Investigation of synthetic compounds in commercially available peeled root vegetable products

Sung-Hee Kwon*, Mi-Sook Yeom, Byung-Kyu Park, Se-Youn Han, Min-Jeong Kang, Kwang-Sig Joo, Myung-Je Heo, Mun-Ju Kwon

Department of Samsan Agricultural Products Inspection on the Food and Drug Administration, Incheon Metropolitan City Institute of Public Health and Environment, Incheon 22320, Korea

Abstract The browning of peeled root vegetables causes a major deterioration in the quality of the products, which significantly affects consumer purchasing behavior decisions and is a major cause of disposal during distribution. Sulfate and chlorine dioxide are representative additives used in commercially available peeled root vegetables. Therefore, this study investigated residual concentration of subchlorite ions and chlorate ions, which were the decomposition products of sulfur dioxide and chlorine compounds used for antioxidants, preservatives, and bleach in peeled root vegetables distributed online and offline. As a result of the survey, in 12 of 67 cases, sulfur dioxide was detected below the available standards. Through this survey, the content of synthetic ingredients can be estimated and used as a foundation for material development to suppress browning in the future.

Keywords peeled root vegetables, sulfur dioxide, chlorate ions, browning

1. Introduction

With the recent changes in dietary culture and interest in health, the demand for fresh products such as convenience foods of vegetables and fruits has increased. Therefore, simply processed fruits and vegetables are gaining popularity. These simple processed products are frequently used by busy modern people because they can be consumed immediately after purchase without preprocessing (Kim, 2017). However, as these products undergo processing such as peeling, cutting, coring, and slicing, quality deterioration such as moisture loss, tissue softening, and microbial contamination are unavoidable, resulting in respiration, ethylene generation, and browning. Therefore, preservability and stability are significantly lower compared to raw agricultural products. The main cause of the deterioration of preservability is tissue damage that occurs during the peeling and cutting processes, which are essential manufacturing processes. Generally, browning occurs first under modified atmospheric packaging (MAP), followed by odor, softening, and decay (Park et al., 2003). In particular, browning is a major factor in discarding fresh convenience foods during distribution, with a high
distribution loss rate of about 25% (Jeong, 2012), as it is a criterion for consumers’ freshness judgment and purchasing behavior. In most cases, when the appearance and flavor of these products are damaged, consumer preference is lowered, thereby directly or indirectly affecting the commercial value. Therefore, food storage and processing are critical (Kim and Uyama, 2005; Park et al., 2013). In particular, the browning of peeled root vegetables is the main quality deterioration phenomenon, which significantly affects consumer purchasing decisions and is a major cause of waste during distribution (Choi et al., 2013; Oh et al., 2019). Therefore, synthetic compounds are used to inhibit browning and disinfect during the manufacturing processes of washing, peeling, and cutting. However, as consumers’ interest in health has increased recently, their use has been discouraged (Lee and Kim, 2020). Typical additives widely used in peeled root vegetable products are sulfites and chlorine dioxide (Kim et al., 2000). These sulfites generate sulfurous acid with strong reducing power. When sulfurous acid is oxidized to sulfuric acid, a strong bleaching action reduces colored substances. Therefore, it is widely used to prevent browning by strongly inhibiting the action of polyphenol oxidase, which is involved in the browning of foods (Kim et al., 2000). The sulfur dioxide (SO₂) management is subject to ‘Standards and Specifications for Food Additives’ (Ministry of Food and Drug Safety Notice No. 2021-19, 2021. 3. 9.) II. Food Additives and Mixed Formulations 5. Standards for Use by Item a. Food Additives’ (MFDS, 2021). In the United States, the EU, and Canada, sulfites are considered allergens. Therefore, if more than 10 mg/kg of SO₂ is used in food, it must be labeled on the product. Like sulfur dioxide, chlorine dioxide used in food is a chlorine-based compound. Hypochlorous acid series (for example, sodium hypochlorite) and aqueous chlorine dioxide are mainly used. They exist as chlorite ions and chlorate ions, which are major decomposition products (KFDA, 2008). The effects of chlorine-based disinfectants on health were mainly reported in drinking water. Chlorine dioxide, which is used to disinfect drinking water, decomposes rapidly in water into chlorite (ClO₂⁻), chlorate (ClO₃⁻), and chlorine (Cl⁻). In particular, chlorite is the main chemical species (WHO, 2016). As the use of chlorine-based disinfectants in food increases, there are concerns about health risks. However, a systematic and standardized analysis method for chlorite and chlorate, which are decomposition products, has not yet been proposed worldwide. Therefore, synthetic compounds are used to inhibit browning and disinfect during the manufacturing processes of washing, peeling, and cutting. However, as consumers’ interest in health has increased recently, their use has been discouraged (Lee and Kim, 2020). Typical additives widely used in peeled root vegetable products are sulfites and chlorine dioxide (Kim et al., 2000). These sulfites generate sulfurous acid with strong reducing power. When sulfurous acid is oxidized to sulfuric acid, a strong bleaching action reduces colored substances. Therefore, it is widely used to prevent browning by strongly inhibiting the action of polyphenol oxidase, which is involved in the browning of foods (Kim et al., 2000). The sulfur dioxide (SO₂) management is subject to ‘Standards and Specifications for Food Additives’ (Ministry of Food and Drug Safety Notice No. 2021-19, 2021. 3. 9.) II. Food Additives and Mixed Formulations 5. Standards for Use by Item a. Food Additives’ (MFDS, 2021). In the United States, the EU, and Canada, sulfites are considered allergens. Therefore, if more than 10 mg/kg of SO₂ is used in food, it must be labeled on the product. Like sulfur dioxide, chlorine dioxide used in food is a chlorine-based compound. Hypochlorous acid series (for example, sodium hypochlorite) and aqueous chlorine dioxide are mainly used. They exist as chlorite ions and chlorate ions, which are major decomposition products (KFDA, 2008). The effects of chlorine-based disinfectants on health were mainly reported in drinking water. Chlorine dioxide, which is used to disinfect drinking water, decomposes rapidly in water into chlorite (ClO₂⁻), chlorate (ClO₃⁻), and chlorine (Cl⁻). In particular, chlorite is the main chemical species (WHO, 2016). As the use of chlorine-based disinfectants in food increases, there are concerns about health risks. However, a systematic and standardized analysis method for chlorite and chlorate, which are decomposition products, has not yet been proposed worldwide.
not established (KFDA, 2008). Therefore, this study checked the residual concentrations of chlorite ions and chlorate ions, which are decomposition products of sulfur dioxide and chlorine-based compounds used as antioxidants, preservatives, and bleaching agents for peeled root vegetable products distributed online and offline. In addition, this study investigated the actual use of synthetic compounds. Based on the results, this study sought to secure the safety of peeled root vegetables by developing a naturally-derived anti-browning agent to replace synthetic compounds.

2. Materials and methods

2.1. Materials

The materials used in this experiment were peeled root vegetables (balloon flower, deodeok, lotus root, and greater burdock) sold in online marts, supermarkets, and traditional markets from February to October 2021. All the materials were fresh. The residual amounts of sulfur dioxide and chlorine ions were investigated for 67 cases of 4 types of vegetables—38 cases of balloon flower, 6 cases of deodeok, 13 cases of lotus root, and 10 cases of greater burdock. A list of tested products is shown in Table 1.

2.2. Standards and reagents

For sulfur dioxide analysis, sodium bisulfite, dimedon (5,5-dimethyl-1,3-cyclo hexanediene), sodium azide, and pararosaniline were purchased from Sigma Chemical Co. (St. Louis, Mo, USA). HPLC-grade ethanol was purchased from Fisher. 171.0 mg of sodium hydrogen sulfite (100 mg as sulfur dioxide), a standard material, was precisely weighed, and 0.1 N sodium hydroxide was added to make 100 mL, which was used as the standard stock solution. For the analysis of chlorite ion (ClO₂⁻) and chlorate ion (ClO₃⁻), each standard solution (100 μg/mL) was purchased from a high-purity standard company. Sodium carbonate concentrate (Sigma Chemical Co.) and sulfuric acid (95-98%, Sigma Chemical Co., St. Louis, MO, USA) were used. Distilled water purified by a water purification system (Milli-Q Direct 16, Merk Millipore, Germany) was used as purified water. A standard solution for a calibration curve was prepared by diluting a standard substance, 100 μg/mL of each chlorite and chlorate ions, with ultrapure water.

2.3. Analysis method

2.3.1. Sulfur dioxide analysis

In a flask, 20 mL of water, 1 mL of 5% dimethone/ethanol solution, 1 mL of 1% sodium azide solution, 2 mL of ethanol, 2 drops of an antifoaming agent, and 10 mL of 25% phosphoric acid were added, and the flask was installed in the heating distillation apparatus (Jeong et al., 2003; Kim et al., 2000). Next, 20 mL of 0.1 N sodium hydroxide solution was added to the sulfur dioxide collection flask, and the flask was purged with

| Table 1. Classification of peeled root vegetable items and country of origin |
|-------------------------------|----------------|-----------------|-----------------|-----------------|
| Group                        | Balloon flower | Deodeok         | Lotus root      | Burdock         |
| Domestic products            | 17             | 4               | 4               | 9               |
| Imported products            | 19             | 2               | 9               | 1               |
| Not registered               | 2              | 0               | 0               | 0               |
| Total                        | 38             | 8               | 13              | 10              |
nitrogen for 5 min. A certain amount of the sample was placed in the flask and heated for 20 minutes. When measuring absorbance, a solution obtained by adding 0.1 mL of water to 5 mL of the collected sulfur dioxide (SO₂) solution was designated as (A) solution, and a solution obtained by adding 0.1 mL of 0.1% hydrogen peroxide solution to 5 mL of a newly collected solution was designated as (B) solution. To solutions (A) and (B) each, 1 mL of para-rosaniline/formaldehyde solution was added, shaken, and left at temperature for 20 min. Absorbance was measured at a wavelength of 580 nm with a UV spectrophotometer (Agilent, USA). The concentration of SO₂ in the test solutions (μg/mL) was obtained from the calibration curve using the absorbance of the test solutions (absorbance of A-absorbance of B). The samples’ SO₂ content (g/kg) was calculated using the following equation (MFDS, 2022).

\[
\text{SO}_2 \text{ content in the sample (g/kg)} = \frac{C}{50W}
\]

\[
C = \text{SO}_2 \text{ concentration in the test solution (μg/mL)}
\]

\[
W = \text{Sample weight (g)}
\]

### 2.4. Chloride ion analysis

Sample pretreatment was performed by referring to the ‘Test method for by-products of chlorine-based disinfectant in seasoned dried fish (NIFDS Additives Packing, 2014)’ (Fig. 1). The selected four types of peeled root vegetables were cut into small pieces, with 5 g of each vegetable precisely weighed. Then, 50 mL of ultrapure water was added, followed by ultrasonic extraction for 30 min. After centrifuging the extract at 5,000 rpm for 10 min, the supernatant was filtered with a 0.2 μm syringe filter (Advantec, Otowa, Tokyo, Japan) to use as test solutions. A Professional IC Vario model was used as an ion chromatography–conductivity detector (Metrohm, USA). The conditions of the instrument analysis used for quantitative analysis of chlorite ions and chlorate ions are shown in Table 2.

The concentration of chlorite ion and chlorate ion in the sample (μg/g) is given by the following equation:

\[
\text{C} = \text{Measured ion concentration in the sample solution (μg/mL)}
\]

\[
\text{V} = \text{Volume (mL) of ultrapure water added to the sample}
\]

\[
\text{m} = \text{Weight of sample used for analysis (g)}
\]

### Table 2. Analytical conditions of IC–CD

| Parameter       | Conditions                                                                 |
|-----------------|-----------------------------------------------------------------------------|
| Instrument      | IC–CD (Professional IC Vario, Metrohm, USA)                                 |
| Column          | Analytical column: Metrosep A Supp 7–250/4.0                                |
| Guard column    | Metrosep RP 2 Guard                                                        |
| Eluent          | 3.6 mM sodium carbonate solution                                            |
| Flow rate       | 0.7 mL/min                                                                 |
| Detector        | Conductivity detector                                                      |
| Suppressor      | Metrohm suppressor module (100 mM H₂SO₄)                                   |
| Oven temperature| 50°C                                                                        |
| Injection volume| 20 μL                                                                      |
3. Results and discussion

3.1. Validation

As the test method for sulfur dioxide is specified in the food code, the test method was not validated (MFDS, 2022). However, the specificity, linearity, accuracy, precision, detection limit, and quantitation limit of the test methods for chlorite ion and chlorate ion in peeled root vegetables are investigated to verify the test method because there is currently no standardized test method for chlorine dioxide. And its validity was confirmed (MFDS, 2016).

3.1.1. Specificity

To investigate whether the analysis method performed was specific to chlorite ion and chlorate ion, each ion was added at a concentration of 1.5 μg/mL to greater burdock, a peeled root vegetable in which the corresponding ions were not detected, and then the greater burdock was analyzed. In the greater burdock negative sample and greater burdock negative sample spiked with standard material, chlorite ion in standard material was found at 8.2 minutes, chlorate ion was detected at around 16.2 minutes, and the peak was detected at the same retention time in the greater burdock sample to which standard material was added. In addition, the sample was selectively analyzed because the peak was separated from the baseline, and there were no other interfering substances (Fig. 2).

3.1.2. Linearity

Standard solutions of chlorite ion and chlorate ion were prepared at 0.5, 1, 5, and 10 μg/mL, 

| List | Chromatogram |
|------|--------------|
| Chlorite ion, chloride ion standard solution | ![Chlorite ion and chloride ion standard solution](https://www.ekosfop.or.kr) |
| Burdock negative sample | ![Burdock negative sample](https://www.ekosfop.or.kr) |
| Add a standard solution to the negative sample | ![Add a standard solution to the negative sample](https://www.ekosfop.or.kr) |

Fig. 2. Chromatogram of chlorite ion and chlorate ion specificity from burdock root.
respectively, and a calibration curve was obtained through three repeated tests. As a result of regression analysis of the integrated area of the peak, the slope and standard deviation were 0.0851±0.0028 for chlorite ion and 0.0689±0.0029 for chlorate ion in the corresponding concentration range. In addition, the correlation coefficient (R²) was 0.999 or more, showing excellent linearity (Fig. 3).

### 3.1.3. Accuracy

To investigate the accuracy, the standard material of each ion (1.5, 2, and 4 μg/mL when measured by the instrument) was added to greater burdock, a peeled root vegetable in which the corresponding ions were not detected, and the recovery rate was calculated. As a result of examining the recovery rate in 3 repeated tests for 3 different concentrations, it was confirmed that the recovery rate of chlorite ions from burdock was 83-89.1%, and that of chlorate ions was 96.6-102.0%. The measured recovery value was within the 80-110% recovery range, consistent with the criteria suggested in EC Regulation and AOAC International Appendix F. Therefore, the established test method was confirmed to have good accuracy (Table 3).

### 3.1.4. Precision

The precision was evaluated with the relative standard deviation (RSD) of the recovery rate obtained from the accuracy test. The precision RSD of chlorite ions was 4.1-6.5%, and the precision RSD of chlorate ions was 0.9-5.1%. These values were within the range of precision standards presented in EC Regulation, AOAC International Appendix F. Therefore, the analysis method was confirmed to have good precision (Table 4).

### 3.1.5 Limits of detection and quantification

The limits of detection and quantitation were calculated by the following formula using a method based on the reaction’s standard deviation and the calibration curve’s slope.

![Calibration curves and regression linear equations for chlorite ion and chlorate ion.](https://doi.org/10.11002/kjfp.2022.29.4.601)
### Table 4. Precision measurement of chlorite ion and chlorate ion

| Element                     | Spiked concentration (µg/mL) | Measured concentration (µg/mL) ±SD | Relative standard deviation (%) |
|-----------------------------|-------------------------------|-----------------------------------|---------------------------------|
| Chlorite ion (each n=3)     | 1.5                           | 1.337±0.070                       | 5.3                             |
|                             | 2                             | 1.776±0.115                       | 6.5                             |
|                             | 4                             | 3.321±0.137                       | 4.1                             |
| Chlorate ion (each n=3)     | 1.5                           | 1.530±0.078                       | 5.1                             |
|                             | 2                             | 1.933±0.016                       | 0.9                             |
|                             | 4                             | 3.890±0.040                       | 1.0                             |

Limit of detection = $3.3 \times \sigma / S$

Limit of quantitation = $10 \times \sigma / S$

- $\sigma$: Standard deviation of the y-intercept in the regression line
- $S$: The slope of the calibration curve

As a result, the detection limit was 0.1 mg/kg, and the quantitation limit was 0.3 mg/kg.

### 3.2. Test results for sulfur dioxide and chlorine dioxide

Recently, the market for fresh food consumption, such as livestock and aquatic products, as well as agricultural products such as vegetables and fruits, has been steadily expanding due to an increase in single or two-person households and increased interest in health care. This study validated the established analytical method by analyzing sulfur dioxide and chlorine dioxide contained in peeled root vegetable products and identified residual concentrations that may exist, reflecting the situation. Among the target peeled root vegetables, lotus loot products had the highest number of labels containing sulfur dioxide with 10 cases (83.3%) out of 12 cases, followed by greater burdock with 1 in 10 cases (10%) and balloon flower with 1 in 23 cases (4.3%). No deodeok products had the label (Table 5). Suppose food additives are added to primary products such as agricultural products for simple washing, sterilization, and film coating. In that case, they are judged as agricultural products (simple processed agricultural products). When sulfur dioxide is added to prevent browning, it should be classified as processed food (processed fruits and vegetables, pickled foods, and other processed agricultural products). However, products labeled as containing sulfur dioxide in peeled root vegetables investigated in the study were limited to processed fruits and vegetables and pickled foods. In addition, there was no indication that simple processed agricultural products contained sulfur dioxide. In particular, there were no cases labeled as containing sulfur dioxide in other agriculturally processed products that do not have standards for using sulfur dioxide. Moreover, as a result of analyzing sulfur dioxide in peeled root vegetable products that are not labeled as containing sulfur dioxide, there were no such cases violating the labeling regulation regarding sulfur dioxide in processed fruits and vegetables, other agriculturally processed products, and pickled foods. However, a small amount (2.8 mg/kg) of sulfur dioxide was detected in one simple processed agricultural product of greater burdock. According to the Study on the Establishment of the Sulfur Dioxide Instrumental Analysis Method for...
A survey on synthetic compounds of peeled root vegetables

Table 5. Results of sulfur dioxide analysis by food type

| Group      | Food type                        | Sulfur dioxide content indication product (case) |
|------------|----------------------------------|-------------------------------------------------|
|            |                                  | Un-marked                                      | Marked                                      |
| Bellflower | Processed fruits and vegetables  | 2                                               | 0                                           |
|            | Other agricultural products      | 2                                               | 0                                           |
|            | Pickles                          | 0                                               | 1                                           |
|            | Simple processed agricultural products | 34                                         | 0                                           |
| Deodeok    | Simple processed agricultural products | 6                                           | 0                                           |
| Lotus root | Processed fruits and vegetables  | 0                                               | 7                                           |
|            | Other agricultural products      | 1                                               | 0                                           |
|            | Pickles                          | 0                                               | 3                                           |
|            | Simple processed agricultural products | 1                                           | 0                                           |
| Burdock    | Processed fruits and vegetables  | 1                                               | 0                                           |
|            | Pickles                          | 0                                               | 1                                           |
|            | Simple processed agricultural products | 8                                           | 0                                           |
| Total      |                                  | 56                                              | 12                                          |

Food. of the Korea Food and Drug Administration (2011), the detection limit of the modified Rankine method used in this experiment is 0.4 mg/kg, while the limit of quantitation is 1.0 mg/kg (NIFDS, 2011). In the current food code, however, 10 mg/kg or less is considered non-detection. Therefore, it was concluded that the greater burdock, in which a small amount of sulfur dioxide was detected, did not violate the "Standards and Specifications of Food". In addition, as a result of examining the concentrations of chlorite ions and chlorate ions in dermabrasion root vegetables for 67 cases of 4 items of target samples, chlorite ions were found to be 5.01 mg/kg, 5.22 mg/kg, and 10.94 mg/kg in 3 cases of bellflower (Table 6). In one case of lotus root, 21.74 mg/kg of chlorate ion was detected. However, in Korea, there are only standards for using additives containing chlorine in food, but there is no standard for residual chlorate ions in food. Therefore, it is not possible to determine suitability. In 2008, as a result of measuring the free residual chlorine concentration twice for a total of 32 fresh convenience foods (salads) from major discount stores and department stores in Seoul, no chlorine was detected in all samples (MFDS, 2008). Therefore, when compared with the previous results, attention should be paid to the results of this study. Therefore, based on these results, as chlorine- based disinfectants are still used in the distribution of products such as fresh convenience foods, it is necessary to review the test methods and standards for providing safe food. In addition, as there are concerns about the safety of residues in food, efforts should be made to supply safe food to consumers by developing a browning inhibitor using natural substances as an alternative to chlorine-based disinfectants.

4. Conclusions

This study investigated the synthetic compounds (sulfur dioxide, chlorite ion, and chlorate ion)
contained in 67 peeled root vegetables (bellflower, deodeok, lotus root, greater burdock) from February to October 2021. Out of 67 cases of 4 types of peeled root vegetables, 12 cases contained sulfur dioxide. Chlorite ion was detected in three cases of bellflower and chlorate ion in one case of lotus root. Although the detection rate and amount were insignificant, it was possible to confirm the use of the synthetic compound, which was the purpose of this investigation. By confirming specificity, linearity, accuracy, precision, detection limit, and quantification limit, this study verified the reliability of the chlorine dioxide analysis method for peeled root vegetables, for which an analytical method has not been established. As chlorine-based disinfectants are still used in food to increase storage and processing efficiency, health risks remain a concern. Nevertheless, the systematic and standardized management of chlorite and chlorate, which are decomposition products, has not yet been proposed. Accordingly, it is urgent to prepare countermeasures. More studies are necessary to develop a browning inhibitor using natural materials as an alternative to synthetic compounds to supply safe food to consumers.

Conflict of interests
The authors declare no potential conflicts of interest.

Table 6. Summary of test results of chlorite ion and chlorate ion in peeled root vegetables

| Group        | Number of cases | Number of detections (detection rate, %) | The detected concentration (μg/g) |
|--------------|-----------------|------------------------------------------|----------------------------------|
|              |                 |                                          | Chlorite ion | Chlorate ion |
| Balloon flower | 39              | 3 (7.7)                                  | 5.01, 5.22, 10.94 | ND           |
| Deodeok      | 6               | 0 (0)                                    | ND          | ND          |
| Lotus root   | 12              | 1 (11.1)                                 | ND          | 21.74       |
| Burdock      | 10              | 0 (0)                                    | ND          | ND          |
| Total        | 67              | 4 (6.0)                                  | –           | –           |

ND, not detected.

Author contributions
Conceptualization: Kwon SH, Joo KS, Heo MJ, Kwon MJ. Formal analysis: Kwon SH, Park BK. Methodology: Kwon SH, Yeom MS, Han SY. Validation: Kang MJ. Writing – original draft: Kwon SH. Writing – review & editing: Kwon SH.

Ethics approval
This article does not require IRB/IACUC approval because there are no human and animal participants.

ORCID
Sung-Hee Kwon (First & Corresponding author)
https://orcid.org/0000-0001-8394-4098
Mi-Sook Yeom
https://orcid.org/0000-0001-9771-2992
Byung-Kyu Park
https://orcid.org/0000-0002-1010-3244
Se-Youn Han
https://orcid.org/0000-0001-9182-8898
Min-Jeong Kang
https://orcid.org/0000-0002-9231-2006
Kwang-Sig Joo
https://orcid.org/0000-0002-6038-0282
Myung-Je Heo
https://orcid.org/0000-0003-3801-2798
Mun-Ju Kwon
https://orcid.org/0000-0001-9556-9950

https://www.ekosfop.or.kr
References

Asami M, Kosaka K, Yoshida N. Occurrence of chlorate and per chlorate in bottled beverages in Japan. J Health Sci, 55, 549-553 (2009)

Choi DJ, Lee YJ, Kim YK, Kim MH, Choi SR, Cha HS, Youn AR. Effect of washing methods on the quality of freshly cut sliced Deodeok (Codonopsis lanceolata) during storage. Korean J Food Preserv, 20, 751-759 (2013)

Gumes G, Lee CY. Color of minimally processed potatoes as affected by modified atmosphere packaging and antibrowning agentst. J Food Sci, 62, 572 (1997)

Iammarino M, Taranto AD, Muscarella M, Nardiello D, Palermo C, Centonze D. Development of a new analytical method for the determination of sulfites in fresh meats and shrimps by ion-exchange chromatography with conductivity detection. Anal Chim Acta, 672, 61-65 (2010)

James F, Lawrence R, Chaha K, Menard C. Comparison of three liquid chromatographic methods with FDA optimized Monnier-Williams methods for determination of total sulfite in foods. J Assoc Off Anal Chem, 73, 77-79 (1990)

Jeong MC. Browning control technology trend of fresh pickled agricultural products: Focused on natural browning inhibitory materials. Food Preserv and Processing Industry, 11, 22-29 (2012)

Jeong SY, Kim IY, Kim SD, Jang MR, Chang MS, Han KY. Determination of sulfur dioxide in pickles by acid distillation-HPLC method and Monnier Williams modified method. Korean J Food Sci Technol, 35, 1028-1032 (2003)

KFDA. A Study on the Safety Management of Residual Chlorine by Products in Fresh Convenience Foods. Korea Food and Drug Administration (2008)

Kim HY, Lee YJ, Hong KY, Kwon YK, Lee YK, Ko HS, Lee CW. Studies on the contents of naturally occurring of sulfite in foods. Korean J Food Sci Technol, 32, 544-549 (2000)

Kim JG. Fresh food packaging technology. Food Sci Ind, 50, 12-26 (2017)

Kim YJ, Uyama H. Tyrosinase inhibitors from natural and synthetic sources: Structure, inhibition mechanism and perspective for the future. Cell Mol Life Sci, 62, 1707-1723 (2005)

King AD, Bolin HR. Physiological and microbiological storage of minimally processed fruit and vegetables. Food Technol, 43, 132-139 (1989)

Lee HJ, Sung JH, Choi CD, Choi YH, Kim I, Kim KS, Lee SK, Choi JH, Lee JY. Monitoring of Sulfur Dioxide Content in Fresh Foods. MFDS, Research Report 6, 539-545 (2002)

Lee JY, Kim CY. Anti browning and anti oxidant properties of Foeniculum vulgare seed extracts. Korean J Food Preserv, 27, 188-196 (2020)

MFDS. Food Additive Exhibition. Ministry of Food and Drug Safety (2021)

MFDS. Food Code. Ministry of Food and Drug Safety (2022)

MFDS. Study on Establishing an Analytical Method for Chlorinated Disinfectants in Food. Ministry of Food and Drug Safety (2016)

Michalski R, Mathews B. Occurrence of chlorite, chlorate and bromate in disinfected swimming pool water. Pol J Environ Stud, 16, 237-241 (2007)

NFDS. Chlorine-Based Disinfectant by Product Test Method among Dried Fish and Shellfish. National Institute of Food and Drug Safety Evaluation (2014)

NFDS. Study on Analytical Method of Sulfur Dioxide in Foods. National Institute of Food and Drug Safety Evaluation (2011)

Oh SI, Kim CW, Lee U. Changes in the quality of peeled chestnut achieved by browning inhibition treatments during storage. Soc For Sci, 108, 610-617 (2019)

Park M, Kim GH. The antioxidative and antibrowning effects of citrus peel extracts on fresh-cut apples. Korea J Food Sci Technol, 45, 598-604 (2013)

Park YJ, Choi SY, Kim YO, Moon KD. Search for
inhibitors to inhibit browning of minimally processed fruits. Korean J Food Preserv, 4, 119 (2003)
Pisarenko AN, Stanford BD, Quinones O, Pacey GE, Gordon G, Snyder SA. Rapid analysis of perchlorate, chlorate and bromate ions in concentrated sodium hypochlorite solutions. Anal Chim Acta, 659, 216-223 (2010)
Robinson D, Mead GC, Barnes KA. Detection of chloroform in the tissues of freshly eviscerated poultry carcasses exposed to water containing added chlorine or chlorine dioxide. Bull Environ Contam Toxicol, 27, 145-150 (1981)
Suzuki J, Okumoto C, Katsuki Y, Tomomatsu T, Tamura Y, Ito Y, Ito Y, Ishimata H, Nishijima M. Determination of residual chlorite in vegetables and eggs treated with sodium chlorite by UV-ion chromatography and effect of soaking in water. J Food Hyg Soc Jpn, 38, 22-26 (1997)
Wang S, Cui X, Fang G. Rapid determination of formaldehyde and sulfur dioxide in food products and Chinese herbals. Food Chem, 103, 1487-1493 (2007)