Properties Investigation of Washed Sawdust/UPE Composites

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ABSTRACT:
In this study, sawdust filler from White Cham washed with distilled water in order to increase their compatibility with a polymeric matrix, and their properties were compared with unwashed sawdust used as filler for Unsaturated Polyester (UPE) resin used with three volume fractions (20, 30 and 40%). Samples of unwashed and washed sawdust were characterized by tensile and thermal conductivity. The treatment with water was effective in increasing the surface roughness, and crystallinity, thereby increasing the thermal conductivity of the washed sawdust/UPE composites. However, results showed that the addition of washed sawdust/UPE composite provided an improvement in mechanical properties of composites. The maximum percentage in improvement of tensile strength, toughness and elongation at break were (7.7, 23.1 and 4.4%) respectively at (V_f =20%) in comparison with unwashed sawdust/UPE composites. Also, the results showed an increase in volume fraction of sawdust decrease the mechanical properties and thermal conductivity.

INTRODUCTION
Recently, composite materials have successfully substituted the traditional materials in several light weight and high strength applications. The reasons why composite are selected for such applications are mainly their high strength to weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness [1]. The major fibers in use today are glass, carbon and aramid. Recently research on engineering interest have been shifting from traditional synthetic fiber composite due to their advantages like high strength to weight ratio, non-carcinogenic and biodegradability. The term natural fiber covers a broad range of vegetables, animal and mineral fibers. Availability of natural fibers and easy of manufacturing is tempting researcher to try locally available inexpensive natural fibers as reinforcement material fibers as reinforcement material in polymer matrix [2].

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Table (1) Composition of few natural fibers [1].

Natural Fiber	Cellulose (%)	Lignin (%)	Ponto sans (%)	Ash (%)
Coir	43	45	-	-
Banana	65	5	-	-
Sisal	47-62	7-9	21-24	0.6-1
Jute	41-48	21-24	18-22	0.8
Bamboo	26-43	21-31	15-26	1.7-5
Kenaf	44-57	15-19	22-23	2-5
Cotton	85-90	0.7-1.6	1.3	0.8-2
Wood	40-45	26-34	7-14	<1

The major disadvantages of natural fiber reinforced composites (NFRPCs) are the incompatibility between the hydrophilic natural fiber and hydrophobic polymer leading to formation of narrow and weak interphase. This could also lead to the non-uniform dispersion of fiber with the matrix. Interphase formed in (NFRPC) are relatively weak compared to conventional composite made of glass, Carbon or aramid due to the inherent polar and non-polar nature of fiber and polymer respectively. This can be improved only by either physical or chemical modifications of the fiber or polymer. Various surface modification have been developed in order to improve the composite,(i.e.) ; the natural fiber made less hydrophilic [3]. Alkaline treatment or mercerization is one of the best used chemical treatments for natural fibers [4]. Due to alkali treatment there is an increase in the amount of amorphous cellulose at the expense of crystalline cellulose. By this treatment there is a removal of hydrogen bonding in the network structure. Reaction which takes place during this treatment as shown below:

$$\mathbf{NF-OH^{+}+Alkaline\ treatment\ (NaOH)\ {-}{-}{-}{>}NF-O-Na+Water\ (H_2O)}$$

The alkaline treatment directly influences the extraction of lignin. Besides, the treatment also gave better surface roughness (i.e. removing foreign impurities and entanglements of fine hair) which improved the interlocking characteristics of fiber and matrix. This phenomenon has been confirmed by the alkaline treatment with two effects on the fiber:

1. It increases surface roughness resulting in better mechanical interlocking.
2. It increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites [5]. The type of alkali treatment such as KOH, LiOH, NaOH and its concentration will influence the degree of swelling and degree of lattice transformation into cellulose. Alkali solution affects the cellulose components such as hemicelluloses, lignin and pectin [6]. Abdullah (2010) [7] studied the chemical treatment with (Maleic, NaOH, HCl) solutions at a constant concentration with different times (3, 18, 72, 168, 240 Hours) conducted in natural fibers. Date palm is used as reinforcing phase in polyester matrix to form composites. Mechanical properties of these composites such as flexural strength, impact are evaluated. Maleic treatment should give a relatively good improvement. Rokbi et al. (2011) [8] focused on the study of the effects of chemical treatments of fibers by alkalization on the flexural properties of polyester matrix composite reinforced with natural fibers. The used reinforcement Alfa fiber is subjected to NaOH at (1, 5 and 10% for a period of 0, 24, and 48 to 28 ^{o}C). The main objectives of this proposed work are preparing sawdust / UPE composites to be a good mechanical properties and resistance for

environment effects, like rain and humid environments and to study the effect of washing of sawdust, volume fraction on the tensile and physical properties of the composites.

Materials and methods

Materials

The raw materials needed for manufacturing the composites are:

a. Sawdust

Sawdust was obtained from wood carpentry and wood working processes .The average granular size of sawdust used in this work was (<425µm).

Table (2) show the properties of sawdust used in this research.

Sawdust name	Type	Origin	Density(gm./cm^3)
Jam white	LE	Russia	0.21

b. Unsaturated polyester resin

Unsaturated polyester resin in the form of a transparent viscous liquid at room temperature was used as a matrix which was supplied from Saudi Arabia. It is one kind of thermosetting polymers that turn from liquid to solid states by adding the hardener to it. Table (3) depicts the properties of unsaturated polyester resins used in this research according to the product company.

Table (3): specifications of the unsaturated polyester resin.

Resin	Unsaturated polyester
Trade name	M390B unsaturated polyester resin
Color	Light amber liquid
Specific density	1.194 kg/m^3
Specific weight	1.15
Percentage of styrene	32%
Viscosity	1000 CP.
Transformation time to gel	6 min. (25°C)
Tensile strength	41.4-89.7 Mpa.
Modulus of elasticity	2.06-4.11 GPa.
Percentage of elongation	<2.6
Fracture toughness	0.6 Mpa. m$^{1/2}$
Specific heat	710-910

Hardener

The hardener used is a "Methyl Ethyl Ketone Peroxide" (MEKP). It was added to unsaturated polyester resins by 1.25 (%wt.) of resin at room temperature as shown in Fig. (2). Table (4) shows the properties of the hardener which that used in this research.

Table (4): Specification of the hardener.

Hardener: methyl Ethyl Ketone Peroxide (MEKP).

Density: 1170 kg/m^3 (25°C).
Specific gravity: 1.05 – 1.06 (25°C).
Percentage used: 1.25 (%wt.).

Cast Mold

The cast molds used for casting the composite specimens, with dimension (30 cm*21cm), have two tensile mold specimens and four molds of hot disk specimens as shown in Fig.(1).This mold was made from iron and consists of two plates. Before casting, the iron mold was cleaned to remove any dirt or dust that may be present on the surfaces. Then the mold was coated with wax for the purpose of facilitating the removal of samples.

Figure (1): Tensile and hot disk mold.

Preparation of Composites

1. Sieving process to the following granular size (<425μm) was done by using sieves shaker found in the laboratories of materials engineering department in university of technology (FRITSCH -Germany). As shown in Fig. (2).

Figure (2): Sieves shaker.

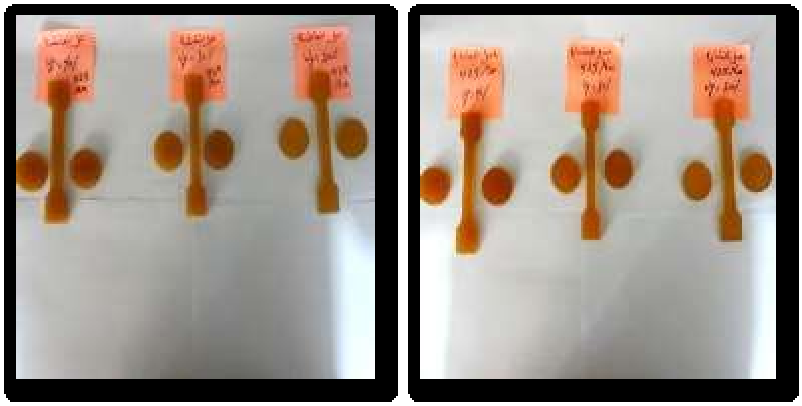
2. Sawdust was dried at (80 ˚C) for a period of three hours.

3. The weight of sawdust and resin were determined by using a sensitive balance (four digits).

4. Sawdust was washed with distilled water for 3 hours. Washed sawdust was then dried under the sun for a period of 72 hours.

They were dried at (80°C) for 3 hours to remove moisture content, and to prevent the sticking together and clogging of the fibers with each other.

5. The sawdust washed and unwashed with a distilled water at different volume fractions (20, 30 and 40%) have been mixed with unsaturated polyester by uniformly mixing for (8-10) minutes until the mixture homogeneously. Fig. (3) illustrates the composite samples before and after the treatment.



Figure(3): a. Samples before sawdust washing . b. Samples after sawdust washing.

Preparation of Samples

Washed sawdust polymer composites were prepared by mixing the sawdust with unsaturated polyester composites in a beaker. Thee volume fractions (20, 30 and 40%) were used. The following formula was utilized in preparation of the composites [9]:

$$V_f = \frac{\frac{w_f}{\rho_f}}{\frac{w_f}{\rho_f}+\frac{w_m}{\rho m}}$$

Where

W_f : the weight of fiber.

W_m : the weight of matrix.

V_f :the fiber volume fraction.

ρ_m and ρ_f : the density of matrix and fiber respectively.

Mechanical test

Tensile test:

The standard test method is as per ASTM 638-01. The length of the test specimen used is (150 mm). The tensile test is performed in universal testing machine (UTM) with a loading capacity of 50k. The tests were performed with a cross head speed of (5mm/min). For each test composite of all samples were tested and average value was taken for analysis. Toughness was calculated from the area under the curve of the scheme (stress-strain) for all samples which used in this research by using Mat. Lab. Math. Works program (Trapezoidal method). Fig. (6) shows the machine used for the test and the sample in loading condition.

Physical test

a. Experimental density of composite.

The weight of the composite samples was calculated using a sensitive balance (four digits), and the density was calculated from the following equation:

$$\boldsymbol{\rho} = \frac{Weight\ of\ the\ composite\ sample(gm)}{Volume\ of\ the\ composite\ sample\ (cm3)} \quad \ldots \text{(I)}$$

b. Thermal conductivity test of sawdust/UPE composites.

The thermal conductivity (TC) provides the thermal properties of developed composites. The test was performed on Hot Disk Thermal constants analyzer device (type: TPS 500, made in Sweden). and The samples used in this test in diameter (40 mm) and have (10 mm) in thickness. The testing machine is shown in Fig. (4).

Figure (4) Hot disk device.

Results and Discussion

Mechanical testing

a. **The effect of volume fraction on mechanical properties**

Mechanical properties such as (tensile strength), see Fig. (5), for raw and treated sawdust decreased gradually with the increasing volume fraction, where the highest value was obtained when V*f*=20%. This happens because as the sawdust content increases that's caused an increase in weak interfacial area between the sawdust and the matrix by hydroxyl group in the sawdust [12]. In other words, the increase of filler content also produced more filler end. This means that there is a considerable stress concentration points taking place by agglomeration of the filler particles. De-wetting of the polymer at interphase aggravates the situating by creating stress concentration points. The poor interfacial bonding causes partially separated micro spaces between sawdust and polymer matrix [10, 11], where, the reduction of the volume fraction of sawdust which indicates the ability of saw dust filler to impart greater stiffness to the matrix. This is due to cellulose has a high degree of polymerization and crystallinity and is responsible for strength in wood filler. This is the same reason that explains the increase in the volume fraction of sawdust filler in polymer matrix will require less strain in order to fracture as shown in Fig.(6). For toughness, see Fig. (7), where toughness values were obtained by calculating the area under the curve of the scheme (stress-strain) curve. The results showed that the toughness values decrease with increasing volume fraction of sawdust. This can explain why the higher sawdust content increases the probability of filler agglomeration which results in regions of stress concentrations that require less energy to elongate the crack propagation. In other words, increase in toughness values mean increase in impact strength of composite which is governed by two factors, first, the capability of the filler to absorb energy that can stop crack propagation and second, poor interfacial bonding which induces micro-spaces between the sawdust and the matrix, resulting in easy crack propagation [12, 13, and 14].

b. **The effect of washing of sawdust on the mechanical properties of composite**

Figs. (5, 6 and 7) show the mechanical properties of sawdust/UPE composites before and after sawdust washing.

Results showed that washing of sawdust causes a considerable effect on the sawdust or on the properties of the composites compared to untreated ones. It caused improved mechanical properties of composites, due to better interfacial adhesion between the sawdust and the matrix, imparting improvement in the mechanical properties of the composites. This indicates that interfacial bonding between the filler and the matrix has been significantly improved upon washing leading to increased stress transfer efficiency from the matrix to filler [14].

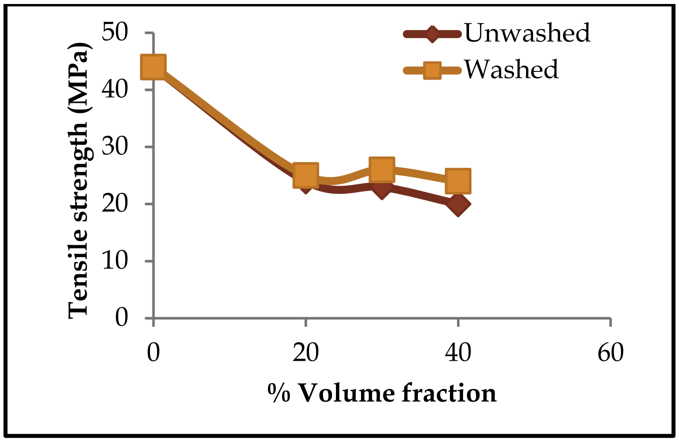
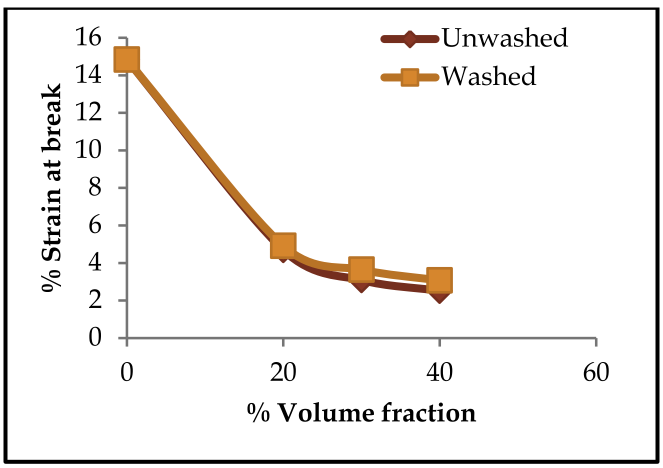


Figure (5): Tensile strength of unwashed and washed sawdust/ UPE composites.



Figure(6):% Strain at break of unwashed Sawdust/ UPE composites

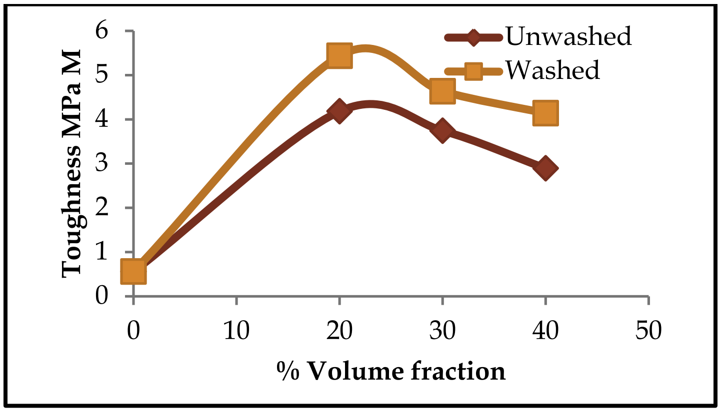


Figure (7): Toughness of unwashed and washed sawdust/UPE composites.

c. **Thermal conductivity test results**

The results of thermal conductivity were obtained from hot disk thermal analyzer constant device, see Fig. (8). It shows the thermal conductivity test results.

a. **The effect of volume fraction of sawdust on thermal conductivity of composite**

It can be seen that from Fig. (8) V_f = 20% of sawdust reinforced polymer matrix exhibit high thermal conductivity followed by 30 and 40 % volume fraction of sawdust. This is caused by the following reasons:

1- As the percent of filler increases reinforced into the polyester matrix, the heat conductivity of the composite material decreases which in turn provides the orientation of the fiber role in the matrix. This feature can be taken into consideration in designing the house- hold products / components which are subjected to heat and temperature [15].

2- Increase of the sawdust content increases the number of micro-voids in the composite caused by the bigger amount of poor bonded area between sawdust and polymer matrix. When thermal energy moves through matrix material by the vibratory motion of the atoms, and when the atoms reach to interface region, the medium will differ which will move through it, and this causes obstruction to the transition of thermal energy and thus will decrease thermal energy transmitted values and will cause drop of thermal conducting values.

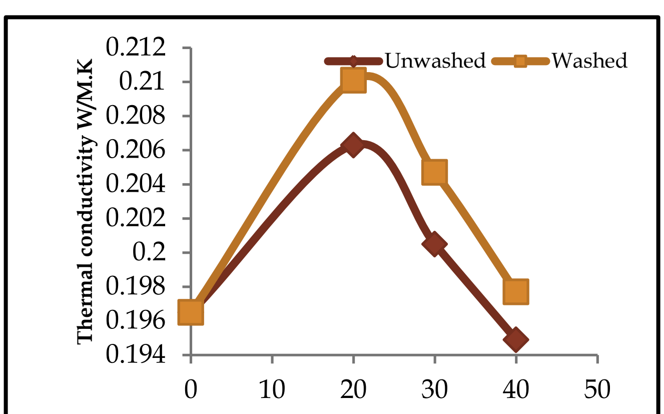
b. **The effect of washing of sawdust on thermal conductivity of composite**

From Fig.(8) thermal conductivity increased with increase of volume fraction percent for composite prepared from washed sawdust this can be attributed to the following reasons:

1- Due to washing of sawdust the cementing materials get dissolved. The inter-fibriller region becomes less dense and less rigid. The crystallinity of the washed sawdust increases because of the removal of the cementing materials which leads to a better packing of cellulose chains [16].

2- Surface area of the fiber increases due to the dissolution of lignin, hemi-cellulose and other substances associated with the fiber .This results in large area of the contact between the fiber and the matrix leading to increase in thermal conductivity [16].

3- The dissolution of many substances on the fiber surface leads to increased polarity this ultimately leads to increased polar-polar interaction with the matrix leading to higher thermal conductivity values [16].



Figure(8):Thermal conductivity of unwashed and washed sawdust/UPE composited.

CONCLUSION

The obtained results are:

1) The mechanical properties as well as thermal conductivity were improved when sawdust was washed with distilled water.

2) The mechanical and thermal conductivity decreased with an increase in volume fraction of sawdust.

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