Using Wheat and Barely Legs for Manufacturing Multi-Applications Composite Material

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Abstract. This research focuses on recycling agriculture waste to produce a composite material that could be utilized for different purposes. The current work is interested to study the role of the interface and the mechanism to enhance the bonding between this type of fibers with resin. This paper introduces an idea to perform chemical treatment with (Ethanol, HCl, NaCl, NaOH) solutions on the fibers to improve the adhesion. The natural fibers named (wheat and barley legs) were used as a reinforcing phase within the polyester resin as a matrix phase to prepare the composite material. The composite material was prepared by hand lay-up method with weight fraction (40%) of natural fibers. Mechanical tests of these composite such as impact, flexural strength, compression tests were carried out. It is found that the treating of these fibers with ethanol gives positive results and enhances the adhesion of the interface between the fibers and the matrix of the composite which leading to an increase in the strength of composite under effect the applied force.

Keywords: Agricultural waste, Composite material, Wood-plastic composites, Unsaturated polyester resin, Naturals fibers.

Introduction
Agricultural wastes can be defined as non-product outputs of growth and processing of agricultural products that may include material that can benefit man but whose economic amounts are lower than the cost of collection, transportation and processing for beneficial application. Assumptions of agricultural waste arising are rare, but they are generally thought of as contributing a significant role in the total waste matter in the modern world [1]. Agricultural development is often accompanied by wastes come from the irrational use of intensive farming methods and the abuse of chemicals used in cultivation, obviously affecting rural environments in particular and the global environment in general. However, agricultural wastes are generated from several sources notably from cultivation, livestock and aquaculture. These wastes are currently utilized for many applications by the ‘3R’ strategy of waste management, which means (reduce, reuse, recycle of waste) [2]. Agricultural wastes have a toxicity potential to plant, animals and humans by many direct and indirect factors [3, 4].

In the current scenario of the fast-developing world, the wastes are increasing day by day with large quantities that extensively influence the health of ecosystems and ultimately the human community. Therefore, every agro-industrial sectors have an urgent demand for the safe utilization of agro-materials by the recycling process of these wastes. Agro-industry releases a lot of waste materials that be utilized in many fields such as energy production, composting and also the textile industry. In the recent years, energy consumption and economic factor of industries need sustainability in the utilization of resources and to get the optimum yield. Agro-industrial wastes can be a good choice to meet the desires of the present-day generation without compromising the next generations, so there is
A bigger need for more interest in the depth of agro-industrial waste exploitation and recycling methodologies [5]. Agricultural waste fibers have great potential in the fabrication of composite materials due to their high strength, eco-friendly nature, low cost, availability and sustainability. Agricultural waste is one of the most important problems that must be resolved for the protection of the global environment [6].

In 2010, Aseel [7] studied the effect of chemical treatment of various solutions such as NaOH, HCl and Maleic on the mechanical properties of polyester reinforced by date palm. It was found that the bending strength and absorbed energy required for fracture increase after chemical treatment. Maleic had clear effects on the mechanical properties, the treatment gave (2.912 MPa) as a maximum value of bending and the maximum value of the absorbed energy required for the fracture was 3.4J after 18 hours of immersion while it increased when the immersion was increased to 240 hours.

In 2016, Awham et al. [8] studied the mechanical properties of a polymeric compound (unsaturated polyester) reinforced with natural fibers (jute fibers, date palm, reed fibers) as substitutes for synthetic fibers (glass fiber) and all fibers were used without chemical treatment. Jute fiber-reinforced composites showed impact strength and fracture toughness higher than that of glass fiber composite. This work aims to fabricate composite material by using some types of agriculture waste as fillers for polymer matrix. These materials could be used in different applications as well as this project maintains the environment from the negative effects of this waste by recycling process of it.

1. Experimental

1.1 Materials

The materials used to prepare the composite samples can be divided as follows:

- Matrix material: Unsaturated Polyester Resin (UPE)

  It is a transparent liquid with low viscosity, easily handled, quickly cured and has stable dimensions after solidification while the cobalt octoate acts as a catalyst to accelerate the solidification process which leads to change its color to the violet. UPE can be cured to the solid-state by adding (Methyl Ethyl Ketone Peroxide, MEKP) as a hardener. Unsaturated polyester resin "UPE" supplied by Saudi Industrial Resins (SIR) Company, Saudi Arabia. The solidification of resin starts after adding the hardener with a ratio of "2%", the accelerator is added in the percentage of "0.5%", the density of UPE "1.2 gm/cm³" [9].

- Reinforcement material

The wheat and barley legs which are natural fibers obtained directly from the plant were cut in small dimensions (1cm). Both types were used as fillers to fabricate the composite material.

1.2 Chemical treatment

The prepared fibers were treated in different chemical solutions (ethanol, HCl, NaCl, NaOH). It is vital to indicate that the concentration of (HCl, NaCl and NaOH) is (5%). The chopped wheat and barley legs were immersed inside sealed containers for two hours and then dried under the effect of the sun to become ready for use. Figures (1, 2) represent photographic images for the wheat and barley legs used as fillers.
1.3 Molding
At the first stage, molds of polymer sheet (type PVC) were prepared with 11 cm length and 6 cm width.
Hand lay-up molding method was performed to prepare the casts. The reinforcing fibers with weight fraction (40% wt.) were mixed with the matrix (UPE), and then the hardener was added to the mixture. The mixing process was continued for 8-10 minutes until obtaining the complete homogeneity. After that, the mixture was poured into the molds and left inside them until the solidification is complete. These solidified casts were removed from the molds and cured in the air at room temperature (25°C) for one day to complete the crosslinking of polymer chains. Figures (3,4) illustrate some of the prepared samples for the different tests.
Figure 3. UPE Samples before the reinforcement.

Figure 4. UPE samples after the reinforcement with (a) Wheat legs. (b) Barley legs.

2. Test Instrument
2.1 Flexural strength
The flexural strength test was performed using a 3-point bending method according to (ASTM D-790). The samples were cut with dimensions of (length 100mm, thickness 10mm, and width 10mm) by universal testing machine (UTM) from (Leybold Harris)/Germany Company. The samples were tested at a crosshead speed of 2 mm/min. The test was conducted at lab temperature. Three samples were tested for each state and the average value was recorded. The flexural strength (MPa) of composites samples was calculated using the following equation [10]:

\[
F.S = \frac{3PL}{2bd^2} \quad \text{(MPa)}
\]

Where:
F.S is the flexural strength, P: the applied load (N), L: the distance between two supports (mm), b: the width of sample (mm), and d: the thickness of the sample (mm). Also, the shear strength (τ) (MPa) was calculated by the equation [8]:

\[ \tau = \frac{3P}{4bd} \text{ (MPa)} \] (2)

2.2 Impact Test

Charpy impact test instrument made by (Testing Machines INC, AMITYVILLE, New York, ISO179) was used to determine the impact energy of the prepared samples before and after reinforcement (unnotched samples). The technique of the instrument was done through lifting the pendulum to the highest point and fixing it well, then the sample is placed on supports or anvil so that the blow of the striker is opposite to the notch. The potential energy by a swinging movement will change to kinetic energy and loses part of it in breaking the sample; the pointer of the gauge will read the energy value required to break the sample.

The value of impact strength (I.S) is calculated by the relation below [11]:

\[ \text{I.S} = \frac{U_c}{A} \] (3)

Where:

I.S: impact strength, Uc: energy of fracture (Joul) which is determined from Charpy impact test instrument, and A: cross-sectional area of the sample (mm²)

2.3 Compression Test

A compression test was used to calculate the compressive strength using a hydraulic press type (Leybold Harris No.36110) manufactured by a British company. A compression strength test (ASTM-D695) was carried out after taking off the pointed tool from the instrument. The load was applied gradually to the longitudinally fixed sample, then the reduction in the length of the sample was determined by the fixed digital vernier, the increasing of applied load continued until sampling failure. The value of the maximum load represents the ultimate compressive strength of the sample. The instrument gives the relation (P-∆L) which can be modified for obtaining the relationship of (σ-ε) to study the mechanical behavior of the material under compression loading.

By applying the following equations [12]:

\[ \sigma = \frac{P}{A} \] (4)

Where; \( \sigma \) is the stress, P: is the applied load to obtain the final failure.

\[ \varepsilon = \frac{\Delta L}{L_0} \] (5)

where; \( \varepsilon \) is the strain, \( \Delta L \): the change of sample length, \( L_0 \) = the original length of the sample.

3 Results and discussion

It is well known that the interface has an important role in the properties of composite materials as well as the roles of matrix and reinforcement, thus this work interests with this factor and its effect on the prepared composite. Chemical treatment is one of the methods to enhance the bonding between matrix and fibers. Figures (5, 6) show the values of (F.S) for UPE and its composites. It can be found that the reinforcement with agriculture waste under use lead to an increase in the flexural strength of UPE resin. The best value is 11.82 of UPE reinforced with barley legs. The chemical treatment with Ethanol and NaCl gives the optimum values of (F.S) with different increment ratios. This means that these types of treatment increase the interfacial bonding at the interface and then the values of (F.S) and shear strength will be increased as shown in Figures (7, 8). Also, the composite which has fibers treated with ethanol records the maximum value of Impact Strength as shown in Figures (9, 10), this means that the toughness of this composite is higher than UPE and its other composites. Figures (11,12) represent the relation of (stress-strain) under the compression load. It can be seen that the fibers treated with the base (NaOH) or acid (HCl) produced composite has the ductility property while
the other types of treatment gave the maximum values of compressive strength as illustrated in Figures (13, 14). The reason behind all these improvements of properties after the treatment of fibers with ethanol is related to increase the roughness of the fiber surface and then to obtain good adhesion between the matrix and fibers. Finally, this work gives an idea to invest in agriculture waste to produce a new type of composite material as a method to save the natural sources and recycling it and protect the environment from unhealthy effects resulted from the accumulation of those waste. It is worth to mention that some previous studies [13, 14, 15] were indicted to the same concept with other methods and gave this problem (pollution of the environment) great attention.

Figure 5. Flexural strength values of UPE and its composites after the reinforcement with wheat.

Figure 6. Flexural strength values of UPE and its composites after the reinforcement with barley.
Figure 7. Shear strength values of the composite as a function of the wheat composite.

Figure 8. Shear strength values of the composite as a function of barley composite.
Figure 9. The relation between the type of wheat composite and the values of impact strength.

Figure 10. The relation between the type of barley composite and the values of impact strength.

Figure 11. Stress-strain curves of wheat composite with different chemical treatments.
Figure 12. Stress-strain curves of barley composite with different chemical treatments.

Figure 13. Maximum compressive strength values of the composite as a function of the wheat composite type.
Conclusions
From this work, it can be concluded that the chemical treatment of natural fibers with ethanol leads to an increase in the mechanical properties of the composites reinforced by using these types of agriculture waste. This means that ethanol is the best chemical treatment among other treatments. Thus, this work encourages us to employ and invest in this waste for using to manufacture the wood-plastic composites.

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