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Application and Properties of Chicken Feather Fiber (CFF) a Livestock Waste in Composite Material Development

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Abstract
Rapid advancement in the field of Natural and biomaterial composites have directed in the enlargement of various innovative materials and products which are eco-friendly as well as biodegradable. Importance is being given by many researchers to the natural plant fibers like bamboo, coir, jute, sisal, cotton, wheat straw and wood etc. Here the review based information is pileup to get the wide-ranging information about the Mechanical properties, Physical properties, Thermal properties etc. of Chicken Feather Fiber (CFF) based Composites. Also the application and making of different CFF based composites for industrial application and the use of CFF as a matrix, as a reinforced material and as a particulate. The efforts are made to focus on advanced technology and uplift the use of CFF as a Natural Biomaterial which is at present serve as a waste of poultry industry and to enhance the use of livestock waste in a sustainable growth of the earth and healthy environment.

Keywords- Composites, Chicken Feather Fiber, Natural Fiber, Biodegradable, Properties.

1. Introduction

Environmental concerns have always appreciated the study to substitute synthetic materials with the diverse range of naturally occuring materials. Natural fibers have always attracted scientist’s attention due to their benefits from the ecological standpoint, but almost all the exploration has been focusing on cellulose from diverse vegetables. Many scientists have engrossed their research work on expending materials from nature. Composite material can be defined as a mixture of material with two or more unlike constituents, which are differing in forms, insoluble in each other, chemically inhomogeneous and physically distinct (Gupta, 2006). One such illustration is the operative use of cellulose achieved from plants that have been explored for several decades (Brostow et al., 2010). Presently, the large sum of chicken feather disposed by various poultry based industry as a waste is a strict solid-agricultural dispose problem.

Tang et al. (2012) clearly defined 2 kinds of biopolymers: First from living creatures and another which is essential to be polymerized but are biodegradable and come from renewable resources.

Keratin fibers are strictly Nonabrasive, low density, biodegradable, renewable, eco-friendly, insoluble in organic solvents, hydrophobic behavioral, warmth retention and cost effective too. These properties make it a suitable material for using in high structural reinforcement in polymer based composites (Meyers et al., 2008). However, only very few are related to keratin fibers and bio-polymers (Griffith, 2001; Gassner et al., 1998).

Chicken feathers contain 91% protein (keratin), 1% lipids, and 8% water (Fraser and Parry, 1996). It is largely composed of glycine, cysteine, proline, and serine, and contains almost no histidine, lysine, or methionine (Shalwan and Yousif, 2013). The amino acid sequence of a CFF is almost as contents of other feathers (Jagadeeshgouda et al., 2014).

2. Background of CFF

CFF are deliberated as an unwanted product from the poultry production. Large amount of waste feathers generated and disposed each year by the poultry processing plants results in severe solid waste trouble (Bartels, 2003).

Feathers are greatly ordered, hierarchical branched structures (shown in Figure 1), that is standing among the most complex of keratin structures establish in vertebrates.

3. Washing and Cleaning of CFF

For casting of biocomposite by using CFF as fiber it has to be cleaned first in order to remove the dirt and other unwanted particles present on the feather surface. Feathers are generally washed with running water and partial C_2H_5OH to obtain clean, sanitized and odor free feathers. The fibers were obtained conferring to a patented process by Barone and Schmidt (2005). Ethanol has been shown by Griffith (2001) to remove a fatty layer from the surface of feathers, and the removal of this layer.

The efforts were made in the G. B. Pant University’s dynamics lab to clean the chicken feathers using water and hair drying shampoo. After completely washing the feathers two to four times in a bucket it was then kept in an open atmosphere for 24 hours. Results obtained showed complete dry, clean and less sticky appearance. Thus the cost effective method was produced but it has lesser effectiveness as compared to other chemical processes.

Shalwan and Yousif (2013) studied the significance of alkaline treatment on different natural fiber and the different polymer matrix and found that TS, wear strength of treated fibers was better than untreated (Subramani et al., 2014). So, the concept of using clean feathers came into existence in order to achieve better results.

Jagadeeshgouda et al. (2014) also explained the washing method of CFF in order to remove dirt and moisture content from the feather. The fibers were cleaned in running water and dried, and then the solution was prepared by adding 6% Sodium Hydro Oxide to distilled water. Later, the mechanically treated and dried fibers were constantly soaked in the solution for 3 hrs and then washed again properly in running water. The CFF were then dried for ten hours under the natural light. Chemical Treatment (using NaOH) helps to remove moisture content from the fibers thereby improving strength of the materials (Reddy et al., 2014). We can also use KOH for the same purpose.

3.1 CFF as a Reinforced Material

Technologies for processing CFF and particulate (quill) fractions have been introduced and patented (United States Patent Application 20020079074 and United States Patent 5705030) (Barone and Schmidt, 2005; Shalwan and Yousif, 2013).

Acda (2010) studied waste CFF as reinforcing element for cement-bonded composites. This study reflected the use of waste CFF (barbs and rachis) as reinforcement in cement bonded composites. Boards containing 5% to 10% fiber and/or ground feather by weight showed similar strength and dimensional stability to commercial wood fiber-cement composites of similar thickness and density. Results from the sample tests exposed that the higher proportions of feather, however, showed a increase water absorption and thickness swelling after 24 hrs of socking in water and also a remarkable reduction in MOE & MOR. Therefore, waste CFF can be used as reinforcement in CBC but only up to about 10 % feather content (Bonser and Purslow, 1995).

Uzun et al. (2011) declared that the impact Strength of the CFF reinforced composites are significantly better than the control composites however the insignificant outputs were observed in the tensile and the flexural properties of the CFF reinforced composites compared to the control composites. Based on the final results obtained it was concluded that CFF reinforcement improves impact strength of the composite (Adetola et al., 2014).

3.2 CFF as Matrix

Use of CFF as matrix component in composite manufacturing leads to high specific strength and the large amount of waste utilization. It provides low cost output in high strength composite design application by mixing it with other reinforcing materials. Barone and Schmidt (2005) studied polyethylene reinforced with keratin fibers obtained from CF. Here, bra bender mixing head technique was used. The results obtained from mechanical testing are compared to theoretical outputs based on a simple composite micro-mechanical model (Uzun et al., 2011).

Similarly, Subramani et al. (2014) investigated Mech-Property in polyester and phenyl-ester composites reinforced with CFF and presented comparative relation between them. Here it was found that the compressive Strength of CFF based Composite is better than the control composite and it can be used in any engineering application due to its improved behavior and structural applications (Belarmino et al., 2012).

Reddy et al. (2014) demonstrated that chicken feather can be used as a matrix to develop complete biodegradable composites with properties similar to that of composites having polypropylene (PP) as matrix and uses jute fiber reinforcement also. Utilizing feathers as matrix could enable us to develop low cost 100 % biodegradable composites containing feathers or other biopolymers as the reinforcement (Amieva et al., 2015).

3.3 Mechanical and Thermal Properties CFF

Studies related to the use of CFF as a major constituent in composite design has been under process from last two decades. Various properties are examined by different researchers in different conditions and environment. Bonser and Purslow (1995) investigated the value of E for keratin feather. Tensile tests on keratin from 8 species of birds belonging to different orders showed similar moduli (mean E=2.50 GPa) except grey heron (E=1.78 GPa). It was concluded that from the species studied, the Flexural Stiffness of the whole rachis is principally controlled by its cross-sectional morphology rather than by the materialistic properties of the keratin (Jang and Lin, 1989).

The research continued for long for various applications. Later, Cheng et al. (2009) reported the thermo-mechanical properties of CFF/PLA green composites processed using the twin-screw-extruder and an injection molder. The tensile moduli and the morphology were evaluated by SEM. These properties were than compared using DMA, TMA and TGA. The outcome obtained from the study assists the development of ecofriendly composites from biodegradable polymers (Bansal et al., 2016). Also, Bansal et al. (2016) studied the behavior of CFF reinforced with epoxy polymeric composites and it was found that the impact property of the CFF mixed composites are suggestively better than the control composites.

Further, Adetola et al. (2014) investigated mechanical and physical properties of few selected CF mostly found in Nigeria. Here the grinding of feathers is done using Welay Milling Machine and Portland cement is used as binding material and calcium chloride is used as cement setting accelerator. It was finally concluded that the TS and strain were found to be inversely relative to volume fraction (V_F) while the Young's modulus was proportional to volume fraction up to 0.20 and inverse at V_F above this value (Wang et al., 2013).

3.4 Morphological Structure of CFF

Morphological Study of Chicken feathers have proved its advance application and structural importance in various manufacturing units. (Belarmino et al., 2012) performed lab experiments for the morphological and physical characterization of CFF (Keratin Bio fiber) in naturally, chemically and thermally modified forms. During the experiment 5 samples of the CFF were analyzed by XRD & SEM Tests. Also the micro porous carbon material from chicken feathers (KF) could be competently gotten through pyrolysis (Gururaja and Rao, 2012).

Cheng et al. (2009) performed SEM analysis of CFF reinforced polylactic acid and concluded that good dispersion occurred below 5 wt. % of CFF. DMA revealed the hike of storage modulus with respect to pure polymer. TGA test showed good thermal stability of composite and with TMA results best thermal stability was obtained at 5 wt. % of fiber.

Amieva et al. (2015) fabricated recycled-polypropylene/quill composites with different wt. % of fiber as 5, 10 and 15% using an extruder. SEM revealed that due to their hydrophobic nature, quill showed good dispersion into the matrix making it compatible. At 10 wt. % of fiber, thermal stability was improved. The transition temperature remained more or less unaltered (Chinta et al., 2013).

3.5 Alkali Treatment of CFF

Shalwan and Yousif (2013) studied various natural fibers and polymer matrix when they are alkaline treated and found that the TS, wear strength of treated fibers was better than untreated. As mentioned above Jagadeeshgouda et al. (2014) explained the washing method of CFF in order to remove dirt and moisture content from the feather (Reddy et al., 2014).

3.6 Application of Natural Fibers

Chicken feather and other natural fibers have been continuously examined for various biocomposites and its application has expanded in multi direction.

Giraldo and Moreno-Piraján (2013) found a momentous improvement in impact energy of hybrid composites incorporating either particulates or ceramic whiskers. Attempts to appreciate the alterations in the tribological behavior of any polymers with the addition of fillers or fiber reinforcements have been made by a few researchers (Wang et al., 2013; Tuna et al., 2015).

Hybrid composite materials have wide engineering applications due to low cost, good strength-to-weight ratio and ease of manufacturing (Gururaja and Rao, 2012). Chinta et al. (2013) described application of CFF in technical textiles. They added by interpreting that nonwoven which is prepared by CFF has wide application in the technical textiles (Singh et al., 2016; Singh et al., 2016). Giraldo and Moreno-Piraján (2013) expressed the use of rachis of CFF for hydrogen storage. Here the samples were characterized through nitrogen adsorption isotherms at -196^0C, FTIR, SEM and XPS.

Wang et al. (2013) suggested the application of CFF in high-capacity carbon which was prepared from renewable CF biopolymer for developing super capacitors. In this research work the author concluded that the CF carbon is acted as electrode materials for the first time.

Jagadeeshgouda et al. (2014) performed characterization on behavior of CFF as the reinforcing material for composites. Also Reddy et al. (2014) determined the non-food

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applications of CFF in industries. Recently, Bhattacharyya et al. (2015) studied about the superficial use of Natural fibers, their composites and various flammability characterizations. Here the sub classification of natural fiber is done like plant fiber, animal fiber and mineral fiber and its applications are discussed. The proper explanation of the characteristics and properties of different fibers have been discussed by the author.

3.7 Conversion Methodology

Tuna et al. (2015) presented the method for thermo-chemical conversion of poultry CFF of unlike colors into micro porous fibers. In the research work the carbon nitrogen fiber is derived from CFF and the role of different colors on chicken feather fiber char characteristics was investigated.

Sekhar et al. (2015) studied conversion methodology and biodegradation of Emu feather fiber reinforced epoxy composites. Here, composites were primed with epoxy (Araldite LY-556) as resin and 'emu' bird feathers as fiber and are tested for chemical resistance. Observations after three months were plotted and studied. The result showed that there will be weight gain for all the samples including pure epoxy when buried beneath Earth and weight loss was observed when exposed to atmosphere. The experimental characterizations for different mechanical properties were examined for various natural fibers and the outcomes were exposed to real life applications.

4. Conclusion

Through the review made here it can be concluded that the CFF has immense importance and great scope of improvement and discovery through advanced research in the field of advanced composite material. All the properties, structure and its effect can be easily examined. Further research on CFF based composite can be easily made by referring the above information. Different combinations can be made along with CFF as Matrix, Particulate or Fiber and also the amalgamation of all the forms can be added in various percentages to design hybrid composites. Highly improved and hybrid materials can be designed through modification in the existence material and property enhancement can be done. Further scope in the bio composite design is the use of CFF in hybrid composite manufacturing.

CFF has good fibrous nature, its morphological results relate to the uniform dispersion. If fiber orientation is made systematic instead of random and sizing is manipulated also if the mixing technique of fiber with matrix during casting is improved, then an enhanced characterization of developed composite can be achieved with much cost effective applications.

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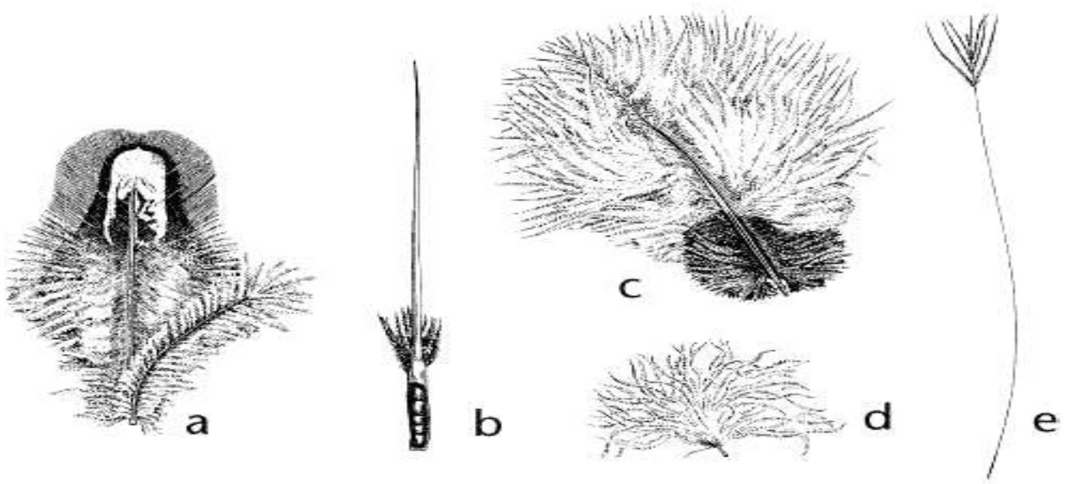

Figure 1. Five types of chicken feathers: (a) contour, (b) bristle (c) semi plume (d) down (e) filo plume (Bartels, 2003)

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