

A Focus on Chlorine Dioxide: The Promising Food Preservative

Zhao Chen*

Department of Biological Sciences, Clemson University, Clemson, SC 29634, USA

*Corresponding author: Zhao Chen, Department of Biological Sciences, Clemson University, Clemson, SC 29634, USA, Tel: 864-650-5244; E-mail: zchen5@clemson.edu

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Editorial

Chlorine dioxide (ClO₂) is an unstable green-yellowish gas with an irritating odor [1]. In water, ClO₂ exists as free radicals and as a powerful oxidizing agent, it reacts easily with reducing agents. The end products of ClO₂ reactions are chloride (Cl⁻), chlorite (ClO⁻), and chlorate (ClO₃⁻) [2]. Chlorine dioxide is a promising food preservative as a substitute for chlorine (Cl₂) because unlike Cl₂, it does not react with organic matters in foods to form harmful organohalogen byproducts [3]. Chlorine dioxide can be used in aqueous and gaseous phases. Studies have demonstrated that both aqueous and gaseous ClO₂ are effective sanitizing agents which can inactivate a broad spectrum of microorganisms, such as bacteria, fungi, viruses, protozoa, and algae [4].

The US Environmental Protection Agency (EPA) has approved the use of ClO₂ as a disinfectant for potable water with a monitoring requirement of 1 ppm ClO⁻ in the treated water [5]. The US Food and Drug Administration (FDA) has also allowed the use of ClO₂ as a bactericidal agent in poultry processing water at a level of 3 ppm residual ClO₂ [6]. Meanwhile, aqueous ClO₂ has been approved by the US FDA for sanitizing fruits and vegetables at concentrations not exceeding 3 ppm residual ClO₂ [7].

Studies have proved the effectiveness of ClO₂ treatment on prolonging the shelf-life and maintaining the storage quality of a wide variety of foods. Chlorine dioxide has been reported to inhibit the activities of some browning-related enzymes to retain the stability of foods. It has been found to be able to inhibit polyphenol oxidase (PPO) activity in Golden Delicious apple [8], lotus root [9], and asparagus lettuce [10], and peroxidase (POD) activity in asparagus lettuce [10]. However, there are some conflicts among findings of different authors. Browning caused by ClO₂ treatment has also been observed in various foods, including shredded lettuce, peach, and apple [11-14]. To inhibit the browning of white cabbage, Gómez-López et al. [15] applied cysteine solution prior to ClO₂ treatment.

Chlorine dioxide can possibly react with carbohydrates, lipids, and proteins in foods [16]. It is also known that ClO₂ can react with phenols [17]. As some phytochemicals in foods are categorized as phenolic compounds, ClO₂ is supposed to have an impact on these compounds. Similarly, since ClO₂ is a strong oxidant, some reducing components as human nutrients (e.g. ascorbic acid) in foods could be readily oxidized. However, published scientific literatures have shown limited negative effect of ClO₂ on these nutrients in various foods, such as salmon, red grouper, green bell pepper, iceberg lettuce, white cabbage, plum, and mulberry [18-23].

Several authors have reported the bleaching or white blushing in lettuce, green bell pepper, tomato, strawberry, blueberry, and mulberry as a consequence of ClO₂ treatment [12,19,24-27]. Nonetheless,

sufficient evidence has demonstrated that ClO₂ generally has no deleterious effect on the sensory quality of foods [4].

Studies have been carried out to investigate the levels of chemical residues in foods after ClO₂ treatment. The application of aqueous ClO₂ followed by a water rinse did not leave any residues of ClO₂, ClO⁻, or ClO₃⁻ in mulberry [23]. For ClO₂ in gaseous phase, Tsai et al. [28] could not detect residues of ClO₂, ClO⁻, or ClO₃⁻ in potatoes stored with ClO₂ gas. Trinetta et al. [29] also reported that after ClO₂ gas treatment, there was minimal to no detectable chemical residues in selected fruits and vegetables. In the study of Kim et al. [30], low levels of ClO₃⁻ were detected in ClO₂-treated sea scallop, mahimahi, and shrimp, which is not expected to pose any health risks to consumers after its conversion to Cl⁻ during cooking. And ClO⁻ residue was not found in any of the ClO₂-treated seafoods.

Regarding toxicity, ClO₂ is not classified as a carcinogen to human by the International Agency for Research on Cancer [31]. No formation of toxic chlorinated byproducts is one significant advantage of ClO₂ as food preservative over Cl₂. It has been reported by López-Gálvez et al. [32] that washing lettuce with 3.7 mg/L aqueous ClO₂ for 30 min did not produce detectable levels (<5 mg/L) of trihalomethanes (THMs), whereas the formation of THMs could be detected in process water and lettuce in which sodium hypochlorite (NaClO) was applied under some conditions.

In conclusion, as a strong oxidizing agent, ClO₂ has the potential to be an alternative to Cl₂ to maintain the postharvest storage quality and enhance the microbiological safety of foods, without posing any health risks to consumers.

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