Causes of Egg Spoilage and Preventing Egg Spoilage

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Eggs are a rich source of protein, minerals, lipids, and vitamins. Eggs are an essential source of bacterial microflora. Controlling antimicrobial resistance and reducing food loss and waste are essential for a sustainable future. To prevent spoilage and to preserve eggs, a variety of techniques, including thermal and non-thermal, are often used. The decontamination methods for egg preservation that have been applied are discussed. In previous studies, the initial contamination of the eggs varied from 2 to 9 log CFU per egg. Either thermal or non-thermal techniques resulted in reduced concentrations of *Salmonella enteritidis*, *Salmonella typhimurium*, and *Escherichia coli*, respectively, on the surface of the egg that ranged 0.62–5.9 log, 1.27–4.9 log, and 0.06–6.39 log, respectively, for the former, and being 1.2–7.8 log, 5.0–7.8 log, and 6.5–6.6 log, respectively, for the latter. Thermal approaches were more effective than the non-thermal approaches. Some of these methods had negative consequences on the egg's functionality, while combination methods, such as thermoultrasonifcation (ozone-UV radiation or heat-ozone), mitigated these effects.

egg food spoilage

1. Causes of Egg Spoilage and Methods of Preventing It

Outbreaks of food-borne diseases involving salmonellosis and campylobacteriosis have been attributed to the consumption of eggs and egg products [1]. The egg can be-come microbially contaminated in two ways: vertically and horizontally. When eggs get contaminated while they are still being formed, whether in the ovary or oviduct, this is known as vertical (trans-ovarian) contamination [2]. Horizontal transmission happens after the egg has been deposited and exposed to germs post-lay, in which case the bacteria penetrate through the shell [3][4]. *Salmonella enterica* serovars represent the greatest risk to the safety of eggs and have been implicated in numerous egg recalls [5]. This is attributed to the fact that *Salmonella* has the genes needed to survive in the harsh conditions of egg white, and also can duplicate in egg yolk [6][7].

Causes of egg spoilage are summarized in **Figure 1** according to previous studies [8][9][10]. Reduced susceptibility to egg spoiling and the incidence of contaminated eggs can be achieved by minimizing microbial contamination on the eggshell. During storage, microbial and non-microbial spoilage of eggs can arise; however, egg spoilage can be reduced by applying the necessary practical approaches, and either direct methods or indirect factors (**Figure 1**).

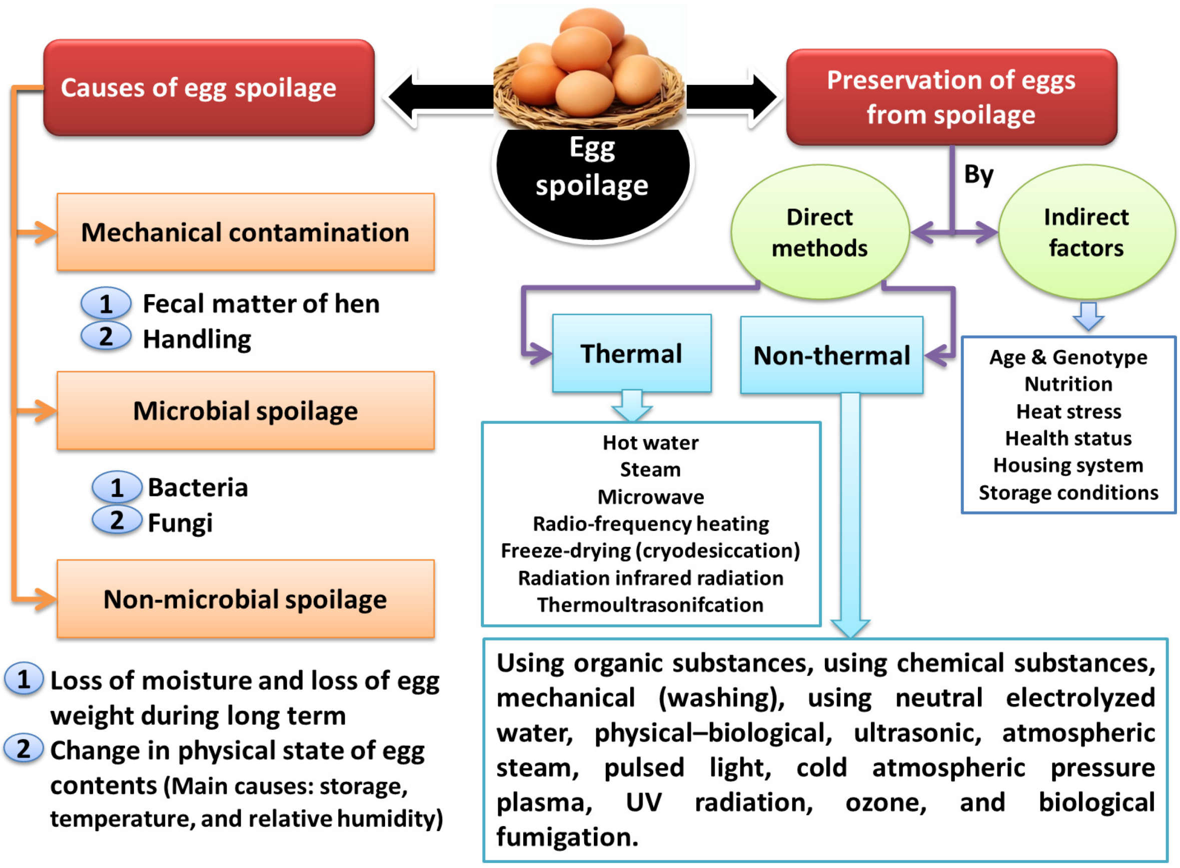

Figure 1. Causes of egg spoilage and methods of preventing it.

2. Direct Methods of Preventing Egg Spoilage

Direct methods of preventing egg spoilage were divided into two methods: (1) non-thermal and (2) thermal methods. Different methods of egg preservation have been used, each with different results and restrictions. The first line of defense to prevent change of the egg's interior components is to decontaminate eggshells. While washing eggshells may reduce the amount of microbes on the surface, it can also damage the cuticle layer and leave residue, which makes it easier for microbes to enter the egg's contents [11][12]. Disinfectants should have a number of critical qualities, including no corrosive effects, minimal negative effects on public health, and environmental friendliness. The findings of Knape et al. [13], Chousalkar et al. [14], and Al-Ajeeli et al. [15] revealed that all treatments that use chemical substances significantly reduced *Salmonella* species, whereas *Salmonella* Infantis penetration did not differ significantly between cleaned and unwashed eggs after washing with hydroxide and hypochlorite. Several sanitizers, including organic acids and chlorine-based sanitizers, have been utilized or mentioned in egg-washing procedures [16][17][18]. In the process of washing eggs, using electrolyzed water (EW) is a promising approach. EW is produced by electrolyzing NaCl in water [19], and its application for the prevention of foodborne diseases has already been documented [20]. Its bactericidal actions can be attributed to three properties: pH, reactive oxygen, and chlorine species, such hypochlorous acid and oxidation-reduction potential. Metabolic flux and ATP generation are altered by high oxidation-reduction potential. It prevents the oxidation of glucose, hinders the synthesis of proteins, and prevents oxygen intake and oxidative phosphorylation, which results in the leakage of certain macromolecules [21], and damages cell membranes [22]. The major components of EW are hypochlorous acid, which generates a hydroxyl radical that affects several pathogens [23]. Since bacteria typically cause proteins denaturation. Due to their low cost and environmental impact, edible coatings, such as chitosan and propolis films, have been widely employed to package food products over the past ten years [24]. Several studies have been completed on coating of egg to increase its shelf life and maintain its quality [25]. Chitosan, used as a cationic biopolymer, was found to have exceptional film-forming abilities and great antibacterial activity against different pathogens, including strains of bacteria, yeast, and fungi [26]. In addition, propolis, a resinous substance, from buds, leaves, stems, and fissures, and combined with beeswax, performs a significant role in the control of the eggshell surface microbiome due to its strong biological properties, such as its antibacterial, antiviral, and antioxidant activities [27][28][29]. Eggs can be decontaminated using a variety of non-thermal methods, such as using organic materials, which had favorable significant impacts on the interior quality of eggs, extending of shelf life, and decreased fungal spores development [30][31]. Modern technologies that do not employ heat to inhibit microbial growth have gained interest due to the detrimental effects that high temperatures can have on egg quality. Several of these non-thermal technologies, including high hydrostatic pressure, ultrasound, pulsed light, cold plasma, and ozonation, have recently been proposed for use in the egg industry [32]. Results of Ragni et al. [33], Dasan et al. [34] and Moritz et al. [35] indicated that atmospheric plasma either gas or pressure significantly decreased in different *Salmonella* species, with no adverse influences on egg quality. It is well-established that Cold Plasma has a germicidal action [36]. When this non-thermal technique is used, microorganisms suffer fatal damage. It has been established that certain plasma components, including charged particles, UV light, and reactive oxygen and nitrogen species, are responsible for this antibacterial activity [37]. Plasma exposes microorganisms to a powerful barrage of radicals that primarily harm the cell surface and prevent it from repairing itself in a timely manner. As a result, cell death and cell wall rupture take place. Furthermore, similar to electrical pulses, the administration of plasma causes the cell membrane to produce pores, which results in the leakage of intracellular substances [37]. Ozone has the ability to inactivate bacteria, fungus, viruses, and protozoa and their spores. It has been proposed that microbial cells contain a number of vulnerable regions to the effects of ozone, including the unsaturated lipids found in the cell membrane. Damage to the membrane encourages component release and results in microbial death [38]. Moreover, it has been demonstrated that using ozone at concentrations of 2 and 4 ppm, respectively, was efficient in maintaining the functional properties and inner quality of fresh eggs throughout storage, destroyed fungal colonies without damaging the cuticle, and significantly reduced *Salmonella* [39][40][41]. Similarly, pulsed light fluence was found to reduce cells of *Salmonella* on the eggshell without opposing influences on the egg albumen quality, and sensory and functional properties, and *Escherichia coli* was completely inactivated [42][43]. Due to the protection of the egg cuticle layer and the ability to increase shelf life without residue issues, pulsed light appears to be an effective decontamination approach when utilized for egg preservation. Through photochemical and photo-thermal effects, pulsed light could successfully inactivate bacteria on the surfaces of food. The high-powered illumination is absorbed by microbial DNA, causing structural alterations in its physical and chemical makeup that eventually result in genetic information loss, unpaired replication, gene transcription, and cell death [32][44]. Furthermore, pulsed light has no harmful on internal egg quality [45]. Al-Ajeeli et al. [15] reported that the application of H_2O_2+UV treatment to shell eggs is a new technology with significant implications for the preservation of egg safety and quality. Each treatment reduced *S. enteritidis* to below the detection n threshold (200 CFU /egg).

Additionally, Sert et al. [46] found that utilizing a 35 kHz ultrasonic wave for 5, 15, and 30 min at 30 °C significantly improved egg quality. The reduction in *Salmonella* was 1.45 and 0.62 log CFU/egg by using neutral electrolyzed water and 2% citric acid, respectively. On the other hand, citric acid 2% solution damaged the cuticle and exposed eggshell pores [20]. Rodriguez-Romo and Yousef [47] found that the combination of ozone and UV radiation caused significant inactivation of *Salmonella*. Using vacuum-packing is a highly effective method for egg preservation, as Aygun and Sert [48] indicated that over the storage period, vacuum packed eggs reduced microbial contamination levels and the egg shelf life was increased by at least 42 days. Similarly, using biological fumigation decreased the number of microorganisms on the eggshell surface and fumigated eggs were found to have significantly higher egg quality than non-fumigated eggs over a range of storage periods [49]. Despite the unquestionable advantages that thermal approaches provide to food safety through microbial membrane damage, a procedure like pasteurization can denature egg proteins and subsequently alter its functional characteristics [50][51]. Eggs lose some of their ability to foam and emulsify when heated over 60 °C [52]. Egg white proteins may coagulate more readily at temperatures higher than 60 °C. This claim is confirmed by the findings of a study conducted by Uysal et al. [53] who found that raising the pasteurization temperature caused denaturation, decreased protein solubility, and loss of egg functional characteristics. Additionally, these authors noted that heat altered the lysozyme and ovalbumin protein compositions. Pasteurization is required to extend the shelf life of eggs and their products, and to decrease consumer risks associated with foodborne pathogens, for instance, heat-resistant *Salmonella*. As a result, the widely used method for preventing food deterioration is thermal pasteurization, which includes hot water immersion [54], steam method [55], microwave [56], using thermoultrasonication [57] and freeze-drying [58].

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