*Food Sci. Biotechnol. Vol. 17, No. 1, pp. 72 ~ 79 (2008)*

Food Science and Biotechnology

# Changes in the Physicochemical Properties and Functional Components of Uncooked Foods Treated with Electrolyzed Water

**Tie-Yan Jin, Deog-Hwan Oh[1], and Jong-Bang Eun[2]***

*School of Biotechnology, Kangwon National University, Chuncheon, Gangwon 200-701, Korea*

*[1]Department of Food Science and Biotechnology and Institute of Bioscience and Biotechnology, Kangwon National University, Chuncheon, Gangwon 200-701, Korea*

*[2]Department of Food Science and Technology and Institute of Agricultural Science and Technology, Chonnam National University, Gwangju 500-757, Korea*

**Abstract** In this study, changes in the physicochemical properties and functional components of uncooked foods, including carrots, cabbage, *shiitake* (*Lentinus edodes*) and white button (*Agaricus bisporus*) mushrooms, sea mustard, and laver treated with electrolyzed water were investigated. No changes were observed in the primary compositions of any of the materials that were hot air- or freeze-dried after being treated with electrolyzed water. The lightness (L), redness (a), and yellowness (b) values of the carrots, *shiitake*, and laver were not affected by drying, while changes did occur in the cabbage (L-, a-, and b-values), mushrooms (a-value), and sea mustard (b-value) specimens that were hot air- or freeze-dried following the treatments with electrolyzed water. The dietary fiber contents of all the materials increased when they were hot air-dried. Vitamin C content decreased when the samples were treated with alkalic electrolyzed water. No changes occurred in the lectin, β-carotene, or total phenolic compound contents after the electrolyzed water treatments, suggesting that electrolyzed water could be used effectively as a pasteurization step for uncooked carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver.

**Keywords:** uncooked food, electrolyzed water, physicochemical property, functional component

## Introduction

Certain uncooked foods obtained from animal or plant sources, and then eaten directly or mixed with water, are first dried and then processed into powders, particles, pastes, gels, and liquids (1). These uncooked foods can contain substantial quantities of nutritional compounds such as starches, proteins, minerals, and vitamins, as well as some dietary fibers and functional compounds such as cellulose and pectin that cannot be broken down by human enzymes (2). Some of these functional compounds are known to have biological activities, including inhibiting cholesterol and preventing constipation. Additionally, some are found to have anticancer and antibacterial effects and to enhance immunity; consequently, these compounds are being extensively used as supplements to make functional foods (4-8). A major issue with uncooked food is the occurrence of microbial contamination, especially by microbes that can cause food poisoning (9). The reduction in quality, and potential negative effects on human health, necessitate the control of microbial contamination in uncooked foods. Vegetables, mushrooms, and algae are sterilized by heating, where some nutritional and functional compounds are destroyed, lowering their nutritional value (10,11). The use of bactericides is also associated with certain issues, such as a limited number of options, and the negative effects of chemical residues on human health. Therefore, additional effective methods to decrease microbial contamination of uncooked foods must be applied (12).

Bactericidal techniques are currently being developed that have no effect on the freshness of fruits and vegetables, and are not harmful to humans. One of these methods involves the use of electrolyzed water, which is applied in the food processing industry. Electrolyzed water is produced by the electrolysis of a sodium chloride solution using a commercially available electrolysis apparatus. By employing a 2-cell chamber and, for example, strong acidic electrolyzed water containing hypochlorous acid, dissolved chlorine gas, and activated chemicals, $OH^-$ radicals are produced in the anode compartment. The electrolyzed water has a strong bactericidal activity, and is rapidly transformed into chlorine, oxygen, and water when it encounters microbes and other organisms. In contrast to the fungicides available for treating food, electrolyzed water does not form a residue and is not harmful to humans (13-15).

In this study, uncooked carrots, cabbage, *shiitake* (*Lentinus edodes*) and white button (*Agaricus bisporus*) mushrooms, sea mustard, and laver were treated with electrolyzed water. One objective was to sterilize these uncooked foods while maintaining their quality. Also, since few studies have investigated changes in the nutritional and biological characteristics of foods after being treated with electrolyzed water, we focused on determining the changes in color along with the contents of certain functional components such as crude protein, crude fat, carbohydrate, crude ash, and dietary fiber, thus investigating the effects of electrolyzed water on these compounds, and discuss the possibility of using electrolyzed water in the production of uncooked foods.

---

*Corresponding author: Tel: +82-62-530-2145 ; Fax: +82-62-530-2149
E-mail: jbeun@chonnam.ac.kr

Received June 11, 2007; accepted August 23, 2007

## Materials and Methods

**Materials** Fresh carrots (*Daucus carota* S.), cabbage (*Brassica oleraced* Var.), *shiitake* (*Lentinus edodes*) and white button (*Agaricus bisporos*) mushrooms, sea mustard (*Undaria pinnatifida*), and laver (*porphra fenera* K.) were purchased from a local market (Gwangju, Korea). The electrolyzed water was produced by an electrolyzed water-making machine (AZ-1000; Ensfirst, Seoul, Korea). The pH value of the acidic electrolyzed water was 2.4, while the alkalic electrolyzed water was 11.0.

**Process of materials** The carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver were soaked for 3 min with the electrolyzed water (acidic and alkalic). After being removed from the water, a portion of the materials was freeze-dried (FDU-540; Eyela, Tokyo, Japan) at −40°C, while another portion was dried with hot-air (FO-450M; Jeio Tech, Changwon, Gyeongnam, Korea) at 50°C, to a water content of 8.0±0.5%. The materials with water contents of 8.0±0.5% that were not treated with the electrolyzed water were used as controls.

**Measurement of the chemical component contents** The chemical component contents of the various samples were measured by the AOAC methods (16). The water content was measured by drying at 105°C. The crude protein content was measured by the micro-Kjeldahl method. The crude fat content was acquired with the Soxhlet method. Ash was measured by dry ashing at 550°C. Finally, the carbohydrate content was calculated by subtracting the water, crude protein, crude fat, and ash from 100.

**Measurement of color** The colors of the samples were measured by a colorimeter (CM-3500d; Minolta Co., Ltd., Osaka, Japan), and expressed as L- (lightness), a- (redness/greenness), and b- (yellowness/blueness) values (17).

**Measurement of dietary fiber content** $\alpha$-Amylase (Sigma, St. Louis, MO, USA) and protease (Sigma) were used to remove the starch and protein, respectively, and 95 % ethanol was added to precipitate the dietary fiber; then, the residue was obtained by drawing the latter through a filter crucible under reduced pressure. The total dietary fiber (TDF) content was expressed by subtracting the protein and ash contents from the residue. The insoluble dietary fiber (IDF) content was measured using the method of Prosty *et al.* (18). The sample was removed of protein and starch by enzymes such as $\alpha$-amylase, protease, and amyloglucosidase (Sigma), and filtered through a crucible while being treated with water. The residue was treated with 95 and 78% solutions of ethanol and acetone, and dried in an oven. After analyzing the protein and ash contents, IDF was determined as the residual value from which the amounts of the protein and ash were subtracted. The soluble dietary fiber (SDF) content was acquired by subtracting the IDF from the TDF.

**Measurement of vitamin C content** Each 10 mL of sample solution was transferred into an Erlenmeyer flask and the solution was directly titrated with indophenol. The color of the reactive solution changed from blue to red, and the reaction was stopped when the solution became colorless; then the data were calculated (19).

**Measurement of β-carotene content** The samples were saponified after adding KOH and pyrogallol solvent. The sample solutions were decompressed and concentrated after being dissolved in petroleum ether, in order to evaporate all of the petroleum ether. The residue was dissolved by a solvent of isopropanol:chloroform (1 : 1), and filtered with 0.45 μm filter paper, and finally, determined by HPLC (20).

**Measurement of total phenolic compound content** Sample (diluted to 80% of the original concentration with ethanol), 7.5 mL of deionized water, 0.5 mL of Folin-Denwas phenol reagent, and 1 mL of $Na_2CO_3$ were mixed in the given order, and then transferred into a test tube after the addition of deionized water to make a volume of 10 mL. Absorbance of the supernatants was measured at 760 nm by a spectrophotometer (UV-1201; Shimazu, Kyoto, Japan). Tannic acid was determined from a standard concentration curve (21).

**Measurement of pectin content** The sample solutions were reacted at 85°C for 30 min after the addition of HCl solvent. The reactive solutions were then centrifuged at 6,500×g for 10 min. The pH value of the upper layer was adjusted to 11.5 by 1.0 N NaOH. Isopropanol was added at 4 times the volume of the reactive solution and allowed to sit for 8 hr. Next, the solution was filtered and treated with isopropanol and acetone, and then dried. Deionized water was added to the dried material to make its concentration 1%. The pectin content was measured after the samples were centrifuged and freeze dried (22).

**Measurement of lectin content** Ethylene diamine tetraacetic acid (EDTA) and phosphate-buffered saline (PBS) were added to the sample solutions, which were then crushed at 4°C for 5 min with a mixer. The solution was centrifuged and freeze-dried to get the lectin content (23).

**Measurement of alginic acid content** The pH value of the sample solutions was adjusted to 3.5-4.5 with 0.1% $H_2SO_4$. Then it was adjusted to 9.8-10.2 with 0.15% $Na_2CO_3$ after being placed at room temperature for 1 hr. Next, the solutions were stirred at 60°C for 4 hr. After the addition of a 5-fold volume of water, the pH of the solutions was adjusted to 1.4-1.5 with 5% $H_2SO_4$. Alginic acid was precipitated with the addition of the same volume of methanol, and its content was determined after being treated and dried at 40°C for 12 hr (24).

**Measurement of porphyan content** The laver was crushed and added to a 50-fold amount (w/v) of 0.1 N HCl, and then stirred in a water bath to extract at 60°C for 3 hr. The extraction was concentrated and low-pressure filtered, and the pH of the filtrate was adjusted to 7.0 with 6 N NaOH. The filtrate was added to a 3-fold amount (v/v) of ethanol, allowed to sit for 12 hr, and than centrifuged. The crude porphyran was obtained from the precipitate that was freeze-dried after being treated (25).

**Statistical analysis** All data are expressed as mean± standard deviation for the number of experiments. Statistical significance was evaluated by one-way analysis of variance (ANOVA) using the SPSS ver. 10.0 package program (26), and individual comparisons were obtained by Tukey's multiple range test (27), which was used to determine the differences between the means. A level of $p<0.05$ was considered to be statistically significant.

## Results and Discussion

**Content of chemical components** The carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver were hot air-dried or freeze-dried after being treated with electrolyzed water. Their chemical compositions are shown in Table 1. After the treatments with electrolyzed water, the protein concentrations in the carrots dried by hot air were 8.52 and 8.58%, as compared to 8.15% for the control, while the protein concentrations were 8.95 and 8.62% after being freeze-dried. The carbohydrate concentrations in the control, the samples treated with electrolyzed water and dried by hot air, and the samples treated with electrolyzed water and freeze-dried were 77.61, 78.04, and 78.03%, and 77.46 and 77.69%, respectively. The control contained 1.24% fat, and after being treated with the electrolyzed water, the fat concentrations were 1.16 and 1.20% with hot air-drying, and 1.19 and 1.28% with freeze-drying. The concentrations of ash in the control, the samples treated with electrolyzed water and dried by hot air, and the samples treated with electrolyzed water and freeze-dried were 4.12, 4.21, and 4.24%, and 4.18 and 4.22%, respectively. No significant differences ($p>0.05$) were observed among these samples. This result was the same as that of Jin *et al.* (28), who found that the chemical compositions of cereal grains showed no differences following treatments with electrolyzed water. The crude

**Table 1. Primary compositions[1] of carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver dried with hot-air or freeze-dried after being treated with electrolyzed water** (unit: %)

| | | Control[2] | Hot air-dried | | Freeze-dried | |
|---|---|---|---|---|---|---|
| | | | Acidic electrolyzed water | Alkalic electrolyzed water | Acidic electrolyzed water | Alkalic electrolyzed water |
| Carrots | Moisture | 8.15±0.54$^{NS}$ | 8.07±0.32 | 7.95±0.53 | 8.22±0.43 | 8.19±0.64 |
| | Protein | 8.78±0.75$^{NS}$ | 8.52±0.56 | 8.58±0.52 | 8.95±0.84 | 8.62±0.72 |
| | Carbohydrate | 77.61±1.16$^{NS}$ | 78.04±0.85 | 78.03±0.76 | 77.46±0.82 | 77.69±1.04 |
| | Fat | 1.24±0.25$^{NS}$ | 1.16±0.15 | 1.20±0.16 | 1.19±0.24 | 1.28±0.21 |
| | Ash | 4.12±0.32$^{NS}$ | 4.21±0.31 | 4.24±0.34 | 4.18±0.32 | 4.22±0.25 |
| Cabbage | Moisture | 7.86±0.26$^{NS}$ | 8.04±0.24 | 7.84±0.35 | 8.12±0.52 | 7.92±0.37 |
| | Protein | 2.32±0.16$^{NS}$ | 2.28±0.13 | 2.21±0.26 | 2.19±0.24 | 2.30±0.23 |
| | Carbohydrate | 87.71±0.52$^{NS}$ | 87.52±0.68 | 87.73±0.63 | 87.46±0.75 | 87.62±0.58 |
| | Fat | 0.78±0.06$^{NS}$ | 0.82±0.07 | 0.76±0.05 | 0.78±0.04 | 0.74±0.06 |
| | Ash | 1.37±0.11$^{NS}$ | 1.34±0.12 | 1.46±0.16 | 1.45±0.16 | 1.42±0.18 |
| *Shiitake* mushroom | Moisture | 7.85±0.24$^{NS}$ | 8.14±0.27 | 7.96±0.26 | 8.06±0.32 | 8.12±0.34 |
| | Protein | 17.16±1.28$^{NS}$ | 17.31±1.24 | 17.56±1.42 | 17.18±1.34 | 17.28±1.52 |
| | Carbohydrate | 69.13±1.35$^{NS}$ | 68.52±0.78 | 68.53±1.62 | 68.79±1.82 | 69.45±1.76 |
| | Fat | 1.62±0.15$^{NS}$ | 1.72±0.11 | 1.73±0.14 | 1.68±0.15 | 1.72±0.15 |
| | Ash | 4.24±0.35$^{NS}$ | 4.45±0.43 | 4.23±0.36 | 4.29±0.28 | 4.43±0.36 |
| White button mushroom | Moisture | 8.21±0.42$^{NS}$ | 8.12±0.29 | 8.02±0.32 | 7.96±0.35 | 8.11±0.46 |
| | Protein | 23.12±1.76$^{NS}$ | 23.62±2.12 | 22.96±1.95 | 23.32±1.46 | 23.65±2.42 |
| | Carbohydrate | 62.96±3.26$^{NS}$ | 62.50±3.42 | 62.30±2.56 | 62.88±2.18 | 62.59±3.25 |
| | Fat | 1.29±0.11$^{NS}$ | 1.41±0.12 | 1.36±0.11 | 1.42±0.13 | 1.36±0.08 |
| | Ash | 4.42±0.41$^{NS}$ | 4.35±0.32 | 4.36±0.27 | 4.42±0.38 | 4.29±0.31 |
| Sea mustard | Moisture | 7.95±0.35$^{NS}$ | 8.22±0.50 | 8.05±0.16 | 8.08±0.33 | 7.98±0.21 |
| | Protein | 26.16±1.25$^{NS}$ | 26.75±2.42 | 26.62±1.58 | 26.16±1.52 | 26.57±1.26 |
| | Carbohydrate | 37.81±2.32$^{NS}$ | 37.03±1.84 | 37.85±2.15 | 38.11±1.28 | 38.55±2.56 |
| | Fat | 3.16±0.34$^{NS}$ | 3.12±0.12 | 2.96±0.25 | 3.02±0.28 | 3.04±0.42 |
| | Ash | 24.92±1.36$^{NS}$ | 24.88±1.35 | 24.52±1.45 | 24.63±1.38 | 24.86±1.52 |
| Laver | Moisture | 8.25 ± 0.34$^{NS}$ | 8.12±0.42 | 8.06±0.12 | 8.16±0.45 | 8.08±0.36 |
| | Protein | 39.52±2.53$^{NS}$ | 39.72±1.52 | 40.16±3.31 | 39.62±2.72 | 39.56±2.16 |
| | Carbohydrate | 42.61±3.26$^{NS}$ | 42.33±2.36 | 42.79±3.86 | 42.26±3.37 | 42.28±3.26 |
| | Fat | 1.48±0.12$^{NS}$ | 1.57±0.15 | 1.64±0.16 | 1.72±0.11 | 1.57±0.13 |
| | Ash | 8.14±0.64$^{NS}$ | 8.26±0.52 | 8.35±0.77 | 8.24±0.82 | 8.51±0.68 |

[1] Mean±SD (n=3); $^{NS}$values in the same row are not significantly different ($p>0.05$).

[2] Carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver without being treated and freeze dried.

protein, crude fat, carbohydrate, and crude ash contents were also measured in the cabbage, *shiitake* and white button mushrooms, sea mustard, and laver after being treated with electrolyzed water and then hot air-dried or freeze-dried. These concentrations were not different ($p$>0.05) between samples.

Since the crude protein, crude fat, carbohydrate, and crude ash contents of the uncooked materials did not change with the electrolyzed water treatments, the results indicate that the electrolyzed water did not adversely affect these uncooked materials in terms of their chemical compositions.

**Measurement of color** Table 2 shows the changes in color for the carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver treated with electrolyzed water and then hot air-dried or freeze-dried. The lightness (L), redness (a), and yellowness (b) values of the control carrots and the samples treated with electrolyzed water and then hot air-dried or freeze-dried showed no changes, and no significant differences ($p$>0.05) were detected in these samples. This result likely occurred because hot air-drying and freeze-drying denature lipoxygenase and peroxidase (29), which supports the findings of Izumi (30) where L-, a-, and b-values remained unchanged following treatments with electrolyzed water. The L-values of the control cabbage and freeze-dried samples were higher than the samples dried by hot air. A difference ($p$<0.05) occurred in these samples because hot air-drying accelerates browning and lowers the L-value (31). The a-value of the control was lowest at −12.26, followed by the samples treated with alkalic electrolyzed water at −10.24 and −10.16. The a-values of the samples treated with acidic electrolyzed water were the highest at −8.32 and −6.85. Except for the samples treated with alkalic electrolyzed water and hot air- or freeze-dried, the other treated samples showed significant differences ($p$<0.05). The primary green pigments, chlorophylls *a* and *b*, decreased by 12 and 16% after treatment with acidic electrolyzed water, while no changes occurred after treatment with alkalic electrolyzed water (32), which was the reason why the a-value increased in the cabbage when it was treated with the acidic electrolyzed water. In addition, some brown components, including pheophytin and pheophorbide, that were produced when the sample was hot air-dried, caused the a-value to increase. The b-values of the cabbage samples treated with alkalic electrolyzed water were 28.82 and 28.75, which were higher than the control, because the alkalic electrolyzed water caused the production of some yellow carotenoids to increase (33).

The L-, a-, and b-values of shiitake showed no changes in the control and the samples treated with electrolyzed water and then hot air-dried or freeze-dried, and no significant differences ($p$>0.05) were observed in these samples. According to research by Lee *et al.* (34), this is because *shiitake* browns itself, and electrolyzed water and hot air- or freeze-drying have no affect on it. The L-value of mushrooms was the highest in the control at 67.75, followed by the samples treated with electrolyzed water and then freeze-dried. The lowest L-values occurred in the samples treated with electrolyzed water and dried by hot air. Significant differences ($p$<0.05) were observed in these

**Table 2. Color values[1)] of carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver dried with hot-air or freeze-dried after being treated with electrolyzed water**

| | | Control[2)] | Hot air-dried | | Freeze-dried | |
|---|---|---|---|---|---|---|
| | | | Acidic electrolyzed water | Alkalic electrolyzed water | Acidic electrolyzed water | Alkalic electrolyzed water |
| Carrots | L | 47.26±1.52$^{NS}$ | 48.17±1.38 | 47.76±1.35 | 47.86±1.58 | 47.48±1.26 |
| | a | 28.96±0.32$^{NS}$ | 27.57±1.56 | 28.12±1.54 | 28.48±0.85 | 27.86±0.76 |
| | b | 24.56±1.48$^{NS}$ | 25.16±1.72 | 24.96±0.85 | 25.12±1.58 | 25.05±0.88 |
| Cabbage | L | 62.52±1.22$^{b}$ | 55.26±1.52$^{a}$ | 54.85±1.65$^{a}$ | 61.85±1.58$^{b}$ | 62.59±1.48$^{b}$ |
| | a | -12.26±0.82$^{d}$ | -8.32±0.56$^{b}$ | -10.24±0.88$^{c}$ | -6.85±0.46$^{a}$ | -10.16±0.87$^{c}$ |
| | b | 24.58±1.45$^{a}$ | 24.76±2.53$^{a}$ | 28.82±1.86$^{b}$ | 23.88±1.72$^{a}$ | 28.75±2.16$^{b}$ |
| *Shiitake* mushroom | L | 43.85±0.78$^{NS}$ | 42.92±1.56 | 43.22±1.48 | 43.56±1.08 | 43.65±1.26 |
| | a | 10.24±1.26$^{NS}$ | 10.48±1.67 | 10.84±2.12 | 10.56±1.28 | 9.88±1.32 |
| | b | 16.72±1.58$^{NS}$ | 16.55±1.14 | 16.72±2.02 | 17.08±1.76 | 17.15±1.62 |
| White button mushroom | L | 67.75±1.66$^{c}$ | 61.32±1.36$^{a}$ | 61.54±2.24$^{a}$ | 65.59±0.82$^{b}$ | 65.16±1.64$^{b}$ |
| | a | 4.46±0.18$^{NS}$ | 4.72±0.22$^{a}$ | 4.84±0.26$^{a}$ | 4.82±0.38$^{a}$ | 4.37±0.12$^{a}$ |
| | b | 21.27±1.36$^{NS}$ | 20.78±1.56 | 25.06±1.45 | 21.69±1.47 | 24.86±1.38 |
| Sea mustard | L | 33.42±1.24$^{NS}$ | 32.95±1.52 | 33.55 ± 0.84 | 33.24±0.86 | 32.84±0.68 |
| | a | 8.52±0.33$^{c}$ | -5.52±0.56$^{a}$ | -7.16 ± 0.35$^{b}$ | -5.64±0.29$^{a}$ | -8.24±0.48$^{c}$ |
| | b | 12.56±1.24$^{NS}$ | 12.88±1.21 | 12.71 ± 1.32 | 12.62±1.28 | 12.29±0.67 |
| Laver | L | 22.67±0.23$^{NS}$ | 23.13±0.42 | 22.85 ± 0.36 | 23.16±1.26 | 23.92±1.15 |
| | a | 1.86±0.11$^{NS}$ | 1.79±0.82 | 1.88 ± 0.12 | 1.82±0.08 | 1.77±0.06 |
| | b | 3.56±0.52$^{NS}$ | 3.63±0.16 | 3.71 ± 0.21 | 3.66±1.58 | 3.62±1.28 |

[1)] Mean±SD (n=3); $^{NS}$values in the same row are not significantly different ($p$>0.05); $^{a\text{-}d}$values in the same row not sharing a common superscript are significantly different by Tukey's multiple range test ($p$<0.05).

[2)] Carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver without being treated and freeze-dried.

samples. This result is in accordance with a study by Ha *et al.* (35) when mushrooms were dried by hot air. The a- and b-values of mushrooms showed no changes in the control, the samples treated with electrolyzed water and dried by hot air, and the samples treated with electrolyzed water and freeze-dried, and no significant differences ($p$>0.05) occurred in these samples. There were no changes in the a- and b-values because the acidic and alkalic electrolyzed water inhibited the activity of polyphenol oxidase and decreased browning (36).

The L- and b-values of the sea mustard showed no differences in the control and the samples treated with electrolyzed water and then dried by hot air or freeze-dried. The a-value of the sea mustard was highest in the samples treated with acidic electrolyzed water, and then hot air-dried or freeze-dried (−5.52 and −5.62, respectively), followed by the samples treated with alkalic electrolyzed water and dried by hot air (−7.16). The lowest values were obtained in the control and the samples treated with alkalic electrolyzed water and freeze-dried (−8.52 and −8.24, respectively). Significant differences ($p$<0.05) were observed in these samples. The primary pigments in sea mustard are chlorophyll *a*, β-carotene, and fucoxanthin (37). Most of the chlorophyll *a* was destroyed when it was treated with the acidic electrolyzed water, which made the a-value increase. The L-, a-, and b-values of the laver showed no changes in the control or in the samples treated with electrolyzed water and dried by hot air or freeze-dried, and no significant differences ($p$>0.05) were detected in these samples because the electrolyzed water had no effect on the pigments of the laver. These results suggest that the acidic electrolyzed water caused the a-value to increase in the cabbage and sea mustard; while it had no effect on the carrots, *shiitake* and white button mushrooms, and laver, which contained little chlorophyll. Therefore, from the perspective of not altering pigmentation, electrolyzed water can effectively sterilize uncooked foods that contain little chlorophyll.

**Dietary fiber content** Table 3 shows the total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) contents of the carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver treated with electrolyzed water and then hot air-dried or freeze-dried. The TDF, IDF, and SDF contents in the samples treated with electrolyzed water and hot air-dried were greater than those in the control and the samples treated with electrolyzed water and freeze-dried, and significant differences ($p$<0.05) were exhibited in these samples. The Maillard reaction occurred during hot air-drying, and the tannins in the dietary fiber caused an increase in the dietary fiber content (38). Some resistant starches that are not enzymatically degraded by heating are determined as IDF, which increases the content of the IDF (39). Also, cellulose is released from the cell wall when it is destroyed by heating, which increases the dietary fiber content (40,41). Based on this, the dietary fiber content increased when the samples were dried by hot air. We can also conclude that the electrolyzed water had no effect on the IDF content.

**Table 3. Contents[1] of total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) of carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver dried with hot-air or freeze-dried after being treated with electrolyzed water**

(unit: %)

| | | Control[2] | Hot air-dried | | Freeze-dried | |
|---|---|---|---|---|---|---|
| | | | Acidic electrolyzed water | Alkalic electrolyzed water | Acidic electrolyzed water | Alkalic electrolyzed water |
| Carrots | IDF | 22.65±1.04$^{a}$ | 24.47±0.66$^{b}$ | 24.98±0.84$^{b}$ | 22.45±1.06$^{a}$ | 22.15±1.57$^{a}$ |
| | SDF | 3.34±0.23$^{a}$ | 3.95±0.22$^{b}$ | 4.01±0.34$^{b}$ | 3.14±0.24$^{a}$ | 3.10±0.23$^{a}$ |
| | TDF | 25.98±0.91$^{a}$ | 28.42±0.87$^{b}$ | 29.00±1.16$^{b}$ | 25.59±1.21$^{a}$ | 25.25±1.34$^{a}$ |
| Cabbage | IDF | 14.85±0.71$^{a}$ | 16.60±0.46$^{b}$ | 16.75±0.70$^{b}$ | 14.69±0.93$^{a}$ | 14.61±0.57$^{a}$ |
| | SDF | 6.33±0.53$^{a}$ | 7.42±0.29$^{b}$ | 7.35±0.38$^{b}$ | 6.06±0.37$^{a}$ | 5.91±0.33$^{a}$ |
| | TDF | 21.18±0.64$^{a}$ | 24.02±0.74$^{b}$ | 24.10±0.32$^{b}$ | 20.75±1.29$^{a}$ | 20.52±0.24$^{a}$ |
| *Shiitake* mushroom | IDF | 34.31±1.78$^{a}$ | 37.46±1.29$^{b}$ | 37.69±1.76$^{b}$ | 33.87±1.76$^{a}$ | 33.30±2.29$^{a}$ |
| | SDF | 7.03±0.61$^{a}$ | 8.65±0.56$^{b}$ | 8.40±0.70$^{b}$ | 6.60±0.68$^{a}$ | 6.82±0.77$^{a}$ |
| | TDF | 41.34±2.31$^{a}$ | 46.11±1.74$^{b}$ | 46.09±2.11$^{b}$ | 40.47±2.44$^{a}$ | 40.12±2.59$^{a}$ |
| White button mushroom | IDF | 12.15±1.28$^{a}$ | 14.63±1.64$^{b}$ | 14.42±1.30$^{b}$ | 11.86±0.99$^{a}$ | 11.66±1.04$^{a}$ |
| | SDF | 1.54±0.11$^{a}$ | 2.62±0.17$^{b}$ | 2.89±0.28$^{b}$ | 1.66±0.20$^{a}$ | 1.46±0.09$^{a}$ |
| | TDF | 13.69±0.40$^{a}$ | 17.25±1.74$^{b}$ | 17.31±1.30$^{b}$ | 13.52±0.92$^{a}$ | 13.12±1.01$^{a}$ |
| Sea mustard | IDF | 31.75±1.00$^{a}$ | 34.82±1.43$^{b}$ | 35.20±1.15$^{b}$ | 31.23±1.17$^{a}$ | 31.78±0.95$^{a}$ |
| | SDF | 4.69±0.38$^{a}$ | 6.18±0.44$^{b}$ | 5.92±0.45$^{b}$ | 4.53±0.15$^{a}$ | 4.37±0.32$^{a}$ |
| | TDF | 36.44±1.38$^{a}$ | 41.00±1.39$^{b}$ | 41.12±0.86$^{b}$ | 35.76±1.20$^{a}$ | 36.15±0.78$^{a}$ |
| Laver | IDF | 28.43±1.34$^{a}$ | 31.12±0.85$^{b}$ | 30.81±1.31$^{b}$ | 27.94±1.56$^{a}$ | 28.16±1.37$^{a}$ |
| | SDF | 3.83±0.33$^{a}$ | 5.19±0.39$^{b}$ | 4.95±0.24$^{b}$ | 3.43±0.34$^{a}$ | 3.62±0.35$^{a}$ |
| | TDF | 32.26±1.65$^{a}$ | 36.31±0.79$^{b}$ | 35.76±1.22$^{b}$ | 31.37±1.54$^{a}$ | 31.79±1.21$^{a}$ |

[1] Mean±SD (n=3); $^{a\text{-}b}$values in the same row not sharing a common superscript are significantly different by Tuke's multiple range test ($p$<0.05).

[2] Carrots, cabbage, *shiitake* and white button mushroom, sea mustard, and laver without being treated and freeze-dried.

The SDF contents of the samples dried with hot air following electrolyzed water treatment were more than in the freeze-dried and control samples. The galacten uronic acid chain was broken when a potato was heated by Huges *et al.* (42), causing the SDF content to increase. In addition, IDF changed into SDF when carrots were heated, causing the SDF content to increase. As mentioned above, the IDF in the samples that were heated increased in this study (43). The TDF contents of the samples that were dried with hot air were more than those of the other samples. TDF increased because both the IDF and SDF increased in the process of hot air-drying.

As the results above show, TDF, IDF, and SDF were increased by the hot air-drying process. No relationship was observed with the process of treating with electrolyzed water.

**Contents of vitamin C, β-carotene, pectin, and total phenolic compounds in carrots and cabbage** Table 4 shows the changes in the functional components of the carrots and cabbage that were dried with hot air or freeze-dried after electrolyzed water treatment. The vitamin C contents of the control carrots, and the samples that were freeze-dried after treating with the acidic electrolyzed water, were highest at 5.12 and 4.88 mg/100 g, respectively. The sample dried with hot air after being treated with acidic electrolyzed water showed a content of 3.86 mg/100 g. The samples dried with hot air or freeze-dried after treatment with the alkalic electrolyzed water showed the lowest contents of 1.35 and 1.37 mg/100 g, respectively, and significant differences ($p<0.05$) were observed among these samples. Vitamin C is stable below pH 4.0, according to Ha *et al.* (29), and a 19% loss in vitamin C occurred in mandarin orange samples dried with hot air (44). The samples treated with acidic electrolyzed water showed the highest vitamin C contents, and the samples dried with hot air showed the lowest. No changes occurred in the β-carotene contents of the control or the samples dried with hot air or freeze-dried after treatment with the electrolyzed water, and no significant differences ($p>0.05$) were detected. This was because the electrolyzed water reduced the activity of enzymes such as lipoxygenase and peroxidase, preventing them from degrading β-carotene (45). The pectin contents of the samples dried with hot air after the electrolyzed water treatments were greater than those in the control and the samples that were freeze-dried following electrolyzed water treatment, and significant differences ($p<0.05$) were observed. This was because pectin is a type of SDF, and the large molecular weight of dietary fiber can affect the analysis of SDF. Therefore, the pectin contents of the samples dried with hot air increased (46).

The vitamin C contents of the control cabbage, and the samples that were freeze-dried after treatment with acidic electrolyzed water, were highest at 17.72 and 17.28 mg/100 g, respectively. The sample dried with hot air after treatment with the acidic electrolyzed water showed the highest content of 12.36 mg/100 g. The samples dried with hot air or freeze-dried after treatment with the alkalic electrolyzed water showed the lowest contents of 6.42 and 7.72 mg/100 g. Significant differences ($p<0.05$) were observed among these samples. No changes occurred in the total phenolic compound contents in the control and samples dried with hot air or freeze-dried following the electrolyzed water treatments, and no significant differences ($p>0.05$) were observed. The total phenolic compound contents did not change due to the denaturation of polyphenol oxidase after treating with the electrolyzed water and then drying with hot air (47).

Little change occurred in the vitamin C contents of the carrots and cabbage after treating with the acidic electrolyzed water, and no changes were observed in the β-carotene or total phenolic compound contents; the pectin content increased after drying with hot air. None of the functional components changed by being treated with the electrolyzed water, except vitamin C; therefore, carrots and cabbage can be treated with electrolyzed water if they are to be used as uncooked food.

**Content of lectin in *shiitake* mushroom and total phenolic compounds in white button mushroom** The contents of lectin in *shiitake*, and the total phenolic compounds in white button mushrooms, after treating with electrolyzed water and then hot air- or freeze-drying, are shown in Table 5. The lectin content of *shiitake* mushroom showed no change in the control or in the samples treated with electrolyzed water and then dried by hot air or freeze-dried, and no significant differences ($p>0.05$) were observed in these samples. Lectin is composed of protein or glycoprotein; thus, its structure would be destroyed and its content would change if treated under high temperatures;

**Table 4. Contents1) of vitamin C, β-carotene, pectin, and total phenolic compounds in carrots and cabbage dried with hot-air or freeze-dried after being treated with electrolyzed water**

| | | Control2) | Hot air-dried | | Freeze-dried | |
|---|---|---|---|---|---|---|
| | | | Acidic electrolyzed water | Alkalic electrolyzed water | Acidic electrolyzed water | Alkalic electrolyzed water |
| Carrots | Vitamin C (mg/100 g) | $5.12\pm0.36^{c}$ | $3.86\pm0.21^{b}$ | $1.35\pm0.11^{a}$ | $4.88\pm0.37^{c}$ | $1.37\pm0.12^{a}$ |
| | β-Carotene (mg/100 g) | $3.10\pm0.12^{NS}$ | 2.85±0.22 | 2.96±0.24 | 3.18±0.31 | 2.82±0.16 |
| | Pectin (g/100 g) | $2.62\pm0.34^{a}$ | $4.12\pm0.25^{b}$ | $3.78\pm0.36^{b}$ | $2.48\pm0.22^{a}$ | $2.36\pm0.15^{a}$ |
| Cabbage | Vitamin C (mg/100 g) | $17.72\pm1.45^{c}$ | $12.36\pm0.85^{b}$ | $6.42\pm0.53^{a}$ | $17.28\pm1.52^{c}$ | $7.72\pm0.65^{a}$ |
| | Total phenolic compounds (g/100 g) | $0.29\pm0.02^{NS}$ | 0.31±0.02 | 0.26±0.01 | 0.29±0.03 | 0.27±0.02 |

1)Mean±SD (n=3); NSvalues in the same row are not significantly different ($p>0.05$); a-dvalues in the same row not sharing a common superscript are significantly different by Tukey's multiple range test ($p<0.05$).

2)Carrots and cabbage without being treated and freeze-dried.

**Table 5. Contents[1] of lectin and total phenolic compounds in *shiitake* and white button mushrooms dried with hot-air or freeze-dried after being treated with electrolyzed water**

| | | Control[2] | Hot air-dried | | Freeze-dried | |
|---|---|---|---|---|---|---|
| | | | Acidic electrolyzed water | Alkalic electrolyzed water | Acidic electrolyzed water | Alkalic electrolyzed water |
| *Shiitake* | Lectin (g/100 g) | 1.82±0.12$^{NS}$ | 1.57±0.16 | 1.59±0.13 | 1.77±0.06 | 1.62±0.13 |
| White button | Total phenolic compounds (g/100 g) | 0.22±0.03$^{NS}$ | 0.17±0.02 | 0.21±0.02 | 0.19±0.02 | 0.18±0.03 |

[1] Mean±SD (n=3); $^{NS}$values in the same row are not significantly different ($p$>0.05).

[2] *Shiitake* and white button mushrooms without being treated and freeze-dried.

**Table 6. Contents[1] of vitamin C, β-carotene, alginic acid, and porphyran in sea mustard and laver dried with hot-air or freeze-dried after being treated with electrolyzed water**

| | | Control[2] | Hot air-dried | | Freeze-dried | |
|---|---|---|---|---|---|---|
| | | | Acidic electrolyzed water | Alkalic electrolyzed water | Acidic electrolyzed water | Alkalic electrolyzed water |
| Sea mustard | Vitamin C (mg/100 g) | 6.86±0.42$^{b}$ | 6.73±0.55$^{b}$ | 4.26±0.37$^{a}$ | 7.12±0.36$^{b}$ | 4.98±0.48$^{a}$ |
| | β-Carotene (mg/100 g) | 3.94±0.35$^{NS}$ | 3.26±0.26 | 3.48±0.21 | 4.12±0.28 | 3.87±0.34 |
| | Alginic acid (g/100 g) | 18.58±1.51$^{a}$ | 22.19±2.16$^{b}$ | 21.86±1.65$^{b}$ | 17.97±1.56$^{a}$ | 18.16±1.38$^{a}$ |
| Laver | Vitamin C (mg/100 g) | 92.26±4.16$^{d}$ | 52.18±3.72$^{b}$ | 35.78±3.48$^{a}$ | 89.76±3.75$^{d}$ | 76.32±4.28$^{c}$ |
| | β-Carotene (mg/100 g) | 25.72±1.54$^{NS}$ | 26.19±2.78 | 26.12±3.22 | 26.32±2.21 | 26.27±2.46 |
| | Porphyran (g/100 g) | 4.26±0.38$^{a}$ | 5.67±0.26$^{b}$ | 6.11±0.48$^{b}$ | 4.53±0.52$^{a}$ | 4.18±0.37$^{a}$ |

[1] Mean±SD (n=3); $^{NS}$values in the same row are not significantly different ($p$>0.05); $^{a\text{-}d}$values in the same row not sharing a common superscript are significantly different by Tukey's multiple range test ($p$<0.05).

[2] Sea mustard and laver without being treated and freeze-dried.

but its structure and content would not change when dried at 50°C, or when treated with acidic and alkalic electrolyzed water (48). The total phenolic compound content of white button mushroom showed no change in the control or in the samples treated with electrolyzed water and dried by hot air or freeze-dried. No significant differences ($p$>0.05) were observed in these samples because the polyphenol oxidase that produced the total phenolic compounds was denatured; its content did not change when treated with electrolyzed water and dried by hot air (47).

The electrolyzed water had no effect on the lectin content in *shiitake* or on the total phenolic compound content in white button mushrooms. Therefore, these 2 uncooked food sources could be treated with electrolyzed water. However, the content changes for other functional components need to be studied further.

**Contents of vitamin C, β-carotene, alginic acid, and porphyran in sea mustard and laver** Table 6 shows the contents of the functional compounds in the samples when treated with electrolyzed water and then hot air- or freeze-dried. The vitamin C contents of the mustard and laver in the control, and the samples treated with acidic electrolyzed water, were higher than those of the samples treated with alkalic electrolyzed water, and significant differences ($p$< 0.05) were observed in these samples. The reason for this was the same as for the lack of change in the vitamin C content in the carrots and cabbage. The β-carotene contents of the sea mustard and laver did not change in the control and the samples treated with electrolyzed water and then hot air- or freeze-dried; no significant differences ($p$>0.05) were detected because lipoxygenase and peroxidase were denatured by treating with the electrolyzed water (45). The alginic acid content in the sea mustard, and the porphyran content in the laver, when treated with electrolyzed water and dried by hot air, were higher than those in the control and the samples treated with electrolyzed water and freeze-dried; significant differences ($p$<0.05) were observed in these samples. The reason for this was that some IDF changed into SDF, including alginic acid and porphyran, when heated, which made its content increase (43). The vitamin C content decreased when treated with the alkalic electrolyzed water, while very little loss occurred with the acidic electrolyzed water treatment. The contents of the other functional components showed no differences with the electrolyzed water treatments.

These results suggest, with the exception of vitamin C, that the functional components such as β-carotene, lectin, and total phenolic compounds in the uncooked carrots, cabbage, *shiitake* and white button mushrooms, sea mustard, and laver, did not change when treated with electrolyzed water, while the contents of certain other components such as pectin, alginic acid, and porphyran increased when dried by hot air; this increase, however, was not related to the electrolyzed water treatments. With the exception of vitamin C, these uncooked food sources can be treated with electrolyzed water in view of preserving their functional components.

## Acknowledgments

This Study was supported by Technology Development Program for Agriculture and Forestry, Ministry of Agriculture and Forestry, Republic of Korea.

## References

1. Chang TE, Moon SY, Lee KW, Park JM, Han JS, Song OJ, Shi IS. Micoroflora of manufacturing products and final products of *saengsik*. Korean J. Food Sci. Technol. 36: 501-506 (2004)
2. Lee YJ, Lee HM, Park TS. Effects of uncooked powdered food on antioxidative system and serum mineral concentrations in rats fed unbalanced diet. Korean J. Nutr. 36: 898-907 (2003)
3. Park JY, Yang MZ, Jun HS, Lee JH, Bae HK, Park TS. Effect of raw brown rice and Job's tear supplemented diet on serum and hepatic lipid concentrations, antioxidative system, and immune function of rates. J. Korean Soc. Food Sci. Nutr. 32: 197-206 (2003)
4. Park MH. The staus of uncooked food industry and its future. Food Ind. Nutr. 7: 1-3 (2002)
5. Yoon OH. The effect of uncooked food for human health. Food Ind. Nutr. 7: 4-10 (2002)
6. Han JH, Park SH. The effects of uncooked powdered food on nutrient intake, body fat, and serum lipid compositions in hyper-lipidemic patients. Korean J. Nutr. 36: 589-602 (2003)
7. Song MK, Hong SK, Hwang SJ, Park OJ, Park MH. Improved effects of *saengsik* on patient with fatty liver and hyperlipidemia in murine. Korean J. Nutr. 36: 834-840 (2003)
8. Kang SM, Shin JY, Hwang SJ, Hong SG, Jang HE, Park MH. Effects of *saengsik* supplementation on health improvement in diet-induced hypercholesterolemic rats. J. Korean Soc. Food Sci. Nutr. 32: 906-912 (2003)
9. Park BK, Oh MH, Oh DH. Effect of electrolyzed water and organic acids on the growth inhibition of *Listeria monocytogenes* on lettuce. Korean J. Food Preserv. 11: 530-537 (2004)
10. Lee JS, Kim SJ, Ahn RM, Choi HS, Choi HR, Yoon SK, Hong WS, Whagng HS, Kwon DJ, Kim YJ. The effect of UV-B irradiation and hot-air drying on vitamin D2 content of *shiitake* mushroom. Korean J. Food Cook. Sci. 18: 173-178 (2002)
11. Cho SY, Joo DS, Kim OS, Jeong IH, Kim SM. Preparation of water soluble alginic acid prepared form sea mustard and sea tangle by microwave and hot water. J. Korean Fish. Soc. 32: 779-783 (1999)
12. Jung SW, Park KJ, Park BI, Kim YH. Surface sterilization effect electrolyzed acid water on vegetable. Korean J. Food Sci. Technol. 28: 1045-1051 (1996)
13. Kim C, Hung YC, Rrackett RE. Roles of oxidation-reduction potential in electrolyzed oxidizing and chemically modified water for the inactivation of food related pathogen. J. Food Protect. 63: 19-24 (2000)
14. Park KJ, Jung SW, Park BI, Kim YH, Jung JW. Initial control of microorganism in *kimchi* by the modified preparation method of seasoning mixture and the pretreatment of electrolyzed acid-water. Korean J. Food Sci. Technol. 28: 1104-1110 (1996)
15. Venkitanarayanan KS, Ezeike GO, Hung YC, Doyle MP. Efficacy of electrolyzed oxidizing water for inactivating *Escherichia coli* O157: H7, *Salmonella enteritidis*, and *Listeria monocytogenes*. Appl. Environ. Microb. 65: 4276-4279 (1999)
16. AOAC. Official Methods of Analysis of AOAC Intl. 13th ed. Method 930.04, 930.05, 979.09, and 957.13. Association of Official Analytical Chemists, Washington DC, USA (1990)
17. Song JC, Park HJ. Physical functional, textural, and rheological properties of foods. Ulsan University, Ulsan, Korea. p. 82 (1995)
18. Prosky L, Asp N, Schweizer T, Devries J, Furda I. Determination of insoluble, soluble, and total dietary fiber in foods products, interlaboratory study. J. Assoc. Off. Anal. Chem. 71: 1017-1025 (1988)
19. Korea Food and Drug Administration. Food Standards Codex. Korean Foods Industry Association, Seoul, Korea. pp. 904-907 (2004)
20. Nills HJ. Isocratic non aqueous reversed-phase liquid chromatography of carotenoids. Anal. Chem. 55: 270-275 (1983)
21. Zhang X, Koo JH, Eun JB. Antioxidant activities of methanol extracts and phenolic compounds in asian pear at different stages of maturity. Food Sci. Biotechnol. 15: 44-50 (2006)
22. Shin HH, Kim CT, Cho YJ, Hwang JK. Analysis of extruded pectin extraction from apple pomace by response surface methodology. Food Sci. Biotechnol. 14: 28-31 (2005)
23. Chung SR, Choi IS, Jeune KH. Studies on lectin from marine animal *Chlorostoma argyrostoma turbinatum*. Korean J. Pharmacogn. 25: 121-131 (1994)
24. Cho SY, Joo DS, Kim OS, Jeong IH, Kim SM. Preparation of water soluble alginic acid prepared from sea mustard and sea tangle by microwave and hot water. J. Korean Fish. Soc. 32: 779-783 (1999)
25. Koo JG, Park JG. Chemical and gelling properties of alkali-modified porphyran. J. Korean Fish. Soc. 32: 271-275 (1999)
26. SPSS. Statistical Package for Social Sciences for Windows. Rel. 10.0. Statistical Package for Social Sciences Inc., Chicago, IL, USA (1999)
27. Jung CY, Choi LG. SPSSWIN for Statistics Analysis. Ver. 10.0, 4th ed. Muyok Publishing Co., Seoul, Korea. pp. 276-283 (2002)
28. Jin TY, Oh DH, Rhee CO, Chung DO, Eun JB. Change of physicochemical characteristics and functional components in the cereals of *saengsik*, uncooked food by washing with electrolyzed water. Korean J. Food Sci. Technol. 38: 506-512 (2006)
29. Ha JO, Lee SC, Bae HD, Park OP. Food Chemistry. Dooyangsa, Seoul, Korea. pp. 218-344 (2004)
30. Izumi H. Electrolyzed water as a disinfectant for fresh-cut vegetables. J. Food Sci. 64: 536-539 (1999)
31. Jin TY, Oh DH, Eun JB. Change of physicochemical characteristics and functional components in the raw materials of *saengsik*, uncooked food by drying methods. Korean J. Food Sci. Technol. 38: 188-196 (2006)
32. Chung HS, Song SD, Roh KS, Song JS, Park KE. The effects of acidic electrolytic water on the development of barley chloroplast. J. Korean Environ. Sci. Soc. 8: 255-261 (1999)
33. Koseki M, Fujiki S, Tanaka Y, Noguchi H, Nishikawa T. Effect of water hardness on the taste of alkaline electrolyzed water. J. Food Sci. 70: 249-253 (2005)
34. Lee JS, Yoon KH, Shin WS. Effect of UV-B irradiation on the content of vitamin $D_2$, color, and flavor pattern in *Lentinus edodes*. Korean J. Food Cook. Sci. 19: 121-126 (2003)
35. Ha YS, Park JW, Lee JH. Physical characteristics of mushroom (*Agaricus bisporus*) as influenced by different drying methods. Korean J. Food Sci. Technol. 33: 245-251 (2001)
36. Li LT, Wu L, Eizo T. The research of electrolyzed functional water on maintaining the quality of fresh-cut potato. J. Chinese Food Sci. 26: 139-143 (2005)
37. White RC, Jones IO, Gibbs E, Butler LS. Flurometric estimation of chlorophyllides, pheophytins, and pheophorbides in mixtures. J. Agr. Food Chem. 20: 773-778 (1972)
38. Matthee V, Appledorf H. Effect of cooking on vegetable fiber. J. Food Sci. 43: 1344-1349 (1978)
39. Englyst HN, Anderson V, Cummings JH. Starch and non-starch polysaccharides in some cereal foods. J. Sci. Food Agr. 34: 1434-1442 (1983)
40. Vidal-valverde C, Frias J. Legume processing on dietary fiber components. J. Food Sci. 56: 1350-1357 (1991)
41. Lee CH, Oh SH, Yang EJ, Kim YS. Effects raw, cooked, and germinated small black soybean powders on dietary fiber content and gastrointestinal functions. Food Sci. Biotechnol. 15: 635-638 (2006)
42. Huges JC, Grand A, Faulks RM. Texture of cooked potatoes: Relationship between the compressive strength of cooked potato disks and release of pectic substance. J. Sci. Food Agr. 26: 731-738 (1975)
43. Nyman M, Palsson KE, Asp NG. Effect of processing fiber in vegetables. Lebensm.-Wiss. Technol. 20: 29-35 (1987)
44. Chung YJ, Yook HS. Effects of gamma irradiation and cooking methods on the content of thiamin in chicken breast and vitamin C in strawberry and mandarine orange. J. Korean Soc. Food Sci. Nutr. 32: 864-869 (2003)
45. Koseki S, Yoshida K, Kamitani Y, Isobe S, Itoh K. Effect of mild heat pre-treatment with alkaline electrolyzed water on the efficacy of acidic electrolyzed water against *Escherichia* coli O157:H7 and *Samonella* on lettuce. Food Microbiol. 21: 559-566 (2004)
46. Lee EY, Kim YA. Effects of heat treatment on the dietary fiber contents of soybean sprout and spinach. Korean J. Food Cook. Sci. 10: 381-385 (1994)
47. Wellelr A, Sims CA, Matthews RF, Bates RP, Brecht JK. Browning susceptibility and changes in composition during storage of carambola slices. J. Food Sci. 62: 256-260 (1997)
48. Lyu SY, Rhim JY, Park YH, Suh KB, Park WB. Changes of lectin activity of kidney beans by heating and fermentation. J. Korean Soc. Food Sci. Nutr. 31: 1-6 (2002)