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Assessing the Potential of Particleboard Production from Food Waste: Analysis of the Input Materials

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Abstract

The use of organic urban solid waste for the recovery of materials is considered a decisive step for sustainable waste management, the economic viability of waste management plans and the minimization of land use. This work aims to provide a pathway for the exploitation of alternative biomaterials and to help the roadmap for a cyclical economy and sustainable waste management. The present communication has the scope to introduce the concept of producing particleboards by mixing sawdust with dried food waste. In the framework of this study the available dried food waste are assessed for their characteristics and their suitability for utilization.

Keywords: Drying; TGA; HPLC; Wood products; Waste reuse; Biomaterials

Introduction

Under the EU Waste Directive, bio-waste includes household and household waste, green waste and other similar waste from cooking and food processing establishments [1]. Centralized management of household bio-waste faces many implementation problems. In the European Union, 88 million tons of food is discarded annually, with an estimated cost of 143 billion euros. The recently adopted legislation aims at enhancing the efficiency of alternative resources, such as waste, and the low-carbon economy. The goal is not only to provide more effective solutions but also to increase the life-cycle of products, particularly in the food sector [2]. The FUSION report identified 53 EU legislation on food waste [3]. The ultimate goal is to "close the circle" by turning waste into resources.

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One of the main pillars of this study is to promote the re-use of waste and to stimulate industrial co-existence by turning waste into raw material. The typical waste management pyramid includes waste, scrap, reuse, recycling, recovery, and disposal with a decreasing order of priority. Great effort focuses on recycling waste streams or energy recovery, but the goal is always to apply higher priority management strategies to the management pyramid, such as waste reuse. Therefore, the present work aims to assess the “reuse-potential” of food waste by investigating their suitability as raw material for the production of particleboards. In this framework, the study proposes the concept of utilizing fluctuating ratios of dried food waste and wood sawdust for the production of particleboards. The basic aspects of the idea are presented in FIG.1. The mixture of sawdust/dried bio-waste and additives will be done with a container and a stirrer for a predefined period which can be between 2 and 5 minutes. Then the glued particles will be pressed together by means of a hydraulic press at temperatures above 160 °C. The exact size of the particleboard will be decided according to the "European Standard BS EN 309 Particleboards”.

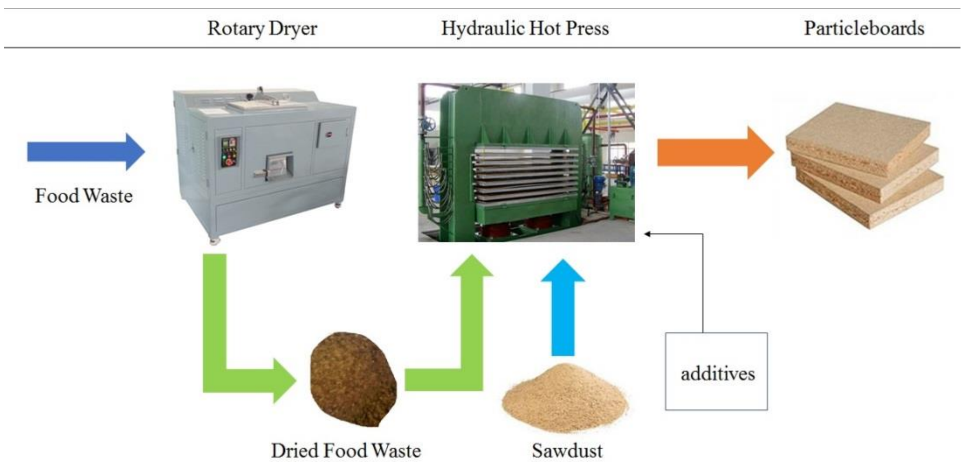

FIG. 1. **Proposed concept for particleboard production from mixtures of wood sawdust and dried food waste.**

In principle, food waste is difficult to handle due to the high water content, the inhomogeneity and the biodegradability of the feedstock [4] Nonetheless, Sotiropoulos et al. [5] showed that with an intermediate step of drying/milling in a commercial dryer, food waste because inert homogenized and have low moisture content which is usually below 7 %. The substitution of wood sawdust with dried food waste enhances the sustainability of the process and reduces the material use. But the compatibility of dried food waste for particleboard production is not straightforward and intuitive. On one hand, the material needs to be dried below 10% moisture and milled before the initiation of production [6]. For the case of the dried food waste, this is step that has already being filled from the previous drying/milling in the commercial dryer. On the other hand, food waste contain sugars and other macromolecules, like lignin and starch, which under elevated pressures and temperatures are plasticized [7] and could assist the reduction of adhesives like urea-formaldehyde during the production process.

The initial step of this scientific endeavor and the aim of this present work is the analysis of the characteristics of the available food waste with the following steps:

- Measuring the content of sugars, starch and lignin.

- Assessing the degradation of sugars.
- Implementing thermo gravimetric analysis.

Materials and Methods

A sampling campaign has been developed in two targeted municipalities with the aim of segregating at the source and collecting organic household waste. In previous studies of the prospective fellow student, this organic waste was collected at a central facility and dried. The dried material (from organic waste) has a sawdust-like texture while drying has rendered it inert. Vakalis et al. [8] analyzed dry food waste and highlighted their high starch.

The analysis of household organic wastes has been done in accordance with the following international standards:

- UNI EN 15104 (CHN) for the determination of carbon-hydrogen-nitrogen;
- UNI EN 14775 for the determination of the content of Ash,
- UNI EN 14774-3 standard for the determination of humidity.

The elemental analysis has been performed in an “Elementar Vario Micro Cube” analyzer. The moisture has been assessed after drying the (already commercially dried) food waste at 105 °C for 24 h. The ash content has been assessed after combustion at 550 °C.

The thermo gravimetric analysis of the dried food waste was performed in a STA, i.e. Simultaneous Thermal Analyzer, at the Free University of Bozen-Bolzano (449F3, Netzsch). The applied heating rate was 40 °C, the heating agent was pure nitrogen and along with the TGA curve also the first derivative TGA curve was extrapolated. This analysis shows the mass loss in respect to increasing temperature and highlights the points that specific macromolecules start to degrade. The sugars, along with other macromolecules, were assessed by means of High performance liquid chromatography, i.e. HPLC (Agilent Infinity 1220 Series) at the National Technical University of Athens. The feeding tubes of the HPLC instrument were filled with dried food waste. After an initial mixing with sulfuric acid, the dried food waste was treated in an autoclave in order for the liquid phase to be separated. A series of analysis was performed in the samples for several days in order to assess the degradation of sugars and the moisture content.

Results and Discussion

The results from the elemental analysis and the determination of moisture and ash can be found in TABLE 1. An interesting result is the relatively high ash content in respect to conventional woody biomass. This can be attributed to the high ratio of peels in the waste stream. The level of ash content creates some concern if the scope is the utilization of dried food waste for energy production. Thus, the production of biomaterials seems to be a favorable scenario. The level of moisture was measured at 6.89 % and follow-up measurements showed that it never exceeded 7 % after one year of storage.

	Dried Food Waste
C (% wb)	49.8
H (% wb)	6.09
O (% wb)	31.45
N (% wb)	3.25
Ash (% wb)	2.52
H_2O (% wb)	6.89

TABLE 1. **Characteristics of the food waste after commercial drying**

The HPLC analysis (FIG.2.) showed a total amount of 13.83 g of sugars for every 100 g of dried food waste. Glucose has the biggest fraction with 5.28 g, followed by Sucrose and Fructose which were 4.6 g and 3.95 g respectively.

The high sugar content shows a potential for compactness of the produced particleboards and potential for less utilization of adhesives like urea-formaldehyde because the sugars will be partially plasticized during the hydraulic pressing. FIG. 3 shows that the sugars in dried food waste do not degrade through time contrary to the sugars in untreated (wet) food waste. The main expentation for this is that the water content is reduced significantly and the process of hydrolysis cannot initiate. Also there is a possibility that the drying process destroyed the microorganisms that would anaerobically digest the material.

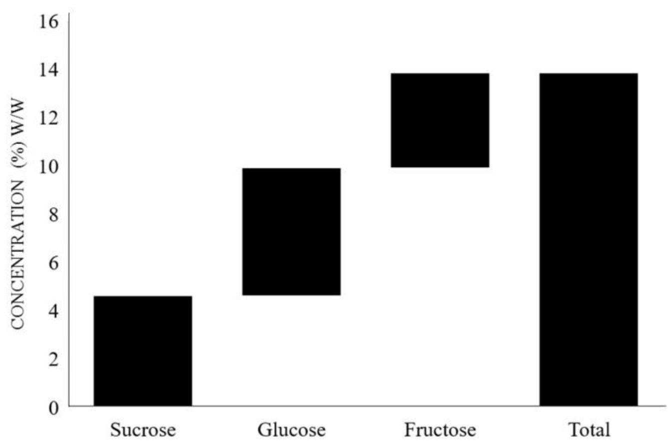

FIG. 2. **Content of sugars in dried food waste**

This preservation of the sugar content is an interesting result because it shows the stability of the material and the potential for long-term use. Of course further follow-up studies need to be performed in order to assess the long term stability of the material.

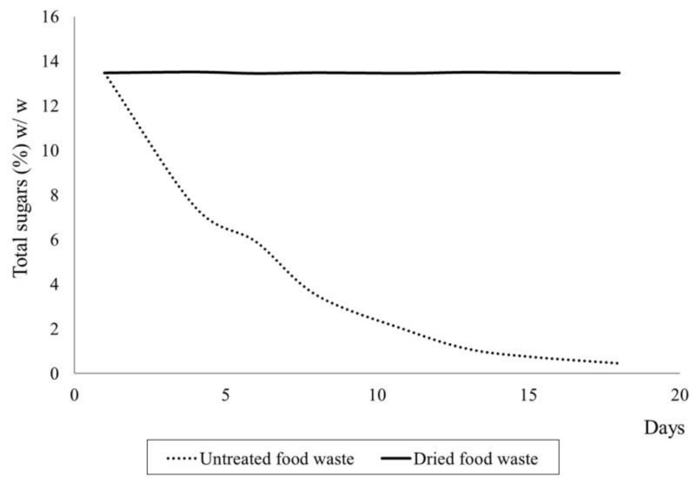

FIG. 3. **Comparison of sugars degradation between untreated and dried food waste**

Finally, FIG. 4 shows the results from the TG analysis. The curves clearly show that the feedstock is reach in starch, which is the reason for the steep reduction of the first derivative curve over the 120 °C. The TG curve is very different from the common woody biomass curves where the majority of the mass loss takes place around the area of 400 °C due to the high contents of cellulose. Also, the curviness of the TG curve at the point of 500 °C shows that there is also significant content of lignin. The high contents of lignin and starch along with the high contents of sugars indicate that dried food waste have promising potential as materials for particleboard production.

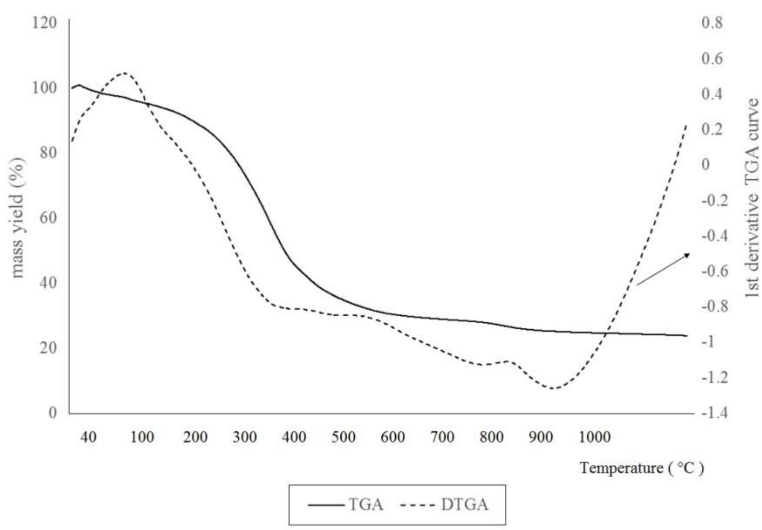

FIG. 4. **Thermogravimetric analysis (TGA) of dried food waste.**

The next step of this research will be the production of different types of particleboard made from different ratios of wood sawdust and dried food waste and the products will be compared for the physical and mechanical characteristics. The secondary scope is to replace up to 50% of urea-formaldehyde with starch glue. Applications of starch glue as wood adhesive has some recent applications that can be found in the literature, like Moubarik et al. [9], but this aspect is far beyond the scope of this short communication.

Conclusion

This short communication aims to introduce the concept of particleboard production from food waste in the framework of reusing waste and stimulating industrial symbiosis by converting waste into particleboards. In this study, the concept of mixing wood sawdust and dried food waste was introduced and the characteristics of the dried food waste were assessed for their suitability. Dried food waste had high content of sugars, starch and lignin. Also drying nullified the degradation/ digestion processes and has converted food waste into a practically inert feedstock that can be stored for several months. The upgrading of organic household waste to biomaterials that can replace conventional materials helps to manage natural resources properly and contributes to reducing overall carbon dioxide emissions in the country. According to our knowledge, the production of particleboards from food waste is a unique topic and no similar efforts can be found in the literature.

Acknowledgement

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