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Harnessing the potential of vegetable waste: A path towards sustainable development in Marrakech (Morocco)

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Abstract: This study illustrates how rational management of daily green waste generated by the numerous green spaces in Marrakech can contribute to sustainable development. In order to transform these three green spaces into models of sustainable development within the circular economy framework, we selected them as experimental samples for our study: Moulay Abdessalam Park (home to a wide variety of species), Ghabat Chabab Park (with olive trees), and the palm grove (where palm trees are located).

The study's results revealed several valuable conclusions. First, in the case of Moulay Abdessalam Park, the adoption of composting and vermicomposting techniques led to the production of natural and ecological fertilizers. In the second case, Ghabat Chabab, opportunities arose to harness renewable energy sources such as biogas and electricity. Lastly, the study of the palm grove demonstrated the potential for producing ethyl alcohol from palm tree waste.

Keywords : green waste; Moulay Abdessalam park; Ghabat Chabab park; la palmeraie; valorization; sustainable development.

Résumé : Cette étude montre comment une gestion rationnelle des déchets verts quotidiens générés par les nombreux espaces verts de Marrakech, peut contribuer au développement durable. Afin de transformer ces trois espaces verts en modèles de développement durable dans le cadre de l'économie circulaire, nous les avons sélectionnés comme échantillons expérimentaux pour notre étude : le parc Moulay Abdessalam (qui abrite une grande variété d'espèces), le parc Ghabat Chabab (avec des oliviers) et la palmeraie (où se trouvent les palmiers). Les résultats de l'étude ont révélé plusieurs conclusions précieuses. Tout d'abord, dans le cas du parc Moulay Abdessalam, l'adoption des techniques de compostage et de vermicompostage a permis la production d'engrais naturels et écologiques. Dans le deuxième cas, Ghabat Chabab, des opportunités se sont présentées pour exploiter des sources d'énergie renouvelable telles que le biogaz et l'électricité. Enfin, l'étude de la palmeraie a démontré le potentiel de production d'alcool éthylique à partir des déchets des palmiers.

Mots-clés : déchets verts ; parc Moulay Abdessalam ; parc Ghabat Chabab ; la palmeraie ; valorisation ; développement durable.

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1. Introduction

We live in a contradictory global context characterized by population growth (essential needs to be met) in the face of resource scarcity (to meet human needs), which has affected raw materials and made them scarce. Furthermore, in seeking to establish a balance between demand and consumption, detrimental consequences on the global environment have emerged (Ouharon, A. 2006), necessitating a revision of the development process and the search for more rational methods and techniques of consumption to ensure resource sustainability and longevity.

On the other hand, the world generates a significant amount of waste every year (over 2 billion tonnes), of which 44% is plant waste, contributing to the emergence of several problems through outdated waste disposal methods (environmental pollution, loss of organic matter, etc.), making it necessary to adopt effective methods for treating plant waste (Lu et al., 2022).

Among the analytical techniques aimed at preventing environmental pollution and motivated by economic benefits such as cost savings in energy and new materials (Laufenberg & Al., 2003), we find the recovery, recycling, and valorization of green waste, which are increasingly practiced in most developed countries worldwide due to urbanization and the expansion of urban green spaces (Liu et al., 2022).

At the local level, the city of Marrakech has a dynamic and diverse plant environment that generates thousands of tonnes of waste daily (mowed grass, dead leaves, pruning and branch residues, etc.) through gardening and green space maintenance activities but suffers from poor management of this type of waste (96% of waste is disposed of through outdated methods).

In particular, the valorization of this waste through biotechnological processes intersects environmental, social, and economic issues rather than considering them as mere waste to be disposed of (Meisel et al., 2014), as numerous studies have shown that these wastes are rich in organic matter and could serve as new raw materials for various uses (energy, agri-food, industry, etc.) (F. et al., 2001), thus meeting the criteria of sustainable development.

Among the green spaces affected by this valorization process and generating thousands of tonnes of waste in public landfills without benefitting from it, we find the Arsat Moulay Abdessalam Park, covering an area of 14 hectares, which stands out for its abundance of cultivated species both quantitatively (4395 plants) and qualitatively (Bitter orange, Carob tree, grass, etc.), the Ghabat Chabab Park, covering an area of 80 hectares with olive trees, and finally, the palm grove, occupying an area of 1200 hectares with 120,000 adult date palm trees.

All these factors lead us to pose the central question: *To what extent could the valorization of plant waste contribute to the sustainable development of Marrakech?*

2. Materials and Methods:

1.1. Research Methodology:

1.2. Hypotheses:

It is estimated that:

- A rich and diverse amount of green waste is generated daily.
- Vegetable waste suffers from bad/weak management.
- The valorization of this type of waste could promote the city of Marrakech's long-term development.

1.3. Research approach and materials:

- **Bibliographic reading:** the collection and analysis of scientific material in order to identify the scientific gaps that will allow us to position ourselves.
- **Empirical work:** consists of visiting the field (observation, data collection, etc.) and interviewing the actors of the service (the urban commune, the urban agency, etc.).
- **Mapping:** the use of geographic information systems to produce maps.
- **Descriptive/analytical approach:** It is primarily concerned with making a diagnosis and describing the potential of some green spaces (interest in vegetal waste, the valorization procedure, and so on), through which we analyze data obtained in the field to answer the problem.

1.4. Study Area:

Marrakech is a city located in central Morocco at the foot of the Atlas Mountains; it is part of the Marrakech-Safi region; It consists of 5 districts (Medina, Gueliz, Menara, SYBA, Annakhil) and an urban commune (Méchouar-Kasbah).

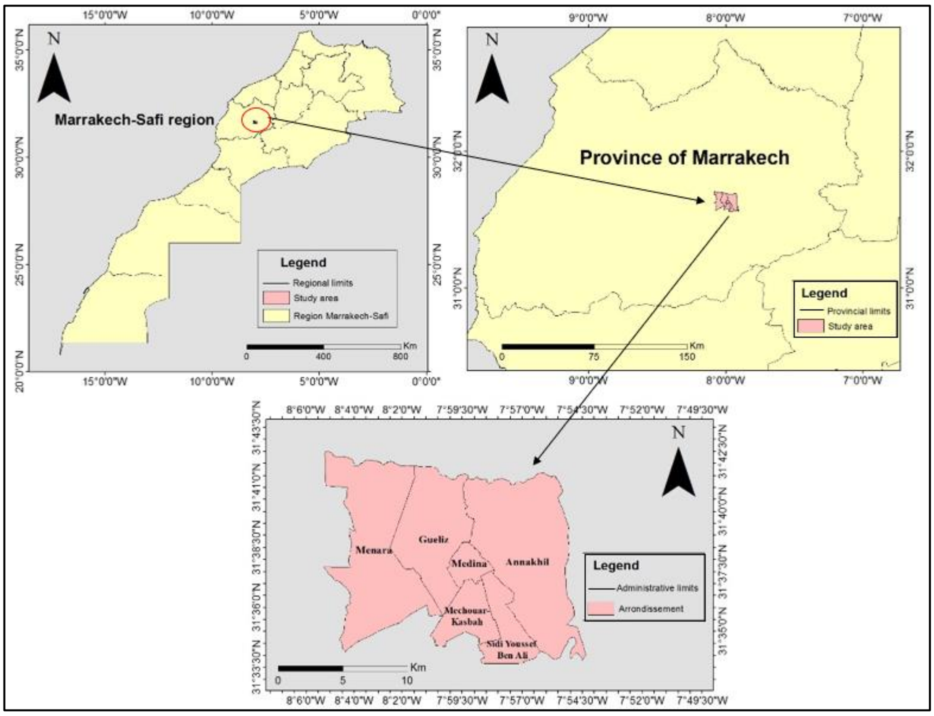

Figure 1. Location of the study area. **Source:** Author (2023)

3. The study sample:

1.5. Arsat Moulay Abdessalam Park

The Arsat Moulay Abdeslam Garden is a historic park established in the 18th century under the rule of Sultan Sidi Mohammed Ben Abdellah. It is a princely garden named after Prince Moulay Abdeslam. Situated in the bustling city center, in a popular tourist zone near the renowned Jamma el Fna square, the park boasts a diverse range of local and Mediterranean vegetation. It is home to approximately 13,000 shrubs and over 4,523 trees, resulting in a substantial daily production of green waste.

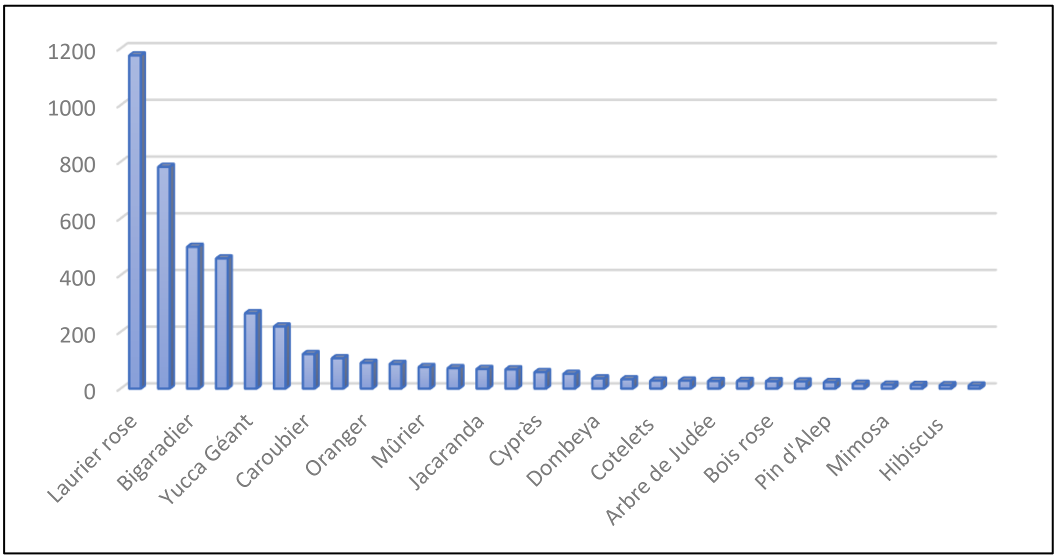

Figure 3: Number and biological type of plants in the park. **Source:** Author (2023)

1.6. Ghabat Chabab Park:

Covering an impressive expanse of 80 hectares, the "Ghabat Chabab" Park in Marrakech is a captivating green space and one of the city's oldest forests. Its origins can be traced back to the era of Morocco's independence, specifically in 1960, when King Hassan II invited the youth to partake in an olive tree planting program in a barren area situated between the old city and the Menara. This noble initiative stemmed from the king's profound interest in the agricultural sector and its central role in territorial development.

1.7. the palm grove:

The palm grove is located in the northeast of the city and is of particular ecological interest because:
- It is the northernmost palm grove in Africa.
- It presents an incredible biodiversity: approximately 250 plant species, of which 30 are rare in Morocco; it accommodates 30 species of sedentary and migratory birds.
- It is a bio-genetic reserve used during the improvement programs of the date palm.
- Its important surface (1200 ha) allows it to play the role of "green lung" of the agglomeration of Marrakech.

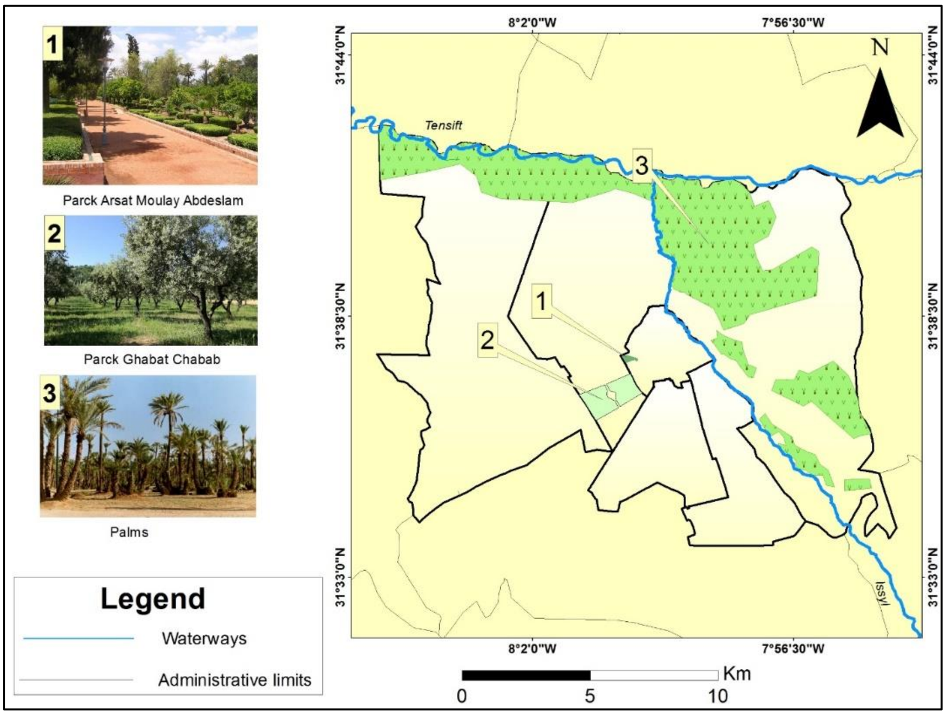

Figure 4: Geographical location of the study samples. **Source:** Author (2023)

4. Results:

1.8. Arsat Moulay Abdessalam Park: a source of natural and organic fertilizer production:

The waste generated by Arsat Moulay Abdessalam Park is natural and sustainable and offers numerous advantages. Reclaiming this waste utilizes advanced biotechnologies, effectively reducing the environmental risks associated with green waste management. The two primary methods of reclamation are as follows:

-**Composting:** Composting relies on the involvement of diverse communities of microorganisms that succeed one another, depending on their metabolic potential, at different stages of organic matter transformation and maturation (Albrecht, R. (2007)).

-**Vermicomposting:** Also known as worm composting, utilizes earthworms to transform green waste (as illustrated in Figure 6). This natural and odourless aerobic process involves a symbiotic relationship between microorganisms and earthworms (Ali, U., Sajid., & Al. 2015). Earthworms consume organic waste, and through their digestion process, they excrete nutrient-rich, dark, odourless vermicompost pellets and organic-rich sludge. This vermicompost serves as an excellent soil amendment. It is a readily usable fertilizer that can be applied in larger quantities than traditional compost since its nutrients are released at an appropriate rate for plant growth.

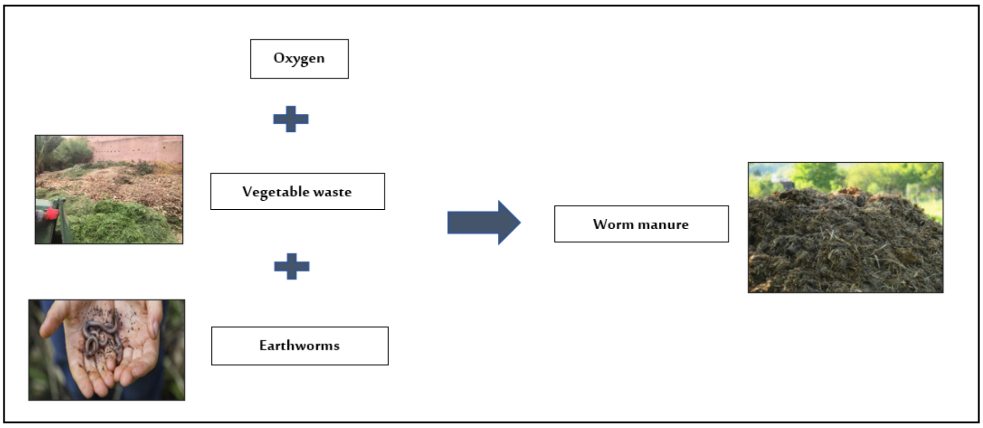

Figure 6: The transformation process of plant waste by earthworms. **Source:** Author (2023)

The concept revolves around establishing a facility dedicated to transforming waste from Arsat Moulay Abdessalam Park through composting and vermicomposting processes. The objective is to generate a valuable output: a natural and organic fertilizer that can be exported. This initiative aligns with the principles of the circular economy, ensuring environmental preservation while tapping into economic potential through such exchanges.

To efficiently manage the waste, dedicated collection centres can be established to consolidate the substantial contributions. These centres would then send the waste to collective composting platforms. Furthermore, establishing waste management companies can be explored to handle these waste streams effectively.

By implementing these measures, the park can effectively convert its waste into a valuable resource, fostering sustainable practices, preserving the environment, and creating economic opportunities.

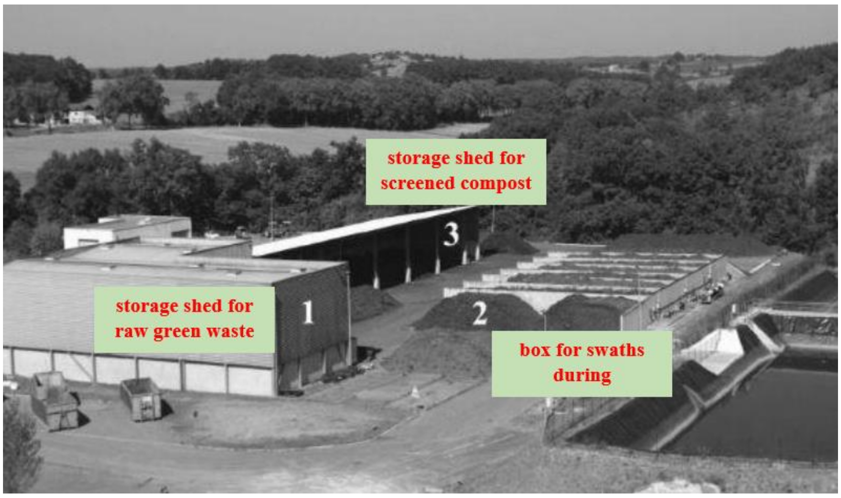

figure 9: A composting platform in Pihourc. **Source:** Turlan, T. (2018)

This initiative will have significant benefits across multiple levels:

-Social Level: Creating new jobs will reduce the unemployment rate and improve living standards. As evidenced by the recycling sector in 2014, the creation of direct and nonrelocatable jobs reached 26,500, with 85% being permanent positions (FEDEREC Statistical Observatory, 2014).

-Economic Level: Embracing the principles of the circular economy and striving for zero waste, the park's transformation from a consumable green space to a productive space will foster the development of a new industrial and commercial activity. This shift will reduce the cost of sourcing raw materials and foster greater independence in the production process. Furthermore, this enhancement process will yield positive outcomes at multiple levels, strengthening the park's appeal to tourists and enhancing the city's overall attractiveness. Moreover, it will contribute to establishing a circular and sustainable garden, promoting a harmonious relationship between nature and human activities.

-Environmental Level: A natural and organic fertilizer will preserve nature and soil components while increasing fertility. Additionally, it will eliminate the harmful practice of burning this type of waste, which causes odours and smoke pollution and poses environmental and public health risks. The initiative will also help prevent the spread of fires by mitigating these issues.

In summary, this comprehensive approach to waste valorization will bring about positive social, economic, and environmental outcomes while enhancing the park's appeal and contributing to the overall sustainability and attractiveness of the city.

1.9. Ghabat Chabab Park: an excellent source of renewable energy:

They are aware that poor management of olive waste, including solid and liquid by-products, can lead to significant water, soil, and air pollution, often resulting from their direct disposal into the environment without recognizing their potential value. On average, olives comprise approximately 40-50% water (vegetation water or margins), 25-35% pomace, and 20-25% oil. The production of olives generates two main types of waste:

-**Solids:** The pomace consists of the stone, pulp, skin, and sometimes the vegetation water of the olives.

-**Liquid:** The margins originate from the liquid fraction of the olives and any water added during the crushing process.

However, this waste can be highly beneficial as it is a form of biomass, opening up new possibilities for its utilization, particularly in energy production through biotechnological processes such as cogeneration and gasification. These processes enable the production of substantial amounts of green and renewable energy in electricity and thermal energy. In this study, our focus will be on the valorization of the margins and pits.

According to Fiestas Ros de Ursinos (1982), 1 m^3 of margins with 70 kg of Chemical Oxygen Demand (COD) can produce approximately 24.5 m3 of methane, containing 65-70% methane. It is important to note that methane energy can be utilized thermally or converted into electrical energy.

Methane fermentation is a complex process involving multiple microbial reactions in different stages, driven by a unique metabolic synergy. It starts with the hydrolysis of organic substrates, followed by producing organic acids such as acetic and formic acid. It ultimately results in the release of biogas, a complex gas rich in methane and CO2, along with other gases in smaller amounts depending on the type and initial composition of the organic substrate (Elamin et al., 2019).

This fermentation process occurs strictly without oxygen, known as anaerobic conditions. The ideal temperature for methane fermentation is typically around 30°C while maintaining a pH of approximately 7. Additionally, it is crucial to keep the organic load (8 to 15%) relatively low to ensure successful results within a timeframe of less than 30 days.

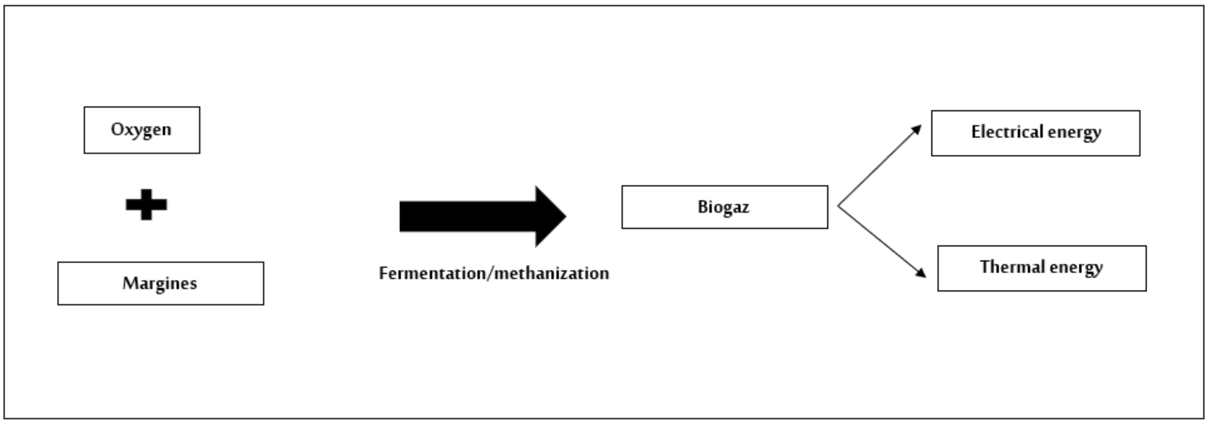

figure 10: The fermentation/methanization process of olive margines. **Source:** Author (2023)

Furthermore, it has been found that 2 kg of olive pits can produce energy equivalent to a litre of diesel, approximately 10 kW (Mchich, R. et al., 2022). This substantial amount of energy not only enhances the potential of this biomass but also brings about environmental and socioeconomic benefits.

The concept of valorization revolves around establishing an industrial unit, a factory specifically designed to recycle waste from olive crushing, including margins and pits. This initiative will enable us to generate a significant quantity of green and renewable energy in electricity and thermal energy. Such an approach adds value across various levels:

-**Economic level:** The development of this new industrial activity will reduce energy production and distribution costs, aligning with the principles of the circular economy (aiming for zero waste). Moreover, it will create a remarkable presence for the city, fostering economic and tourist dynamics and stimulating investments in the energy sector.

-**Social level:** The energy unit will ensure energy security and reduce consumption costs. This will result in cheaper, renewable, and sustainable energy bills. Additionally, this initiative will facilitate the expansion of the electrical network, benefiting all municipalities surrounding the city, including vulnerable areas.

-**Environmental level:** The implementation of this project will contribute to reducing pollution of vital natural resources, including water, air, and soil. Additionally, it will aid in curbing greenhouse gas emissions.

Overall, establishing an industrial unit to valorise olive waste holds immense potential, offering economic advantages, societal benefits, and positive environmental impacts.

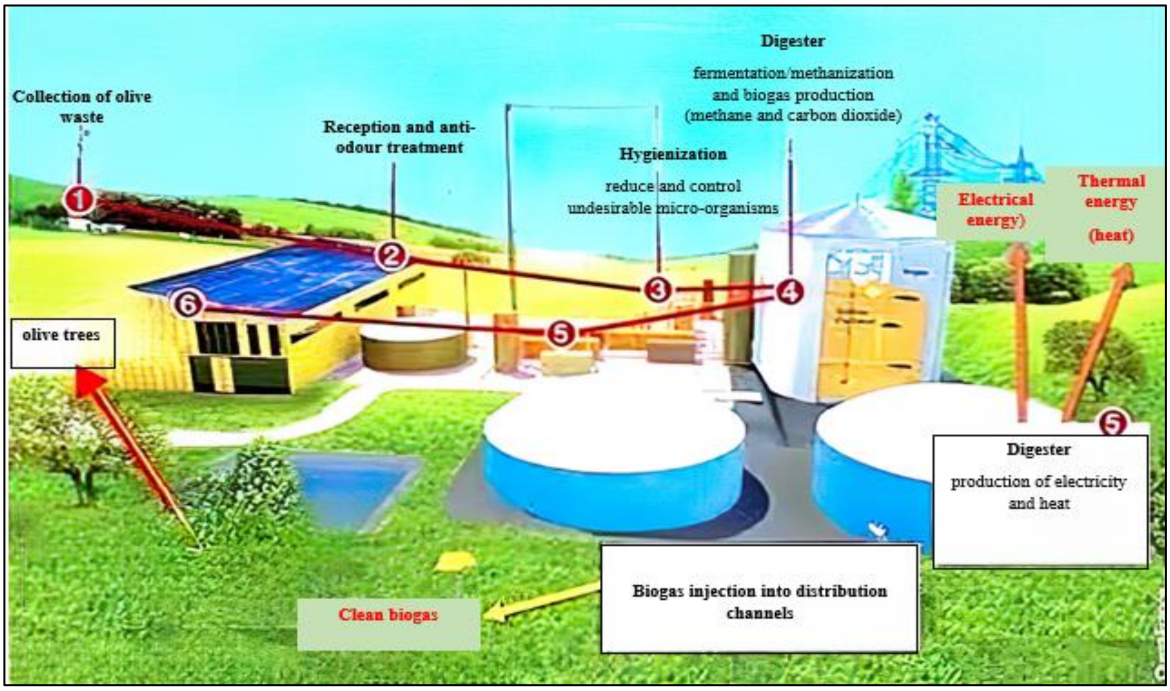

Figure 11: The chain of valorization of the margines of olives. **Source:** Fonroche Biogaz (2023)

1.10. The palm grove: a giant laboratory for the production of ethyl alcohol

The palm grove in Marrakech, being a pivotal part of the oasis ecosystem and a significant producer, generates substantial waste during each harvesting season. However, these waste materials can be valorized through biotechnological processes, mainly through the production of ethyl alcohol, which can be marketed and sold as a new generation of alcoholic products in high demand at various levels.

Ethanol production aims to utilize its strategic energy properties, as it has a wide range of industrial applications. These applications include its use as a chemical intermediate in cosmetics, perfumes, pharmaceuticals, laboratory solvents, detergents, disinfectants, organic acids, and more (Kaidi & al. (2001)).

The waste from dates contains approximately 60-65% fermentable sugars. The process employed for their conversion is the traditional alcoholic fermentation, where yeasts transform the sugars into alcohol and carbon dioxide through anaerobic conditions. This reaction releases energy in the process:

Sugars + Yeasts ==> Ethanol + CO2 + Energy

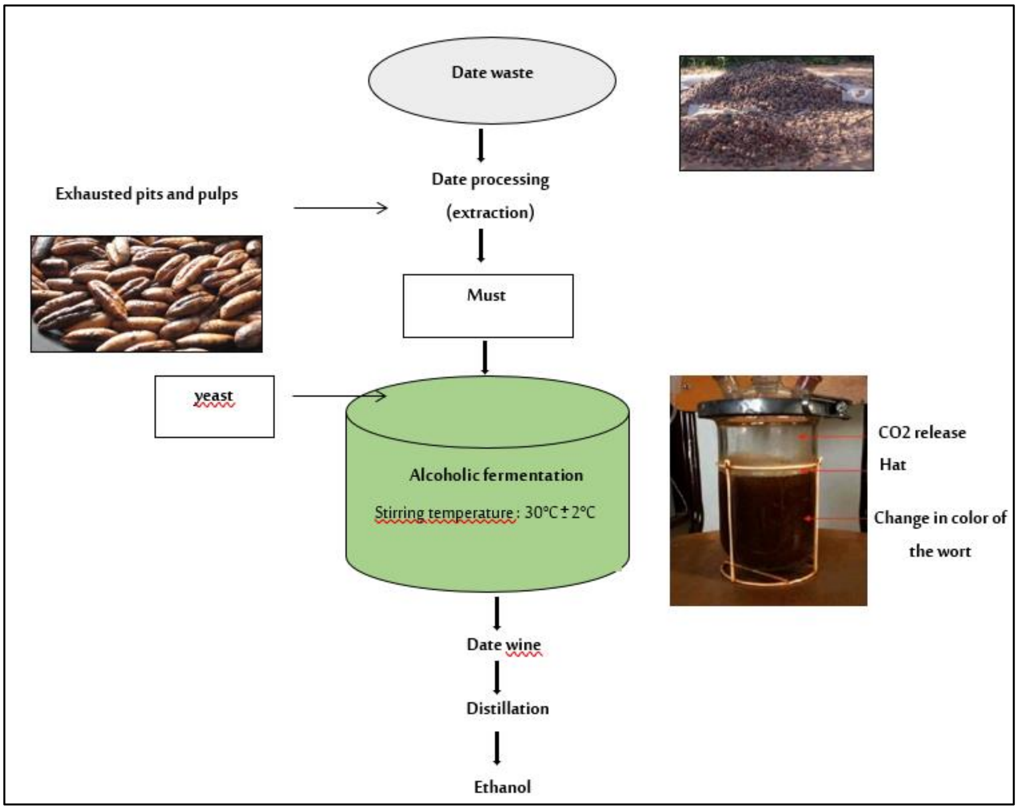

Figure 12: Steps in the manufacturing of ethanol from date waste. **Source:** Boulal, A.& Al. (2010)

The concept of valorization involves establishing a productive unit, such as a cooperative or a firm, to produce ethyl alcohol. This endeavour holds promising potential for adding value across multiple levels:

-**At the economic level:** The production of ethyl alcohol provides an intriguing alternative to chemically obtained materials. It can potentially replace hydrocarbons and contribute to the improvement of various sectors.

Table1. Sector and type of production

Sectors	Type of production
Chemical industry	Ethyl alcohol can be a raw material for synthesizing chemical products, laboratory solvents, disinfectant, and more.
Industrial applications	It finds use in producing paint, varnish, ink, plastics, adhesives, cosmetics, pharmaceuticals, cleaning products, insecticides, and other industrial goods.

-**At the social level:** Establishing this production unit will create jobs, thereby reducing unemployment and improving living standards for individuals with diverse educational backgrounds. Opportunities will be available for chemists, entrepreneurs, and the unemployed.

-**At the environmental level:** The production of ethyl alcohol contributes to waste reduction by utilizing biomass that would otherwise end up in landfills or be burned. Additionally, it aids in reducing greenhouse gas emissions, both compared to landfill burning and fossil fuel usage (such as gasoline and diesel). Ethyl alcohol, a renewable and biological material, embodies the ecological dimension in the sectors it impacts, including the industry and chemical sectors.

Overall, establishing a productive unit for ethyl alcohol production brings economic advantages and social and environmental benefits, contributing to sustainable development in various sectors.

5. Discussions:

Although the valorization of green waste through biotechnological processes offers a remarkable opportunity to activate various latent and sustainable resources, such as natural and organic fertilizers, thermal and electrical energy, and ethyl alcohol, it faces several obstacles. These obstacles encompass technological, political, and commercial limitations that hinder the progress of this initiative, despite its potential for significant socio-economic benefits.

-Technologically, there are various obstacles related to efficient conversion, pre-treatment, and scaling of plant waste to produce valuable products such as composting, vermicomposting, and fermentation. These challenges include expensive biotechnological materials involved and the need for cost-effective and efficient conversion methods. To address the complex composition of plant waste, it is crucial to develop effective pre-treatment techniques. Moreover, transitioning from laboratory processes to large-scale commercial implementation presents technical and operational difficulties, particularly in the absence of proper coordination and collaboration between research laboratories and stakeholders.

-Politically, despite efforts made by Morocco, such as implementing Law 13-09 on renewable energies focusing on electricity production from renewable sources and establishing an energy strategy in 2009 aiming to achieve a 42% share of renewable energy in installed capacity by 2020 and 52% by 2030, there is still room for improvement regarding the utilization of plant waste. Existing regulatory frameworks and incentives/subsidies need to be strengthened to fully exploit the potential of plant waste. Currently, policies often overlook specific opportunities related to plant waste utilization. It is imperative that these policies encourage environmentally friendly industries to adopt sustainable practices and provide guidelines for responsible and efficient use of plant waste resources.

-Additionally, significant trade barriers require special attention. The feasibility of using plant waste faces significant challenges due to substantial costs associated with their collection, transportation, storage, and processing. Moreover, the demand for plant waste-derived products, such as fertilizers, ethanol, etc., varies depending on the country, culture, and prevailing market conditions.

Conclusion

The valorization of waste from these green spaces through biotechnological processes offers a unique opportunity to generate various valuable resources. One of these resources is a natural and organic fertilizer derived from the green waste of Asat Moulay Abdessalam Park.

Additionally, the waste from the olive trees in Ghabat Chabab can produce thermal and electrical energy. In contrast, the waste from date palm trees can be utilized to ensure a steady supply of ethyl alcohol.

This green and environmentally friendly approach to valorization brings significant socio-economic benefits. Activating the employability/entrepreneurship dimension of these green spaces as an untapped resource and commercializing the mentioned products promotes the growth of green jobs and makes Marrakech a green city. Moreover, it creates opportunities for attracting investments in various sectors, such as industry and energy, particularly by introducing innovative products like fertilizers, ethyl alcohol, and renewable energy sources. Consequently, this initiative addresses the city's social, economic, and environmental requirements.

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