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The use of Olive Stone Waste for Production of Particleboard using Commercial Polyester Sealer as a Binding Agent

Eman Elsahli[1,*], Wael Elhrari[2], Abdalah Klash[2], Anour Shebani[2]
[1]Department of Interior Design, University of Tripoli, Tripoli, Libya
[2]Polymer Research Center, Tripoli, Libya
[*]Corresponding Author: em.elsahli@uot.edu.ly

Abstract

In part to take advantage of solid waste of olives pressing (olive stone) and to reduce their negative environmental impact, using olive stone to produce particleboard is meeting the growing demand for finding new resource as an alternative to wood. This because olive stones is a lignocellulosic materials, with hemicellulose, cellulose and lignin as main components. This paper represents the research work on the production of particleboards using olive stone waste and commercial polyester sealer as a binding agent. The boards were tested for physical and mechanical properties based on the European standards (EN) for particleboard. Furthermore, properties such as porosity, particle size, particle density, distance size, permeability, and presence of fungi and bacteria were evaluated. The results showed that the physical and mechanical properties of produced particleboard in term of moisture content, water absorption, thickness swelling and bending strength are in good agreement with EN standards for particleboard. Properties such as porosity, particle size, particle density, distance size, permeability, and presence of fungi and bacteria had somehow influenced the quality of particleboard.

Keywords: Environment; olive stone; particleboard; polyester.

1. Introduction

The resulting residues during the production of olive oil mainly composed of hard woody endocarp called olive stone [1, 2]. These materials are highly polluted materials because they are not easily degradable by natural processes, and their disposal creates a major environmental issue in the main olive producing countries. Accordingly, research into finding new possible uses for olive industry by-products, particularly the olive stones, is of a great relevance not only to the economy but also to the environment in these countries [3].
Different approaches have been reported in the literature to use the solid by-products generated by the olive oil production to reduce the negative environmental impact [3-5]. The solid wastes can be burned to generate electric energy or heat (green electrical energy) [6]. Also, it is possible to turn the solid wastes into activated carbon, which widely used for adsorption of pollutants from gaseous and liquid phases [7, 8]. On the other hand, solid wastes can be consumed as fuel, fertilizer and animal feed [9]. Moreover, the use of the olive stones as a filler in polymer-based composite also constitutes an interesting potential application within the field of materials technology [10-13]. Products such as panels, pipes, tubes or profiles amongst others, have been elaborated by different processes [14].
Mediterranean countries including Libya suffer from the environmental problems that cause by the solid wastes of olive oil production. This because Mediterranean countries produce nearly 99% of the world olive oil production [15, 16]. Libya attains the 12^{th} position among olive oil producers in the region. Number of trees is estimated at nearly 7 million, producing 200,000 million tons of olives, whereas annual olive oil production is estimated at 40,000 metric tons [17, 18]. Olive oil milling operation in

Libya produces nearly 40,000 metric tons per year of solid residues [18]. Although many local studies have been focused on the utilization of these residues [18-21]. Yet, no studies on utilization of solid wastes (practically, olive stone) in preparing composite materials such as particleboard have been reported in Libya. Particleboard has a homogenous structure and can be manufactured in different sizes, thickness, densities and grades for numerous uses. Particleboard is commonly used for cabinetry, tabletops, shelving, wall and floor panels, doors, furniture, and other non-structural architectural applications [22].

Particleboard, is an engineered wood product manufactured from wood chips, sawmill shavings, or even sawdust, and a synthetic resin or other suitable binder, bonded together under heat and pressure. According to Muruganandam *et al.* [22] many materials were used for the production of particleboard. These materials include bark, sawdust and shavings, wheat straw, waste wood chips, rice straw, maritime pine, bamboo waste, kenaf particles, mixture of baggase and industrial wood particles, sago particles, fonio husk and many more. Urea formaldehyde (UF), phenol formaldehyde (PF), melamine formaldehyde (MF) resins, are the glues (binder) commonly used in particleboard making [23, 24]. Other binders that can be used to make particleboard are polyurethane, polyester, epoxy resins etc. [22, 25]. Most importantly, the both physical and mechanical properties of particleboards depend on the raw material used for the manufacturing process. However, properties of the particleboard play a major role after the manufacturing process when compared with the standards [22].

In this current study, in order to minimize the negative impact of olive stones on the environment, and to find a new resource as an alternative to wood, olive stones were used for the production of particleboard. This because their chemical composition are similar to that of wood, which mainly composed of lignin, hemicellulose and cellulose [11]. Moreover, a new binding material namely commercial polyester sealer was used for the production of particleboard. In fact, polyester commercial product produces a smooth, hard seal coat without any influence on natural wood grain. Not enough work has been studied the possibility of using olive stones in the production of particleboard [26-28].

2. Experimental

2.1. Materials and equipments

Olive stone used in this study were collected from the region of Imslata, which located in the east of Tripoli, Libya. The unsaturated polyester liquid resin (Jet sealer) from MIDO with a solid content of 43% in styrene was used as a binder. The mould used in this study was made in Advance Centre for Technology, Tripoli-Libya. The dimensions of the mould were 14.6X8.6X1.9 cm. Air circulating oven was used during the preparation of particleboard.

2.2. Preparation of the polyester binder

Addition of 2 wt% accelerator agent to the sealer was performed with stirring. Then 2 wt% hardener was added to the mixture with stirring as well.

2.3. Making particleboard

Olive stones were cleaned and washed with warm water by hand in order to remove the impurities. Then they placed under the sun for 48 h for drying. Sun drying is primarily preferred for drying of raw materials for particle board making [22]. Then 80 wt% olive stones were mixed with 20 wt% polyester resin, manually in stainless steel container. The mixture after that were transferred into the mould coated with thin layer of Vaseline as release agent. The samples was pressed by pressing machine at 8 tons for 10 min, then the mould was placed into oven at 70 ^{o}C for 15-20 min. The particleboard was removed from the mould to cooled down in dissector and their properties such as moisture content, density, water absorption, thickness swelling, bending strength were determined. The tested samples (seven samples for each test) were in the form of a rectangle shape (14.6 x 8.6 x 1.1 cm). Figure 2.1 shows the shape and profile of the produced particleboard sample.

2.4. Testing and evaluation

Moisture content (MC) (EN322, 1993), density (EN323, 1993), water absorption (WA) and thickness swelling (TS) (EN317, 1993), bending strength (BS) (EN310, 1993) of particleboards were tested according to European Standards, respectively [29-32]. Properties such as porosity, particle size, particle density, size dimensions and permeability were evaluated using Helium expansion gas porosimeter ERGO Tech. The fungus resistance test was performed to determine the resistance of particleboard to fungi. Seven replicates were used for each test.

Figure 2.1: Photograph of the particleboard sample.

3. Results and Discussion

The olive stones and polyester were mixed with each other at different ratio. The ratios were (olive stone/polyester 52/48, 60/40 and 80/20). It was difficult to obtain good quality particleboard and even to test and evaluate these particleboards due to the handling difficulties, using ratios of (52/48 and 60/40). On the other hand, good quality particleboard was produced by the ratio of (80/20). Most of the values of the tested properties were in agreement with the values prescribed by British, American and European Standards and are presented in Table 3.1.

Table 3.1 summarize the all results of physical and mechanical properties and their standard deviation (STD) of particleboard in contrast with European standards (EN Standards). Muruganandam *et al.* [22] stated that physical and mechanical properties of the particleboard are very important, which help to find the right application where the product is being utilized. They believed that the effects of MC, WA, TS, BS, tensile strength, compressive strength, hardness, rate of loading, press temperature and pressing time are the most important physical and mechanical properties of the particleboard.

Density results of particleboard are shown in Table 3.1. Density is a measure of the compactness of the individual particles in a board. Density results (1.54 g/cm^3) was in agreement with EN Standards. The minimum value of density according to EN Standards is almost 0.6 g/cm^3. The average board density can be dependent on the quantity and density of the olive stone used to make a particleboard of a given thickness. Also, it can be influenced by the pressing parameters. It can be emphasised that the mechanical and physical properties can be influenced by board density and particle sizes [33]. The increment in the density value increases the mechanical properties of wood [34].

As shown in Table 3.1, the average value of MC was 1.10%, which is lower than the minimum value of EN 322 standard (5-13%). The good obtained MC resistance could be due to the nature of polyester which can make coating layer that prevents olive stone to absorb moisture. This probably reduces the presence of olive stone on the board surface, which decreases the possibility of void formation that could form pathways for entry by water and fungal hyphae. This is an indication that the cohesive and binding forces of the polyester resin are strong and more sustainable.

WA is most important property for any type of particleboards [22]. Because the effect of water on the properties like BS and bending stiffness is very severe. It is believed that the most serious impediment related to the use of lignocellulosic in composite materials is its high sensitivity to water, which adversely affects its mechanical performance as well as its long term durability, particularly for outdoor use [3]. The results of WA in Table 3.1 show that the water uptake increased with time (from about 2.5% after 2 h immersion in water to about 6.4% after immersion 24 h in water). These results are extremely excellent because they are in good agreement with EN Standards [27].

The effect of TS in the particleboards is because of the moisture and WA properties. TS results in Table 3.1 showed that the value of TS for the samples that immersed 2 h in water was equal to maximum value of the EN 317 Standard, while the value of TS for the samples that immersed 24 h in water was a bit higher than that in EN standards. According to EN 312 (2003) and American National Standard A208.1 (ANSI A208.1) (2009) standards, maximum thickness swell values for home decking and load bearing particleboards are 15 and 8%, respectively [37]. Furthermore, according to EN standards the maximum TS requirement for 24 h water immersion is 15% [38]. It can be concluded in this stage that the amount of polyester resin covers and produces a strong board, which reduces the MC, WA and TS. Karr *et al.* [40] provided a quite similar explanation.

As can be seen from Table 3.1, BS value (15.56 N/mm^2) (which are a direct measurement of the performance of the binder) of produced particle-

Table 3.1: Properties of the produced particleboard (80/20).

Experiment	Test method	Unit	MC	MC	STD
Density	EN 323	g/cm^3	0.6* [35]	1.54	0.009
MC	EN 322	%	5-11 [36]	1.10	0.16
WA after 2 h	EN 317	%	30** [24]	2.46	0.15
WA after 24 h	EN 317	%	40** [27]	6.40	1.55
TS after 2 h	EN 317	%	8** [37]	9.09	0.00
TS after 24 h	EN 317	%	15** [38]	18.18	0.00
BS	EN 310	N/mm^2	12.56* [37]	15.56	1.12

*Minimum value, **Maximum value.

board was higher than the minimum BS in EN 312 Standard. Based on ANSI A208.1 (2009) and EN 312 (2003) standards for general purpose particleboard, the minimum requirements for BS of particleboard panels for general uses are 11 N/mm^2 and 12.5 N/mm^2, respectively [37]. This is due to the strength of binding resin (polyester). This indicates that the binder was positively influenced BS of the board. Generally, earlier studies by Eusebio *et al.* [41] and, Zhou and Kamdem [42], Wang and Sun [43] and Papadopoulos *et al.* [44] observed that density of particleboards and wood components significantly influenced the particleboard strength properties.

Properties such as porosity, particle size, particle density, size dimensions, permeability, and presence of fungi and bacteria were evaluated. These properties are presented in Table 3.2. Porosity of particleboard, as shown in Table 3.2, was found to be about 14%. In general, porosity of wood can affect the mechanical and absorption properties of polymer composites [45]. However, some knowledge about the porous structure of a particleboard and its influence on the quality of a board is to be found fragmentary condition [46].

Particle size and shape used in particleboard play an important role in affecting the properties of particleboard. The influence of particle size and shape on mechanical properties of boards is well described in several papers in the research literature [47]. For example, quality of bonding can be affected by the geometry and size of particles and its influence on the strength of the manufactured boards [48]. As shown in Table 3.2, particle size is found to be 22.06 cm^3, while the average size of distance is found to be 3.65 cm^3. According to the above obtained physical and mechanical properties, the particle size and shape of olive stones used to produce the particleboard play role in overall final board strength.

Table 3.2: : Porosity, particle size, particle density, distances size and permeability and total fungi and bacteria of the particleboard (80/20).

Properties	Value
Porosity, %	14.21
Particle size, cm^3	22.06
Particle density, g/cm^3	1.39
Size dimensions, cm^3	3.65
Permeability, mD	12.70
Total Fungi account, cfu/g	Absent
Total bacteria account, cfu/g	Absent

Olive stone particles density was determined and presented in Table 3.2. Wood density is a determining factor in particleboard density. Density of olive stone particles is found to be 1.39 g/cm^3, which lower than the overall density of the particleboard (as shown in Table 3.1). The results of Barboutis and Philippou [50] indicated that increase in wood density reduced the bending strength of particleboard. The effect of wood species density on particleboard density is interdependent. Wood species of lower density than final particleboard density are required to produce high quality particleboard satisfactory [51-53].

The permeability result of the produced particleboard (80/20) is shown in Table 3.2. It is found to be 12.70 m/s. Permeability is an important physical property of wood as a porous material that determines many of its applications. It is practically impossible to show the effect of wood permeability on particleboard properties. Permeability is influenced by porosity and capillary structure of wood. However, it is postulated that highly permeable species will produce poor quality particleboard

[54].
No fungi or bacteria were found in the produced particleboard, as presented in Table 3.2. This enhances our explanation for the sustainability and good performance of the polyester resin as a binder. Polyester resin covers the surface of particleboard properly, leading to produce a strong board, which provide good bending properties and excellent resistance to the MC, WA, TS, fungi and bacteria.

4. Conclusion

Based on the results found in this study, the following conclusions can be drawn:

- The olive stones have potential to be used as an alternative to wood for producing particleboards. Although, this result was known and proved by many researches, but using a new type of binder such as polyester was remarkable. Thus, the use of an alternative materials to wood such as olive stones for manufacturing particleboards could help to alleviate the scarcity of raw material for the particle board industry and reduce the negative impact of olive stone on the environment.
- Particleboard were successfully produced from the olive stone and commercial unsaturated polyester sealer as a binder. High quality particleboards were obtained by using the ratio of (olive stone/ polyester 80/20).
- The physical and mechanical properties of produced particleboard met the European standard requirements.
- Properties such as porosity, particle size, particle density, distance size, permeability, and presence of fungi and bacteria were evaluated and had somehow influence the quality of particleboard. The additional research will be needed to confirm these findings.
- Further investigations on other performance characteristics like tensile strength, compressive strength, hardness, rate of loading, pressing conditions (temperature, time, etc.) and durability parameters are recommended.

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