				APHA, 6200
Nitrate	P,G	Cool at 4^{o}C;	2	APHA: 4500
Nitrite	P,G	Cool at 4^{o}C;	2	4500-NO_2- B.
Ammonia	P,G	Cool at 4^{o}C; H2SO4 to	28	
KN	P,G	Cool at 4^{o}C; H2SO4 to	28	4500-Norg
COD	P,G	Cool at 4^{o}C; H2SO4 to	28	Closed Reflux,
pH	P,G	-	immediately	
PO4	P,G	Cool at 4^{o}C; after	2	APHA, 4500-P
BOD	P,G	Cool at 4^{o}C;	2	APHA, 5210 B.
Fe	p	filtered pH<2(HCl),	7	3500-Fe
Phenol	G	Cool at 4^{o}C; H2SO4 to	28	APHA, 5530

The Fe concentration was measured by using atomic absorption spectroscopy with flame atomization (AAS-FA) using a Perkin Elmer analyzer 400 spectrometer (CT, Norwalk, United States). A carbon analyzer (LECO CR-412, United States) was used to determine total carbon (C) in substrates, and the Kjeldahl method was used to estimate total nitrogen (TKN), which presents the total concentration of organic ammonia and nitrogen (Goulding et al., 2020). The C/N ratio of the CM and OMW was 8.52 ± 2.46 and 38.56 ± 4.09, respectively. Where the desirable ratio of C/N is in the range of 20–30, this range can be achieved by co-digestion of substrates of CM and OMW at a specific ratio. The Fe concentration of CM and OMW was 132.4 ± 0.77 mg/kg and 34.06 ± 1.68 mg/kg, respectively.

2.3. Experiment Setting

The test was performed in a vessel (reactor) with volume of 1L with one primary outlet closed with a stopper. The vessel outlet includes two holes; the first one is used for sampling collection, pH control, and measurement, while the second hole is used for collecting biogas as shown in Figure 1. The two substrate (CW&CM) were mixed in ratios of: 0:100, 25:75, 50:50, 75:25, and 100:0% (v/v). The initial pH was adjusted at about 7.3, and maintained in the same range during the experiment period. To ensure a good interaction between substrates and microorganisms, the vessels were manually shaken twice a day for 1-2 minutes.

Daily Biogas production was measured in volume and was analyzed to determine the CH4 content. Also, the effluents substrates were analyzed to investigate the percentage of VS., TCOD, BOD5, and phenols removal efficiency.

Fig 2-10: Digester instrument

3. Main Results

The general results can be summarized as illustrated below, while the full results can be shown in the original paper.

1. The pH value of the substrates decreased sharply during the first stage to a value of 6, but control of pH maintained it at the neutral range and improved the production rate of the co-digestion.
2. Biogas production started from the first day of digestion and reached a stable condition after 30-32 days (Figure below).
3. The rate of gas production was higher in the first stage (up to 12 days) with slope of 0.14-0.086 Nm3/kg Vs.
4. The ratio of CM: OMW has a significant impact on the rate of biogas production, where the ratio of 25:75 resulted in the optimum biogas production.
5. in terms of gas production, mixed waste (CM&OMW) provided better results than a single waste.
6. Regarding the components of the biogas, it was found that the mixing ratio of 25:75 provided the optimum methane content up to 71% while the other ratios generated methane with ratios

of 59%, 56%, 63%, and 27% for 100OMW, 100%CM, 50:50 CM: OMW and 75: 25 CM: OM respectively as shown in figure …

7. There is no significant correlation between the accumulative gas production and methane content, while methane content depends strongly on the mixing ratio of waste.
8. The VS./TS ratio was 51.51%, 49.24%, 47.83%, 46.88% and 55.8 of 25:75, 50:50, 75:25 (v/v), 100% of CM, and 100% of OMW, respectively.
9. The removal effectiveness of TS and VS. was found to be IONP25 > IONP30 > control > IONP20 > IONP35 > IONP40> and IONP15, respectively.
10. Insignificant difference in VS/VT for all mixing ratios indicating high decomposition rates for wastes.
11. While the initial COD was about 41,000mg/l, it decreased significantly with the digestion period and reached less than 30,000mg/l for the control sample without nanoparticle addition.
12. The dose of 25INOPs provided the optimum COD, color, and turbidity removal reaching 85%, 73% and 80% respectively.

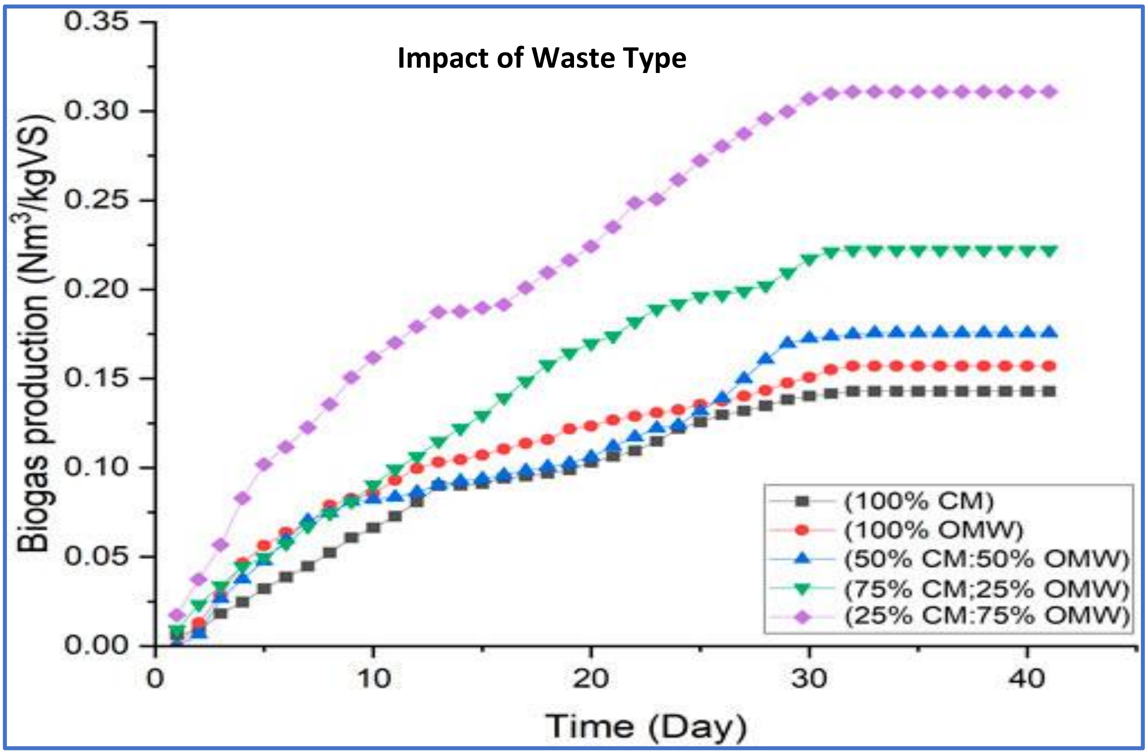

Figure 2-11: Biogas production for different types of waste

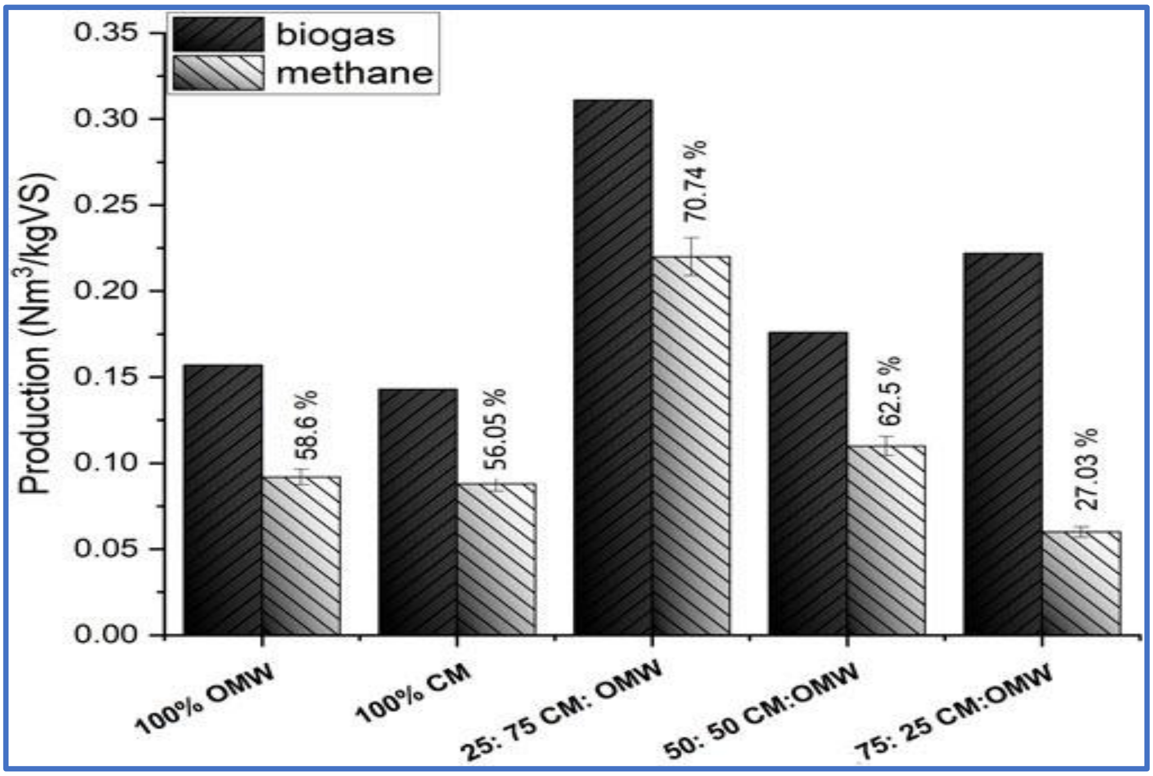

Figure 2-12 : methane content for different types of waste

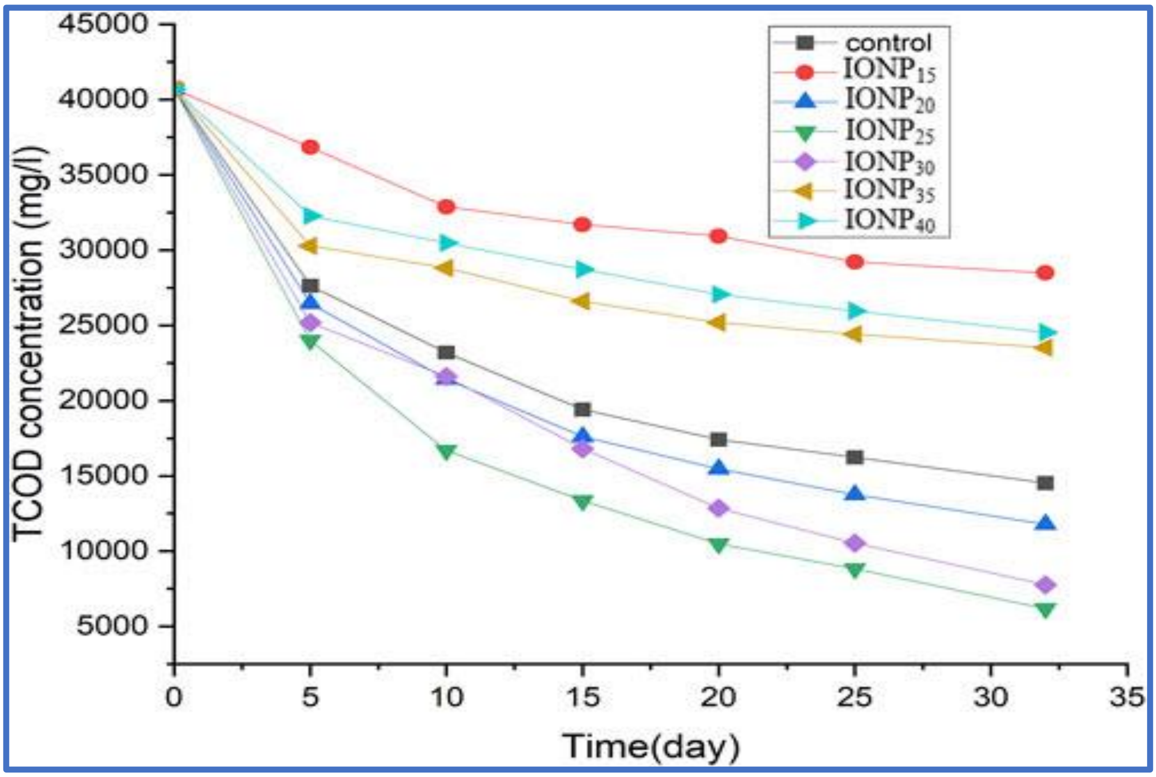

Figure 2-13: Impact of IONP on TCOD

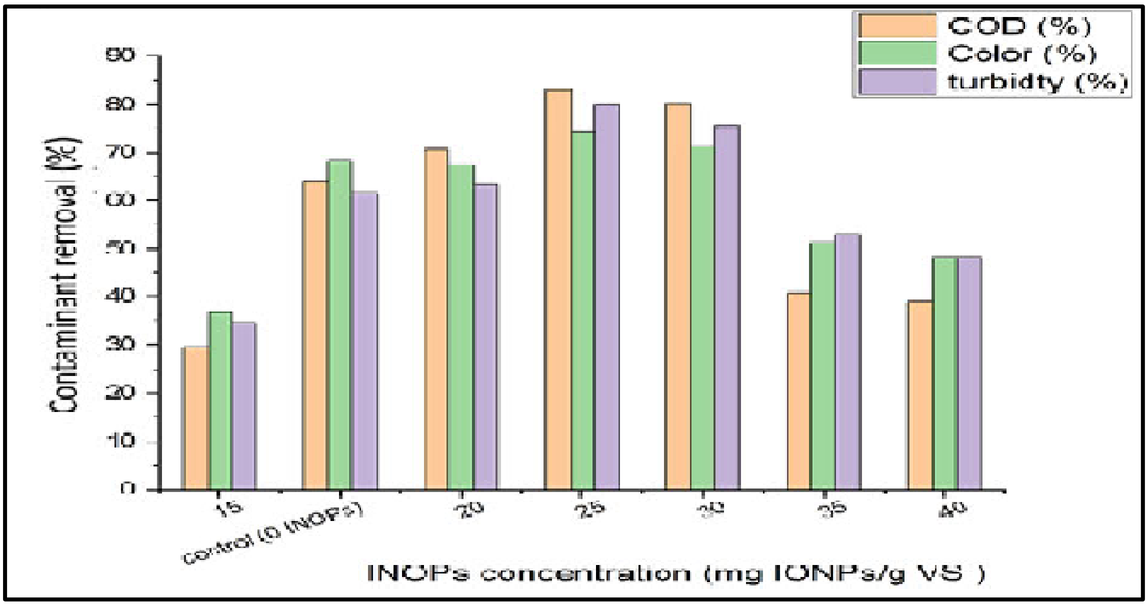

Figure 2-14: Impact of IONP on COD, Color and Turbidity.

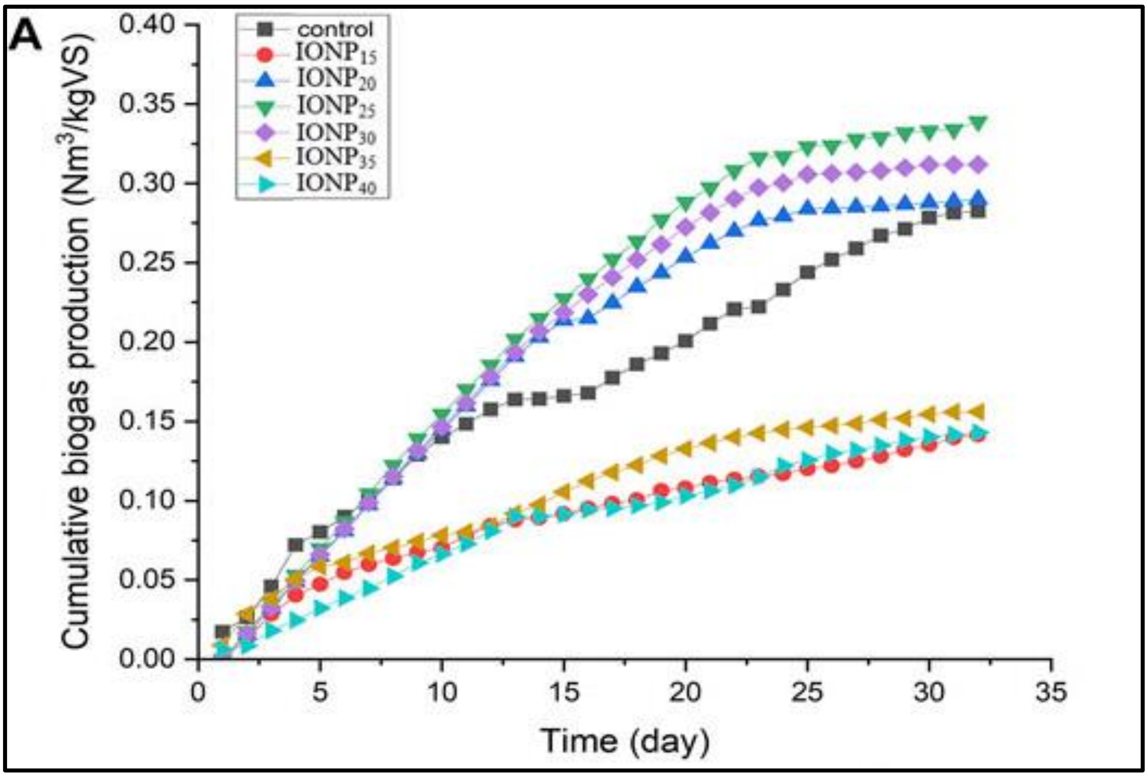

Figure 2-15: Impact of IONP on Biogas production.

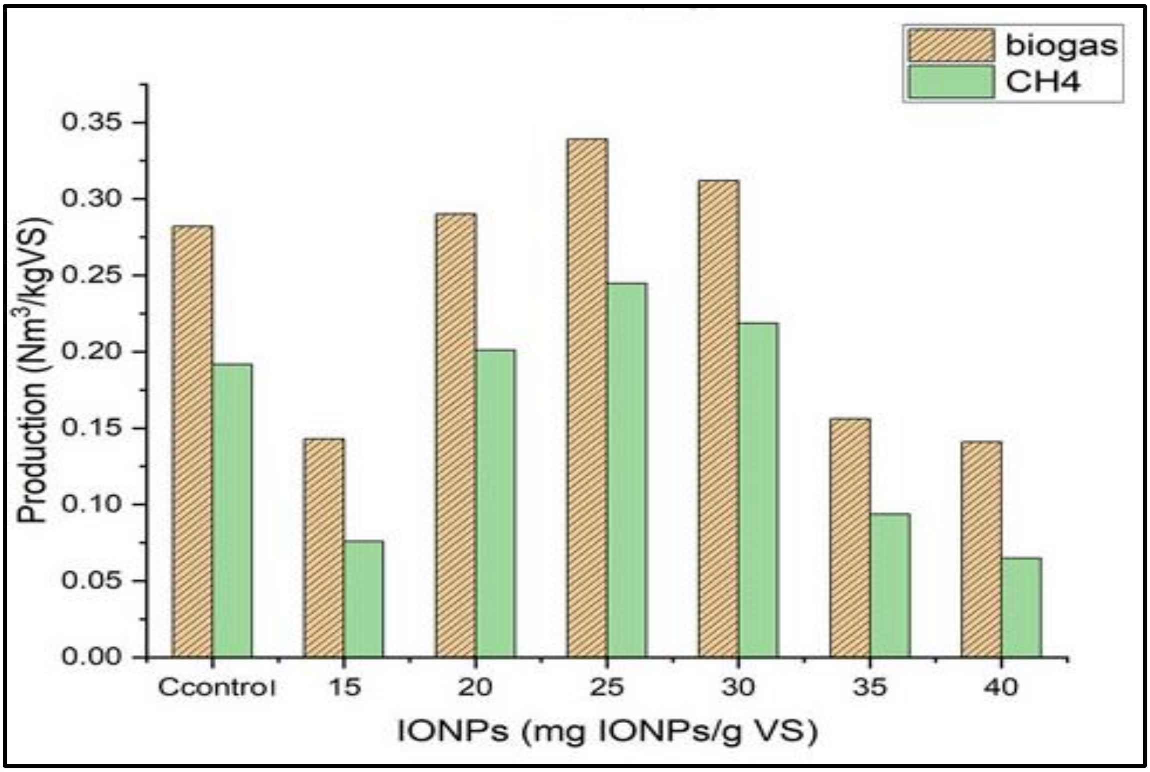

Figure 2-16: Impact of IONP on Ch4 production.

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Chapter Three

Reuse of OMWW in irrigation of Crops

A.

B. Objectives:

This chapter aims to cover the following proposal goals:

- **Investigate the applicability of reusing OMWW for plant irrigation(experiment 1).**

  Liquid wastewater from olive mills was subjected to simple treatments by natural local materials (sand, Volcanic tuff, ..) to remove solids and other undesirable materials. Then the treated water was used for the irrigation of crops. The impact of wastewater reuse on plant germination was investigated.

- **Investigate the applicability of reusing fermented OMW for the improvement of soil nutrients.** The produced biomass from the digester "after biogas production was applied with different rates for soil used for planting crops (maize). The applied biomass will act as a soil amendment and as bio-fertilizer (Experiment 2).

- **Determine the impact of OMWW reuse on plant germination, growth, and productivity(Experiment 1&2).**

Reuse of Fermented Olive Mill Wastewater as a Fertilizer

Working group:

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- Zaydoun Abu Salem
- Jalal Al-Tabbal
- Moawiya A. Haddad
- Nabeel M. Bani-Hani

1. Introduction

The produced biomass from the digester "after biogas production", contains valuable materials especially nutrients and the organic matters. It will be applied with different rate for soil used for planting crops (beans and maize). The applied biomass will act as soil amendment and as bio-fertilizers. It is expected that reuse of biosolids will improve the soil characteristics, soil fertility and increase the plant yield.

The purpose of using OMWW to irrigate crop plants is to safely dispose of effluents that may be harmful to the environment and human health, as well as to maximize fertilizer value. The quality of irrigation water is critical for plant growth since it can change various physical soil properties such as TDS, EC, temperature, turbidity, hardness, and sedimentation, as well as chemical properties such as alkalinity and acidity. The primary goal of this comparative research was to assess the suitability and effects of reusing OMWW at different concentrations on the growth performance of green beans. The fermented olive wastewater came from different manufacturers; therefore, it was not exclusive to one species' production process. Green bean (Phaseolus vulgaris) plants were chosen for this study because they are a fast-growing plant that can be grown in the home since they are easy to nurture and provide a good crop for the garden space required.

2. Methodology:

2.1. Soil media

The soil used in this study was fine-loamy, mixed, thermic, and Calcic Paleargid calcareous soil with a low microbial activity collected from the surface (0–20 cm) of the Research Station at Al- Huson University College of Al-Balqa Applied University in northern Jordan (32◦27N, 35◦27E). The soil was sieved using a 2 mm sieve after it had been air-dried. The soil was evaluated for main physicochemical parameters, while particle size distribution was assessed using a hydrometer [23]; soil electrical conductivity (EC)was measured on 1:1 soil: water extracts. The organic matter content was assessed using the Walkley-Black technique, and accessible phosphorus by sodium bicarbonate extraction. It should be noted that this soil was never really subjected to OMWW before. Experiments were conducted at the greenhouse of Al-Huson University College. OMWW was fermented with a liquid culture through each biologically active phenol-degrading bacterium, Enterobacter asburiae, and Pseudomonas aeruginosa. In comparison to unfermented OMWW has a higher level of total nitrogen, soluble nutrients(nitrogen and potassium), and lower COD, BOD, and total phenolic content.

2.2. Planting

Eighteen pots were filled with dry soil, in these pots, 10 kg of dry soil was added, along with five seeds of Phaseolus vulgaris were planted at a depth of 5–7 cm in each pot. As a source of irrigation water, the settled OMWW with and without dilution with potable water was applied to the soil. A greenhouse pot experiment used a randomized complete block design with three replications to examine the following treatments.

The physiological and chemical analyses of irrigated water at various concentrations are shown in Table 1.All pots were irrigated to saturation with tap water on the first day, and then 1 L per pot was irrigated for two weeks until a vigorous shoot formed. Following the two-week period, each sub-group was watered with its treatment. Finally, once the plants had ceased growing, measurements of the dry weight of the plant, number of pods, weight of pods, and length of pods, total chlorophyll, chlorophyll and were taken. The number of pods, length of the pods, fresh and dry weight were obtained at the end of the experiment. The plant was covered in aluminum foil and placed in an 80 ◦C oven for 24 h. Weighing was done with a single-pan electrical balance. The pigment analyses, chlorophyll a, chlorophyll b, and total chlorophyll, were calculated after 15 days of germination in varied levels of effluent. Chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD5), pH, phenol, ammonia, phosphate, and electrical conductivity were all determined in the collected samples (EC). All these analyses were carried out in accordance with the Standard Methods for the Examination of Water and Wastewater (1995). All treatments were repeated three times, and the findings were statistically analyzed as the averages of the three replicates.

Table 3-1: Physiochemical characteristics of each treatment.

Sample ID	OMWW, %, V/V	Tap water, %, V/V	TSS, mg/l	Phenol, mg/l	P, mg/l	EC, ms/cm	BOD, mg/l	COD, mg/l
T100	100	0	1300	71	115	21	3005	6400
T0	0	100	5	ND	ND	ND	ND	ND
T1	4	96	52	3	5	0.9	120	250
T2	6	94	78	4	7	1.3	180	384
T3	8	92	100	6	9	1.7	240	510
T4	10	90	130	7	12	2	300	640
ND: not detected								

3. Main Results

The main findings are as shown below, while full results are available at: *The effects of fermented olive mill wastewater mixtures on the growth and development of bean (phaseolus vulgaris)*. Available from: https://www.researchgate.net/publication/367440609_The_effects_of_fermented_olive_mill_wastewater_mixtures_on_the_growth_and_development_of_bean_phaseolus_vulgaris.

1. Fermented OMWW contains high concentrations of BOD and COD which make it unsuitable for direct reuse.
2. Also, high phenol content may affect plant growth and the environment.
3. The salinity of OMWW is high (TDS=20ms/cm= 12800ppm) and will affect soil or plant growth, especially for sensitive plants.
4. Dilution of OMWW with tap water makes it an acceptable concentration of contaminants.
5. OMWW has positive impacts on the number of pods, where the average number of pods/pot was: 22.3, 24, 23.3, 22.67, and 23 for T0, T1, T2, T3, and T4 respectively. this indicates that Plants irrigated with varied percentages of OMWW significantly produced more pods per plant, ranging from 2.3 to 12.7% more than the control ($p \leq 0.05$) with the highest results obtained when irrigated with 4% OMWW.
6. Similarly, the length of pods increased significantly, ranging from 5 to 23% more than the control ($p \leq 0.05$)with the highest results obtained when irrigated with 4% OMWW. The average length of the pods was: 4.15, 5.38, 4.72, 4.72, and 4.34 cm for T0, T1, T2, T3, and T4 respectively.
7. MWW 4% and 6% scored the highest shoot fresh weight of pod (5.78 and 5.69 g, respectively) and the lowest (5.16 g) under control Treatment.
8. Plant dry weight was the highest (9.26 g) at OMWW 4% and the lowest(7.66 g) at OMWW 0% (control). The increased percentage of plant dry weight was 20.9%, 9.7%, 3.3%, 2.59%, for T1, T2, T3, and T4 respectively.
9. Fermented olive mill wastewater irrigation at 4 and 6 % significantly increased chlorophyll a (Fig. 5). With 4% and 6% fermented OMWW irrigation, chlorophyll a was increased by about 31% and 15%, respectively.
10. The results of irrigation with fermented OMWW at different percentages showed a significant effect in total chlorophyll content in the early growth stages. The irrigation with fermented OMWW 19% scored the highest total chlorophyll content (9.2) followed by 8., 6, and 1.3% underwater treatments of : T1, T2, T3, and T4 respectively.

Figure 3-1: Growth of beans under fermented OMWW

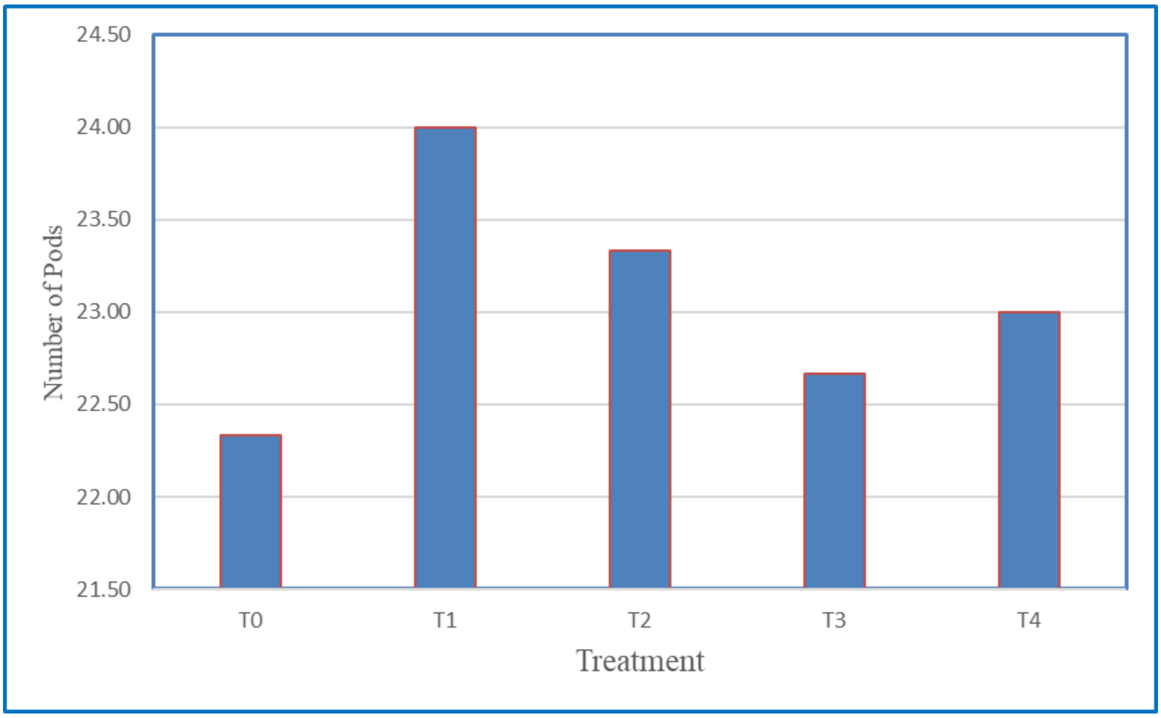

Figure 3-2: Effect of OMWW irrigation on the number of pods

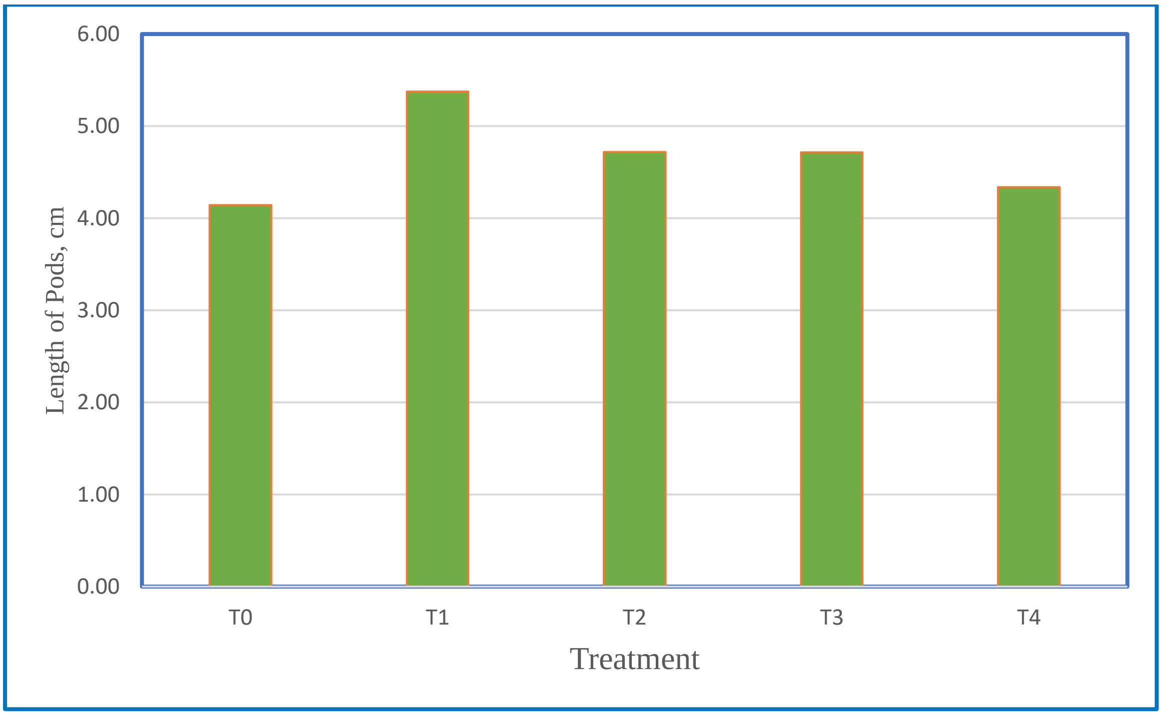

Figure 3-3: Effect of OMWW irrigation on the length of pods

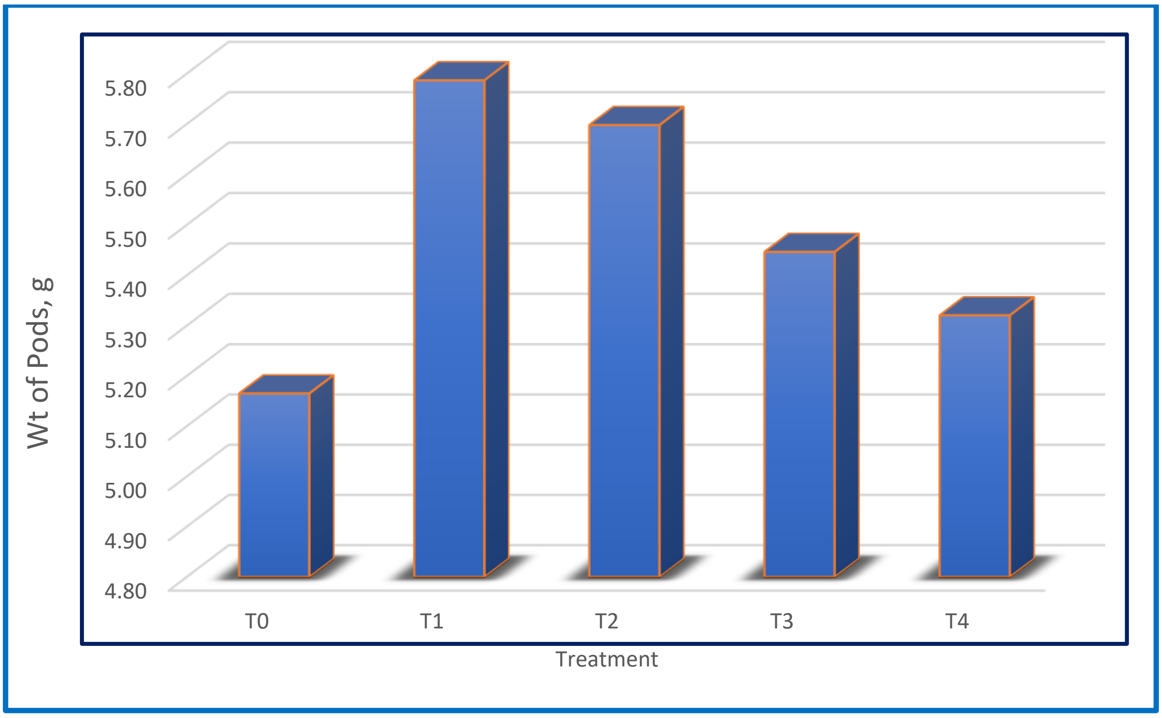

Figure 3-4: Effect of OMWW irrigation on the weight of pods

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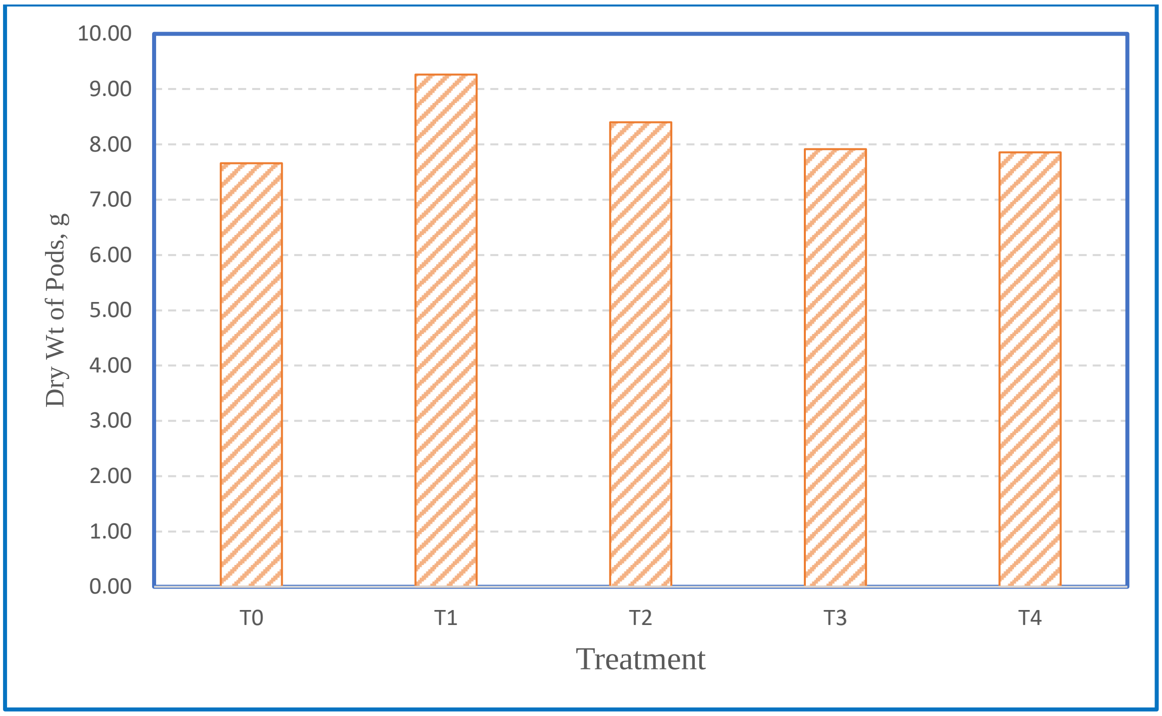

Figure 3-5: Effect of OMWW irrigation on the dry weight of pods

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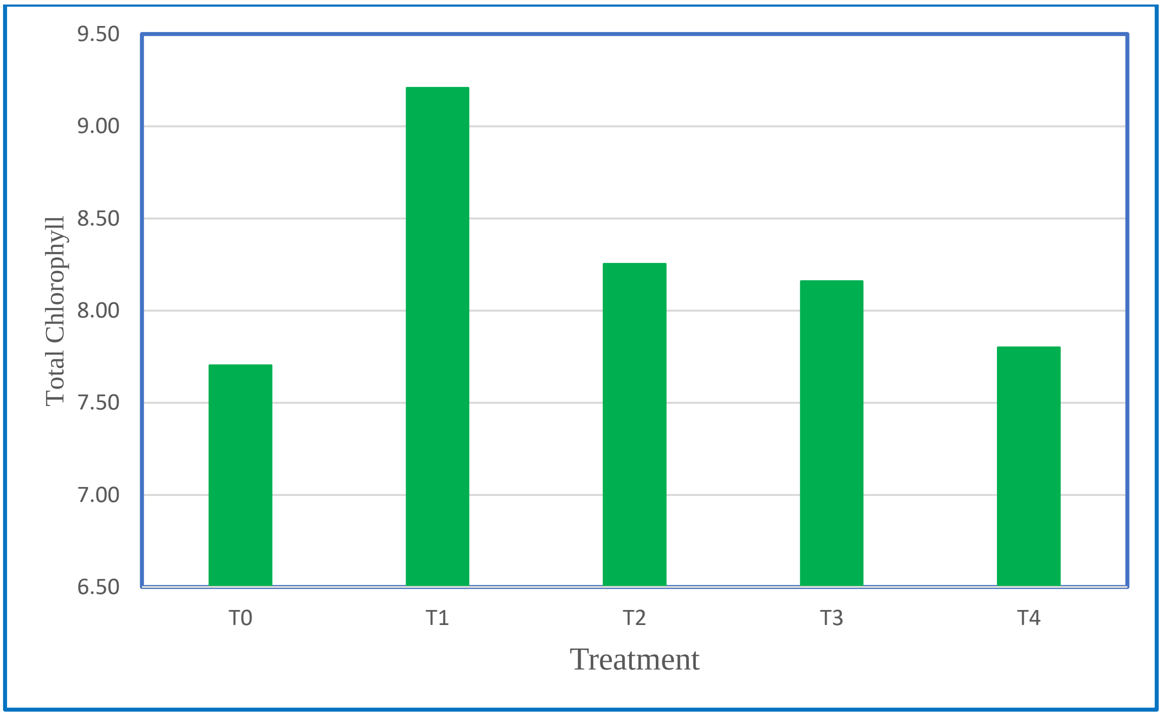

Figure 3-6: Effect of OMWW irrigation on the total chlorophyll

Conclusion

1. The irrigating agricultural land with a water mix containing a specified quantity of OMWW enhanced physicochemical parameters and influenced plant characteristics. T
2. The plant characteristics were substantially affected when wastewater irrigated agricultural areas with water polluted with OMWW at concentrations no more than 4%.
3. According to the findings of this study, utilizing 4% OMWW resulted in the best bean plant growth response, with an increase in growth indices and photosynthetic pigments.
4. It is recommended to reuse fermented OMMWW for irrigation of crops after dilution by a ratio of 1:25(4%v/v).

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Experiment 2

Reuse of Olive mill Wastewater for Crops Germination

Working group

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- Bashaar Y. Ammary
- Omar A. Rimawi
- Jalal A. Al-Tabbal
- Kamel Alzboon.

1. Introduction

OMW in Jordan is characterized by elevated levels of phenolic content, chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and high concentrations of cations and anions, as well as a low pH value. The significant organic load, with chemical and biochemical oxygen demands that can reach up to 100-200 g/L, poses challenges in terms of effective management and meeting legal discharge thresholds(Al-Hmoud, 2020). Furthermore, the presence of toxic compounds within its composition makes conventional biological treatment methods ineffective.

Consequently, several methods have been proposed and developed to reduce the environmental impact of OMW. These methods are based on chemical, biological, and physical scientific aspects and have often used more than one form.

Physical methods for treating OMW include liquid extraction, filtration/non-filtration, flotation, adsorption, flocculation, coagulation, used alone or in combination with one another. For instance,.

The utilization of treated wastewater for agricultural irrigation is being seen as a potential solution to the shortage of freshwater resources in some countries. There are numerous types of effluent that are suitable for reuse, including olive mill wastewater (Ben Rouina et al., 2006). Managing olive mill wastewater (OMW) can be challenging due to its properties, which can result in practical and financial difficulties. One option is to spread OMW into the soil as a regulated approach for effective management. (Mohawesh et al., 2019) explore the sustainable reuse of OMW through land application to enhance soil quality and wheat growth performance under rain-fed conditions. OMW was spread at various rates (20, 40, 60, 80, and 120 m3 ha^{-1}) at two sites, and soil physical and chemical properties were measured after OMW application and after harvest. Wheat growth performance and leaf nutrient content were also analyzed. The study found no negative impact of OMW application on soil properties or wheat growth at either location and for all OMW application doses. Moreover, the land spreading of OMW significantly improved wheat growth by increasing the biological yield (BYLD) (8.4 to 36.5%), grain yield (GYLD) (20.1 to 79.4%), and harvest index (HI) (4.2 to 60.2%). Based on the measured soil chemical parameters and wheat grain yield, the study suggests that an OMW application rate of 60 m3 ha−1 could significantly improve wheat growth without significant negative impact on soil properties. In conclusion, the study recommends using OMW as suggested for wheat, but long-term application assessment and local legislative adaptation are still necessary.

Al-Tabbal and Al-Zboon (2019) employed olive mill cake and stone-cutting sludge as soil amendments. They found that the addition of olive cake harmed maize development. The addition of stone-cutting sludge to olive mill cake on clayey soil, however, resulted in improved maze development metrics.

The recycling and reuse of waste materials can help to reduce costs and increase efficiency, and there is potential for new technologies and processes to support more sustainable and cost-effective waste management practices. However, there are also threats to effective waste management in Jordan, including competition for resources and funding with other sectors such as energy and water management, resistance to change and innovation among some producers and processors, and uncertainty and changes in government regulations and policies related to waste management.

2. Material and Methods

2.1. Experimental Setup

At Al-Huson University College, a germination experiment was carried out to determine the impacts of OMW generated by various filter types. Twenty barley seeds were sterilized with sodium hypochlorite solution (Khan et al., 1992) and dried before being grown on Petri plates lined with a double layer of filter paper. Each petri plate received 10mm of OMW from the effluent of several filters. The filter paper was replaced daily to prevent contamination. The seeds sprouted at 26°C ± 1°C for 10 days. The seeds were considered germinated when the radicle reached 2 mm in length.

2.2. The Treatments

The table below shows the different treatments of OMWW and the types of media.

Table 3-2: Experiment layout

Treatment	Layer 1*, 10cm	Layer 2, 10cm	Layer 3, 10cm,	Lyer 4, Filter, 50cm	Layer 5, 20cm
T1	coarse gravel	fine gravel	sand	Zeolite	OMWW
T2	coarse gravel	fine gravel	sand	Hay	OMWW
T3	coarse gravel	fine gravel	sand	Pomace	OMWW
T4	coarse gravel	fine gravel	sand	Rubber	OMWW
T5	coarse gravel	fine gravel	OMWW	Clay loam soil	OMWW
T6	coarse gravel	fine gravel	OMWW	Loamy sand soil	OMWW
T7	coarse gravel	fine gravel	OMWW	: Fruit peel	OMWW
T8	coarse gravel	fine gravel	OMWW	Saw dust	OMWW

T9	coarse gravel	fine gravel	OMWW	Coal	OMWW
T10	coarse gravel	fine gravel	OMWW	Rubber + Zeolite	OMWW
*From the bottom.					

3. Results

The results of the experiments can be summarized in the following points.

1. The generated treated water from all filters has high turbidity (4000-11000) in comparison with the control untreated sample of 15000NTU.
2. Cod decreased significantly by using filters of clay loamy soil, rubber, and loamy sand soil and reached about 10ppm in comparison with about 50ppm of the control sample.
3. Similarly, phenol concentrations decreased by 45% by using zeolite and loamy sand soil.
4. The highest germination percentage was recorded after irrigation with tap water (96.7%) compared to 66,7%, 25%, 23%, 18%, 16%, 8.4%, 6.7%, 5% after irrigation with OMW that was filtered with clay loam , rubber, loamy sand, rubber+ zeolite , pomace, fruit peel, zeolite and coal, respectively.
5. The germination speed index was noticed for seeds irrigated by tap water (22.44%) compared to 12.46%, 7.65%, 5.25%, 5%, 4.95%, 3.5%, 3%, 2.71% clay loam soil, rubber, loamy sand soil, pomace, rubber + zeolite, fruit peel, zeolite and coal filter, respectively.
6. Shoot length was: 7.6, 7.2, 7.2, 7.5, 7.5, 7.3, 7.2, 7, and 7.2 cm for tap water, zeolite, pomace, rubber, clay loam soil, loamy sand soil, fruit peel, coal and rubber + zeolite filter respectively,
7. Root length was: 10.5, 8.8, 9, 10,10.5, 10, 9, 8.2, and 9.6cm for tap water, zeolite, pomace, rubber, clay loam soil, loamy sand soil, fruit peel, coal and rubber + zeolite filter respectively,
8. Shoot dry weight was: 1.6, 1.30, 1.4, 1.5, 1.5, 1.5, 1.3, 1.3, and 1.5 g/plant for tap water, zeolite, pomace, rubber, clay loam soil, loamy sand soil, fruit peel, coal and rubber + zeolite filter respectively,

9. Root dry weight was: 10.5, 0.30, 0.3, 0.45, 0.5, 0.45, 0.3, 0.25, and 0.45 g/plant for tap water, zeolite, pomace, rubber, clay loam soil, loamy sand soil, fruit peel, coal and rubber + zeolite filter respectively,
10. The applied filters can be ranked according to the Seeding vigour index as: tap water>clay loam soil> rubber> loamy sand soil> rubber zeolite> pomace.>Zeolite>coal.
11. The use of treated OMW has a negative effect on the germination process of barley as compared to germination when tap water was used.
12. Treated OMW using most filter media types used in this research improved the germination percentage and seedling growth, as compared to untreated OMW, especially effluent generated from clay loam and loamy sand soil filters.
13. The treatment of OMWW is useful in reducing the impact of OMWW on the germination of barley.

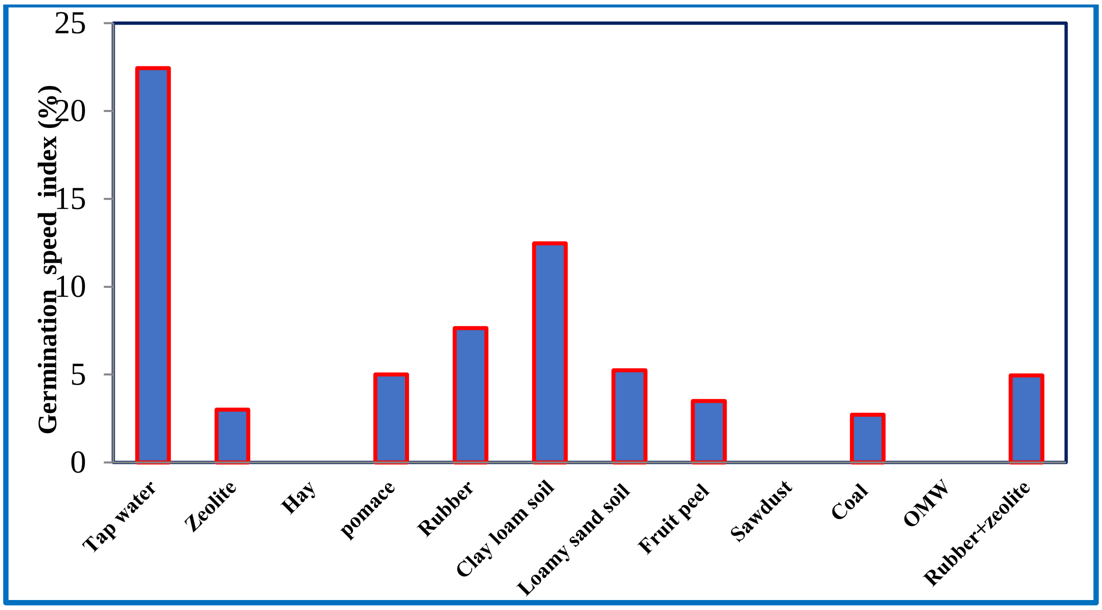

Figure 3-7: Germination speed index of the Experiments.

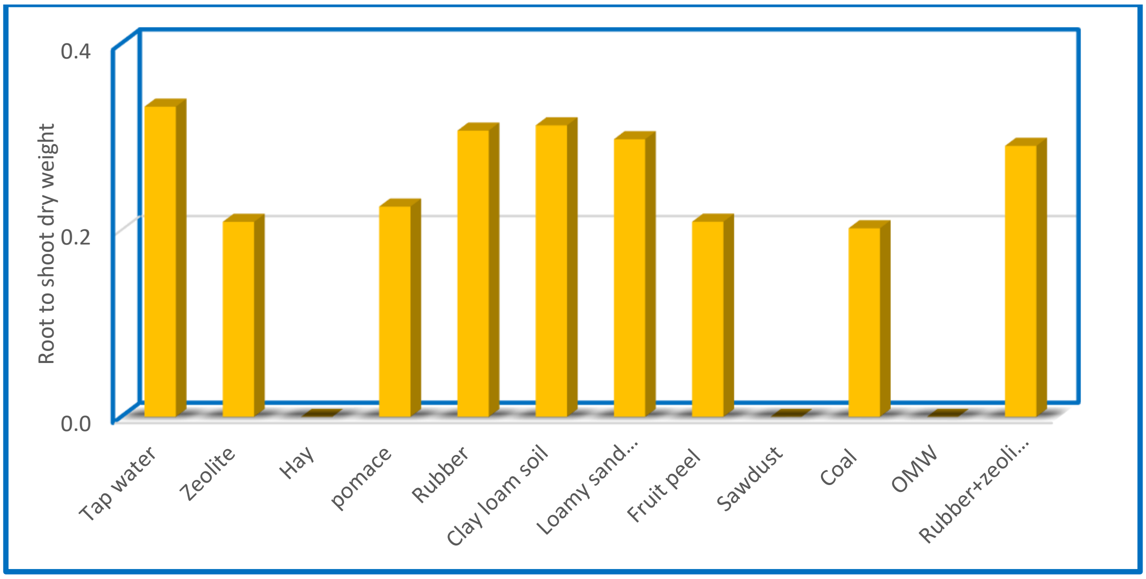

Figure 3-8: Root to shoot dry weight of barley seeds.

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Chapter Four

Public Awareness

Objectives:

- Sharing experiences between all entities engaged in OM sector.
- Provide opportunities for stakeholder meetings, discussions and cooperation.
- Focus on the obstacles facing each party.

Five workshops have been conducted, three in Jordan, one in Egypt, and one in Tunis.

Workshop1: Management of OMWW in Jordan

A. Purpose of the workshop

- Sharing experiences between all sectors.
- Identify Stockholders' roles and responsibilities.
- Receive stakeholder's comments and suggestions on OMWW management.

B. Number of Participants: sixty-two participants**.**

C. Participated organizations:

- Ministry of the Environment(MoE).
- Universities Professors.
- Ministry of Agriculture(MoA).
- Ministry of Health (MoH).
- Ministry of Industry (MoI).
- Royal Scientific Society(RSS).
- Society for Human and Environmental Development.
- Jordan Olive Oil Producers Syndicate (JOOPS).
- The Agricultural Engineering Association(AEA).
- Royal Department for Environmental Protection(RDEP)
- Owners of the olive mills(OOM).
- Amman Chamber of Industry(ACI).
- Municipality of Irbid (MoI).
- Jordan Food and Drug Administration(JFDA)
- Stakeholders/NGOs from the local community.
- Students from the Environment& Water Department, Huson college.
- Project partners: Prof. Shaimaa Farsi, Tunis, Tunis. Prof. Yaser Deswoki, Egypt, prof. rebhi Daamsah, Jordan.

D. Presentations &Lecturers:

- Prof. Kamel Alzboon: the project coordinator,
  He welcomed the participants and expressed his thanks to the Perez-Guerrero Trust Fund for South-South Cooperation, for their support of this project: "Cooperative Action in Recycling and Reuse of Olive Mill Waste for Food and Agriculture Production. He also discussed the significance of OMWW management and how it affects both the environment and human health. Alzboon made sure that everyone understood the value of working together to solve environmental issues and the part that local communities play in this.
- Eng. Fawzi Okour, the manager of the environmental department/ministry of the Environment(MoE):
  Outlines the difficulties the Ministry of Environment is facing as a result of the waste from the olive mill. Additionally, he outlined the duties of the MoE concerning capacity building, waste monitoring, licensing, disposal site, and olive mill site selection. In closing, he expressed his hope that Jordanian researchers would help solve this issue scientifically and emphasized the Ministry's ongoing efforts to engage with different stakeholders in order to save the Jordanian environment.
- Dr. Saleh Shdefat: from Agriculture Faculty- Jerash University.
  He provided a presentation about the olive trees in Jordan, olive oil production, olive milling technologies, types of waste, characteristics of waste, available solutions, local and international efforts in waste management.
- Dr. Dia Safadi, Royal Scientific Society,(RSS).
  His presentation was about the quality of Jordanian olives and oil, the impacts of the season on the type of oil and generated waste, RSS projects in waste management, scientific research in this field, available tests for oil and waste and instrumentations.
- Dr. Saed Rabadi, from chemical Engineering, Huson College.
  He provided a scientific paper concerning biogas from OMWW. According to his paper, the OMWW was mixed with wastewater sludge and cow manure. Then the mix was put in the digester for about 30days to generate methan. The results revealed that the biogas production for OM-SS and-C exceeded 0.07 and 0.31 LBiogas/(LFerm·day), respectively. Regarding the COD reduction, its removal efficiency was obtained as 46.1 and 53.8% for OM-SS and-C respectively. For economic concerns, significant methane yields were attained as 56.8 and 115. [LCH4/kgCOD] for the OM-SS and-C substrates, respectively.

- Mr. Nidhal Saadoun, owner of many olive mills and member of the Jordan Olive Oil Producers Syndicate.
  He offered practical experiences in managing OMWW and olive mills in general. He also discussed the various technologies that are currently in use, how they affect the kind, volume, and quality of waste streams, the cost of waste transportation, the alternatives that are available for managing and disposing of OMWW, the challenges that owners face, the requirements set forth by governmental bodies and academic institutions, the use of waste for energy and industry, and suggestions for making the best use possible of waste.

- Prof. Cheima Fersi, Tunisia

  She shared Tunisia's experience with managing OMWW, planting olive trees, the technologies that are currently available, the amount of waste, the process for treating, disposing, and reusing it, challenges, scientific research, and projects undertaken. She also provided examples of the Tunisian laws and regulations that are in effect as well as their shortcomings. There are currently 150 water storage sites, and the management of liquid management is primarily dependent on these storage and evaporation in collective ponds of OMWW discharges, according to her report. The owners of the oil mills construct nearly half of the landfill sites on their own private property. Tank trucks guarantee the OMWW's transportation.
- Eng. Nabi Obidat, Ministry of Agriculture (MoA),
  His prepared presentation covered the following topics: the role of the MoA in OMWW; licensing of mills; necessary conditions; site selection; monitoring; post-construction inspection; operation inspection; OMWW generation; management options; challenges to OMWW management; opportunities and threats; oil quality; inspections; and quality control.
- officer. Omar Rmethan, Royal Department for Environmental Protection(RDEP)
  He explains RDEP's roles and responsibilities in managing OMWW. Their responsibilities include legislative and regulatory oversight, transportation tracking, control violations, fees, transporter licensing, illegal disposal control, and collaboration with other parties.

E. Working Groups

At the end of the workshop, the participants were divided into three working groups as follows:

- The Academic group includes professionals from Balqa Applied University, Jerash University, Al-AlBeit University, RSS, and MSc students.
- The Owners group: this group includes the owners of olive mills, technology providers, Jordan Olive Oil Producers Syndicate, farmers of olive trees and Amman Chamber of Industry.
- The Governmental group: this group represent the: MoE, MoA, RDEP, JFDA.

The working group's task is to answer two questions:

- What solutions can you offer to solve the problem?
- What do you expect from the other parties to solve the problem?

The general outcomes of the working groups are shown in table below:

	Solution You can offer	Expectations from other parties
Group 1	• Research for low-cost treatment • Research for EIA • Design of treatment process. • Design of landfill.	• Sharing data with the academics. • Engage the research centers in the management process. • Strict monitoring. • Fund for research.
Group2	• Apply the regulations. • Ready for upgrading. • Provide new technologies	• Clear, stable regulations. • Determine suitable sites for OMWW disposal. • Fund for OMWW management.

Group 3	• Monitoring. • Flexible licensing. • Waste tracking.	• New technologies. • Compliance with regulations. • Transparency.

F. General outcomes.

The workshop provided an opportunity to meet partners from various sectors, and the following are the general outcomes:

- Participants shared their experiences and knowledge about OMWW management.
- Participants discussed the main challenges they face in OMWW management.
- Participants identified strengths, weaknesses, threats, and opportunities for OMWW management.
- Participants determined their roles and responsibilities within this field.
- Participants identified the required actions from other parties.

G. Recommendations:

Based on the presentations and working group outcomes, the participants recommend the following points:

- Improving the current landfill to minimize its impact on groundwater and the environment.
- Design a specific site for disposing of OMWW.
- Switching to a two-phase continuous centrifugation system.
- Encourage mill owners to reuse waste for land applications and energy generation.
- Provide funds for olive mills to improve their environmental practices.
- Monitoring illegal waste disposal and enforcing strict penalties.
- Foster strong cooperation among all parties.
- All parties should promote transparency and equators.

H. List of participants

N.	Name	Organization	N.	Name	Organization
1	Dr. Deaa Al-safadi	RSS	31	Hadeel Khatatbeh	BAU
2	Dr.Saleh Shdefat	Jerash University	33	Raneem Shdefat	BAU
3	Ansam Khazaleh	RDEP	34	Sali Harahsheh	BAU
4	Eng. Fawzi Al-Okour	MoE	35	Aziz Yaqub	BAU
5	Eng.Hanan Hamad	MoA	36	Lain Alomari	BAU
6	Eng. Ahmad Mqdadi	MoA	37	Enas Abd ELYAS	BAU
7	Eng. Mutaz Jaradat	MoA	38	Raghad Nsairat	AEA
8	Nedal Sadoun	JOOPS	39	Rasha Qazan	BAU
9	Ahmad Abdelaziz	MoI	40	Eman Al-Shorman	MoA
10	Mutaz Jadan	MoH	41	Eng.Alya Al-hourani	MoE
11	Dr.Sayd Al-Rabadi	BAU	42	Eng.Hanan Hamad	MoA
12	Dr.Muath AL-Qayam	Jerash University	43	Dr.Khetam Altawalbeh	Local community
13	Amani Al-Sadi	JFDA	44	Sami AL-Ramthawi	MoA
14	Ruba Al-Ibrahim	JFDA	45	Khalid Al-Sbai	NGO
15	Heba Azam	NGO	46	Mouawea Musa	MoA
16	Eng.Bayan Bani Hani	MoE	47	Razan Bani Ismail	Local community
17	Sulaiman Marji	MoH	48	S. Bani Hamad	BAU
18	Eng.Aseel Obaidat	MoA	49	Ayat Hazaimeh	RSS

19	Mohammad Hamadneh	MoA	50	Eyas Al-Momani	MoE
20	Murad Abu Sbaih	MoA	51	Raydah Tashtosh	BAU
21	Jamilah Ali	MoA	52	Amal Onaim	BAU
22	Anas Hayajneh	MoA	53	Eng.Sana Algol	MoA
23	Amal Bani Ismail	BAU	54	Medhat Ananzeh	MoE
24	Hashem Almiqdadi	AEA	55	Reham Bani Esa	MoA
25	Eng.Ayman Alawneh	BAU	56	Lana Bani Hani	MoA
26	Hayat Kurdi	MoI	57	Eng.Tuqa Nawafleh	Local community
27	Fatemah AL-Dhoun	MoI	58	Feras Al-Faleh	MoI
28	Yara Jad	BAU	59	Ashraf ABU-Khalel	NGO
29	Dr.Saba Al-Safadi	RSS	60	Shatha Ababneh	NGO
30	Mahmoud Aldraizi	MoE	61	Ahmad Al-Sharif	NGO
31	Eng.Jamal Bataineh	MoA	62	Mais Ababneh	Local community

Workshop2: Management of OMWW in Jordan, Obstacles and Solutions

Available: https://petra.gov.jo/Include/InnerPage.jsp?ID=254306&lang=ar&name=news.

A. Purpose of the workshop

- Determine the problems facing the owners of OM concerning waste management.
- Potential solutions for PMWW.
- Receive stakeholder's comments and suggestions on OMWW management.

I. Number of Participants: fouty-three participants**.**

J. Participated organizations:

- Ministry of the Environment(MoE).
- Universities Professors.
- Ministry of Agriculture(MoA).
- National center for Agriculture Research (NCAR).
- Jordan Olive Oil Producers Syndicate (JOOPS).
- The Agricultural Engineering Association(AEA).
- Royal Department for Environmental Protection(RDEP)
- Owners of the olive mills(OOM).
- Stakeholders/NGOs from the local community.
- Students from the Environment& Water Department, Huson college.
- Project partners: Prof. Shaimaa Farsi, Tunis, Tunis. Prof. Yaser Deswoki, Egypt, prof. Rebhi Daamsah, Jordan.

K. Presentations &Lecturers:

- **Prof. Kamel Alzboon: the project coordinator,**
  He greeted the attendees and thanked the Perez-Guerrero Trust Fund for South-South Cooperation for funding this initiative: "Partnership in the Recycling and Reuse of Olive Mill Waste for the Production of Food and Agriculture." He emphasized how crucial it was to understand the issues the OM owners were encountering and how to get over them at the workshop. In order to assess the issue and identify potential solutions, he also emphasized the significance of collaboration across all sectors. He discussed the results of the last workshop as well as the work and experiences of BAU in OMWW treatment, waste management, and research.
- **officer. Omar Rmethan, Royal Department for Environmental Protection(RDEP)**
  He described the tasks and duties of RDEP in managing OMWW, their efforts to control of OMWW and the illegal disposal of this waste. Their responsibilities include monitoring, sharing with other agencies in setting legislations and regulations, transportation tracking, control violations, charging fees, obtaining transporter licensing, controlling illegal disposal, and collaborating with other parties.

- **Mr. Qasim Rousan, Vice President of the Jordan Olive Oil Producers Syndicate.**
  He listed the main obstacles that face the owners of Om including the high cost of production, the needs for a license, the existence of several organizational bodies, long distance to the landfill site, the cost of waste disposal, marketing, fees, and fines. He talked about the many technologies now in use, how they affect the nature, volume, and quality of waste streams, the cost of waste transportation, and the options available for managing and disposing of OMWW. He also shared his practical experience managing olive mills and OMWW.
- **Eng. Laith Qudah, Ministry of Agriculture (MoA),**
  His prepared presentation illustrated the procedure for OM licensing: the role and responsibilities of MoA in OMWW; Application for a license, necessary conditions; site considerations; preconstruction requirements; the required area, production area, waiting area, services area, storage area, management area specifications, post-construction inspection;

operation inspection; OMWW generation; management options; challenges to OMWW management; opportunities and threats; oil quality; inspections; and quality control.

- **Mr. Fayad Alzyoud, owner of many OM.**
  His presentation illustrated the applied technologies both domestically and internationally, as well as their advantages and disadvantages, production lines, waste streams, OMWW, sources, specifications, current management, obstacles, what the owners are looking for, each party's responsibility, and the need for an OMWW comprehensive management plan.
- **Mr. Mahmoud Omari: from JOOPS.**
  He shared his experiences in Jordan's several OMs. He gave details on the olive mill industry in Jordan, its history, development, cooperation between different sectors, legislations, fees and penalties the creation, history, and collaboration of the olive mill business in Jordan as well as information on laws, fines, fees, and penalties. He also discussed the technologies that are currently accessible and how OMWW may be managed efficiently.

L. General outcomes.

The general outcomes of the workshop are as follows:

- OMWW has caused a serious environmental problem, for which numerous entities are accountable for finding a solution.
- Determining each party's specific responsibility is the first stage in managing OMWW.
- A national plan is required for the management of OMWW.

M. Recommendations:

Based on the presentations and the open discussion, the following recommendations can be pointed:

- Establishing a nationwide OMWW management strategy.
- All parties should promote transparency and equators.
- Determine the role and responsibilities of each party and reduce the number of organizations engaged.
- Provide the owners of OMs financial support to improve their environmental practices.

N. List of participants

N.	Name	Organization	N.	Name	Organization
1	Dr. Deaa Al-safadi	RSS	31	Hadeel Khatatbeh	BAU
2	Dr.Saleh Shdefat	Jerash University	33	Raneem Shdefat	BAU
3	Ansam Khazaleh	RDEP	34	Sali Harahsheh	BAU
4	Eng. Fawzi Al-Okour	MoE	35	Aziz Yaqub	BAU
5	Eng.Hanan Hamad	MoA	36	Lain Alomari	BAU
6	Eng. Ahmad Mqdadi	MoA	37	Enas Abd ELYAS	BAU
7	Eng. Mutaz Jaradat	MoA	38	Raghad Nsairat	AEA
8	Nedal Sadoun	JOOPS	39	Rasha Qazan	BAU
9	Ahmad Abdelaziz	MoI	40	Eman Al-Shorman	MoA
10	Mutaz Jadan	MoH	41	Eng.Alya Al-hourani	MoE
11	Dr.Sayd Al-Rabadi	BAU	42	Eng.Hanan Hamad	MoA
12	Dr.Muath AL-Qayam	Jerash University	43	Dr.Khetam Altawalbeh	Local community
13	Amani Al-Sadi	JFDA	44	Sami AL-Ramthawi	MoA
14	Ruba Al-Ibrahim	JFDA	45	Khalid Al-Sbai	NGO
15	Heba Azam	NGO	46	Mouawea Musa	MoA
16	Eng.Bayan Bani Hani	MoE	47	Razan Bani Ismail	Local community

17	Sulaiman Marji	MoH	48	S. Bani Hamad	BAU
18	Eng.Aseel Obaidat	MoA	49	Ayat Hazaimeh	RSS
19	Mohammad Hamadneh	MoA	50	Eyas Al-Momani	MoE
20	Murad Abu Sbaih	MoA	51	Raydah Tashtosh	BAU
21	Jamilah Ali	MoA	52	Amal Onaim	BAU
22	Anas Hayajneh	MoA	53	Eng.Sana Algol	MoA
23	Amal Bani Ismail	BAU	54	Medhat Ananzeh	MoE
24	Hashem Almiqdadi	AEA	55	Reham Bani Esa	MoA
25	Eng.Ayman Alawneh	BAU	56	Lana Bani Hani	MoA
26	Hayat Kurdi	MoI	57	Eng.Tuqa Nawafleh	Local community
27	Fatemah AL-Dhoun	MoI	58	Feras Al-Faleh	MoI
28	Yara Jad	BAU	59	Ashraf ABU-Khalel	NGO
29	Dr.Saba Al-Safadi	RSS	60	Shatha Ababneh	NGO
30	Mahmoud Aldraizi	MoE	61	Ahmad Al-Sharif	NGO
31	Eng.Jamal Bataineh	MoA	62	Mais Ababneh	Local community


UNDP
تحت رعاية عطوفة رئيس جامعة البلقاء التطبيقية
الاستاذ الدكتور احمد العجلوني الاكرم
يتشرف عميد كلية الحصن الجامعية الاستاذ الدكتور كامل الزبون بدعوتكم لحضور
الورشة العلمية: تكنولوجيا ادارة مخلفات معاصر الزيتون
وذلك يوم الاربعاء الموافق ١٦/٨/٢٠٢٢ الساعه العاشره صباحا

Workshop3 / Training : Site Visit for Olive mill

1. Training and Site Visit

A. Purpose of the workshop

- Site visit to an olive mill to Share experiences between industry and stakeholders.
- Identify the sources of OMWW and its characteristics.

B. Number of Participants: 21 participants.

C. Participated organizations:

- Ministry of the Environment(MoE).
- Universities Professors.
- Ministry of Agriculture(MoA).
- Jordan Olive Oil Producers Syndicate (JOOPS).
- Owners of the olive mills(OOM).
- Stakeholders/NGOs from the local community.
- Students from the Environment& Water Department, Huson College.

D. Activities:

- Opening

  Registration, distribution of materials, Event memorial gifts, ..
- Prof. Kamel Alzboon: The project coordinator,

  He welcomed the participants and expressed his thanks to the Perez-Guerrero Trust Fund for South-South Cooperation, for their support of this project: “Cooperative Action in Recycling and Reuse of Olive Mill Waste for Food and Agriculture Production. He also explained the objective of the training day, the man activities and the expected outcomes, the main pollutants from OMWW, methods of treatment, and impacts on the environment.

- Eng. Ahmad Bani Hani, from the Environmental Lab -Huson College
  He showed the participants the main instruments in the lab, the required tests for OMWW, the main contaminations that should be considered, planning for sampling, filed sampling, labeling, sample preservation, storage, reagents, removal of turbidity, removal of phenol, removal of COD, removal of O&G. MSc students did some of these experiments.

- Site visit:
  Site visit to a known olive mill in Jerash area. At the beginning, the owner welcomed the participants and introduced the head of the production section, and the head of the quality control section. Then the head of the production showed and explained to the participants the production line through all stages including receiving the olive fruit, the olives will have to be aired to remove vegetable portions such as leaves and twigs as well as dust and stones, cleaning the olives, passing over vibrating screens to remove water and the last foreign residues., milling or crushing which allows to obtain a coarse paste thanks to the crushing of the whole olives (skin, pulp, and stone, malaxation(During the malaxing phase the olive paste is subjected to a slow continuous kneading, aimed at breaking off the emulsions formed during the crushing process and facilitating adequate coalescence.), centrifugal separation of olive oil and water (separate olive oil from the other materials (water and solids) on the basis of Stoke's law that determines the speed at which two non-miscible liquids are separated under a centrifugal force. Separation is carried out inside a decanter, a cylindrical bowl with a co-rotating scroll with helical blades that rotate at 3500-3600 rpm) and storage and bottling of the olive oil in a stainless-steel bottle with a capacity of 17kg.
  The head of the quality control section explained the sources of OMWW and he mentioned: that there are three sources of OMWW, washing of fruit, the separation process of phase 1, and the separation process of phase 2. Concerning the OMWW management, he mentioned that the solid materials are used as an energy source for the boiler inside the plant while the remaining solids are sold to be used for heating. The liquid OMWW is collected in concrete storage and transported by trucks to be disposed of in the landfill.

- Sampling and analyses.
  MSc collected samples from OMWW with a capacity of 20lite. Then they used it in the lab to determine the characteristics of OMW and potential treatment methods. They applied different technologies including settling, coagulation, filtration, biological treatment, nanomaterials, and reus.

E. Working Groups

The project manager asked MSc students to prepare:

- Technical report about the excursion.
- Their suggestion to solve the problem of OMWW.

F. General outcomes.

The training day gave participants a hands-on chance to observe an OM, as well as all relevant processes and pollutant generation. The principal outcomes were

- Participants had an opportunity to see the stages and processes of olive milling.
- Participants had an opportunity to determine the sources of OMWW.
- Participants gained a solid understanding of OMWW management practice.
- Participants shared their recommendations for OMWW management.

G. Recommendations:

Based on the excursion, and lab experiments, the participants recommend the following points:

- Segregation of OMWW generation from each production line.
- Resue of OMWW from washing process for direct irrigation.
- Provide funds for researchers to enhance of OMWW management in Jordan.
- Encourage mill owners to reuse waste for land applications and energy generation.
- Foster strong cooperation among all parties.

N.	**Name**	**Organization**
1	Ahmad Bani Hani	Huson lab
2	Dr.Zaydoun Abu Salem	Huson college
3	Mohammad Hawadmeh	Local community
4	Eng. Fawzi Al-Okour	MoE
5	Eng.Hanan Hamad	MoA
6	Bashar Ammary	BAU
7	Nedal Sadoun	JOOPS
8	Asia Bool	NGO
9	Ansam Momani	BAU
10	Anwar Sobih	BAU
11	Taqwa Frehat	BAU
12	Nidhal Saadoun	Owner OM
13	Taima Jehad	BAU
14	Rima Alshareef	NGO
15	Rinati fakhori	BAU
16	Sundos Bani Hani	BAU
17	Sabrin Abo Hamdan	BAU
18	Dhoha lababnah	NGO
19	Qusai Koor	BAU
20	Lara Shorman	BAU
21	Heba Amawi	BAU


PIERALISI
Hamda AL-Wardat


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Hamda AL-Wardat


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Hamda AL-Wardat


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Hamda AL-Wardat

Workshop4: Training session for early-stage researchers in TUNIS

A. Purpose of the workshop

- Educate participants about the concept of circular economy in the context of olive oil production.
- Explore innovative methods to convert olive oil by-products into high-value bio-based products.
- Discuss the economic, environmental, and societal benefits of implementing circular strategies in the olive oil industry.

B. Number of Participants: 35 participants**.**

C. Participated organizations:

35 Tunisian early-stage researchers from the National Institute of Research and Physio-chemical Analysis (INRAP), Higher Institute of Biotechnology of Sidi Thabet (ISBST), and Faculty of Science of Tunis (FST).

D. Presentations & Lecturers:

The workshop included four animated lectures led by expert researchers from INRAP and four laboratory activities, separated by a coffee break and a lunch break as detailed on the workshop program.

9 : 00 – 9 : 15	**Opening of the training and welcoming remarks**	**10 : 45 – 16 : 15**	**Hands-on practice activities**
9 : 15 – 9 : 30	**Conference 1:** Tunisian olive oil value chain	10 : 45 – 11 : 45	**Lab activity 1:** Recovery of active extracts from olive by-products
9 : 30 – 9 : 45	**Conference 2:** Circular Business Model Canvas Elements in the Olive Oil Sector	11 : 45 – 12 : 45	**Lab activity 2:** Characterization of active extracts
9 : 45 – 10 : 00	**Conference 3**: Extraction, purification, and characterization of active compounds	**12 : 45 – 13 : 45**	**Lunch break**
10 : 00 – 10 : 15	**Coffee break**	14 : 00 – 15 : 00	**Lab activity 3:** Development of active packaging films from olive by-products
10 : 15 – 10 : 30	**Conference 4:** Applications of active compounds from olive by-products in food packaging	15 : 00 – 16 : 00	**Lab activity 4:** Characterization of bioactive films
		16 : 00 – 16 : 15	**Concluding remarks and recommendations**

- **Dr. Eng. Cheima FERSI** (The Tunisian representative of the project)

Dr. Cheïma FERSI is researcher at the National Institute of Research and Physicochemical Analysis (INRAP, Tunisia) and got a PhD in Environmental Chemistry. Her research work is related to Water treatment, especially industrial wastewater treatment, as well as the valorization of agro-food by-products and several other wastes. She has demonstrated her expertise in international and national projects management and partnership. She is also very active in social and community life. Dr. Fersi is the President of the Tunisian Association of Chemical Engineers ATIC, member of the African Membrane Society AMS and member of the NCP team of H2020 & Horizon Europe programs (Climate Action, Environment, Resource Efficiency & Raw Materials (CaRE) + Nanotechnologies, Advanced Materials, Advanced Manufacturing and Processing, and Biotechnology (NMBP)).

- **Prof. Khaoula KHWALDIA**

Khaoula Khwaldia is researcher at the National Institute of Research and Physicochemical Analysis (INRAP, Tunisia) and got a PhD in Food Science and Engineering. She has been involved in many collaborative research projects, including international collaboration with many key people in the food science and packaging field in Africa, Europe and Canada. Dr Khwaldia has also demonstrated her expertise in international and national projects management. Her research work is related to the development of biopolymers and their application in new generation of sustainable packaging and edible films as well as the valorisation of plant extracts and by-products through the sustainable recovery of value-added components. She has contributed to the publication of numerous innovative research articles, scientific reviews and books related to these topics.

- **Dr. Borhane MAHJOUB**

Dr. Borhane Mahjoub received his MSc and PhD in Waste Sciences and Technologies from the National Institute of Applied Sciences (INSA) of Lyon and lEcole des Mines de Saint-Etienne (France). Then, he went to the Polytechnic Higher Institute of Montréal (Canada) for a post-doctoral research study in 1999-2000 on organic complex mixtures in water and soils.

He is a Researcher and Lecturer at the National Institute of Research and Physicochemical Analysis (INRAP, Tunisia). His research topics cover Environmental Chemistry and Quality monitoring, Behavior and fate of contaminants in Soils, Water Quality and Treatment processes and especially Solid waste valorization. He has a special interest in Sustainable Chemistry concept and approaches.

He is in the editorial board of Sustainable Chemistry and Pharmacy Journal, Elsevier, the Current Opinion in Green and Sustainable Chemistry, Elsevier and of the International Journal of Environment and Waste Management (IJEWM), the International Journal of Environmental Engineering (IJEE), Inderscience, and the International Journal of Environmental Engineering Science (IJEES), Serials Publications.

Dr. Mahjoub was a regional coordinator of an important German-Tunisian project EMPOWER Tunisia, a cooperation program between Technical University of Braunschweig (Germany), University of Carthage and University of Sousse about Emerging Pollutants in Water and Wastewater in Tunisia (2011-2014).and he was also an active member in other Euro-Mediterranean projects (EXCEED SWINDON, XNEM-TEMPUS, SOWAEUMED FP7, ...). He has a strong network within the Arab countries.

E. Working Groups

Four Working Groups were created and participated to the Laboratory activities which are described in the workshop program.

F. General outcomes.

Participants gained comprehensive insights into the potential of circular economy practices in utilizing olive oil by-products, fostering innovation, and creating value from waste in the industry.

G. Recommendations:

- The participants proposed to organize other sessions of longer duration (3 days) in order to become more familiar with the laboratory activities.

- They also offered to take visits to the olive oil distribution and packaging industries.
- The participants recommended setting a national strategy for OMWW management.

2. Lab activity 1 – Recovery of active extracts from olive by-products

A. Purpose

Evaluating the effect of extracting solvent, temperature and pH on the yield of phenolic compounds from olive leaves.

B. Principle

Phenolic compounds can be extracted by different methods from olive leaves. In laboratory-scale the choice of extraction solvent, temperature, pH, contact time, solvent to feed (S/F) ratio play an important role in process efficiency and the chemical profile of the extract. In this training, olive leaves powder will be extracted using conventional techniques according to the conditions outlined in Table 1. The total phenolic content of recovered extracts is determined spectrophotometrically using Folin-Ciocalteu reagent using gallic acid as standard.

C. Materials and reagents

- Thermostatic water bath
- Analytical scale
- Eppendorf tubes, 96-well plates
- Microplates reader
- Methanol and ethanol
- HCl solution with pH adjusted to 3
- Gallic acid stock solution (1g / L)
- Folin-Ciocalteu reagent and Na_2CO_3 (7.5g/L)

D. Preparation of calibration curve

Prepare six tubes and add into each one the following concentrations of gallic acid: 0.01, 0.025, 0.05,0.1, 0.15 and 0.2 mg/ mL.

E. Olive leaves extractions

Prepare the samples (2g) of powdered dried olive leaves according to the following conditions.

TABLE 1. EXTRACTION CONDITIONS

#	Method	Solvent	Temperature	pH	S/F ratio	Time
1	Maceration	Methanol 80%	Ambient	7	5	15 minutes
2	Maceration	Ethanol 80 %	Ambient	7	5	
3	Maceration	Ethanol 80 %	Ambient	7	10	
4	Reflux	Ethanol 80 %	> 80°C	7	5	
5	Maceration	Water	60°C	7	5	
6	Maceration	Water	60°C	3	5	

At the end of extractions perform centrifugation and pipette 1mL of each sample in a test tube.

F. TPC determination

Using an adequate 96-well plate layout add volumes from the calibration points, samples followed bythe reagents. Read absorbance at 725nm and deduct the TPC per volume unit of samples extracts (µgof gallic acid equivalents / mL). Calculate the extraction yield expressed as mg of GAE / 100 g of olive leaves.

G. Conclusions

Compare the yield of extraction methods, and draw conclusions.

3. Lab activity 2 - Characterization of active extracts

A. Purpose

Evaluating the antiradical (DPPH$^{\bullet}$) and reducing capacity (FRAP) of olive leaves extracts.

B. Principle

Olive leaves extracts (OLE) are considered as a rich source of antioxidants (oleuropein, hydroxytyrosol, etc.). In vitro antioxidant assays are based on Trolox equivalent antioxidant capacity (TEAC). The capacity of a substance to inhibit free radicals or reduce transition metals by electron transfer is measured and compared to standard (Trolox). TEAC of OLE is evaluated by 2,2-Diphenyl-1-picrylhydrazyl (DPPH$^{\bullet}$) radical scavenging capacity assay and ferric ion reducing antioxidant power (FRAP) assay.

C. Materials and reagents

- Eppendorf tubes, 96-well plates
- Microplates reader
- Methanol and ethanol
- OLE
- Trolox solution of 1mM
- DPPH solution (0.1 mM) prepared in methanol
    - FRAP reagent solution prepared by mixing 0.3 M acetate buffer (pH 3.6) and 10 mM TPTZ in40 mM hydrochloric acid and ferric chloride (20 mM) at a ratio of 10:1:1 (v/v/v).
- OLE solution (1mg / mL) prepared in ethanol 50%

D. Preparation of calibration curve

Prepare six tubes and add into each one the following concentrations, in µM, of Trolox: 25, 50, 75,100, 150, 200.

E. Determination of OLE TEAC

Add sample OLE dilutions and Trolox concentrations levels to 96-well plate according to the providedmethods (DPPH and FRAP). Calculate the TEAC expressed as µmole of TE/ g of OLE.

F. Conclusions

Explain obtained values using oleuropein (a major phenolic compound in OLE) as a modelantioxidant.

4. Lab activity 3 - Active rutin-CMC films food contact testing

A. Purpose

Illustrating the migration in food simulants of rutin added to CMC polymer films.

B. Principle

Migration of components or compound from food contact material to food is very important property ofpackaging films. Migration of compounds is not one-way but two-way process, because compounds orcomponents of food contact materials can migrate from materials into food equally compound of food can migrate into material. Rutin (a flavonoid) was added to CMC films in order to enhance active properties related to the antioxidant capacities of this molecule.

C. Materials and reagents

- Eppendorf tubes, 96-well plates
- Microplates reader
- Ventilated oven (65°C)
- 10% (v/v) ethanol solution, substitution of fruits and vegetables A
- 3% (w/v) acetic acid solution, substitution of acidic food (juices) B
- Rutin 1mg/ mL solution prepared in 80% ethanol
- Distilled water

D. Accelerated migration assay

Weight a portion of CMC-rutin film and put in contact by immersion with simulants A and B. Accelerated migration assay is performed at 65 °C for 15h.

E. Preparation of calibration curve

Prepare six levels of rutin concentrations from the stock solution in corresponding simulant i.e.: 10, 20, 50, 100, 200, 300, 500. Perform a calibration at 365 nm.

F. Sample measurement

Do absorbance measurement for diluted volumes of incubated samples. From calibration curve deducethe amount of migrated rutin in µg/mL.

G. Calculation

Express specific migration of rutin in µg/ g and µg/dm² of film.

H. Conclusions

Compare the migration of rutin in the two simulants and draw conclusions about suitability of this additive.


ISN
Optimization of cellulose extraction from olive by products


Introduction
Primary metabolites (macronutrients)
Micronutrients

Workshop5: Management of OMWW in Egypt

A. Purpose of the workshop

- Sharing experiences between the olive oil producer, the academic researcher, the olive farmers and the SMEs.
- Identify Stockholders' roles and responsibilities.
- Receive stakeholder's, the producer as well as the farmers comments and suggestions on OMWW management.
- Declaring the valorization of the agriculture wastes, the OMW wastes, and their ecological and economic values.

B. Number of Participants: 32 participants.

C. Participated organizations:

- Ministry of the Environment.
- Universities Professors.
- Ministry of Agriculture.
- Olive oil producer
- Olive farmers
- Agricultural Engineering
- Students from the agriculture college.

D. Presentations &Lecturers:

A. Dr. Essam Abdel-mawla: Dean of the aquaculture research center.

E. General outcomes.

The workshop provided an opportunity to meet partners from various sectors, and the following are the general outcomes:

- Participants shared their experiences and knowledge about OMWW management.

- Participants discussed the main challenges they face in OMWW management.
- Participants determined their roles and responsibilities within this field.
- Participants identified the required actions from other parties.
- Participants identified the valorization processes of the different wastes of olive and olive oil production steps.

F. Recommendations:

Based on the presentations and working group outcomes, the participants recommend the following points:

- Improving the infrastructure needed for making a valorization system for the different production steps.
- Identified the environmental impact of the OMWW.
- Switching to a two-phase continuous centrifugation system.
- Understanding the importance of using the reuse waste for land applications and energy generation.

G. List of participants

Attendance Sheet: Cooperative Action in Recycling and Reuse of Olive Mill Waste for Food and Agriculture Production Project

Thursday 20 / 12 / 2023 Location: Abu Kir Campus, Arab Academy for Science, Technology and Maritime Transport

No.	Name	Job	Email	Signature
1	د. سامح صبري	صاحب مزرعة زيتون		[signature]
2	م. محمد الشوربجي	فني بمركز البحوث الزراعية		[signature]
3	م. محمود السيد	فني مركز البحوث الزراعية		[signature]
4	م. نادية محمد السيد	فني مركز البحوث الزراعية		[signature]
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6	م. محمود علي عبد اللطيف	مركز البحوث الزراعية		[signature]
7	م. عبد السلام محمد	فني معصرة زيتون		[signature]
8	م. علي عبد المنعم	مركز البحوث الزراعية		[signature]
9	د. مصطفى السيد محمد	مركز البحوث الزراعية		[signature]
10	م. سعيد محمد أحمد	فني معصرة زيتون		[signature]
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12	الحاج رجب عبد السلام	صاحب مزرعة زيتون		[signature]
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20	Mahmoud Hafez	Director	Mahmoud1996..@yahoo.com	[signature]

No.	Name	Job	Email	Signature
21	Rania Ragel	Head of Research Data	rania.rugeh@aast.edu	R. Rugeh
22		Science & Academic Ranking		
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29				
30				
31