

## A Focus on Chlorine Dioxide: The Promising Food Preservative

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### Editorial

Chlorine dioxide ( $\text{ClO}_2$ ) is an unstable green-yellowish gas with an irritating odor [1]. In water,  $\text{ClO}_2$  exists as free radicals and as a powerful oxidizing agent, it reacts easily with reducing agents. The end products of  $\text{ClO}_2$  reactions are chloride ( $\text{Cl}^-$ ), chlorite ( $\text{ClO}_2^-$ ), and chlorate ( $\text{ClO}_3^-$ ) [2]. Chlorine dioxide is a promising food preservative as a substitute for chlorine ( $\text{Cl}_2$ ) because unlike  $\text{Cl}_2$ , 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  $\text{ClO}_2$  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  $\text{ClO}_2$  as a disinfectant for potable water with a monitoring requirement of 1 ppm  $\text{ClO}_2^-$  in the treated water [5]. The US Food and Drug Administration (FDA) has also allowed the use of  $\text{ClO}_2$  as a bactericidal agent in poultry processing water at a level of 3 ppm residual  $\text{ClO}_2$  [6]. Meanwhile, aqueous  $\text{ClO}_2$  has been approved by the US FDA for sanitizing fruits and vegetables at concentrations not exceeding 3 ppm residual  $\text{ClO}_2$  [7].

Studies have proved the effectiveness of  $\text{ClO}_2$  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  $\text{ClO}_2$  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  $\text{ClO}_2$  treatment.

Chlorine dioxide can possibly react with carbohydrates, lipids, and proteins in foods [16]. It is also known that  $\text{ClO}_2$  can react with phenols [17]. As some phytochemicals in foods are categorized as phenolic compounds,  $\text{ClO}_2$  is supposed to have an impact on these compounds. Similarly, since  $\text{ClO}_2$  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  $\text{ClO}_2$  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  $\text{ClO}_2$  treatment [12,19,24-27]. Nonetheless,

sufficient evidence has demonstrated that  $\text{ClO}_2$  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  $\text{ClO}_2$  treatment. The application of aqueous  $\text{ClO}_2$  followed by a water rinse did not leave any residues of  $\text{ClO}_2$ ,  $\text{ClO}_2^-$ , or  $\text{ClO}_3^-$  in mulberry [23]. For  $\text{ClO}_2$  in gaseous phase, Tsai et al. [28] could not detect residues of  $\text{ClO}_2$ ,  $\text{ClO}_2^-$ , or  $\text{ClO}_3^-$  in potatoes stored with  $\text{ClO}_2$  gas. Trinetta et al. [29] also reported that after  $\text{ClO}_2$  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  $\text{ClO}_3^-$  were detected in  $\text{ClO}_2$ -treated sea scallop, mahimahi, and shrimp, which is not expected to pose any health risks to consumers after its conversion to  $\text{Cl}^-$  during cooking. And  $\text{ClO}_2^-$  residue was not found in any of the  $\text{ClO}_2$ -treated seafoods.

Regarding toxicity,  $\text{ClO}_2$  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  $\text{ClO}_2$  as food preservative over  $\text{Cl}_2$ . It has been reported by López-Gálvez et al. [32] that washing lettuce with 3.7 mg/L aqueous  $\text{ClO}_2$  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 ( $\text{NaClO}$ ) was applied under some conditions.

In conclusion, as a strong oxidizing agent,  $\text{ClO}_2$  has the potential to be an alternative to  $\text{Cl}_2$  to maintain the postharvest storage quality and enhance the microbiological safety of foods, without posing any health risks to consumers.

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