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Characterization of Chicken Feather Fibre as Novel Protein Fiber for Commercial Applications

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ABSTRACT: *The copiousmass of poultry feathers produced annually is viewed as a lower value by-product of poultry industry and the most commonly proposed methods for its man-agement are burning in incineration plants, burial in landfills or recycling into low quality animal feeds, with the third one being the least opted one. The composition of chicken feather makes it an attractive material to be employed for a range of usual to high end use applications. However,hitherto, chicken feather has not been fully exploited and a little is known about the material properties of feather keratin. Hence, an attempt has been made to study the physical and morphological structures and properties of chicken feather fibres for potential use as natural protein fibres. The physico-mechanical tests such as length determination, tensile strength and elongationwere performed. Scanning electron microscopicanalysis was done to have a better insight of the complete fibre structure and the thermal stability of the fibre was checked through thermo gravimetric analysis.*

Keywords: *Chicken feather fibre, protein fibres, keratin, scanning electron microscopic analysis, thermo gravimetric analysis.*

INTRODUCTION

Environmental concernspersistentlyencourage study to replace synthetic materials with a variety of natural materials. Use of different agricultural waste for recovering valuable fibrous textile materials for wide range of technical applications has gained momentum in recent years to promote sustainable development that combine economy, ecology and functionality. The undue exhaustion of natural resources, increasing waste disposal problem andsimultaneous environmental dilapidationhas propelled the researchers all over the world to concentrate their efforts on renewable raw materials for the design and development of novel components. Nature is almost full of high performance materials that are to be critically studied to establish them as basis for innovative technologies and nurturing useful raw materials. Poultry feathers in this case seem just perfect.

Poultry feather generation is enormous. Presently, they might be considered as "waste" because their current uses are economically marginal and their clearance is difficult often demanding space. Around 24 billion chickens are killed per year across the world and 8.5 billion tons of feathers are discarded from them and this includes India's contribution alone 400 million tonnes. India was ranked the fifth largest poultry producer in the world (Jagadeeshgouda *et al.*, 2014). Considering the rising cost of disposal, reduction in available space and increasing environmental concerns, research is critically needed on innovative recycling technologies which could potentially consume a large amount of virtually waste poultry feathers.

Accompanying these reasons, the composition of chicken feather (approximately 91% keratin) also makes it an attractive material to be employed for a range of usual to high end use textile applications. Keratin, an insoluble and highly durable protein consists of a number of amino acids that tend to cross-link with one another by forming disulfide or hydrogen bonds resulting in fibres that are tough,

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strong, light-weight and with good thermal and acoustic insulating properties. It can be proposed that using chicken feathers for fiber production may be a good way to add value to chicken feather waste. Therefore, this study was taken to examine the suitability of chicken feathers as a novel source of protein fiber by scrutinizing their various properties. This study proves the potential of chicken feather fibersfor the production of textile materials, based on their structural, physico-mechanical and thermal properties.

MATERIALS AND METHODS

Chicken feathers were collected from a poultry processing facility of G.B.P.U.Ag. and Tech., Pantnagar (Uttarakhand, India) representing zero costs.To clear out the foreign materials clung to the feathers, they were first washed with the 5% non-ionic liquid soap solution (genteel) followed by rinsing and exposed to natural light until completely dried. It was assumed that untreated feathers may contain many kinds of bacteria which can attack feather keratin and make it weak. Hence, the feathers were sterilized with 95% ethanol at 21°C for 30 min. (Fan, 2008).

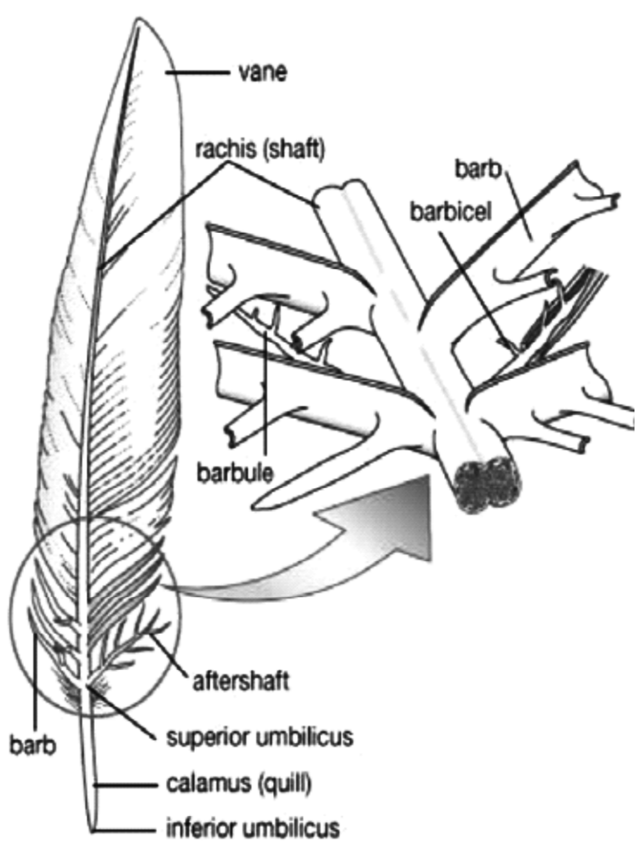

Figure 1: Schema of contour chicken feather (Qin, 2015)

They were then rinsed with water and dried. The sterilized feathers were then processed to get fibers.

Fibers were achieved by manually stripping the barbs from the rachis with the help of scissor followed by opening the fibers in a household blender. The obtained chicken feather fibers (CFF) were then tested to characterize their different properties.

CHARACTERIZATION OF CFF PROPERTIES

Morphological Structure

A Scanning Electron Microscope (SEM) was used to study the longitudinal and cross sectional features of the fiber. Barbs were mounted on a conductive adhesive tape and sputter coated with gold palladium prior to observation in the SEM by using JEOL JSM-6610LV high resolution. The applied voltage spot size was 5.0 Kv. The test was conducted in Electron Microscopic Lab, College of Veterinary Sciences, G.B. Pant Univ. of Ag. and Tech., Pantnagar (Uttarakhand).

Fiberlength

Length is the longest dimension of the fiber in its natural state. The length of the feather fibre was determined bysingle fibre measurement method given by Booth (1974). Fiber length was measured manually with the help of a scale and a pair of forceps by applying tension just to straighten the fibres.

Mechanical Properties (Denier, Tenacity, Elongation, Modulus)

Feather fibres were tested to measure the fineness and tensile properties. Fineness of textile fiber is expressed in terms of denier which is the weight in grams of 9000 m of the material. The tensile tests measure the behavior of the fibers when a deformation force is applied along the fiber axis in terms of tenacity and percent elongation.The tests were carried out as directed in ASTM D1577:07 (fiber fineness) and ASTM D-3822:07 (tensile) with LENZI G VIBROSKOP-400 and VIBRODYN-400 instrument in Northern India Textile Research Association (NITRA), Ghaziabad. A gauge length of 10 mm and speed of 10 mm/min was used for testing the chicken feather fibers.

Thermo Gravimetric Analysis (TGA)

Thermo gravimetric analysis studies the change in weight of a material in relation to change in temperature. Weight, temperature and temperature change are three crucial measurements that affect the accuracy of such analysis. The rate of heating, sample weight, mode of heating and temperature range used for this study were 10°C/min, 2.5mg, nitrogen and 0-1000°C respectively. The TGA test was conducted according to ASTM E1131at NITRA, Ghaziabad.

RESULTS AND DISCUSSION

The results obtained are reported and discussed as below:

Morphological Structure

The structural analysis of CFF fiber revealed that three separate parts namely; rachis, barb and barbules are absolutely interlock with each other to constitute a single unit called feather. Rachis, the thick and rigid central part run the whole length of the feather to which attached are the secondary structure called barbs. Barbs are soft and flexible and contain tertiary structure of the feather called barbules. The SEM micrographs of a single barb and its cross sectional view is shown in Fig. 4.1 and Fig. 4.2 respectively.

Rachis of a feather will easily break down due to its stiff nature when subjected tomechanical load however feather barbs will endure the sameowing to its flexible structure that makes them suitable as protein fiber. The diameter of barb was observed 58.31 mm which is in the range between 34.94 mm and 95.54 mm reported byAdetola *et al.* (2014). According to Saravanan and Dhurai (2011) two qualities of feather fiber make it exclusive, its molecular order and its morphological order. The fiber is both highly microcrystalline and very strong that is strong against to both mechanical and thermal stress.The distinctive cross sectional view of barb deliver more functional properties to the fiber. As shown in Figure 3, the barb cross-section contains many hollow honeycomb like cells that are not seen in natural protein fibers *i.e.* wool and silk.This hollow feature of barb is attributable for light weight and good air, heat and sound insulation.Reddy and Yang (2007) also reported that the presence of hollow honecomb structures makes barb to be very light in weight. The light weight combined with heat insulating abilities makes feathers preferable for applications such as outer wear jacket and composites used for automobiles. The presence of barbules can provide anexceptional structural contact with other fibers when barbs are used to produce blended yarns and can too improve the mechanical properties of fibrous composites.

Fiber Length

Fiber length was observed in the range of 1.5 to 4.5 cm. The difference in length may be attributed to the position of the barbs in the quill. With this

Table 1
Mechanical properties of CFF

Fiber properties	*Chicken feather fiber*
Fineness (denier)	36.48
Tenacity (g/den)	1.32
Elongation (%)	10.75
Modulus (g/den)	22.61

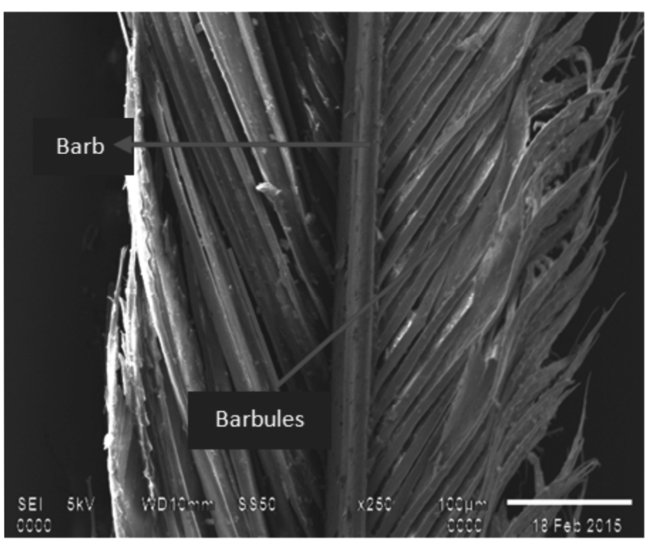

Figure 2: SEM image of a barb along with tertiary structure of feather, the barbules attached to it

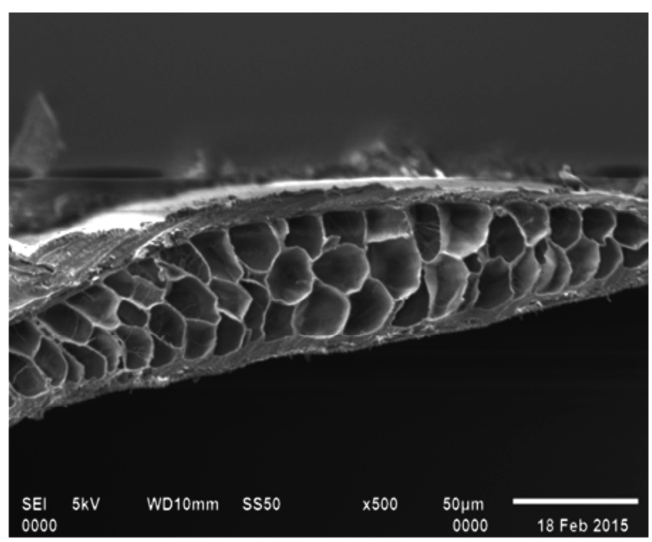

Figure 3: SEM image of the cross section of a barb showing hollow honeycomb structures

small length though feather fiber cannot be processed alone as textile yarn but they can directly be utilized to make web structures which can further be exploited for numerous applications. It has been reported previouslyby Jagadeeshgouda *et al*. (2014) thatsince chicken feather fibers are naturally smaller in length which accommodates more number of fibers for the similar volume fraction, hence increase in surface area and number of defects reduced which intern improves the efficiency of load transferability.

Mechanical Properties (Denier, Tenacity, Elongation, Modulus)

The development of successful applications for chicken feather fibers will be aided by an understanding of their mechanical properties. The mechanical properties of CFF arepresented in the Table 1.

It can be seen from the above table that the fineness of chicken feather fiber is 36.48 denier. The tensile strength (1.32 g/den) wascomparable to that of wool fiber (1.2-1.8g/den). Elongation of CFF was observed as 10.75% and modulus was found to be22.61 g/den. Reddy and Yang (2007) found that chicken feather fibres had strength of 1.4 grams per denier (180 MPa), tensile modulus of 36 grams per denier (4.7 GPa) and elongation of 7.7% for untreated intact barbs from contour feathers.Chinta *et al*. (2013)reported the Young's modulus ofchicken feather fibers was found to be in the range of 3 - 50 GPa and the tensilestrengthof oven-dried chicken feather fibers in the range of 41-130 MPa. The slight disparity in values may be due to the difference in processing conditions and also possibly due to form of the feather fiber studied.

THERMOGRAVIMETRIC ANALYSIS (TGA)

Thermogravimetric analysis of CFF (Figure 4) showed a decrease of 10% in mass from about 25°C to 80°C due to the loss of free water and a second dramatic decline of weight at about 205°Cfrom where the CFF graduallystarts to decompose. These results suggest that the drying temperature for CFF should be above 80°C, while the processing temperature for CFF should be controlled below 205°C.The chicken feather fiber starts to lose weight which is attributed to moisture evaporation from the fibers starting at 80 °C. Thepercentage of weight reduction at 500°C reflects the amount of residues left after the CFF were degraded.

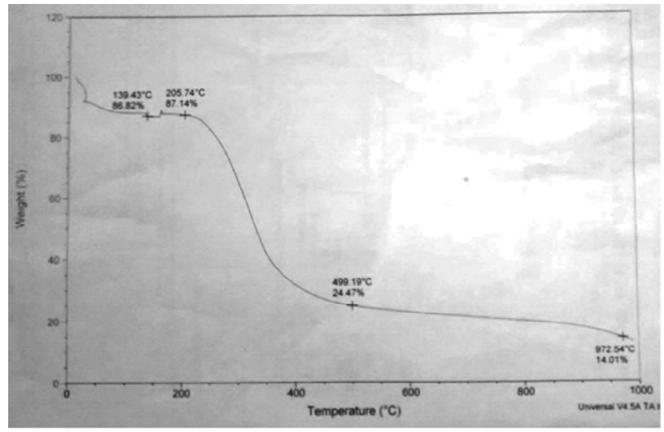

Figure 4: Thermogravimetric analysis of chicken feather fiber

CONCLUSION

Chicken feather fiber posses unique structure and properties that can be effectively explored for their diverse applications especially in the fields where functionality is required. As seen from the SEM analysis the internal part of barb is having several voids and at the external small branches called barbules are attached to it that impart resiliency to the fiber. The hollow structure of CFF resulting in amaterial that is light in weight with good acoustic and thermal insulation properties. These featurescan be exploited for different applications such as filter media, storage material, composite material and in wide subsets of technical textiles. Being profusely available at low cost with exclusive structural properties makes CFF preferable as novel protein fiber.

However, the expected performance of the fibers can only be observed when the material developed from them will be subjected to a series of tests confirming whether or not the indications given by the structure of the fiber apply. Hence further research is needed to develop products employing CFF as core material to understand its behavior and contribution to the processability and properties of various products.

ACKNOWLEDGEMENT

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