Journal of Experimental Food Chemistry

Chen, J Exp Food Chem 2017, 3:1
DOI: 10.4172/2472-0542.1000e107

Editorial Open Access

A Focus on Chlorine Dioxide: The Promising Food Preservative

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Received date: February 20, 2017; **Accepted date:** February 21, 2017; **Published date:** February 27, 2017

Editorial

Chlorine dioxide (ClO_2) is an unstable green-yellowish gas with an irritating odor [1]. In water, ClO_2 exists as free radicals and as a powerful oxidizing agent, it reacts easily with reducing agents. The end products of ClO_2 reactions are chloride (Cl^-), chlorite (ClO^-), and chlorate (ClO_3^-) [2]. Chlorine dioxide is a promising food preservative as a substitute for chlorine (Cl_2) because unlike 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 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 ClO_2 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 ClO_2 [6]. Meanwhile, aqueous ClO_2 has been approved by the US FDA for sanitizing fruits and vegetables at concentrations not exceeding 3 ppm residual ClO_2 [7].

Studies have proved the effectiveness of 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 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 ClO_2 treatment.

Chlorine dioxide can possibly react with carbohydrates, lipids, and proteins in foods [16]. It is also known that ClO_2 can react with phenols [17]. As some phytochemicals in foods are categorized as phenolic compounds, ClO_2 is supposed to have an impact on these compounds. Similarly, since 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 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 ClO_2 treatment [12,19,24-27]. Nonetheless, sufficient evidence has demonstrated that 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 ClO_2 treatment. The application of aqueous ClO_2 followed by a water rinse did not leave any residues of ClO_2, ClO^-, or ClO_3^- in mulberry [23]. For ClO_2 in gaseous phase, Tsai et al. [28] could not detect residues of ClO_2, ClO-, or ClO_3- in potatoes stored with ClO_2 gas. Trinetta et al. [29] also reported that after 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 ClO_3^- were detected in ClO_2-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 ClO_2-treated seafoods.

Regarding toxicity, 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 ClO_2 as food preservative over Cl_2. It has been reported by López-Gálvez et al. [32] that washing lettuce with 3.7 mg/L aqueous 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 (NaClO) was applied under some conditions.

In conclusion, as a strong oxidizing agent, ClO_2 has the potential to be an alternative to 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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Citation: Chen Z (2017) A Focus on Chlorine Dioxide: The Promising Food Preservative. J Exp Food Chem 3: e107. doi: 10.4172/2472-0542.1000e107

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