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Sunflower Seed Hulls as a Sustainable Material in the Composites Industry: An Overview

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Abstract

Due to the abundance of sunflower by-products and the difficulty of digesting them, they constitute a large percentage of agricultural waste. Our goal here is to transform this waste into sustainable materials that can be used in many industrial applications. The multiple uses of sunflower have been discussed in our lives as a concrete stabilizer and corrosion inhibitor, in addition to its environmental benefits and mechanical, thermal and acoustic properties. Advanced studies have proven that sunflower husks are more than just waste, due to their promising future benefits when combined with other materials to become useful and environmentally friendly compounds It has chemical components that make it a material with a future in the composite materials industry, as the peel consists of hemicellulose, lignin, phenolic compounds and fatty acids, which enhances its mechanical properties when combined with polymers. Studies have also shown that combining peels with polymers such as polypropylene or epoxy will improve tensile and compressive resistance, in addition to having good thermal stability. From the above, it is clear that sunflower peels represent a vital resource for use in various industries. In this study, the uses of sunflower seed shells in various industrial applications will be highlighted, through which these applications will be developed.

Keywords: Sunflower seed hulls, alternative applications, composite materials, mechanical properties

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1. Introduction

One of the most common problems in recent years is the presence of huge amounts of waste. Therefore, there is a need to introduce sustainable materials as a contributing factor in reducing it, as they are recyclable and renewable, thus reducing waste, harmful gas emissions, and environmental pollution. An example of this is sunflower hulls, which can be used in production in many industrial fields. Global production of sunflower seeds in the 2023/2024 season reached one million tons and may exceed 1.4 million tons, according to the German (Oil World). This means that there is a large amount of sunflower hull waste, as hulls represent 21-30% of sunflowers.

Therefore, our goal is to move towards environmentally friendly compounds containing these hulls to benefit from them as fillers when combined with other materials to form compounds. Here, we touched on their industrial applications, such as their use in the production of oil, pesticides, etc Here it becomes clear that waste has benefits as it is considered a raw material used in many industries, including polymeric compounds Among the most famous wastes that are used in these compounds are rice husks, sunflower husks, and flax fibers, as they are found in abundance and in large quantities, and their cost is low and their good properties make them good for improving the properties of thermal compounds [1,2].

Sunflower is one of the most abundant crops in the world, as it is used in the production of oils, especially since the oils are produced from the extraction of seeds, which leads to the production of huge quantities of peels that are considered waste, as the peels contain lignin, cellulose, and hemicellulose, which makes them an ideal choice for use as a filler in polymer matrices. The most popular types of polymers used with veneers are epoxy and polypropylene, as they improve mechanical properties, the most important of which are hardness and tensile strength. These additives are considered non-toxic compared to other fillers such as calcium carbonate [3].

Studies have begun to expand on the possibility of introducing sunflower waste into various industries,

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including building materials, insulators in car parts, for example. One of the patents that have been obtained is in introducing sunflower husks into the manufacture of car engine covers or body linings. This means that these materials can enter into commercial applications, and their ash can be combined with polyurethane [4].

Treating sunflower husks as a sustainable material can reduce pollution resulting from agricultural waste in addition to providing an alternative option with low cost and good performance compared to traditional materials. However, there are existing challenges, namely, moisture absorption and mixing homogeneity. These challenges have directed us to many researches on chemical and surface treatments to achieve the best performance [5].

2. Sunflower Seed Hulls (SSHs) Composition

The chemical composition of ground sunflower husks is analyzed into 30-35% cellulose, 26.4% germ, 38.5% sugars, 5-30% proteins, and 5-17% fats, 2.96% of which is wax, which consists of long-chain fatty acids [6]. It also contains hydroxyproline and amino acids, as shown in Table 1. Peels are useful as a lightweight filler because they have a low density due to the presence of air spaces, and the smaller the particle size, the greater the surface area for interaction with the matrix, which improves adhesion; however, agglomerations may increase, which makes their performance poor [7]

Table 1: Chemical composition of sunflower [7]

Component	Achene (wt.%)	Hull (wt.%)	Seed (wt.%)
Proteins	10.0–27.1	–	20.4–40.0
Peptides, amino acids and other non-protein nitrogen	–	–	1–13
Polysaccharides	13–19	51–64	4–6
Klason lignin	5–7	21–26	–
Lipids	34–55	3–8	47–65
Fatty acids	–	–	–
Palmitic (16:0)	–	–	5–7
Stearic (18:0)	–	–	2–6
Arachidic (20:0)	–	–	0.0–0.3
Oleic (18:1)	–	–	15–37
Linoleic (18:2)	–	–	51–73
Linolenic (18:3)	–	–	<0.3
Tocopherol	–	–	0.07
Chlorogenic acid	1.1–4.5	–	0.5–2.4
Total minerals	2–4	–	3–4

3. Sunflower Shell Treatments and Preparations

Surface, mechanical, and chemical treatments have become essential for preparing shells before integration

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with other materials. These treatments aim to improve the mechanical bond between the two materials, clean the surface, and modify the chemical structure.

3.1. Mechanical and Physical Preparation

The physical processing steps begin with washing the shells with distilled water to remove impurities and oils. This is followed by a drying process to reduce the moisture content to 5% or less. This is followed by grinding to obtain the desired particles. A study by Cosereanu and colleagues indicated the effect of particle size on mechanical performance. Small particles (less than 0.5 mm) have a greater curvature and relatively high density. [8] Large particles, on the other hand, lead to porosity and reduced internal bonding, which reduces the strength of the material.

3.2. Alkali Treatment

Alkali treatment with NaOH is an effective method for improving the compatibility between the two materials. This treatment dissolves a portion of the waxy materials, lignin, and hemicellulose, leading to greater surface roughness and activation of hydroxyl groups on the surface. These alkali-treated materials have the ability to form hydrogen bonds with polymers, increasing mechanical adhesion between the phases. [9] demonstrated that treatment with a 5% concentration for 2 hours improved tensile strength by 25% compared to untreated fibres.

3.3. Silane Treatment

Silane compounds contain groups such as epoxides and amines, which act as chemical bridges between the husks and the polymer, leading to chemical surface compatibility. The results of a study [10] showed that treating sunflower husks with silane-amine compounds improved the composite's thermal properties and raised Tg due to improved surface bonding. Additionally, the shrinkage rate and thermal deformation of treated samples decreased compared to untreated samples.

3.4. Acetylated Treatment

Acetylation is an important chemical method for reducing moisture absorption. The hydroxyl groups found in cellulose are replaced with less polar acetyl groups, making the husks more water-resistant. A study [11] showed that fibers treated with this method retain their stiffness for extended periods in humid environments. Acetylated treatment also improves the flexural and tensile strength of sunflower fibers used in damar composites by over 30%.

3.5. Coating with Bio-Resins or Natural Polymers

Using natural resins, such as damar or modified sunflower oil, to coat the husks before incorporating them into the matrix reduces water absorption and increases adhesion between the components, acting as a barrier layer. In a study [2], the impact resistance of composites using damar-coated husks increased compared to a reference sample. This demonstrates the effectiveness of the coating in improving stress distribution within the composite structure.

4. Valorisation and Potential Applications of Sunflower seed hulls (SSHs) in Industry

The peel of sunflowers is considered waste because it is difficult to digest in human and animal food, although it has many benefits because it is a sustainable material.

4.1. Corrosion Inhibitor

Since sunflower shells contain heterogeneous oxygen and nitrogen atoms, in addition to the presence of aromatic rings, these shells were used as corrosion inhibitors in an acidic medium in which steel was tested and succeeded in inhibiting corrosion, as the inhibition efficiency reached 98%, which led to a decrease in corrosion values by 55-60% [12]. Others studied the preparation of sunflower shell inhibitors using soaking, drying and grinding, where the shell powder was soaked with methanol and evaporated when the shells absorbed it, and thus these shells precipitated in the form of oil, and thus these inhibitors work as a corrosion-preventing layer [13].

4.2. Concrete Stabilizer

Some researchers studied the replacement of cement in concrete with sunflower seed husks. The husks were burned after drying and sifting to a particle size of 75 μm. After that, they were burned again and mixed with different proportions of cement replacement, then poured and cured for a week. After conducting several tests, including absorption, flexural strength, and compressive strength, it was found that the compressive strength and flexural strength improved to certain percentages [14]. Others have studied adding the ash of these shells to the concrete mixture, which affects its structure, such as porosity, load resistance, etc. [15]. They can also be used as additives to bricks or concrete to modify their properties, but some formulations affect the interaction with cement if there is silica or mineral components. This is considered a challenge. This problem can be addressed by partial burning before use [16].

4.3. A Source of Antioxidants

Sunflower seeds contain phenolic compounds that are extracted using sodium disulfite and ethanol solutions as antioxidants. Methods have been used by some researchers to evaluate the activity of these antioxidants such as ABTS and DPPH. They also studied the potential of the seeds for biodegradability. It has been shown to be antimicrobial and antibacterial. It has also shown protection of DNA from damage. Due to the presence of chlorogenic acid, it is anti-inflammatory and anti-diabetic. Therefore, sunflower is used as an antioxidant [17].

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4.4. Additive to Cultivation Media

Reusing secondary materials and introducing them into agriculture has become popular in recent years, and the use of sunflower husks is one of them. The biodegradation of fungal compounds after cultivation in ground husks has been studied. Others have studied the cultivation of edible mushrooms in sunflower husks, as well as medicinal mushrooms, with or without the addition of supplements such as Cu or Zn. This cultivation in sunflower husks has achieved good success, yielding a high-quality crop [18].

4.5. Preparation of Composite Materials

A study was conducted on this topic. Samples were prepared by hand-casting them into a glass mold of specific dimensions. Paraffin was used to ensure the material would not stick to the mold. The composite consisted of a mixture of sunflower shell powder and polyurethane resin. Different particle sizes were used in five different ratios, with a hardener added at a ratio of 3:1. The filler was mixed slowly with the resin to prevent air bubbles from forming. The hardener was added to the mixture while stirring continuously. The mixture was poured into the mold and left at approximately room temperature for a full day. It was then left for three days to fully polymerize. The samples were then cut to the required dimensions for testing. It was found that tensile strength increased with increasing sunflower shell particles, along with increased resistance to axial loads and an increase in the modulus of elasticity. However, the problem lies in increased water absorption, which weakens the adhesion between the matrix and the reinforcing material. [18].

4.6. The Impact of Using Agricultural Waste in Promoting Environmental Sustainability and Biofuel Production

The Impact of Using Agricultural Waste in Promoting Environmental Sustainability and Biofuel Production: Agricultural waste is important for the production of biomaterials and energy because it contains significant amounts of cellulose, lignin, and other elements, which are then converted into valuable compounds. A study conducted by researchers [19] showed that pretreatment of agricultural waste, such as corn stover, rice husks, sunflower husks, and others, improves the efficiency of bioconversion to bioethanol. This reduces the environmental impact associated with industrial processes. The study also examined how the use of this waste reduces carbon dioxide emissions and enhances the agricultural economy. Another study [20] focused on converting lignocellulosic mass into biohydrogen using microbial biodegradation techniques. It was found that combining thermal treatment methods with enzymatic hydrolysis increases production efficiency by a certain percentage, making it an environmentally friendly technology as an alternative to fossil energy sources.

5. Environmental Benefits of the Sunflower By-Products

Due to the chemical composition of sunflower husks and their good content of phenol and protein, it has been shown that there are environmental benefits to sunflower by-products.

5.1. Bio-Oil Production

Since sunflower seeds are oily and have medical, health and nutritional benefits, and because they contain dietary fiber, proteins, phenolic acids and many compounds, sunflower oil may be obtained after processing the seeds to extract the oil from them and use it in our daily lives. In 2017, its total production reached 16.1 million tons. Its main composition is linoleic acid 59%, oleic acid 30%, 5% palmitic acid and 6% stearic acid according to [21] There is an environmentally friendly method, which is hydrothermal treatment, because it uses water and chemicals without other additives. Oils produced by pyrolysis differ from oils produced from raw materials, as oils produced by pyrolysis target waste issues.

5.2. Bioinsecticide and Fertilizer

Demineralization by pretreatment is important for the production of bio-oil, which is rich in furfural, responsible for bio-pesticidal activity. Ninkov studied the treated sunflower husks as fertilizing agents, and the analysis results showed a decrease in both water-soluble phosphorus and potassium, which enhances plant growth [22]. One of the first studies to discover the use of peels in the production of pesticides was the presence of bio-oil enriched with furfural and biochar [23].

5.3. Adsorbent

Adsorption is an important technology for water filtration and purification. One of its advantages is its low cost. Given that some types of adsorbents, such as activated carbon, are characterized by their high cost, by-products are used as an alternative, as they are considered low-cost and renewable waste. Among these by-products is sunflower, which has been used as adsorbents to purify water from harmful toxic substances. The absorption values of sunflower adsorbents ranged between 3.28 and 252.52. These are good values for working as adsorbents. Others have studied the use of sunflowers as adsorbents to remove nitrates from water. This has been tested and excellent results have been shown for nitrate absorption at 12.98 mg [24].

6. Mechanical, thermal and acoustical characterizations of Sunflower Seed Hull (SSH)

Has studied (thermal, mechanical and acoustic properties of sunflower when mixed with chitosan and compared to other compounds or insulation materials. [25]. It has been shown that mixing the granules of sunflower legs with the bonding material, which is chitosan with (1-2 %) steak acid with mixing the mixture for 5s. The test using Euler's equation to avoid dentation when the pressure of the

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mixture ratios were 30 g of sunflower stem spores and 2 g of chitosan with 50 ml of acetic acid and the applied pressure was 32 kPa. A thermal test was also carried out using the hot wire method at 21 °C and 40% humidity. The tensile test was carried out with a load of 5 KN and the analysis was based on the stress-strain curve.

The acoustic test was carried out in an impedance tube where the useful frequency is between 500-6400 Hz. The results showed that both the mechanical and thermal performance improved for the better and the thermal conductivity reached 0.06, while no significant improvement was observed in the acoustic insulation performance It was mentioned in another study that the smaller the size of the husk particles, the higher the tensile strength, modulus of elasticity and water absorption due to the increase in porosity. The particle size also affects the epoxy compounds mixed with the husks in terms of bending, hardness and tensile strength, as the best performance is with small husk particles [26].

The bending resistance and internal bonding strength are affected by the type and quantity of adhesive in the application of panels in which sunflower husks are used [27]. The presence of clumps leads to early failure due to weak adhesion between the husks and the matrix. The most important thing in thermal properties is testing the thermal conductivity, thermal stability and thermal conductivity. There is a study that turned the crusts into thermal products, which revealed that the crusts can withstand heat and can work as thermal insulators because they are originally low in thermal conductivity [28].

7. Composite membrane manufacturing

Researchers have studied the production of a composite membrane made from sunflower husks and polyethylene when treated with sodium hydroxide, as shown in Fig. 1 [29].

1. Surface structure:

It is not smooth like pure polyethylene but rather has bumps and fine grains that reflect the presence of plant husk particles. This roughness indicates that the material is not 100% homogeneous, but rather contains organic regions distributed within the polymer matrix.

2. Filler distribution

Plant particles appear as patches/granules embedded within the polymer. If they are homogeneously distributed, this indicates a successful blending and mixing process, which improves mechanical properties. However, if voids or aggregates are present, this may lead to weak areas in the membrane. This is a common occurrence in studies of polymers reinforced with agricultural waste [30,31].

3. Adhesion between the polymer and the filler

By SEM, it is possible to observe if there are gaps between the husk particles and the polymer matrix. Gaps indicate poor bonding, while good adhesion creates a cohesive surface. In a study [32], they showed that chemical treatment (NaOH) improved bonding because removing certain components (such as lignin and impurities) from the husks made the surface more reactive, enhancing its adhesion to polyethylene. This was also confirmed by a similar study on reinforcing polyethylene with plant waste [33].

- The image shows that the addition of Sunflower Husk Particles produced a rougher surface compared to pure polyethylene.
- The presence of acceptable cohesion between the filler and matrix means that the membrane can have better mechanical properties (relatively higher tensile strength) if the ratio is balanced.
- However, any gaps or aggregates visible in the SEM explain the decrease in properties when adding very high husk ratios.

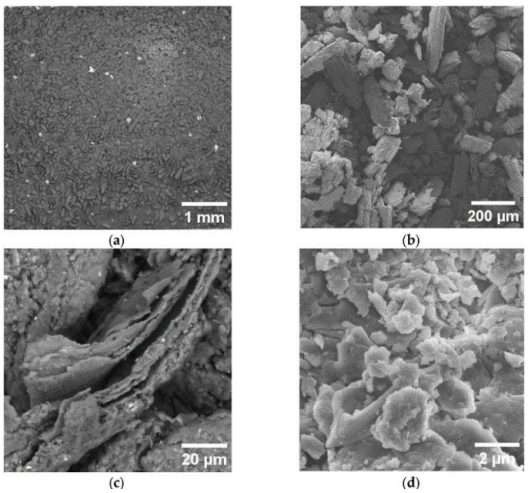

Fig. 1 Shows SEM images of the surface of sunflower seed husk particles after modification at magnifications, (a) 5000 µm (b) 1000 µm (c) 100 µm (d) 10 µm. [29]

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8. Conclusion

Discussing this topic led to the importance of resorting to recycling sunflower seeds, given that they have been used in many applications and have been tested mechanically and thermally, and because of their abundance and low cost, they have been chosen as a suitable alternative to other expensive compounds Combining sunflower husks with polymers reduces reliance on non-renewable materials, and their value is evident in the production of oil and pollutant-absorbing materials. This makes them important in the economy, but there are still challenges in absorbing moisture, and there are matters that still need extensive study, including the possibility of recycling them, this is what will be studded in future research.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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