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1. Introduction

The natural composites are classified mainly in three biomaterial categories: green composites, hybrid biocomposites, and textile biocomposites. In recent times, biological materials have become essential materials for the construction and automotive industry. Natural fibers and particles have been already used in various types of materials such as plastics, concrete, and textile products as strengthening part of the fiber/matrix combination. These composite materials have very good mechanical thermal and acoustical properties; therefore, they have been used in various engineering applications. The wood-plastic composites (WPCs) have been used in many application areas as automotive, constructions, marine, electronic and aerospace areas instead of fiber glass composites and steel materials. As a wood derivative, hemp fibers have been used in generating thermoplastic matrix composites. These composites can find its application area in the following five sectors: the first area is to modify some parts of the internal and external automobile structures and electric cars. The second area is to obtain strong cementation in building construction. Another area is the production of durable clothes for army suppliers. The fourth one is to produce small electric hand tools and the last one is to build supercapacitors in carbon nanosheets which are as strong as graphene. This review covers a general overview of the preparation phase (chemical procedures), test techniques (experiments) and results, and conclusions summaries (the gaining) of current studies on hemp fiber plastic composites. The data obtained by literature search of the 63 publications have been shown in Table A1 [1–63].

2. Scientific researches about natural hemp composites

The quality of the produced compounds depends on the elastic constants of the natural fibers used in the composition and the shape and size of the fibers as well as the properties of the matrix material. Factors influencing the strength of the composite material can be listed in more detail as follows: Morphic structure, chemical composition, density, thickness of wood plastic...
composites (WPCs) as well as the type and amount of bonding agent and fiber percentage used in composite material. According to the literature, the usage rate of the herb composites (WPCs) in the industrial areas is stated as follows: in the field of aviation 1%, in the area of consumer products 8%, in various fields 8%, in the field of electronics 10%, in the maritime field 12%, in the construction industry 26%, in the automotive sector 31%, and miscellaneous 4% [46].

2.1. General properties of natural fibers in plastic composites

Interface conditions have been influenced at the nanoscale level depending on the thermal sensitivity and the water content of the green materials in the process of preparing composite material from natural fiber embedded in a polymeric matrix. The natural fiber and the polymeric matrix interface features and the cell wall structure of the natural fibers influence: (i) the mechanical properties, (ii) the durability, and (iii) the recyclability of the

| Test type | Experimental methods | Test type | Experimental methods |
|-----------|----------------------|-----------|----------------------|
| 1         | Accelerated weathering testing | 20        | Microscopy (optical light microscope, SEM, confocal laser scanning microscopy (CLSM)) |
| 2         | Acoustic emission monitoring | 21        | Moisture absorption method |
| 3         | Biodegradability test | 22        | Nanoindentation test |
| 4         | Chemical techniques | 23        | Nondestructive longitudinal and flexural free/forced vibration test |
| 5         | Compression test | 24        | Sample thickness measurements |
| 6         | Compression molding | 25        | Shear testing |
| 7         | Density measurements | 26        | Single-fiber pullout test |
| 8         | Diffusion measurement | 27        | Static/dynamic/vibration-damping testing |
| 9         | Differential scanning calorimetry (DSC) | 28        | Surface energy and dynamic contact angle measurement |
| 10        | Digital images recording | 29        | Taguchi’s technique |
| 11        | Fatigue testing | 30        | Temperature field measurement |
| 12        | Flexural test | 31        | Tensile testing |
| 13        | Fourier transform infrared spectroscopy (FTIR) | 32        | Thermal techniques (annealing) |
| 14        | Fracture toughness | 33        | Torsion test |
| 15        | Growth test | 34        | Vicat test |
| 16        | Impact test | 35        | Water absorption and volume change test |
| 17        | Liquid chromatography (HPLC) | 36        | Weibull statistics |
| 18        | Mass spectrometry | 37        | X-ray microtomography |
| 19        | Microbond test |

Table 1. The list of performed experimental studies on natural fiber plastic composites.
industrially produced green composites. The literature survey results both on mechanical and chemical properties of the hemp fiber plastic composites and their usage in industrial areas have been listed in Table A1. Table A1 gives brief information on: (i) the aim of this research, (ii) the experimental methods used in compound production, and (iii) conclusions according to the obtained results. In Table A1, 63 research articles have been listed according to the fiber/matrix material characteristics. Of these 63 studies, 59 were related to fiber composites, while only 4 of them were related to particle composites. In the literature survey, the investigations were carried out in two groups: (a) original research articles and (b) review articles. The 52 articles of the 63 articles were original research articles. Researchers performed a series of experimental studies to obtain the information about the following main subjects related with the natural fibers and plastic matrices in biocomposites: (a) mechanical elastic constants, (b) strength, (c) failure stages, (d) the effect of moisture content, (e) biodegradability, (f) fiber matrix interface stresses, (g) cell wall properties, (h) hardness, and (i) the effect of chemical processing. The statistical information according to the performed experiments has been presented in Table 1 and Figure 1. The basic tests have been performed by tensile loading (23%) to obtain the Young’s modulus and tensile strength of the composite material in addition to the microscopic visualizations (optical light microscope, SEM) (17%) to observe deformation patterns of the loaded specimens in micro and nanoscales.

![Figure 1](http://dx.doi.org/10.5772/intechopen.71477)

Figure 1. Curve represents the hemp fiber plastic composites and percentage distributions of the performed experimental studies in literature survey.
3. Conclusions

The results obtained by the literature search were summarized below and very important keypoints about fiber and matrix compositions, the physical features of the hemp fibers and hemp fiber plastic composites were emphasized. The main results were as follows.

(1) It was found that tensile strength, Young’s modulus, and impact strength of the hemp short fiber reinforced composites were increased in proportion to the increase in fiber content. 

(2) Flexural strength of the hemp fiber reinforced polylactide and unsaturated polyester composites were found to be decreased with increased fiber content. Additionally, flexural modulus was found to be increased in proportion to the increased fiber content. 

(3) The impact energy required to damage hemp composites was higher than in conventional laminates. 

(4) The deformation characterization of hemp/epoxy composites has been developed in three stages. 

(5) It was shown that natural fibers when compared to flexible fibers showed scattered and lower mechanical properties. 

(6) Minor variations in terms of the mechanical properties of the woody hemp core (WHC) cell walls were investigated at the nanoscale level. 

(7) The fiber/polymer interface was modified by using two functionalized chemical procedures simultaneously, and in this way, better adhesion capacity was obtained at the interface (between hemp fibers and thermoplastic matrix).

[Figure 2. The comparison for the hemp fiber, polypropylene and polyester resin materials according to the tensile strength and Young’s modulus.]
Variations obtained using nanodrawing tests showed slight variation in the cell wall properties, while the polymer composition was more variable. Hemp fiber composites showed a greater resistance to crack formation and growth than glass fiber composites, although they had lower fatigue strength. Testing natural fiber composites under low impact loading provides important information on the failure mechanisms of hemp (*Cannabis sativa* L.) fiber epoxy composites.

Characteristics of the deformed material such as matrix cracking, delamination, fiber breakage, and fiber pullout phenomenon were examined microscopically [15, 16, 25, 44, 58]. In literature, there were rare experimental studies on the characteristic determination of hemp cell wall structures. In a study on this subject, minor variations at the nanoscale level related to the mechanical properties of the cell wall have been identified [19]. The comparison between the hemp fiber-polypropylene matrix and hemp fiber-fabric reinforced polyester resin in terms of material properties were summarized in Refs. [30, 46, 47, 60, 62]. The graphical results on mentioned values were given in Figure 2.

### A. Appendix

| Author, Reference number | Research subject | Testing methods | Results |
|--------------------------|------------------|-----------------|---------|
| Moyeenuddin et al. [1]    | Mechanical properties of hemp fiber reinforced composites | Tensile testing, impact testing, and fracture toughness testing | Tensile strength, Young’s modulus, and impact strength |
| Summerscales et al. [2]   | A review to obtain high quality fiber | Growth, harvesting, and fiber separation techniques | A review |
| Summerscales et al. [3]   | Properties of natural fiber reinforced composites | Microscopy, mechanical, chemical, and thermal techniques | A review |
| Pickering et al. [4]      | Plane-strain fracture toughness (KIC) | Heat treatment “annealing” | KQ of random short hemp fiber reinforced (PLA). |
| Sawpan et al. [5]         | Flexural strength and flexural modulus | Flexural test | Flexural strength of the composites increased with fiber content |
| Summerscales et al. [6]   | The rules-of-mixture (effects of porosity) | Weibull statistics | A review |
| Newman et al. [7]         | Wood fiber reinforced in polypropylene | Tensile testing | Micromechanical models predicted the tensile modulus |
| Rachini et al. [8]        | Characteristics for hemp fibers and thermoplastic matrix | Chemical process, tensile and impact testing, and SEM | Organosilane coupling agents affecting the tensile strength |
| Michel et al. [9]         | Failure modes of (PHB) and PHB-hemp fiber reinforced composites | Tensile testing and accelerated weathering testing | Changes in the mechanical properties |
| Vasconcellos et al. [10]  | Typical tests of a woven hemp fiber reinforced epoxy composite | Tensile and fatigue testing, optical microscopic, X-ray micro-tomography, | Three stages of damage mechanisms |
| Author, Reference number | Research subject | Testing methods | Results |
|--------------------------|------------------|----------------|---------|
| John et al. [11]         | The classification of composites | temperature field measurement, and acoustic emission monitoring (AE) | A review |
| Ude et al. [12]          | A summary about *Bombyx mori* woven silk fiber and its composite | – | A review |
| Misnon et al. [13]       | An overview of describing natural textile materials | – | A review |
| Shah [14]                | Ashby-type materials selection charts | Tensile testing | A review |
| Caprino et al. [15]      | Natural composites in applications | Impact loading, optical microscope, penetration test, and indentation test | An higher impact energy is necessary to obtain damage inside hemp composites |
| Kim et al. [16]          | The effect of pH on the tensile properties | Tensile testing, microbond test, SEM. | The fracture toughness of the composites |
| Shah et al. [17]         | The mechanical properties of silk | Charpy impact testing and short beam shear testing | Silk fiber composites (SFRPs) offer advantages |
| Marrot et al. [18]       | The mechanical properties of hemp fibers (Fedora 17) | Tensile testing, nanoindentation test, and X-ray diffraction test | Plant fibers showed low mechanical properties |
| Beaugrand et al. [19]    | The micromechanical properties (WHC) cell walls | Nanoindentation test, density measurements, flexural tests, and biochemical analysis | The mechanical properties of the cell walls |
| Salentijn et al. [20]    | Fiber hemp (*Cannabis sativa* L.) breeding programs | – | A review |
| Liu et al. [21]          | The mechanical properties of hemp fibers | Tensile testing, chemical analysis, microscopic tests, and digital images recording | Less variable and high strength fibers |
| Almusawi et al. [22]     | The particle sizes, the moisture content, and the heating temperatures | Three point flexural testing and tensile testing | The importance of particle size |
| Christian et al. [23]    | Diffusion properties and mechanical properties | Tensile testing and diffusion measurement | Larger change in properties of the hemp/cellulose |
| Yan et al. [24]          | The effect of fibers (MAPP) | Tensile testing, flexure testing, and impact testing | (MAPP) improved the fiber-PP adhesion |
| Lu et al. [25]           | The improvement of the fiber-matrix interface by 5 wt% NaOH treatment | SEM and Fourier transform infrared spectroscopy | Mechanical and thermo-mechanical properties |
| Shah et al. [26]         | Investigation of the mechanical testing cases | Tensile testing and fatigue testing | Flax is a potential structural replacement to E-glass |
| Kabir et al. [27]        | The tensile properties of single hemp fibers | Optical microscopy (OM) measuring and tensile testing | The tensile strength of chemically-treated fibers |
| Author, Reference number | Research subject | Testing methods | Results |
|--------------------------|-----------------|----------------|---------|
| Vasconcellos et al. [28] | The resistance for low velocity impact of hemp/epoxy | Tensile testing, impact testing, fatigue testing, acoustic, emission (AE) monitoring, and microscopic observations | A decrease of the residual tensile strength |
| Landro et al. [29] | The characteristics and performance of a thermoset bioepoxy resin | Static/dynamic/vibration-damping testing | Laminated composites reinforced with hemp fibers |
| Sukmawan et al. [30] | Steam exploded bamboo (SEB) fibers | Tensile testing | The tensile strength of alkali treated bamboo fiber |
| Vukcevic et al. [31] | The optimal production of hemp fibers (ACh) | SEM, mass spectrometry, and temperature programmed chemical reaction | High efficiency in pesticides removal on hemp fibers |
| Kord [32] | Mechanical properties of (PP)/hemp fiber | Tensile and impact testing, and X-ray diffraction (XRD) testing | The PP/hemp fiber composites |
| Kavianiboroujeni et al. [33] | The effects of different design parameters | Three-point bending flexural testing, and SEM | Hemp content parameters |
| Alhuthali et al. [34] | A new infiltration method | Three point bending testing, impact testing, and fracture testing | The development of new composite materials |
| Saikia [35] | The mechanical properties of the composite | SEM, the gravimetric moisture absorption method, and three point bending test | The thermodynamic parameters of the absorption process |
| Dalmay et al. [36] | The effects of adding natural fibers | SEM, Vicat test, and three point bending testing. | Flax, lowered the crack propagation |
| Wretfors et al. [37] | The improvement of fiber-matrix interactions | Tensile testing, SEM, (HPLC), (CLSM) | Getting a better fiber distribution |
| Erchiqui et al. [38] | The mechanical and structural properties | – | The variations of the process parameters |
| Elaati et al. [39] | The distribution and effects of the interfacial shear strength (IFSS) | Tensile testing | The hemp fibers had lower tensile properties |
| Fotouh et al. [40] | The effect of strain rate | Tensile testing, (SEM) | The mechanical behavior is dominated by the matrix |
| Han et al. [41] | Surface treatment effects | (FTIR), moisture analysis, (DSC), and Tensile testing | Improvement of the thermal stability of hemp fiber |
| Sawpan et al. [42] | Mechanical properties of chemically treated random short fiber | Impact testing and fracture testing | Mechanical properties of (PLA) increased |
| Mantia et al. [43] | Polymer composites filled with natural-organic fillers. | – | A review |
| Sawpan et al. [44] | The interfacial shear strength (IFSS) | Optical light microscope, Fourier transform infrared spectroscopy (FT-IR), scanning electron microscope (SEM). | (IFSS) of PLA/hemp and UPE/hemp fiber samples |
| John et al. [45] | Cellulosic fiber reinforced polymeric composites | – | A review |
| Ashori et al. [46] | Wood-plastic composites (WPC). | – | A review |
| Author, Reference number | Research subject | Testing methods | Results |
|--------------------------|------------------|----------------|---------|
| Koronis et al. [47]      | Green composites | –              | A review |
| Schirp et al. [48]       | Wood and hemp fibers | Tensile testing, three-point bending test, Charpy impact testing, water absorption and volume change test, and dynamic mechanical analysis test. | Flexural strength values. |
| Wretfors et al. [49]     | Reinforcing wheat gluten (WG) plastics with hemp fibers | Compression molding, tensile testing, SEM, and sample thickness measurements | Hemp fibers in composite material |
| Ismail et al. [50]       | The influence of drilling parameters and fiber aspect ratios | Taguchi’s technique | The delamination factor and surface roughness of drilled holes |
| Jalili et al. [51]       | The acoustic parameters of three different polyester composites | Non-destructive longitudinal and flexural free/forced vibration tests | The results obtained from longitudinal free vibration method |
| Kakroodi et al. [52]     | Hemp fibers and particles, in hybrid composites | Tensile, flexural, three-point bending, torsion and impact tests, and SEM | The mechanical properties of the composites |
| Ochi, et al. [53]        | The hemp fiber reinforced biodegradable plastics | Tensile testing, SEM, and biodegradability test | The tensile strength of the composites |
| Shahzad et al. [54]      | The effects of alkalization surface treatment on hemp fiber properties | Tensile testing, impact testing, fatigue testing, and SEM | The tensile properties, interfacial shear strength |
| Shahzad et al. [55]      | The fatigue properties of nonwoven hemp fiber | Tensile testing and fatigue testing | The hemp fiber composites with less fatigue sensitivity. |
| Terzopoulou et al. [56]  | The study about fully biodegradable (“green”) composite materials | Tensile testing, impact testing, Fourier transform, infrared spectroscopy, X-ray diffraction, differential scanning calorimeter, and scanning electron microscopy | Tensile and impact strength |
| Toupe et al. [57]        | Phase compatibilization of four mechanical properties | Tensile testing, flexural testing, and impact testing | Fiber concentration parameter |
| Kabamba et al. [58]      | The effect of hemp fibers. | Shear testing and elongation test. | The rheological properties |
| Muneer [59]              | Hemp fiber reinforced wheat gluten (WG) composites | Biodegradability test using the ASTM D5988-03 standard | A review |
| Scutaru [60]             | The mechanical properties hemp fiber composites | Tensile testing | The measured Young’s modulus distribution |
| Gassan [61]              | The elastic properties | Analytical solution, SEM. | The experimental data and calculations |
Table A1. Literature survey: the main characteristic properties of the hemp fiber reinforced epoxy composites.

| Author, Reference number | Research subject | Testing methods | Results |
|--------------------------|------------------|-----------------|---------|
| Shahzad [62]             | Physical and mechanical properties of hemp fibers | Tensile testing, thermal characterization, single fiber pull-out test, surface energy and dynamic contact angle measurement, and SEM | The tensile strength, Young's modulus, and surface energy |
| Niyigena [63]            | The impact properties of hemp concrete | Compression test, impact test | Mechanical behaviors of hemp concrete material |

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