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Valorisation of chicken feathers: Characterisation of physical properties and morphological structure

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ABSTRACT

The physical properties and morphological structure of chicken feathers were examined in order to identify possible avenues for the valorisation of waste chicken feathers. The physical properties ascertained were fibre length, fineness, diameter, colour, ash content, moisture content, moisture regain, density, aspect ratio and dimensional measurement. The morphologies of the whole feather and its fractions (barb and rachis) were characterised by scanning electron microscopy. The results indicate that a chicken feather has unique features. The barb, unlike any other natural or synthetic fibre, is a protein fibre that has low density, high flexibility, good spinning length and a hollow honeycomb structure. The rachis has low density, low rigidity, and a hollow honeycomb structure. These characteristics indicate that chicken feather barbs can be utilised to manufacture textile products either on their own or by structural interaction with other fibres. The characteristics of both the barb and the rachis, make them suitable for the manufacture of composite materials. These results illustrate the possibilities of chicken feathers as a valuable raw material. The collection and processing of the chicken feathers from poultry can be a new source of employment and provide income generation opportunities.

1. Introduction

The disposal of waste in an economically and environmentally acceptable manner is a critical issue facing most modern industries. This is mainly due to increased difficulties in locating disposal works and complying with stringent environmental quality requirements imposed by waste management and disposal legislations. 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). According to some available figures of the USA Foreign Agricultural Service post reports, the total domestic per capita consumption of chickens is 59 kg in the United States; 48.0 kg in the Saudi Arabia, 67.1 kg in Hong Kong, 69.7 kg in Israel, and 35.4 kg in Canada (USDA Foreign Agricultural Service, 2014) – in South Africa the consumption rate in 2011 was 36.27 kg (DAFF, 2014). Considering that feathers represent 5–7% of the total weight of mature chickens (Rahayu and Bata, 2015), it is evident that the industry generates a large amount of feathers as a waste product, e.g., more than 258 × 10^6 kg of chicken feathers are produced in the Republic of South Africa alone (DAFF, 2014) (Fig. 1). This large consumption of chicken results in generation of huge amounts of chicken feathers.

The feathers are considered wastes and different approaches have been used for disposing of waste feathers, including landfilling 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 Bube, 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. Burning poultry wastes may actually produce as much or more toxic air emissions than coal plants. For example, analysis conducted by the North Carolina Department of Environment and Natural Resources found that a 57 MW poultry waste combustion plant emitted levels of carbon monoxide, particulate matter, nitrogen oxides, and carbon dioxide per unit of power generated that were higher than

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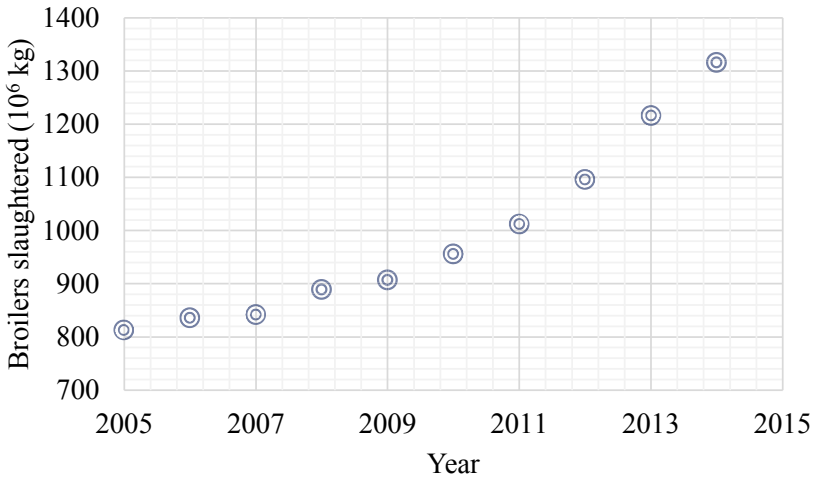

Fig. 1. Annual slaughter of broilers in South Africa (adapted from DAFF, 2014).

those for new coal plants (Stingone and Wing, 2011). An alternative to reduce these environmentally unfavourable disposal options is the utilisation of feather constituents as animal feed. Traditional methods to degrade feathers for subsequent use as animal feed include alkali hydrolysis and cooking under steam pressure. For example, the feathers may be hydrolysed, dried and ground to a powder to be used as a feed supplement for a variety of livestock, primarily pigs (Park et al., 2000). This is a fairly expensive process, however, and results in a protein product of low quality for which the demand is low (Veerabadran et al., 2012). These methods are not ideal in that they not only destroy the amino acids in the feathers but also consume large amounts of energy.

The world poultry industry has struggled with this question: what to do with more than 40×10^9 of poultry feather waste their business generates each year? A closer look at a chicken feather reveals that it is comprised of the rachis or quill, its primary structure, the barbs, its secondary structure, and the barbules, the tertiary structure (Fig. 2).

Can these features and properties of these structures allow for valorisation of chicken feathers? The applications mentioned in the preceding paragraphs utilise only a small portion of waste feathers generated by the poultry processing industry. Therefore, there is need to find or develop valorisation technologies for the waste.

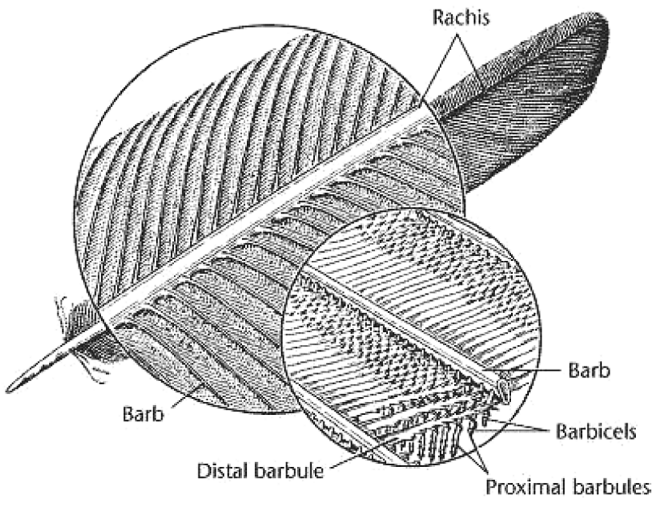

Fig. 2. Structures of a chicken feather (adapted from Bartels, 2003).

Characterisation and analysis of chicken feathers fraction to assess their suitability for valorisation as a source of protein fibre for high-value applications and the textile market is the first step for valorisation. In order to determine their suitability for these applications, it is important to understand the physical properties and the morphological structure of chicken feathers. Studies have been done in this topic, however, the studies were focused on specific applications upfront, e.g., textile applications (Reddy and Yang, 2005; Paul et al., 2014; Reddy et al., 2014), composite building applications (Jeffrey, 2006), biobased plastic resins containing chicken feather fibres (Roh et al., 2012), removal of heavy metals from wastewater (Al-Asheh and Banat, 2003), and a general description of feathers in domesticated birds (Bartels, 2003) none have focused on comprehensive evaluation of physical and morphological properties of feathers to help ascertain their possible valorisation. In this research, results of such comprehensive studies are reported: the morphological structure and physical properties of the whole chicken feather and of the component parts of the feather (barbules, barbs and rachis) were used to evaluate the possibilities for beneficiation of waste chicken feathers.

2. Materials and methods

2.1. Sample collection

Chicken feathers were obtained from a slaughterhouse in the province of KwaZulu-Natal, South Africa.

2.2. Sample preparation

The feathers were dried and conditioned at a relative of humidity 65 ± 2% and a temperature of 20 ± 2 °C. The barbs 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 characterisations were conducted in a lab environment (temperature of 20 ± 2 °C and a relative humidity of 65 ± 2%).

2.3. Measurement of physical properties

The chicken feathers were characterised for their physical properties and morphological structures. The methods used for the physical characterisation were adapted from those used for fibre