Management of Poultry Processing By-Products - Utilization of Feathers

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Abstract

Feathers are produced in large quantities as a by-product at poultry–processing plants, reaching millions of tons annually throughout the world. They too often become a waste disposal/environmental pollution hazard, incinerated or dumped in landfills. However, they have multiple uses in animal feeds, greenhouse industry, erosion control, upholstery, artwork, thermal insulation, paper alternatives (49 percent wood fiber and 51 percent feather fiber), lightweight structural materials, biodegradable composites, water filtration fibers, fabric (that is biodegradable), aircraft and automotive industries and diaper filling. Therefore, technologies for commercial utilization of feathers should be developed and customized. This will benefit poultry producers, end-user industries and the environment. This paper is a review of the various uses of feathers.

Keywords: feathers, keratin, biodegradable composites, rendering, fertilizer

Introduction

Poultry feathers are abundant and inexpensive. They are produced in large quantities as a by-product at poultry–processing plants, reaching millions of tons annually throughout the world (Fakhfakh et al., 2010). In mature chicken, feather accounts for 5-7% of the live weight and is composed of over 90% protein, the main component being keratin, a fibrous and insoluble protein (Schimdt, 1996; Swetlana et al., 2010). Feathers are keratin just like wool, but the surface area is much larger because the diameter of the fibers is much smaller. The fibre can absorb more than wool or cellulose fibres. Yang (2011) reported that the mechanical properties of feather films outperform other bio-based products, such as modified starch or plant proteins. Feathers have multiple potential uses, but too often, they become a waste disposal/environmental pollution hazard, incinerated or dumped in landfills (Yang 2011). Researchers have reported that feathers have uses in animal feeds, greenhouse industry, erosion control, upholstery, artwork, thermal insulation, paper alternatives (49 percent wood fiber and 51 percent feather fiber), lightweight structural materials, biodegradable composites, water filtration fibers, fabric (that is biodegradable), aircraft and automotive industries and diaper filling (Comis, 1998; Schmidt, 1998; David, 2010). Therefore, technologies should be developed and customized for commercial utilization of feathers for the different World (developed and developing) economies. This will benefit poultry producers, end-user industries and the environment. This paper discusses the uses of feathers.

Uses of Feathers

Manufacture of Plastics

Feathers are used in the manufacture of plastics. Plastics are of two groups, thermoplastics and thermosetting plastics. Thermoplastics are manufactured from oil and natural gas. These are expensive raw materials, therefore, research has gone into finding alternative material and processes for making plastic (Yang, 2011). Thermoplastics include nylon, polyethylene, polystyrene, polyvinyl chloride, and many other kinds. They are used to make consumer and industrial products ranging from toothbrush bristles to soda pop bottles to car bumpers. Thermoplastics need heat (or chemicals) to harden from a liquid into a final shape, and can be melted and remolded time and again (American Chemical Society, 2011). On the other hand, thermosetting plastics harden once and cannot be remelted again. Chicken-
feather-based thermoplastics are stable in water while still maintaining strong mechanical properties. They are substantially stronger and more resistant to tearing than plastics made from soy protein or starch, and have good resistance to water (American Chemical Society, 2011). Feather-derived plastic can be molded just like any other plastic and has properties very similar to plastics such as polyethylene and polypropylene (USDA, 2009). This makes them a unique material for packaging or any other application where high strength and biodegradability are desired.

Several commercial pot manufacturers are involved in the development of biodegradable keratin-based resins that can be used to provide environmentally sustainable alternatives to petroleum-based plastic pots, among other products (Huda et al., 2008). The pot manufacturers are involved in determining optimum molding specifications for the containers. The end products will help solve the environmental problem by creating biodegradable plastics, and also provide a cost-effective commercial use for feathers. Huda et al. (2008) developed fully biodegradable planting pots that degrade over variable periods of time, ranging from one to five years. They are made manufactured without any petroleum components, disintegrate naturally without harm to the environment and slowly release beneficial nitrogen to the soil. Regular plastic flower pots last indefinitely, but are not recyclable. The biodegradable plastic is also used in car dash boards, other interior plastic car parts, disposable spoons, forks, and food packaging.

Energy Production

In the world, man is facing two major challenges, waste disposal and the need for an abundant source of clean energy. Feathers, a byproduct of poultry processing, usually poses a disposal challenge. The perfect solution to both of these problems is to turn the waste into energy-biofuel. This energy from garbage could cut carbon emissions by 80% while replacing the need for large amounts of petroleum. Biodiesel is a fuel comprised of mono-alkyl esters of long chain fatty acids that are derived from vegetable oils or animal fats (Fukuda et al., 2001). In the United States, soy, corn, canola, and cottonseed oil are the primary sources for biodiesel production. The use of these feed-stocks for a prolonged time is potentially detrimental to society and the environment (Landis et al., 2007). The main problem the biodiesel industry frequently faces is the availability of cheap and abundant, high-quality feed-stock. Thus, finding alternative, non-food, feed-stocks is a priority. Through research to produce biofuels from non-food sources, it has been discovered that feather meal offers a promising feed-stock source for biodiesel production. Poultry feathers are inexpensive and abundant. Feather meal (hydro-lyzed poultry feathers) is defined as “the product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry”. By boiling chicken feather meal, the 12% fat content is extracted and processed into usable biofuel.

Use as Fertilizer and Root Substrates

Feather contains about 15% protein (Papadopoulos et al., 1986) and has high potential for use as slow-release nitrogen fertilizer in greenhouses and nurseries. However, the release of nitrogen from feathers is slow to be used as a fertilizer (Williams and Nelson, 992). Structural modifications have been made in polypeptide and disulfide bonds to increase mineralization (Choi and Nelson, 1996). Steam hydrolysis of feathers resulted in a 4x increase in N release during the first 5 weeks but did not add the 12- week profile of slow release. Cross linking of amino groups in the feather protein with formaldehyde after steam hydrolysis did not improve the slow-release properties of feather. However, microbial hydrolysis with Bacillus licheniformis increased N release during the 8- through 11-week period (Choi and Nelson, 1996). Veerabadran et al. (2012) reported that chicken feather powder yielded higher amount of solubilized protein by the proteolytic activity of bacillus sp. MPTK6. This microbial enzyme technology is low-energy-consuming and environmentally friendly.

Artificial substrates are commonly used in the production of containerized greenhouse and nursery crops (Nelson, 1998). Peat is commonly used in the formulation of artificial substrates but has raised environmental and cost concerns (Robertson, 1993). This has resulted in the research for development of
alternatives. In a study comparing substrates containing different levels of feather fibre, plants grown in peat and perlite-based substrates or SB-300 commercial substrate containing up to 30% feather fibre had similar dry and shoot weight as those grown in substrates containing 0% feather fibre (Michael, 2004). When the amount of feather fibre exceeded 30%, shoot and root growth declined. Plants grown in substrates containing up to 30% feather fibre were of marketable qualities. Therefore, plants can be grown in substrates containing up to 30% feather fibre, reducing reliance on peat and reducing overall cost of the substrate. In a study investigating the influence of the level of inclusion of feather fibre on the physical properties of greenhouse root substrates, the physical properties of most of the feather fiber-containing substrates differed from the 0% feather fiber control substrates, but the total pore space and the water-holding capacity values were within recommended ranges for greenhouse crops (Michael and Leisha, 2007). Air-filled pore space was higher than recommended levels, but the higher than recommended air-filled pore space did not result in suboptimal water-holding capacities. Therefore, feather fiber can be used at rates up to 30% with peat and perlite substrates without negatively affecting the physical properties of the substrate. However, at 30% feather fiber with peat and bark, aggregation or clumping of the feather fiber occurs during mixing of the final substrate. The tendency of feather fiber to form aggregates during substrate mixing is problematic for substrate mixing.

**Use as Livestock Feed**

Feed ingredient costs have skyrocketed and therefore increased interest in the search for cheaper and readily available alternatives (Wouldroup, 2008). Feather meal is a byproduct made of ground-up poultry feathers. It is produced by heat processing (rendering - clarify or purify by melting-heat processing) at 115° to 145° C that is sufficient to kill bacteria, viruses and many other micro-organisms. The product is an aseptic protein product that is free of potential biohazards and environmental threats (Hamilton, 2012). This makes feather meal safe for inclusion in animal feeds for a wide range of animal species, including fish and shrimp. Done correctly, heat processing also denatures the proteins slightly, which enhances their digestibility.

Feather meal has high protein content and has a great potential as a source of protein and amino acids for animal feed. However, it has low levels of essential amino acids as well as poor digestibility. It has been documented that variation in processing conditions can markedly affect the digestibility of amino acids in poultry feathers (Han and Parsons, 1990, 1991; Wang and Parson, 1997). Feather meal is almost pure keratin, which is not easily degradable by common proteolytic enzymes (Swetlana et al, 2010), but can be efficiently degraded by specific proteases such as keratinase (Onfide et al, 1998). Hydrolysis of feathers by microorganisms possessing keratinolytic activity is an attractive alternative method for improving the nutritional value of feather meal, compared to the currently used physiochemical methods (Papadopoulos et al, 1986; Williams, 1991; Bertsch et al, 2005). Swetlana et al, (2010) reported that Bacillus cereus KB043 caused about 78% feather degradation with a significant release of soluble protein and cystine. Microbial hydrolysis of feather fibre with Bacillus licheniformis increased N release (Choi and Nelson, 1996) while Veerabadran et al. (2012) reported that chicken feather powder yielded higher amount of solubilized protein by the proteolytic activity of bacillus sp. MPTK6. Therefore, Bacillus sp. is a potential keratinolytic strain which is suitable for the bacterial degradation of feather fibre for its conversion to feed ingredients.

Feather meal is hydrolyzed poultry feathers. It is rather unpalatable and should be introduced into cattle diets gradually and limited to 0.45 to 0.75 kg per head per day (Leme et al, 1978). Combinations of feather meal and blood meal are recommended for balanced amino acid supplementation.
Table 1: The nutritional composition of feather meal is tabulated below (NRC, 1994)

<table>
<thead>
<tr>
<th>(%)</th>
<th>(MJ/kg)</th>
<th>Amino acids (%)</th>
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<tbody>
<tr>
<td>C</td>
<td>P</td>
<td>Ca</td>
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<tr>
<td>81</td>
<td>7</td>
<td>0.3</td>
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Animal proteins are normally superior to plant proteins as sources of essential amino acids particularly lysine. The overall mean apparent ileal amino acid digestibility coefficient of feather meal in broilers is 0.563, while that of lysine is 0.540 (Hew, et al., 1997). Some nutritionists underestimate the digestibility and the nutritional value of animal proteins (Hamilton, 2012). This misperception dates back many years when poor processing techniques and equipment were used to render animal by-products. However, new processes, improved equipment and greater understanding of the effects of time, temperature and processing methods on amino acid availability have resulted in significant improvements in the digestibility of animal proteins (Hamilton, 2012). Improved understanding as to how best to incorporate them into commercial formulas and improved formulation procedures has also increased the nutritional value of animal proteins. Data published since 1984 demonstrate that the digestibility of essential amino acids, especially lysine, threonine, tryptophan and methionine, in meat and bone meal, has improved (Hamilton, 2012). Probably the same trend applies for feather meal.

Amino acid content and in vitro protein digestibility and solubility of feather meal, as affected by varying lengths of processing time (30 to 70 min) and moisture content (50 to 70%), were studied. Papadopoulos et al (1986) reported that the quadratic coefficient is negative for lysine and positive for methionine. For moisture, the linear coefficients are negative for threonine, glutamic acid and crude protein. The quadratic coefficients are negative for aspartic acid, serine and glycine, and positive for phenylalanine and pepsin-digestible protein (PDP). For the time × moisture interaction, the only significant coefficients are negative ones for cystine and nitrogen solubility in acid and a positive one for histidine.

Feather meal is a protein ingredient that has been used in fish feeds in America (Bureau, 2010). In many countries, fish feeds are formulated to contain 3-7% feather meal. Crude protein in feather meal is highly digestible to fish. However, results from different studies indicate significant differences exist in the digestibility and nutritional value of feather meal from different origins (Bureau, 2010). Feather meal can be used to reduce supplemental protein costs for dairy cattle, lambs and steers (Leme et al, 1978). However, at higher levels of inclusion (40% of protein source) it should be introduced gradually to overcome palatability problems. Total sulphur amino acids potentially limit growth in cattle. It can provide a portion of the sulphur amino acids limiting growth (Kleemersrud et al., 2000). Feather meal is an excellent source of rumen escape protein and sulphur amino acids. It contributes primarily cystine rather than methionine (Goedeken et al., 1990a, b). A physiological requirement exists for both cystine and methionine but a dietary requirement, however, exists only for methionine (Reis et al., 1973) because cystine can be synthesized from methionine. Therefore, it should be used in combination with a good source of methionine.

Researchers at Johns Hopkins Centre found a wide variety of drug residues in feathers that were banned in poultry production in 2005 (Johns Hopkins Center for a Livable Future, 2012). This is dangerous because humans may become resistant to these drugs through continuous consumption of products from animals fed on diets compounded from feather meal with residual drugs. However, the rendering process in feather meal production is an effective method for ensuring biosecurity because processing conditions and drying denature compounds and create an unfavorable environment for viruses, bacteria and other micro-organisms to survive and grow in the product (Hamilton, 2012). This should assure food safety and protect human and animal health. Processing animal by-products by rendering should allow traceability of
finished products for quality assurance. This can be achieved by developing HACCP programmes for the feather rendering industry. This will evaluate the entire rendering process, identify potential hazards, identify critical points in the process where the hazards can be controlled and develop procedures to control these processes and ensure destruction or removal of the hazards (Hamilton, 2012). Then, the rendered product will be safe for compounding animal feeds.

Other Uses

Feathers fabrics have been used in erosion control. Turkey feather fibre fabrics have similar prevention of erosion, light and water transmittance as commercially available erosion control fabrics (Brian et al., 2003). In prevention of erosion, feather fabrics increased soil moisture content and decreased soil compaction, which are critical properties for successful ecological restoration of habitats. In the textile industry, chicken feather solution is applied onto cotton fabric. The resulting fabric has high tensile strength and more reduction of the UV transmitted, giving more protection to the human skin (Khaled et al., 2006).

Poultry feathers bound with Portland cement, sand and chemical admixtures are used for production of featherboards (Menandro, 2010). Boards containing 5-10% fibre and/or ground feathers by weight showed comparable strength and dimensional stability to commercial wood fibre-cement composites of similar thickness and density. Stiffness, flexural strength and dimensional stability of the boards decreased as the proportion of feathers was increased above 10%. Studies have shown that featherboards are suitable for non structural applications in low cost housing projects in developing countries. Tests in Philippines showed that stiffness, flexural strength and dimensional stability of featherboards are slightly lower or comparable to that of commercially available wood-fiber cement board in the market of similar thickness and density. Cement bonded featherboards have excellent decay and termite resistance which make them good construction materials in tropical climates (Comis, 1998; Menandro, 2010). This offers an environmentally friendly method of disposing a waste product and promotes competitiveness of both the poultry and construction industries.

Feathers are used for water purification. The use of chicken feathers for purification of industrial waste waters and drinking water is economical (Kar et al., 2004). Water purification using feathers has advantages because they are abundant, have a high tensile strength, water insolubility, stability over a wide range of pH and structural toughness (Kar et al., 2004; Rosa de la et al., 2008). Use of chicken feathers for sorption purposes has achieved satisfactory results for the removal of some heavy metals, colorants and toxic organic compounds (Al-Asheh et al., 2003; Kar et al., 2004; Rosa et al., 2008).

Geese and ducks are raised in America, Asia and Europe for their feathers (Ariel, 2012). About 50 % of the down and about 42 % of the coarser feathers of geese and ducks are used to fill pillows and blankets. Feathers are also used for making feather dusters. These are cleaning devices that remove dust from objects (Feather dusters, 2001). The very fine, soft barbs will not scratch, and when rubbed to build up static electricity they will capture and hold dust until shaken out. The buildup of static electricity is essential because it is the property of the feathers that makes them trap dust. The structural character of the feathers gives them the ability to catch the dust. Feathers are also used in making dusters. High quality dusters use feathers from the outer layers of ostrich’s feathers. Feather dusters are also used in interior decorating and can be used to apply paint to interior walls because the feathers produce a unique effect (Feather dusters, 2001).

Conclusion

Poultry feathers are produced in large quantities as a by-product at poultry–processing plants, reaching millions of tons annually throughout the world. Often, they become a waste disposal/environmental pollution hazard, incinerated or dumped in landfills. However, they have multiple uses and are underutilized especially in developing countries. Therefore, appropriate technologies should be developed.
to facilitate their full utilization for the various uses in the different world economies. This will minimize environmental pollution, enhance economic benefits for the poultry producers, processors, consumers of the feather products and stimulate development of feather product industries.

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