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FROM CORK WASTE TO ELECTRICAL THERMAL AND HYDROGEN BIOENERGIES

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Abstract – Several measures have been taken in recent years to reduce the use of fossil fuels and shift toward renewable energy sources such as biomass, particularly cork wastes, which currently generate more than 60% of the energy generated by cork powder energy conversion. This powder's high calorific content ranging from 4,000 to 7,000 Kcal/kg is natural, renewable, and recyclable, and contributes to a reduction in greenhouse gas emissions and carbon footprint. Cork wastes are now considered strategic substances due to their significant environmental and socioeconomic roles in the worldwide. The present research relies on cork wastes as potential of electrical, thermal, and hydrogen bioenergy source. Cork properties and energy usages are discussed beginning with cork's environmental, economic, and energy properties and processing through two types of cork wates conversion processing: industry and energy process. The firstl one is in four stages: preparation, transformation, granulation, and transformation, whereas the second one has three phases: extraction of cork, storage of planks, and from micro agglomerated cork stoppers to energy generation, and at the end of the study the three types of bioenergy that cork wastes may produce based on recent academic and research discoveries. Electrical energy, thermal energy, and hydrogen energy are the three types.

Keywords – Cork Wastes, Properties, Process, Energy, Hydrogen

I. INTRODUCTION

Renewable energies, particularly those generated by wind, water, solar, and biomass, have attracted unprecedented interest in recent years due to their natural, renewable, and sustainable nature. Moreover, remnant biomass cork wastes represent a way to access an infinite supply of energy. According to current estimates, nearly 200.000 tons of cork are harvested each year globally, with Portugal producing half of this (28). Furthermore, cork manufacturing generates a significant amount of cork waste, such as cork powder (from grinding, sanding, etc.) and cork boiling wastewaters, which have a high potential to be energy sources (29). Several research studies have confirmed the ability of cork wastes, like any solid biomass, to generate thermal and electrical energies, as well as solid, liquid, and gaseous fuels (30).

II. CORK PROPERTIES

Cork is a non-wood biomaterial derived primarily from the Cork oak tree (Quercus Suber L.). Portugal, Spain, Algeria, Morocco, Italy, France, and Tunisia are the top cork producers in Europe and North Africa (1). Cork by-products have gained attention recently due to their unique

characteristics and properties. Among its characteristics are:

Firstly, Cork is chemically composed of several components such as :

- Suberin (45%): a major compound responsible for cork elasticity;
- Lignin (27%): an insulating component;
- Polysaccharides (12%): They are components responsible for cork texture composition ;

• Tannins (6%): They are polyphenolic compounds that give cork its color;

- Seroids (6%): They are hydrophobic compounds that ensure the cork's impermeability(2).

Second, cork is regarded as a versatile substance that plays an important role in the preservation of human life, biodiversity, and the economy. Cork oak forests are extremely environmentally suitable for semi-arid areas in southern Europe and North Africa: they improve desertification avoidance, improve water penetration and hydrological regulation, foster soil preservation, and create an adapted environment for animal and plant life. Cork oak forests, in other words, are an excellent source of biodiversity (3) (4). (5). Furthermore, the production of expanded cork agglomerate is an environmentally friendly process. The product is made with superheated steam generated by cork waste-fueled generators. Furthermore, during the cork production process, an important residue known as cork powder is collected. This high-energy content material is burned to generate steam and power, and reused in different ways(6), like using cork stoppers to absorb pollutant materials. For the economy, Saving cork forests leads to increasing cork quantity, enhancing cork quality, and realizing a high value-added (8). Research confirmed that the process of protecting the cork trees from the environmental risks after their bark removal would develop new subrose material. Hence, a large quantity of cork layer is produced by using the bark removal process (4)(6).

Third, in the field of energy, cork has a great potential to be the future source of bioenergy production due to its unrivaled properties, as it is a suitable material for mechanical conversion (less cost conversion), it is a zero fuel carbon, it is a cost-effective fuel, and its technology maturity and performance are high. (31,23).Furthermore, it is good thermal insulation as it provides good thermal quality for buildings according to energy certification systems. Moreover, cork agglomerate and rubber components can convert mechanical energy into heat. They are also composed of low weight and thermal and acoustic insulation (7).

Finally, cork oak grows abundantly in two main world areas: the Mediterranean basin in Europe and North Africa.(see table 1)

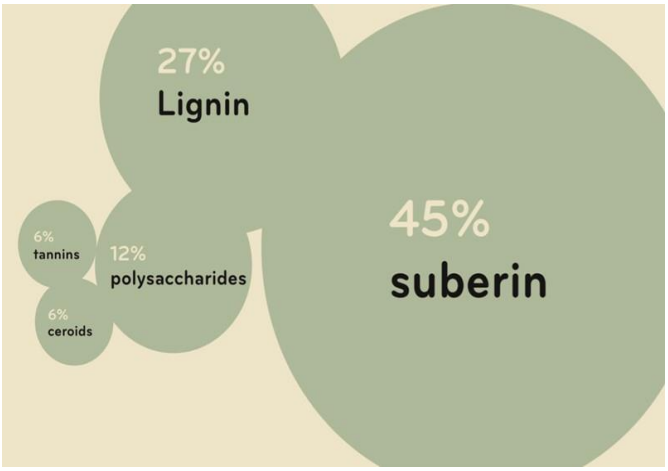

Figure 1 : Chemical carachterisitcs of cork
https://www.corkeen.com

Table 1: Main cork worldwide areas (Silva and Catry, 2006)

Countries	Area (in Hectares)	%
Portugal	730.000	**32.2**
Spain	500.000	**22.0**
Algeria	410.000	**18.1**
Morocco	340.000	**15.0**
France	100.000	**4.4**
Tunisia	99.000	**4.3**
Italy	**90.000**	**4.0**

Table 2: worlwide cork peroduction

COUNTRY	Average annual production(ton)*	%
Portugal	100,00	49,6%
Spain	61,504	30,5%
Morocco	11,686	5,8%
Algeria	9,9154	4,9%
Tunisia	6,962	3,5%
Italy	6,161	3,1%
France	5,200	2,6%
Total	201,428	100%

Source : FAO,Global Forest Resources Assessment 2010. Country reports

III. CORK WASTE PROCESSING

Cork is considered a new energy generation material for being a natural, renewable, recyclable, and safe substance as we move toward a new sustainable energy source. Cork has a variety of industries and energy conversion processes. However, for this research, I will concentrate on two types of cork operations: the cork industry process and the cork energy conversion process.

A. Cork Manufacturing Process

Despite the numerous cork manufacturing processes proposed to produce a plethora of by-products, the cork industry process is generally composed of four primary activities, which are (11,12):

Preparation: cork production is prepared and chosen through boiling, marking, cutting, selecting, and occasionally packing.

Transformation: transforming a plank of natural cork into a variety of natural cork goods by simply cutting or carving it (cork stoppers, disks, cork paper, handicrafts, etc.). Sorting cork planks according to thickness and quality, cutting, pre-drying, rectifying, washing and drying, selecting, marking, commercializing, and shipping are all part of this operation. Generated cork waste is a supply for the granulation process.

Granulation: the process of reusing parings from producing natural cork stoppers and lower-quality cork trash. Cork waste is broken, milled, and classified according to its volumetric mass and granulometric properties.

Agglomeration: the process of pressing or agglomerating various types of inferior-quality cork granulates in autoclaves with superheated steam under high heat and pressure.

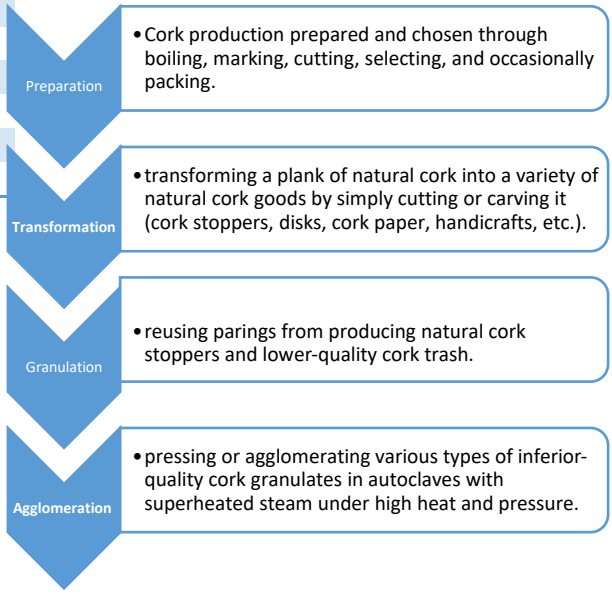

Figure 2 : Cork industry process

B. Cork Waste Energy Conversion Process

In a recent study made in the current year (2022) about how to convert cork waste from bottle stoppers into sustainable substances and upgrade them from biomass to secondary raw material the cork waste processing from cork caps manufacturing goes through numerous stages :

Cork extraction: cork extraction involves the extraction of large sheets of bark called planks. this delicate operation is usually done between May and June when the barks are softer by killed specialists to protect plants from damage.

Planks storage: planks are stored for drying and divided into defective and indefective planks. The defective planks are immediately turned into agglomerates to be used in the construction sector and transformed into wine caps. In comparison, the indefective ones are for manufacturing high-quality cork stoppers(9). During this process, a large quantity of cork residues is recycled to manufacture micro agglomerated cork stoppers. (10)

From micro agglomerated cork stoppers to energy generation: The micro agglomerated cork caps are subjected to a process by which they are converted

into an energy source. The process includes the following steps: virgin cork residue selection, cork additives mixture, compression or pression and dry-cut of the mixture, cork smoothing, and the production of many smooth cork wastes designed for waste-to-energy plants.

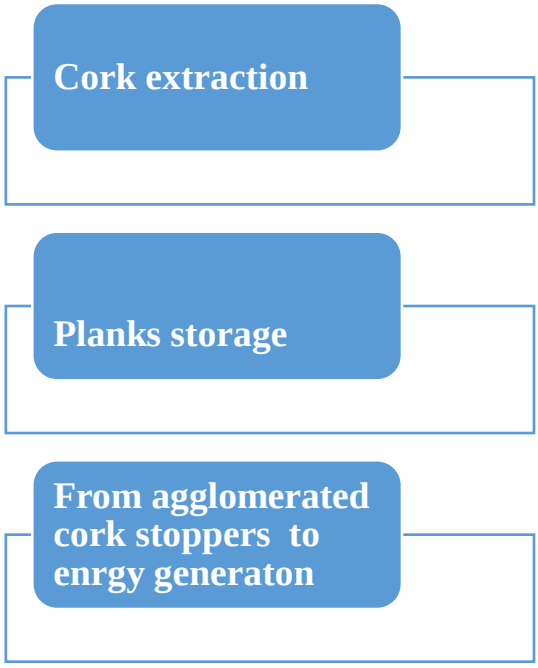

Figure 3: Cork energy conversion process

VI. CORK ENERGIES GENERATION

Today, a new economic and sustainable trend has emerged. It is related to waste industrialization, which means using waste to create a wide range of byproducts or different types of energy sources. Cork waste manufacturing, for example, "has shifted from the traditional cork-wine relationship to quality and environmental concerns." (13), such as developing environmentally friendly energy sources. Among them are:

A. *Electrical power*

Cork waste can be converted into an environmentally friendly source of electrical energy. The Universitat Politècnica de Catalunya - BarcelonaTech (UPC) uses the wine industry cork waste as a power fuel to generate electricity and treat wastewater, according to Manresa Technology Centre Eurecat-CTM. Furthermore, UPC is a leader in the European project LIFE ECORKWASTE (2015-2019) to test the efficacy of cork wastes in absorbing organic contaminants to treat wastewater and generate electricity via a thermal gasification process. The project, which has a budget of two million euros, is a collaboration between the European Union (EU), the company Typsa, the Catalan Cork Institute, and the Innovi Catalan Wine Cluster. Environmental and social progress to assess technical research solutions. (14) The positive Ecork project's final results were announced by the participants in December 2018 at a conference held at the Polytechnic University of Catalonia. They confirmed cork waste's ability to eliminate 95% of pesticides and 90% of COD, as well as they produced a quality SYNGAS with a calorific value (LCP) of 4,943 kJ/m3 or 8748.7 kJ/kg of cork for use in cogeneration engines in the gasification plant. (15)

B. *Thermal Energy*

Because of its thermochemical conversion capability, cork powder has a high potential for use as an energy source. However, understanding the feedstock characteristics and attributes associated with its use as a fuel is critical when using solid biomass for energy. (16) Elemental composition, ash and volatile matter content, heating value, bulk density, and moisture content are all required for biomass thermochemical conversion. Three routes for generating thermal energy from cork waste:

Conversion route A - Suspended combustion: Heat is produced by combining pulverized solid fuel with air in this route. Burners' power output can range from a few hundred kilowatts to (at least) 100 MW. The burners can use a wide selection of powdered biomass, coal dust, fuel oil, and gaseous fuels. (18,19,20,21,22)

Conversion route B - Fluidized bed combustion: During fluidized bed combustion, solid biomass fuels are fed into a bed of inert material (such as sand, gravel, ash, or limestone) (FBC). The gas is then injected from the furnace's bottom at a high enough velocity to cause the fuel particles to flow out of bed and behave like a fluid. (23,24,25)

Conversion route C – Cyclone-type pyrolytic dust burner: In the burner's cyclone chamber, fuel is treated for a pyrolysis or devolatilization process.

The gas is then delivered into the boiler's furnace, where secondary and tertiary air is added. This process enables the furnace to have a controlled combustion flame. (18,16)

C. *Green Hydrogen Energy*

Hydrogen will be a significant source of secondary renewable energy in the future. Today, most produced hydrogen using fossil fuels. Future decarbonized applications that rely on renewable and carbon-dioxide-neutral hydrogen production could benefit from biomass gasification. (26) Gasification plants for biofuels, according to the US Department of Energy, "can provide the best practices and lessons learned for hydrogen production ". In addition, the department "anticipates that biomass gasification could be deployed in the near-term timeframe ". (27)

Any renewable organic resource is referred to as "biomass," including agriculture crop residues, forestry waste, organic municipal solid waste, and even animal waste. These materials are transformed into energy and other useful byproducts, including hydrogen, through a process called gasification. (27)

V.CONCLUSION

The following points include the document's key topics, along with recommendations for additional study:

1. The availability of cork plants in different countries, especially in the Mediterranean basin and, their increased production and manufacturing namely, in Portugal create an opportunity to diversify cork plant exploitation and use it in various eco-freindly environment domains such as construction, pharmaceutical industrialization, environment protection...etc. Thus, it leads to a change in the economic landscape from linear to circular and a more sustainable one.
2. The chemical, human, environmental, and economic cork properties make the cork a vital and strategic material holding great potential proving its energy conversion feasibility, Which may be explored in different sectors, especially in the domain of energy. So, it is time to diversify sources of energy and make further research on cork wastes as another alternative renewable energy.
3. Tow kinds of linked operations in which cork wastes are processed: cork industry process and cork energy conversion process. In the first operation cork residues follow three logical steps: preparation, transformation, granulation, and agglomeration. Whereas the second operation requires three-step to be accomplished: cork extraction, plank storage, and the conversion of agglomerated cork stoppers into a source of energy. these operations show the cork waste conversion ability to be one of the promising cork technology development. Though these operations are expensive and require sophisticated materials, especially for small-budget sources nations, it is possible to overcome the challenge by encouraging scientific research for looking for cost-effective alternatives or by signing conventions with developed countries to benefit from developed scientific research and technologies.
4. The three possible energy sources that may be generated from cork wastes: thermal, electrical, and hydrogen are so effective. Therefore, it would fill the research gap in the area of cork waste energy conversion and suggest feasible solutions. They should be paid more attention to because they are natural, renewable, and will save humanty from the negative healthy, environmental, social, economic, and political impacts of fossil fuel energies. Stimulating internal investments and positive external investments make the conversion operation easy, useful, and fruitful.

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