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Valorisation of waste chicken feathers: Optimisation of decontamination and pre-treatment with bleaching agents using response surface methodology

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ABSTRACT

Environmental concerns, rapid oil consumption, the high price of oil, and limited oil reserves are driving research into cheap, biodegradable, sustainable, renewable, and abundantly available green materials. Waste chicken feathers are abundant and cheap by-products from poultry processing plants and their beneficiation offers possible solutions to these issues. Raw chicken feathers are wastes that are mixed with offal fat, debris, blood, preen oil and other wastes from the poultry process. Consequently, feathers are hazardous wastes that are contaminated with bacteria, which makes them odoriferous and unfit for valorisation as is. These contaminants must be removed before possible valorisation otherwise the feathers will not fit for purpose. The effects of oxidative (hydrogen peroxide and sodium hypochlorite) and reductive (Sodium dithionite) compounds as decontamination agents were studied on chicken feathers to assess their decontamination and pre-treatment efficiency and their effects on physicochemical and mechanical properties of the feathers. Statistically designed experiments were used to optimise the decontamination process using response surface methodology with a Box-Behnken experimental design. Regression equations were obtained to analyse microbial count and the optimum process parameters were identified. Under optimised conditions, the treated chicken feathers were characterised and their properties compared with those of unwashed chicken feathers. From the results, it was deduced that the inorganic bleaching treatments were effective removing the microbial impurities from the feathers and their use resulted in enhanced physicochemical properties of the chicken feathers. The untreated chicken feathers had the highest microbial counts (1.48E+ 07 ± 6.72E05 Cfu/g) whereas decontaminated samples showed a reduction in thousand-fold. The impurity removal after washing was about 8–18%.

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 industry generated more than 258×10^6 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) (Boushy et al., 2000). The disposal of this waste gives rise to environmental and health concerns, guided by legal requirements and contemporary best practice, such as the Zero Waste Initiative in South Africa (Karani and Jewasikiewitz, 2007).

In poultry processing plants, chicken feathers are contaminated with impurities exudates from preen glands, grease, dirt, suints/dried perspiration, burrs/dried vegetable, woody fragments, and mineral materials (Cunningham, 2012; Tseng, 2011; Pourjavaheri et al., 2014). The preen gland secretes lipids essential to maintain the feather's physical properties such as waterproofing and are responsible for the dull yellow colour on feathers (Cunningham, 2012). Suints are soluble in water whereas feather grease is a complex mixture of ester, diester and hydroxyester fatty alcohols like lanoline and fatty acids that are soluble in organic solvents and can be hydrolysed in mild alkali environments (Jones, 2005). Dirt originates from material held by the adhesive action of suits and fats whereas burrs are from vegetable and woody fragments collected during scratching of the chicken bodies against the ground.

During slaughtering, feathers are plucked from chickens, the meat is

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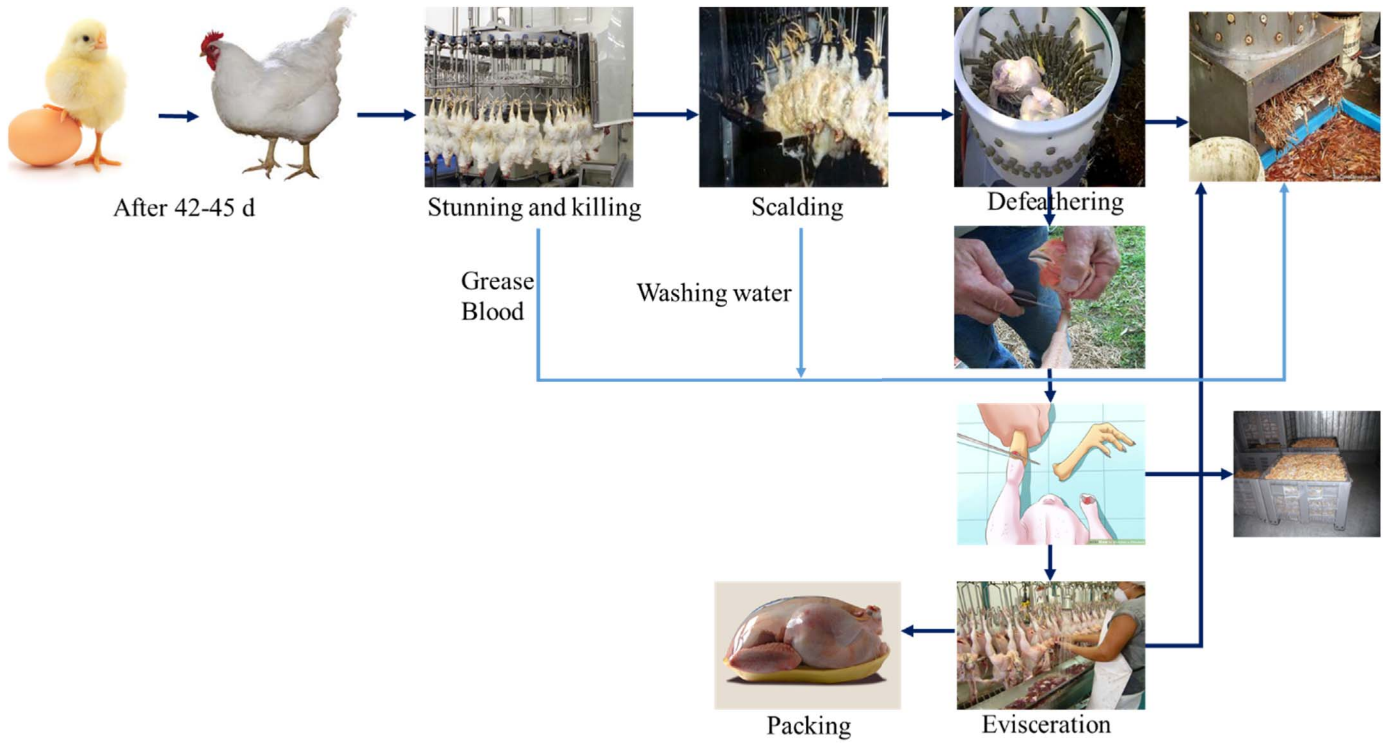

Fig. 1. Slaughtering house process flow.

packed, and the feathers often lie as dirty that contain various foreign materials, such as offal, dilute blood, grease, skin, faeces, many biological organisms, fatty and waxy substances, flesh, and water (Fig. 1). Since chickens are warm-blooded, freshly collected feathers could possibly lead to the presence of a variety of microorganisms (Richard, 2010). Free fatty acids from lipid decomposition can lead to pH changes and lead to microbial growth after slaughter. Microbes that grow on feathers will use feather keratin and decompose it, eventually degrading chicken feathers and making them structurally very weak. Thus, chicken feathers from the poultry industry are a waste disposal/environmental pollution hazard that is incinerated or dumped in landfills. However, feathers can be beneficiated into high value materials and products

Chicken feathers can be used in many applications, such as bedding materials, cosmetics, textiles, yarn production, pharmaceuticals, composites for biomedical engineering, geotextiles, composite manufacturing, carbon nanotube production, biofuel and energy storage (Tesfaye et al., 2017). Pre-treatment and decontamination of chicken feathers should be the first step prior to their valorisation in order to eliminate the microbacterial content and enable beneficiation of the feathers. A variety of processes are available to remove the impurities and the microorganisms from feathers, and to improve the physical, chemical and mechanical properties of the chicken feathers. Cleaning (pre-treatment) of the chicken feathers removes the accumulation of surface contaminants that have resulted from nature, slaughtering, transportation and storage. 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. Decontamination and pre-treatment can be achieved by dissolution in solvents, mechanical detachments, evaporation, or chemical degradation (Bateup, 1986; Hurren et al., 2006) as illustrated in (Fig. 2).

Chemical cleaning can occur due to the chemical nature of the surface that is contaminated or by a chemical agent exposed to the contaminant on the surface (Bateup, 1986; Hurren et al., 2006). Common chemical cleaning agents that are used are oxidative in nature and include hydrogen peroxide (H_2O_2), sodium hypochlorite (NaOCl),

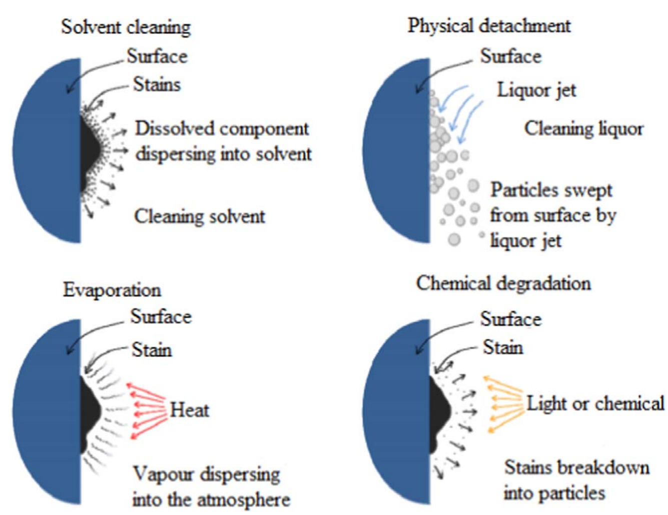

Fig. 2. Cleaning mechanisms for surface contaminants.

sodium chlorite ($NaClO_2$), sodium perborate ($NaBO_3$), or sodium percarbonate ($Na_2CO_3{\cdot}5H_2O_2$); reducing agents like sodium dithionite ($Na_2S_2O_4$) and sodium thiosulphate ($Na_2S_2O_3$) can also be used (Bateup, 1986; Hurren et al., 2006) as well as metal oxides such as titanium dioxide (TiO_2), tungsten oxide (WO_3), and zinc oxide (ZnO) (Hurren et al., 2006). Three bleaching agents we evaluated in this study: H_2O_2, NaOCl, and $Na_2S_2O_4$.

H_2O_2 is a favourable bleaching agent for peroxidation of melanin pigment, chromatophores, and lipids, and, because it does not react with proteins, it is widely used for decontamination of animal fibres (Jones, 1999). This aids in retaining the mechanical properties of the fibres. During the oxidation reaction, H_2O_2 is converted into the perhydroxy species (HO_2^-), which is responsible for bleaching (Christoe, 1984; Jones, 1999; Noyori et al., 2003). Additionally, the rate of decomposition of H_2O_2 rises with increase in temperature and pH, as does the rate of bleaching (Christoe, 1984; Sudalaiyandi, 2012; Tseng, 2011;