Sustainable Chemistry and Pharmacy 8 (2018) 38–49

Contents lists available at ScienceDirect

Sustainable Chemistry and Pharmacy

journal homepage: www.elsevier.com/locate/scp

Valorisation of chicken feather barbs: Utilisation in yarn production and technical textile applications

Tamrat Tesfaye[a,b,*], Bruce Sithole[a,c], Deresh Ramjugernath[a]

[a] *Discipline of Chemical Engineering, University of KwaZulu-Natal, Durban, South Africa*
[b] *Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Ethiopia*
[c] *Biorefinery Industry Development Facility, Natural Resources and the Environment, Council for Scientific and Industrial Research, Durban, South Africa*

ARTICLE INFO

Keywords:
Characterisation
Chicken feathers
Barbs
Technical textiles
Yarn
Beneficiation

ABSTRACT

Waste chicken feathers represent 5–10% of the total weight of mature chickens. Thus, they are produced in large quantities as a by-product of poultry meat processing industries. Currently, disposal of waste chicken feathers is problematic and the methodologies used are not environmentally sustainable. Consequently, technologies for beneficiation of the feathers are needed in order to overcome these problems. Considering that chicken feathers are similar to natural fibres (wool and silk) used in textile applications, it is plausible that protein in feathers can be exploited and used likewise. This paper reports on the physiochemical properties of proteinaceous fibre obtained from chicken feather barbs with the objective of assessing their potential for use in yarn production and technical textile applications. It is demonstrated that chicken feather barbs exhibit the following properties: hollow honeycomb structure, low density, high slenderness ratio, high flexibility, spinnable length, fineness, and high flexibility. These are unique properties that are not found in any other natural or synthetic fibres – the implication being that chicken feathers can be used in diverse manufacturing applications such as production of composites, yarns, technical textiles, nonwovens, and pulp and paper. However, this paper focuses on textile applications and illustrates how the physicochemical properties of fibres from feathers can be useful and applicable for textile applications. Beneficiation of waste chicken feathers in this manner will result in use of environmentally sustainable methods for disposal of the waste.

1. Introduction

Natural fibres [from wool, silk and lignocellulosic (cotton, pulp) fibres] and synthetic fibres (made from petroleum-based materials) are widely used for applications in the textile industry. However, the industry is on the lookout for new sources of natural fibre (s) that can compare with the performance properties of major natural fibres like cotton and linen. However, use of these fibres is fraught with problems, e.g., shortage of land space to grow natural fibres, depletion of petroleum-based materials, and pollution caused by production of non-biodegradable synthetic fibres. Growing cotton is environmentally unfriendly because it consumes > 25% of total insecticides used in the world (Aktar et al., 2009). Synthetic fibres are made from non-renewable petroleum resources and consume more energy than that required to produce fibres from a renewable resource (Jones et al., 1998). Their production processes are environmentally unfriendly and the products made from them are difficult to dispose of after use and/or no longer useful.

In the textile industry, fibres extracted from natural sources should have a certain aspect ratio, i.e., ratio of length to diameter (Reddy and Yang, 2005a, 2005b). Aspect ratio for fibres typically ranges from 200 to several thousand, which could result in different levels of strength in yarns and fabrics. High aspect ratio usually leads to strong yarns (Hearle and Morton, 2008). In fibre-reinforced composites, fibres with high aspect ratio are highly preferred. For example, a high aspect ratio, between 100 and 200, of fibres is essential to endow fibre rubber composites with good performance properties (Munawar et al., 2007). In textiles, the length of fibres is also crucial to their spinnability. Only fibres with a minimum length of greater than 20 mm are processable in the traditional yarn spinning system. In addition, fibres should have similar mechanical properties compared to other natural fibres (Jones et al., 1998), in order to meet the requirements of textile and other industrial applications.

It is estimated that there are 67×10^9 kg of synthetic and natural fibres currently in use worldwide (Reddy and Yang, 2005a, 2005b). Due to the diminishing accessibility and potential cost increases of the raw materials and natural resources required to manufacture textiles and composite products, it is important to discover alternative sources.

---

[*] Corresponding author at: Discipline of Chemical Engineering, University of KwaZulu-Natal, Durban, South Africa.
E-mail address: 214584674@stu.ukzn.ac.za (T. Tesfaye).

https://doi.org/10.1016/j.scp.2018.02.002
Received 28 October 2017; Received in revised form 5 February 2018; Accepted 17 February 2018
2352-5541/

Attempts to use the by-product of a major food crop as a source for fibres will be significant since the world's growing population will require more efficient land use in order to feed and clothe those in the poorer parts of the world. Thus, endeavours are being made to utilise renewable agricultural by-products such as pineapple leaves, soybean husks, corn husks, and rice husk, as unconventional sources for cellulosic fibres (Reddy and Yang, 2006). The production of regenerated fibres from agricultural by-products containing proteins such as zein in soya has been tried (Boyer, 1940). However, none of the attempts to produce high-quality protein fibres from agricultural by-products has been commercially successful.

Worldwide, the poultry–processing industry generates large quantities of feather by-products that amount to 40×10^9 kg annually (Compassion in World Farming, 2013). Considering that feathers represent 5–10% of the total weight of mature chickens (Jeffrey, 2006), it is evident that the industry generates a lot of feathers as a by-product, e.g., more than 258×10^6 kg of chicken feathers are produced in the Republic of South Africa alone (DAFF, 2014). Currently, the feathers are considered as wastes that need to be disposed of, e.g., land-filling and incineration (Veerabadran et al., 2012; Stingone and Wing, 2011). However, improper disposal of these biological wastes by landfilling contributes to environmental damage and transmission of diseases (Tronina and Bubel, 2008). Economic pressures, environmental pressures, increasing interest in using renewable and sustainable raw materials, and the need to decrease reliance on non-renewable petroleum resources behove the industry to find better ways of dealing with waste feathers.

The poultry industry has struggled with the question of what to do with the more than 40×10^9 kg of poultry feather waste their business generates each year. Poultry feathers contain about 90% protein and thus can be a cheap and renewable source for protein fibres. The secondary structures of the feathers, the barbs (see Fig. 1), are in fibrous form and could be a potential source of protein fibres. Understanding physicochemical properties of these fibres are necessary so as to ascertain their suitability for use in various applications. In this research, chicken feather barbs were characterised for their physicochemical properties and the data was used to evaluate their suitability as textile fibres for the production of yarns and various technical textiles.

2. Materials and methods

2.1. Sample preparation

Chicken feathers were obtained from a slaughterhouse in the province of KwaZulu-Natal, South Africa. The feathers were dried and conditioned at a relative of humidity 65 ± 2% and a temperature of 20 ± 2 °C. The barbs with the barbules were separated from the rachis manually by cutting with scissors. The cutting of fibres was performed near the rachis so as not to lose length and the natural properties due to the format of the fibre along the extension. For all samples prepared, their characterizations were conducted in a laboratory environment (temperature of 22 ± 2 °C and a relative humidity of 65 ± 2%).

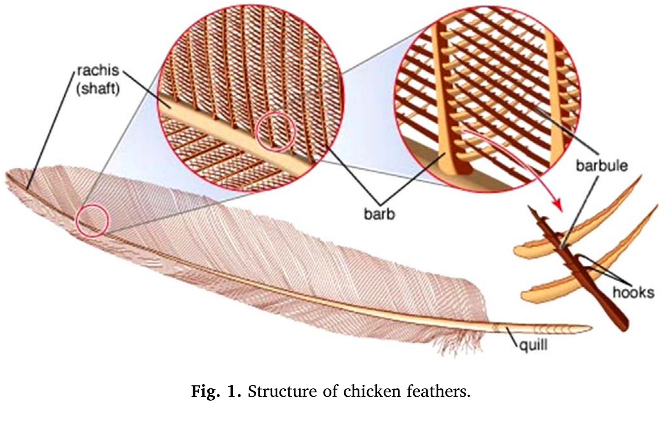

Fig. 1. Structure of chicken feathers.

2.2. Characterisation of physical properties and morphological structures

2.2.1. Physical properties

Fibre length was determined by the "Oiled plate method" (ASTM, 2003) adapted from ASTM D5103-07. Fibre diameter, fibre dimensions (slenderness ratio and flexibility ratio were measured at three different points along each barb using an optical microscope (Nikon H600L). The density of the chicken feather barbs was measured using a liquid pycnometer (Rude et al., 2000). Surface areas of the samples were determined via Brunauer-Emmett-Teller/BET analyser. The BET surface area and micropore volume are determined using the nitrogen adsorption/desorption isotherms collected at liquid nitrogen temperature (77 K) using a Micromeritics TriStar II surface area and porosity analyser (USA). The colour of the samples was determined by using a Konica Minolta CR-410 Chroma instrument. The metre was calibrated with a white plate. Absolute colour readings were recorded in L*, a* and b* space (ASTM, 1998).

2.2.2. Morphological and fine structure

The morphological structure of chicken feather barbs were conducted with the scanning electron Microscope (Carl Zeiss, Oberkochen, Germany) and the Atomic Force Microscopy with a Solver P47H base with a SMENA head, manufactured by NT-MDT was performed to see the fine structure of barbs.

2.3. Characterisation of chemical properties

2.3.1. Proximate and Ultimate analysis

Moisture content (ASTM D 1576–90, 2001), ash content, crude protein content, crude fat content, crude fibre content and nitrogen content (AACC, 2000) were measured to know the proximate properties of the barbs. The amount of elemental carbon, nitrogen, hydrogen and sulphur in the chicken feather barb were determined using an elemental analyser (CHNS analyser).

2.3.2. Other chemical properties

Buring test was conducted to ascertain the fibre types and the fire resistance properties when subjected to fire or high temperature. Feather barbs were burnt at a temperature of 575 ± 25 °C. The burning behaviour, odour and the type and nature of the ash formed were noted. Feather barbs were placed in Petri dishes with various concentrations of cold water, hot water, strong and weak acid, and strong and weak alkali until the fibres were fully covered, for the duration of 2 h, 12 h, 24 h and seven days. chemical resistance of the fibre was calculated after reweighed. The hydrophobic behaviour of chicken feather barbs was examined by comparing it to that of hydrophilic compounds (cotton and wood pulp). Dried chicken feather barbs and hydrophilic compounds were immersed and shaken in excess water-ethyl ether mixture separately, then allowed to stand overnight at room temperature (Takase and Shiraishi, 1989). The swelling of chicken feather barbs was investigated in different solvents such as water, ethanol, dimethylformamide and n-Butanol. The 100 mg of samples were immersed in 100 mL volume of solvent for 24 h. A Fourier transform infrared (FTIR) spectroscope was used to characterise the functional groups of the chicken feather and its barbs. Each spectrum contained an average of 4 scans, recorded at a resolution of $4\,\mathrm{cm}^{-1}$ in the range of $4000–400\,\mathrm{cm}^{-1}$. XRD analyses of the barbs were ascertained using a Bruker D8 Discover model diffractometer, equipped with a diffracted beam monochromator, and a copper target X-ray tube set to 40 kV and 30 mA (Bruker South Africa, Johannesburg). The crystallinity index (Cr) was calculated using empirical equation (Das, and Ramaswamy, 2006).