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Optimisation of surfactant decontamination and pre-treatment of waste chicken feathers by using response surface methodology

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

[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
[d] Natural Resources and the Environment, Council for Scientific and Industrial Research, Stellenbosch, South Africa

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ABSTRACT

Commercially processed, untreated chicken feathers are biologically hazardous due to the presence of blood-borne pathogens. Prior to valorisation, it is crucial that they are decontaminated to remove the microbial contamination. The present study focuses on evaluating the best technologies to decontaminate and pre-treat chicken feathers in order to make them suitable for valorisation. Waste chicken feathers were washed with three surfactants (sodium dodecyl sulphate) dimethyl dioctadecyl ammonium chloride, and polyoxyethylene (40) stearate) using statistically designed experiments. Process conditions were optimised using response surface methodology with a Box-Behnken experimental design. The data were compared with decontamination using an autoclave. Under optimised conditions, the microbial counts of the decontaminated and pre-treated chicken feathers were significantly reduced making them safe for handling and use for valorisation applications.

1. Introduction

With the development of large-scale poultry farming, the disposal of large amounts of waste chicken feathers is a long-standing problem. On a world scale, it is estimated that approximately 40×10^9 kg of chicken feathers are produced from the slaughter of more than 58×10^9 chickens (Compassion in world farming, 2013). In 2013, the South African poultry farming activity generated more than 528×10^6 kg of feathers (DAFF, 2014). Chicken feathers constitute 5–10% of the weight of the chicken and comprise a significant portion of the poultry wastes (Tseng, 2011; Pourjavaheri et al., 2014). Poultry waste is divided into solid waste (feathers, viscera, heads, feet, carcases, skin and bones), and liquid waste (blood and liquid effluents) (EL Boushy et al., 2000). The disposal of this waste gives rise to environmental and health concerns, and are guided by legal requirements and contemporary best practices, such as the Zero Waste Initiative in South Africa (Karani and Jewasikiewitz, 2007). Common disposal techniques such as incineration, landfilling and composting are not environmentally sustainable in that they are energy intensive, and/or take up valuable landfill space, as well as contribute to the emission of greenhouse gases (Sudalaiyandi, 2012; Coward et al., 2006; Tseng, 2011; Pourjavaheri et al., 2014). Hence valorisation of chicken feathers by conversion into valuable materials is a desirable route for dealing with the waste. For example, it has been reported that waste chicken feathers can potentially be converted into high value materials and products such as automotive products (side trims, door inner panels and body panels), medical products (drug delivery carriers, scaffolding and tissue engineering), cosmetics (for skin and hair), bioplastics, paper additives, nonwoven textiles, superabsorbent materials, biodiesel, energy storage, electrical insulators, and composites for use as reinforcements in construction and furniture industries (Tesfaye et al., 2017a, 2017b, 2017c, 2017d).

It has also been reported that chicken feathers can be used in preparation of microbial peptones (Taskin and Kurbanoglu, 2011), protein hydrolysates for use as a nutritional substrate for microbial production of valuable substances, such as carotenoid (Taskin et al., 2011), polysaccharide (Taskin et al., 2012), glutathion (Taskin 2013), and lactic acid (Taskin et al., 2013). Other studies have demonstrated that waste feathers could be used as plant fertilizer (Paul et al., 2013; Jie et al., 2008; Hadas and Kautsky, 1994) and low-grade animal feed (Davis et al., 1961; EL-Boushy et al., 1990; Grazziotin et al. (2006)) immobilization supports for enzymes or chemicals (Chauhan et al., 2016), in paper production (Tesfaye et al., 2017a, 2017b, 2017d), for biogas production

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

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(Patinvoh et al., 2016), and for preparation of carbon nanotubes (Gao et al., 2014).

As mentioned in the preceding paragraphs, waste chicken feathers are biological waste that is loaded with microbial contamination from bacteria in the intestinal tracts of the harvested chickens. Consequently, disinfection of waste feathers is an important prerequisite for valorisation of this waste biomass. Mesophilic or psychotropic organisms can grow on all parts of chicken feathers considering that chickens are warm-blooded mammals (Rajchard, 2010). In poultry processing plants, feathers are plucked from the chickens and they generally lie in heaps, containing smaller amounts of various foreign materials such as offal, dilute blood, biological organisms, grease, skin, faeces, flesh, and water. Due to the contamination with blood, intestinal contents, offal fat, fatty acids, debris and preen oil fresh chicken feathers can be a suitable habitat for many microorganisms (Cunningham, 2012; Gill, 1998). In general, as a by-product of poultry processing, unprocessed raw feathers appear straw-like (the barbs get stuck to the rachis); they have a greasy texture, a brown colour, and are spattered with blood, emitting an obnoxious odour (Tesfaye et al., 2017a, 2017b, 2017c).

There are a variety of reasons for the appearance and texture of plucked feathers. A preen gland secretes lipids to uphold the feather's properties (e.g., waterproofing), giving rise to the greasy texture (Jones, 2005). Free fatty acids from lipid decomposition and pigment cells, called melanocytes, are responsible for microbial growth and the dull yellow colour of feathers after slaughter. The growth of microorganisms on chicken feathers will cause them to decompose and could impart potentially fatal biological hazards for humans. Table 1 shows bacterial control points in a typical waste chicken feather biomass. It is evident that chicken feathers contain different types of hazardous microorganisms and the major ones are enterococci, coliforms, and sulphate reducing bacteria. Indeed, chicken feathers contain the highest total microbial counts (69,457 Cfu/cm^2/cm^3) (Table 1) compared to other control points in poultry slaughtering industries. Consequently, waste chicken feathers need to be adequately disinfected before handling and processing for valorisation purposes. Since the objective is to valorise feathers, it is important to develop technologies for decontamination and pre-treatment of chicken feathers that will render the feathers safe for handling but without negatively impacting the composition and structure of the feathers.

Chicken feathers could be a fatal hazard for humans if they are not processed or disposed of properly. Technologies need to be developed and customised for commercial pre-treatment and decontamination of feathers to a standard that is appropriate for their further use. Most importantly, raw chicken feathers require decontamination and pre-treatment to remove pathogens and impurities that cause objectionable odours, discoloration and to ensure process hygiene. Technologies for cleaning feathers can be adapted from those used for decontamination and pre-treatment of natural fibres used in the textile industry, e.g., washing with organic or inorganic solvents, or washing with surfactants (Augurt and Van Asten, 2000; Falbe, 2012; Sudalaiyandi, 2012; Tseng, 2011; Pourjavaheri et al., 2014). Decontamination is the removal or reduction of microbial count whereas pre-treatment refers to cleaning activities mainly for the removal of grease, fat, sand etc. Cleaning of contaminants from the feather material can be done by dissolution of the contaminants in suitable solvents, mechanical detachment, evaporation, and chemical treatment.

In this study, decontamination by washing with surfactants was selected and the efficacies of the procedures were compared with decontamination by high heat using an autoclave unit. The efficacy of the decontamination was evaluated by monitoring the microbial content of the treated and untreated samples as well as by monitoring grease content of the samples. The use of surfactants for decontamination was selected as this would be more cost effective than using high energy intensive autoclaving technology. Surfactants are commonly used in decontamination and pre-treatment of materials; they are surface-active detergents that provide remarkable benefits in dispersing, chemical or dye absorption, heat transfer, wetting, softening, emulsification, dye fixation, melting, vaporisation, sublimation, foaming and defoaming in the textile industry (EL Boushy et al., 2000; Pletnev, 2001). The surface activity and disinfecting/bactericidal performance of a surfactant is dependent on various factors such as concentration, pH, solid to liquid ratio, the number of treatment cycles, temperature, and contact time (Mandavi et al., 2008). Their bactericidal activity has not been extensively investigated, but it is claimed that they do have strong bactericidal activity (Pletnev, 2001; Tadros, 2006).

2. Materials and methods

2.1. Materials

Waste chicken feathers were supplied by a slaughterhouse in the province of KwaZulu-Natal, South Africa. The surfactants evaluated for use as combined pre-treatment and decontamination agents were: sodium dodecyl sulphate (SDS) – (anionic chemistry); dimethyl dioctadecyl ammonium chloride (DDAC) – (cationic surfactant); and polyoxyethylene (40) stearate (POE) – (non-ionic chemistry), and all were obtained from Sigma–Aldrich. Hexane (Sigma–Aldrich) was used for grease content analysis. Peptone (Merck) and yeast extract agar (Merck) were used for the bacteriological analyses.

2.2. Decontamination and pre-treatment

Pre-treatment was done by removal of materials that were not feathers: these included offal, dilute blood, grease, sand, faeces, and waste water. Decontamination was done to remove blood borne pathogens during slaughtering and microorganisms present in chickens. In this study the materials and contaminants were removed by one pot treatment using various surfactants.

2.2.1. Sampling

The act of obtaining samples from a bulk system is subject to errors that can neither be detected not compensated due to the

Table 1
Bacterial contamination control points in the poultry industry (). adapted from Jones, 2005

Control points	Total viable counts (Cfu/cm^2/cm^3)	Enterococci (cfu/cm^2/cm^3)	Coliforms bacteria (Cfu/cm^2/cm^3)	Sulphate reducing bacteria (Cfu/cm^2/cm^3)
Feathers	69457.0	184.5	0.9	179.1
Bleeding knife	7269.0	227.0	19.6	8.4
Scalding water	6421.0	5.3	0.9	55.2
Pluckers' rubber finger	2362.5	73.1	1.6	21.6
Carcass surface	6984.0	197.1	15.3	4.8
Plucking finishing table	55444.0	793.35	1483.6	225.0

Cfu = colony forming units.

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