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Review on Chicken Feather Fiber (CFF) a Livestock Waste in Composite Material Development

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Abstract

Chicken feather fiber (CFF) that is a clear livestock waste is been used currently in various applications like textiles, crafting, decorations and even in biocomposite manufacturing. The reason for it is the abundance availability and compatible characteristics of the CFF. Here the reviews by various literature sited has been piled up to enhance the awareness of the researchers in the area of using CFF as a reinforcing material in developing various forms of composites. Properties like physical, chemical, mechanical, thermal, acoustical, morphological etc. that are been characterized by different researchers have been put together for the advancement of material development technology. In the past Importance is being given by most of the researchers to the various natural plant fibers. So for the change and the sustainable development the reviews are been formatted.

Keywords: Chicken feather fiber; Livestock waste; Biocomposite; Characterization properties

Introduction

Natural fibers have always attracted scientist's attention because of their advantages from the environmental standpoint, but almost all the research has been focusing on cellulose from vegetable sources. Environmental concerns have always appreciated the study to substitute synthetic materials with the different variety of natural materials. Many scientists have focused their research work on expending materials from nature. Composite material can be defined as a material system composed of two or more dissimilar constituents, differing in forms, insoluble in each other, physically distinct and chemically inhomogeneous [1]. One such example is the operative use of cellulose obtained from plants that have been explored for several decades [2]. Presently, the large sum of chicken feather disposed by various poultry industry as a waste is a stern solid agricultural waste problem [3].

Tang et al. [4] clearly distinguished two kinds of biopolymers: one that comes from living organisms and another which need to be polymerized but come from renewable resources and are biodegradable.

Keratin fibers are non-abrasive, biodegradable, renewable, eco-friendly, insoluble in organic solvents, and also have low density, hydrophobic behavior, ability to dampen sound, warmth retention and cost effective too. These characteristics make keratin fibers from chicken feathers a suitable material to be used as a high structural reinforcement in polymer composites [5-7].

Throughout the last decade, many effective research has been published involving keratin fibers from chicken feather with synthetic polymers, such as grafting with poly methylmethacrylate [8,9] and poly hydroxyethylmethacrylate [10], composites with polyethylene [11,12], polypropylene [13-15], poly methylmethacrylate [16], poly urethane [17] and phenol formaldehyde [18], among others [7], however, there are only a few related to keratin fibers and biopolymers [19,20].

Chicken feathers are around 91% protein (keratin), 1% lipids, and 8% water [21]. The sequence is largely composed of cysteine, glycine, proline, and serine, and contains almost no histidine, lysine, or methionine [22]. The amino acid sequence of a CFF is almost similar to that of other feathers and also has a great deal in common with reptilian keratins from claws [23].

Defining chicken feather fiber

Chicken feathers are deliberated as a waste product of the poultry industry. Large amount of waste feathers generated and disposed each year by poultry processing plants results in severe solid waste trouble [24].

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

Washing and cleaning of CFF: For casting of bio composite y 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 water & ethanol and dried in order to be clean white, sanitized and odor free [25,26]. Then keratin bio fibers were obtained according to a patented process by Baron and Schmidt [27]. Ethanol has been shown by Griffith [23] 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.

In 2013 Shalwan and Yousif studied the significance of alkaline treatment on different natural fiber and the different polymer matrix and found that tensile strength, wear strength of treated fibers were

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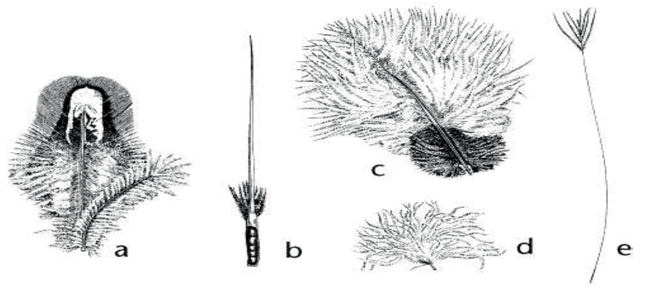

Figure 1: Five primary types of chicken feathers: (a) contour (b) bristle (c) semi plume (d) down (e) filo plume [26].

better than untreated [28]. So the concept of using clean feathers came into existence in order to achieve better results.

Later in 2014 Jagadeeshgouda et al. [29] 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 then the solution was prepared by adding 6% NaOH to distilled water. Mechanically treated and dried fibers were soaked in a solution for 3 hours and then washed again properly in running water. These were dried for ten hours under the natural light. The biggest advantage of chemical treatment (with NaOH) is to remove moisture content from the fibers thereby increasing its strength [29]. We can also use KOH for the same purpose.

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) [23, 24]. In 2010 Menandro N. Acda studied waste chicken feathers as reinforcing element for cement-bonded composites. This study reflected the use of waste chicken feather (barbs and rachis) as reinforcement in cement-bonded composites. Boards containing 5% to 10% fiber and/or ground feather by weight showed comparable strength and dimensional stability to commercial wood fiber-cement composites of similar thickness and density. Results revealed that the higher proportions of feather, however, showed a significant reduction in Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) and increased water absorption and thickness swelling after 24 hours of soaking in water. Therefore it can be concluded that the waste chicken feather can be used as reinforcement in cement bonded composites but only up to about 10% feather content [30].

In 2011 Uzun et al. [31] found that the impact properties of the CFF reinforced composites are significantly better than the control composites however both the tensile and the flexural properties of the CFF reinforced composites showed poorer values compared to the control composites. Based on the final results obtained it was concluded that CFF reinforcement improves impact strength of the composite [31].

CFF as Matrix: Use of chicken feather as a matrix component in composite manufacturing leads to high specific strength and the large amount of waste utilization. Chicken feather provides low cost output in high strength composite design application by mixing it with other reinforcing materials. As in 2005 Barone et al. [27] studied polyethylene reinforced with keratin fibers obtained from chicken feathers. Here the fibers of similar diameter but varying aspect ratio were mixed into low-density polyethylene (LDPE) using a bra bender mixing head. The results obtained from mechanical testing are compared to theoretical predictions based on a simple composite material micromechanical model [27].

Similarly in 2014 Subramani et al. [32] investigated Mechanical Properties in Polyester and Phenyl-ester Composites Reinforced with Chicken Feather Fiber 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 [32].

In 2014 Reddy et al. [33] demonstrated that chicken feather can be used as a matrix in order to develop complete biodegradable composites with properties similar to that of composites having polypropylene (PP) as matrix. The study was related to the use of biodegradable composites containing chicken feathers as matrix and jute fibers as reinforcement. Utilizing feathers as matrix could enable us to develop low cost 100% biodegradable composites containing feathers or other biopolymers as the reinforcement [33].

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. In the year 1995 Bonser et al. [34] investigated the young's modulus of feather keratin. Richard explained that the flexural stiffness of the rachis varies along the length of a primary feather. Tensile tests on compact keratin from eight species of birds belonging to different orders showed similar moduli (mean E = 2.50 GPa) in all species apart from the grey heron (E = 1.78 GPa). It was concluded that in the species studied, the flexural stiffness of the whole rachis is principally controlled by its cross-sectional morphology rather than by the material properties of the keratin [34].

The research continued for long for various applications. Later in 2009 Sha Cheng et al. reported the mechanical and thermal properties of CFF/PLA green composites which was processed using a 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 [20]. Also Uzun et al**.** [31] in the year 2011 studied the behavior of chicken quills and CFF reinforced polymeric composites and it was found that the impact properties of the CFF reinforced composites are significantly better than the control composites [31].

Further in 2014 Adetola et al. [35] investigated Physical and Mechanical Properties of Few Selected Chicken Feathers Commonly 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 tensile strength and strain were found to be inversely proportional to volume fraction (V_F) while the Young's modulus was proportional to volume fraction up to 0.20 and inversely proportional at V_F above this value [35].

Morphological structure of CFF: Morphological Study of Chicken feathers have proved its advance application and structural importance in various manufacturing units. In the year 2012 Belarmino et al. [36] performed lab experiments for the morphological and physical characterization of CFF (Keratin Bio fiber) in naturally, chemically and thermally modified forms. During the experiment five different samples of the feather were analyzed by SEM and XRD Tests. From this study it was concluded that micro porous carbon material from chicken feathers (KF) could be efficiently obtained through pyrolysis [36].

Cheng et al. [20] 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. [37] 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 matrix making it compatible. At 10 wt. % of fiber, thermal stability was improved. The transition temperature remained almost unaltered [37].

Alkali treatment of CFF: In 2013 Shalwan and Yousif [28] studied various natural fibers and polymer matrix when they are alkaline treated and found that the tensile strength, wear strength of treated fibers were better than untreated [28]. As mentioned above Jagadeesh et al. [29] explained the washing method of CFF in order to remove dirt and moisture content from the feather [29].

Application of natural fibers

Chicken feather and other natural fibers are been continuously examined for various biocomposites and its application has expanded in multi direction. In 1989 Jang et al. [38] found a significant improvement in impact energy of hybrid composites incorporating either particulates or ceramic whiskers [38]. Attempts to understand the modifications in the tribological behavior of the polymers with the addition of fillers or fiber reinforcements have been made by a few researchers [39]. Hybrid composite materials have wide engineering applications due to low cost, good strength-to-weight ratio and ease of manufacturing [40]. In 2013 Chinta et al. [41] described application of CFF in technical textiles. Chinta et al. [41] added by interpreting that nonwoven which is prepared by CFF has wide application in the field of technical textiles [41].

Later in 2013 Giraldo et al. [42] expressed the use of rachis of CFF for hydrogen storage. Here the samples were characterized through nitrogen adsorption isotherms at −196°C, FTIR, SEM and XPS [42]. Wang et al. [39] suggested the application of CFF in high-capacity carbon which was prepared from renewable chicken feather biopolymer for developing super capacitors. In this research work the author concluded that the chicken feather carbon is acted as electrode materials for the first time. There are plentiful micro pores for the activated chicken feather carbon and it displays the excellent electrochemical properties [39].

In 2014 Jagadeesh et al. [29] performed characterization on behavior of CFF as the reinforcing material for composites. Here the review on the behavior of the CFF was made to upgrade and understand their usability as a reinforcing material for composite fabrication [29]. Also Reddy et al. [33] in 2014 determined the non-food applications of CFF in industries [33]. Recently in 2015, Bhattacharyya et al**.** [3] 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].

Conversion Methodology

In 2015 Tuna et al. [43] presented the method for thermochemical conversion of poultry CFF of different 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 [43].

In 2015 Sekhar et al**.** [44] 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. The composites thus prepared were exposed to atmosphere and buried under Earth. Observations after three months were plotted and studied. The results reveal that there will be weight gain for all the samples including pure epoxy when buried beneath Earth. Weight loss was observed for all the samples including pure epoxy when exposed to atmosphere [44].

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 biocomposite design is the use of CFF in hybrid composite manufacturing.

CFF has good fibrous nature, its morphological results relates 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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