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Valorisation of chicken feathers: Characterisation of chemical properties

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ABSTRACT

The characterisation of the chemical properties of the whole chicken feather and its fractions (barb and rachis), was undertaken to identify opportunities for valorizing this waste product. The authors have described the physical, morphological, mechanical, electrical and thermal properties of the chicken feathers and related them to potential valorisation routes of the waste. However, identification of their chemical properties is necessary to complete a comprehensive description of chicken feather fractions. Hence, the chicken feathers were thoroughly characterised by proximate and ultimate analyses, elemental composition, spectroscopic analyses, durability in different solvents, burning test, and hydrophobicity. The proximate analysis of chicken feathers revealed the following compositions: crude lipid (0.83%), crude fibre (2.15%), crude protein (82.36%), ash (1.49%), NFE (1.02%) and moisture content (12.33%) whereas the ultimate analyses showed: carbon (64.47%), nitrogen (10.41%), oxygen (22.34%), and sulphur (2.64%). FTIR analysis revealed that the chicken feather fractions contain amide and carboxylic groups indicative of proteinious functional groups; XRD showed a crystallinity index of 22. Durability and burning tests confirmed that feathers behaved similarly to animal fibre. This reveals that chicken feather can be a valuable raw material in textile, plastic, cosmetics, pharmaceuticals, biomedical and bioenergy industries.

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 finding disposal sites and compliance with stringent environmental policy 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) – in South Africa, more than 258×10^6 kg of chicken feathers are produced per annum (DAFF, 2014). The feathers are considered wastes to be disposed of although small amounts are often processed into valuable products such as feather meal and fertilisers (Veerabadran et al., 2012; Stingone and Wing, 2011). The remaining waste is disposed of by incineration or by burial in controlled landfills. Improper disposal of these biological wastes contributes to environmental damage and transmission of diseases (Tronina and Bubel, 2008). 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 problematic in that they not only destroy the amino acids in the feathers but also consume large amounts of energy.

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. It is important to find ways to beneficiate chicken feathers because this would not only recycle a waste product to provide high-value materials, it would provide extra financial resources to the poultry industry. Physical and morphological properties of chicken feathers have been studied with the objective of ascertaining their valorisation based on the properties (Tesfaye et al., 2017). However, there is a lack of comprehensive data on chemical characteristics of chicken feathers in the literature. This report, therefore, focuses on a better understanding of the chemical nature of chicken feathers with the ultimate aim of developing valorisation routes for the waste feathers depending on their chemical characteristics.

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2. Materials and methods

2.1. Collection and preparation of chicken feather waste

Chicken feathers were collected from a slaughterhouse in Durban, South Africa, that processed 3-week old broiler/meat chickens. On collection, the feathers were a wet mass of blood, faeces, skin, flesh and other slaughterhouse residues. They were washed with water at 50 °C to remove easily removable matters and then dried at 105 °C for 24 h and conditioned at a relative humidity 65 ± 2% and a temperature of 20 ± 2 °C. After drying, barbs were separated by manual stripping from the rachis. A portion of the samples were milled into powder using, and the rest were left intact. The material was then packed and stored at normal room temperature (20–25 °C) into three groups (whole feather, rachis and barb).

2.2. Proximate analysis

This refers to the determination of the major constituents of biomass. For chicken feathers, the following components were determined: water, ash, volatile matter, fixed carbon, crude protein, crude fat, and nitrogen-free extracts. All tests were conducted in triplicate.

2.2.1. Ash content

Ash is inorganic residue obtained after combustion of biomass and is an approximate measure of the mineral salts and inorganic matter in feathers. The ash content was calculated in relation to the dry weight of the original sample after overnight ignition of the sample at 575 ± 25 °C.

2.2.2. Moisture content

The moisture content was measured according to ASTM D1576-90 standard by drying samples in an oven dryer (ASTM D1576-90, 2001).

2.2.3. Volatile matter content

Volatile matter in chicken feathers was determined by heating known weights of samples in capped crucibles in an oven at 800 °C for 40 min under an inert atmosphere. The volatiles liberated were calculated by mass difference before and after heating.

2.2.4. Fixed carbon content

Fixed carbon is a value obtained by abstracting the sum of ash, moisture and volatile matter from 100 where all values are on the same moisture reference base. Thus:

$$Fixed\ carbon = 100 - (ash\ \% + moisture\ \% + volatile\ matter\ \%) \quad (1)$$

2.2.5. Crude protein content

This was determined by measuring the nitrogen content of the feathers and multiplying it by a factor (C) of 6.25. This factor is based on the fact that most protein contains 16% nitrogen. The protein was determined using a Kjeldahl digestion method (AACC, 2000).

$$CP\ \% = \frac{(1.401 * M * (V - V_o))}{W} * K * C \quad (2)$$

where,

CP = crude protein
M = Amount of substance of H_2SO_4 concentration (mol/L)
C = Conversion coefficient of crude protein
K = Correction factor for the instrument determination
V_0=Blank value (mL)
V = Titration volume of H_2SO_4 (mL)
W = Weight of sample used.

2.2.6. Crude fat content

Crude fat, also known as the ether extract, is a measure of the free lipid content in a sample and is calculated using hexane as a solvent in a Soxhlet extraction system (AACC, 2000).

2.2.7. Crude fibre content

"Crude fibre" is considered to be a mixture of largely undigestible substances of vegetable origin obtained as the residue of a precisely defined digestion procedure using acetic, nitric and trichloro-acetic acids (AACC, 2000). It consists chiefly of cellulose and other vegetable cell wall substances.

2.2.8. Nitrogen Free Extract (NFE) content

NFE consists of carbohydrates, sugars, starches, and hemicellulose in biomass. When crude protein, fat, water, ash, and fibre are added and the sum is subtracted from 100, the difference is NFE. Thus NFE was calculated as (AACC, 2000):

$$NFE = 100 - (Crude\ protein\ (\%) + crude\ fat\ (\%) + crude\ fiber\ (\%) + moisture\ content\ (\%) + ash\ content\ (\%)) \quad (3)$$

2.3. Ultimate analysis

Ultimate analysis is more comprehensive than proximate analysis and provides information on quantitative analysis of various elements present in biomass samples, such as carbon, hydrogen, sulphur, oxygen, and nitrogen.

2.3.1. CHNS analysis

The amounts of carbon, nitrogen, hydrogen and sulphur in the chicken feathers were ascertained using a CHNS analyser (Leco VTF-900/CHNS-932).

2.3.2. Energy Dispersive X-ray analysis (EDX)

Elemental composition of chicken feather fractions were characterised by EDX using a Field Emission Gun Scanning Electron Microscope with EDX capability (Carl Zeiss, Oberkochen, Germany).

2.4. Fibre classification

Since chicken feathers contain fibres that can be beneficiated into fabrics, it is useful to classify the fibre present. This is especially important to know since the fabrics may need to be dyed and many dyes are very specific to the type of fibres treated.

2.4.1. Burning test

This is one way to ascertain fibre types and also to ascertain their fire resistance properties (Mylsamy and Rajendean, 2010). The samples were burnt by flame using a disposable lighter (temperature of 575 ± 25 °C). Burning characteristics that can be noted include the way that a fibre burns (or melts); the way it smells when burning; and the type of ash or other residue that is left behind. All these provide clues as to the type of fabric under analysis. Appropriate safety precautions were taken before and during the testing (assurance that the tester does not have sinus problems or a cold and does not use matches or refillable lighters with a strong fuel smell).

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