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Review

Non-food industrial applications of poultry feathers

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ABSTRACT

Poultry feathers are one of the unique coproducts that have versatile applications ranging from composites, fibers, tissue engineering scaffolds, nano and micro particles, electronic devices and many others. Despite their low cost, abundant availability, wide applicability and unique properties, non-food industrial applications of feather keratin are very limited. Poor-thermoplasticity, difficulty in dissolving keratin and limited knowledge on the processability and properties of products developed are some of the limitations for the large scale use of feather/keratin. Nevertheless, increasing interests in using renewable and sustainable raw materials and need to decrease dependence on non-renewable petroleum resources make feathers an attractive raw material for bioproducts. This review provides an overview of the products developed from poultry feathers and their limitations and advantages.

Contents

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1. Introduction

There is a critical need and increasing interest across the world to decrease the consumption of petroleum based products and to develop bioproducts using renewable and sustainable sources. Many such efforts have already been made and practiced in both the developing and developed countries. For instance, biodegradable polyesters, renewable fuels for automobiles and domestic use and sustainable farming are being aggressively promoted across the globe. Such efforts are necessary to satisfy the food, clothing and other basic needs of the future generations. Since there are limited natural resources, the recent focus is to utilize the agricultural byproducts and coproducts that are inevitably generated, inexpensive and are sustainable and renewable resources to develop bioproducts. Typically, the amount of byproducts generated during agricultural production is equivalent or higher than the amount of produce harvested. For instance, the amount of wheat straw generated (weight basis) is several times higher than the grain harvested. Currently, most of these agricultural residues are either burnt or buried with limited high value applications (Reddy and Yang, 2005; Reddy et al., 2011, 2013a,b). Several research groups have attempted to utilize the agricultural byproducts and coproducts for industrial applications. For example, lignocellulosic agricultural residues such as corn stover, wheat and rice straw have been used to produce natural cellulose fibers and also as feed stock for ethanol (Reddy and Yang, 2005). Similarly, the coproducts such as oil meals obtained during production of biodiesel have been used to extract proteins and carbohydrates for various applications (Reddy et al., 2014a,b). In addition, oil meals have been chemically modified and used as biothermoplastics.

Compared to other agricultural coproducts, poultry feathers are one of the most ubiquitous, unique and inexpensive byproducts available across the world. Feathers account for up to 10% of the body weight of the birds which means that about 8–9 million tons of feathers are generated in the world every year (Lasekan et al., 2013). In addition to their low cost and large availability, poultry feathers have distinct and unique properties such as low density, a hollow honey comb structure and hierarchical architecture as seen from Fig. 1. Feathers contain >90% protein in the form of keratin which is useful for various applications. At a density of 0.9 g/cm^3, feathers are considerably lighter than natural fibers such as cotton and flax (1.5 g/cm^3) and similar to that of synthetic polymers such as polypropylene. At a structural level, feathers consist of quill, barbs and barbules that are arranged in a hierarchical fashion that provides them unique structural properties. Feathers can also be treated as single fibers similar to wool and silk and used for various applications. It has been demonstrated that feather fibers (barbs) can be blended with cotton and made into hand spun yarns (Reddy and Yang, 2007). A typical stress–strain curve for a feather fiber is shown in Fig. 2. Strength of up to 300 MPa and modulus of up to 6 GPa were obtained for single feathers, better than most wool fibers (Wang et al., 2013). Despite these unique features, feathers are generally considered a waste and either disposed in landfills or used as low value animal feed. For instance, it has been reported that more than 4 billion pounds of feathers generated in the United States every year do not have any industrial application and are disposed in landfills leading to environmental pollution and discarding of a valuable resource (Huda and Yang, 2008).

Realizing the unique properties and low cost of feathers, several attempts have been made to understand the potential of using feathers for high value applications. Feather or keratin extracted from feathers have been made into fibers, films, hydrogels, nano

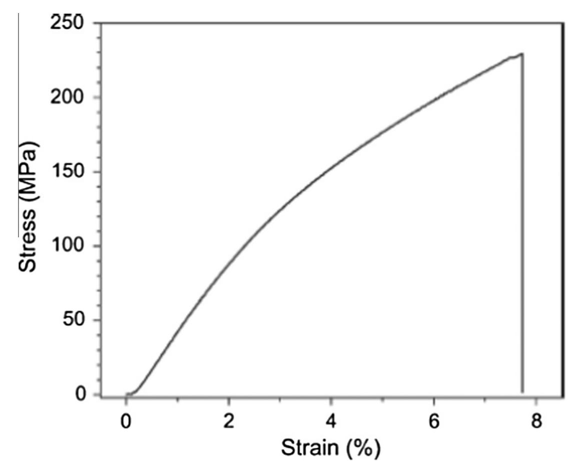

Fig. 2. Typical stress–strain curve of a single feather fiber in chicken. Reproduced from Zhan and Wool (2013) with permission from John Wiley and Sons.

Table 1
Properties of feathers for potential use as electrodes (Wang et al., 2013). BET is Brunauere Emmette Teller method of determining surface area and ESR stands for equivalent standard resistance.

% Feather	BET surface area (m^2/g)	Micropore surface area (m^2/g)	Total pore volume (cm^3/g)	Micropore volume (cm^3/g)	Average pore diameter (nm)	ESR (Ω)
0	0.568	–	0.001	–	–	0.86
1	2426	2096	0.870	0.856	1.196	0.67
2	2126	1838	0.788	0.747	1.203	2.28
3	1.911	1191	1.169	0.508	1.506	0.97
4	1839	1575	1.069	0.850	1.863	0.43
5	1398	1020	0.922	0.555	1.977	0.37

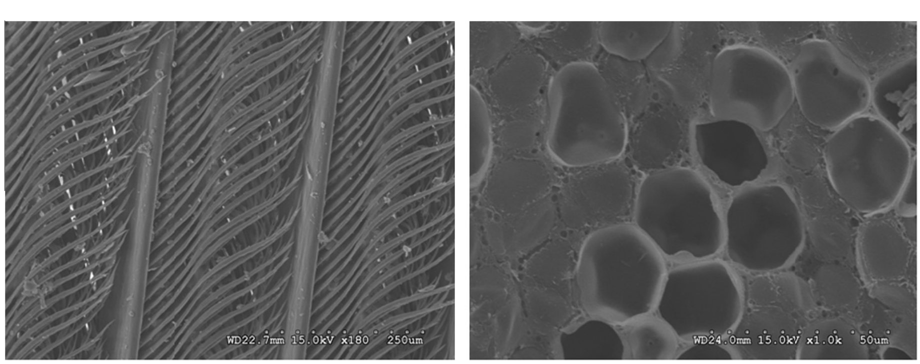

Fig. 1. SEM images of feather revealing the hierarchical architecture (left) and presence of hollow honey combs (right).