S. Enteritidis on Chicken Eggshells

Subjects: Agriculture, Dairy & Animal Science
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Salmonella enterica serovar Enteritidis (S. Enteritidis) is a pathogen that poses a health risk. Shell eggs have been reported as one of the principal vehicles for the transmission of bacterial pathogens. The cuticle on eggshells (the organic layer of freshly laid egg) is damaged during extended storage of the egg, leading to the penetration of pathogens attached to the eggshell surface and in the surrounding environment. Therefore, effective disinfection on eggshells is urgently required to maintain good quality egg products by preventing bacterial contaminants from entering eggs.

Keywords: Salmonella enteritidis ; blue light ; inactivation ; eggshell ; freshness

1. Overview

Salmonella enterica serovar Enteritidis (*S.* Enteritidis) is a pathogen that poses a health risk. Blue light (BL), an emerging sanitization technology, was employed for the first time in the present study to inactivate *S.* Enteritidis on eggshell surfaces and its influence on maintaining eggshell freshness was investigated systematically. The results showed that 415 nm-BL irradiation at a dose of 360 J/cm^2 reduced 5.19 log CFU/mL of *S.* Enteritidis in vitro. The test on eggshells inoculated with *S.* Enteritidis showed that a BL dose at 54.6 J/cm^2 caused a 3.73 log CFU reduction per eggshell surface and the impact of BL inactivation could be sustained in post-5-week storage. The quality of the tested eggs (weight loss, yolk index, Haugh unit (HU) and albumen pH) demonstrated that BL treatments had negligible effects on the albumen pH of eggs. However, compared to the control, BL-treated eggs showed lower weight loss and higher HU after 5 weeks of storage at 25 °C and 65% humidity and yolk index in the control group could not be determined after 5 weeks of storage. Besides, the total amino acid content of the BL-treated egg was higher than the control, exhibiting an advantage of BL irradiation in maintaining the nutrient quality of whole eggs. The current study determined the efficacy of BL against *S*. Enteritidis on eggshell and suggested that BL could be an effective application in maintaining the freshness and quality of eggs.

2. *Salmonella Enterica* Serovar Enteritidis

Chicken eggs are popular foodstuff worldwide due to their valuable nutrients, such as complete protein, including all essential amino acids, easily digestible fats, vitamins (A, B_2, B_6, B_9 and B_{12}) and minerals (iron, calcium and potassium) [1]. According to the data provided by FAOSTAT, the production of eggs hen in shell, in 2019, was 83,483,675 tons and, according to a report from the Food and Agriculture Organization of the United Nations, global egg production will reach 89 million tons by 2030 [2]. However, poultry-borne pathogens lead to food poisoning in consumers and considerable egg loss and waste. Especially, *Salmonella*-contaminated eggs and egg-derived products contribute to many salmonellosis cases [3]. *Salmonella* strains have been frequently isolated from eggshell pieces and different serovars have been linked with egg contamination [4]. Among the *Salmonella* strains, *Salmonella enterica* serovar Enteritidis (*S.* Enteritidis) is frequently recovered from contaminated grade A eggs.

Shell eggs have been reported as one of the principal vehicles for the transmission of bacterial pathogens [5]. The cuticle on eggshells (the organic layer of freshly laid egg) is damaged during extended storage of the egg, leading to the penetration of pathogens attached to the eggshell surface and in the surrounding environment. Therefore, effective disinfection on eggshells is urgently required to maintain good quality egg products by preventing bacterial contaminants from entering eggs.

Nowadays, several antimicrobial approaches have been reported to disinfect *S*. Enteritidis in eggshells, including ultraviolet C (200–280 nm) [3][6][7], H_2O_2 [8], ozone [9] and slightly acidic electrolyzed water (SAEW) [10], but their applications are limited by disadvantages such as photoreactivation, decolorization in certain products at high doses and harmful effects on human [11]. Blue light (BL), especially in the wavelength range of 405–470 nm, has attracted increasing interest because of its intrinsic antimicrobial property [11]. BL excited the endogenous intracellular porphyrins, leading to the production of highly cytotoxic reactive oxygen species and the following cell damage of bacteria [11][12]. BL is

considered to be less detrimental to mammalian cells and human skin cells than ultraviolet irradiation [11]. Moreover, it can penetrate deeper than ultraviolet C [11]. Up to now, BL had been successfully applied in disinfection of some food, including cantaloupe rinds [13], fresh-cut papaya [14], milk [15], cucumbers, processed meat products [16] and packaged sliced cheese [17]. Our previous study demonstrated that methicillin-resistant *Staphylococcus aureus* and *Cronobacter sakazakii* were decreased by 6 log CFU/mL and 8 log CFU/mL under 415-nm BL illumination of 80 and 240.48 J/cm^2, respectively and the outer-membrane damage and lipid oxidation were induced by BL irradiation [12][18]. However, up to now, the efficacy of BL on shell egg disinfection has not been studied. Therefore, the purpose of this research was to verify the effectiveness of BL in inactivating *S*. Enteritidis on eggshells and to explore the effect of BL inactivating *S*. Enteritidis in maintaining the freshness and quality of eggs.

3. Conclusions

The current study evaluated the efficiency of 415-nm BL in egg disinfection and systematically evaluated its influence on egg freshness during 5-week storage. It showed that a BL dose of 360 J/cm^2 led to a 5.19 log CFU/mL reduction in *S*. Enteritidis in vitro and 54.6 J/cm^2 of BL illumination led to a reduction of 3.73 log CFU/eggshell on shell eggs. The remaining *S*. Enteritidis population on eggshells after BL treatment had no significant growth during the 5-week storage. The investigation also showed that 54.6 J/cm^2 of BL illumination with applied dose did not have significant detrimental impact on the quality of whole eggs. The dynamic changes of albumen pH were similar in BL-treated and control group. The decreases in egg weight, yolk index, HU and total amino acid contents were slowed down by BL illumination. The current findings suggested that the 415 nm BL could be an effective application of *S*. Enteritidis decontamination on eggshell with potential of maintaining the quality of egg albumen.

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