

Evaluation of Deodorization Capabilities, Morphologies, and Thermal Stabilities of Baking Soda, Charcoal, Coffee, and Green Tea for *Kimchi* Packaging Application

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Abstract We evaluated the applicability of baking soda, charcoal, coffee, and green tea as a natural deodorant in *Kimchi* packaging. Moreover, to evaluate the potential usage of these deodorants in packaging materials and confirm their applicability in high-temperature melt-extrusion processing, the thermal stabilities of the deodorants were investigated, and heat-treated deodorants were evaluated in terms of the deodorizing function compared with non-treated deodorants. Aroma patterns were decreased after deodorizing treatment with all-natural deodorants. Dimethyl disulfide, methyl trisulfide, and diallyl disulfide, the most significant odorous Volatile organic compounds (VOCs) of *Kimchi*, decreased after treatment with the deodorants. In particular, baking soda and charcoal showed the highest efficiency in removing odorous compounds and VOCs from *Kimchi*, even after high-temperature processing. The acetic acid removal rates for both baking soda and charcoal were $99.9 \pm 0.0\%$. The heating process increases the deodorizing effects of baking soda. Sensory evaluation results showed that there is a significant increase ($p < 0.05$) in the overall preference for *Kimchi* samples packaged with charcoal and baking soda. This study provides useful information for the deodorization effects of natural deodorants for *Kimchi* smell and their applicability for packaging materials.

Keywords Active packaging, adsorption, packaging, sensory analysis, volatile components.

Introduction

Kimchi is a traditional fermented Korean side dish mainly composed of leaf and root vegetables with seasonings such as garlic, ginger, onion, red pepper powder, green onion, fermented shrimp, and anchovies.^{1,2} It has gained popularity as a functional food because of its touted anticancer activity^{3,4} and antitumor effects³ as well as health-promoting effects, including improved fasting blood glucose, serum lipid profiles, and total antioxidant status⁵. However, when *Kimchi* is well-aged, microbiological and enzymatic activities continue, leading to a sour and bitter taste, CO₂ production, off-odors, and softening. These effects are mainly due to the lactic acid bacteria and yeasts naturally present in the raw materials.^{3,6,7} The smell of *Kimchi*, which is caused by several functional groups, is a well-known undesirable characteristic.⁸ The volatile organic compounds (VOCs) released from *Kimchi* contribute to the strong sour taste and smell of *Kimchi*, which is strongly dis-

liked by foreigners. Hence, increasing the consumption of *Kimchi* requires the development of products that can reduce its smell.^{9,10}

The principle roles of food packaging are to protect food products from outside influence and damage, to contain food, and to provide consumers with ingredients and nutritional information.¹¹ In recent times, functional food packaging has been developed using diverse functional materials with features such as absorption, gas control, humidity adjustment, and antibacterial and deodorizing effects to maintain the quality and freshness of food.^{12,13,14}

In packages, odor removers have the potential to scavenge malodorous constituents such as volatile package ingredients, chemical metabolites of food products, microbial metabolites, respiration products, and the off-flavors in raw foods.¹³ One reason for odor removal from the interior of packages would be to obviate the potentially adverse effects of these "confinement odors".¹³ A second reason for incorporating odor removers into packages is to obviate the effects of odors developed in the package materials themselves.¹³ Deodorizing systems, typically available as films, sachets, labels, and trays, eliminate odors via mass-transfer mechanisms.^{8,13,15} Food packaging with odor absorbers such as carbon, silica, alumina, zeolites, α -tocopherol, and charcoal has been investigated.^{8,16} Phenols

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such as gallate and sesamol have also been actively studied.^{8,16)}

Of these potential adsorbents, the use of synthetic active compounds in food packaging has been questioned owing to their possible toxic effects and consequently many consumers do not prefer such packaging components.¹⁷⁾ Sodium bicarbonate (NaHCO₃), commonly known as baking soda, is a widely used food ingredient and is considered one of the most effective adsorbents for eliminating undesirable substances such as volatiles and toxic compounds.^{18,19,20)} Charcoal can be used as an adsorbent with high deodorization performance owing to the high surface area of the material.^{16,21,22,23)} Recently, the deodorizing effects of coffee beans were reported; coffee has been used in several applications to eliminate unpleasant odors.²⁴⁾ In Asian countries, in recent decades, the deodorizing activity of green tea has been empirically demonstrated. Tea catechins exhibit deodorizing activity against methyl mercaptan, and a mechanism has been proposed for its deodorizing action.^{25,26)}

Thus, the objective of this study was to examine the deodorizing effects of natural deodorants such as baking soda, charcoal, coffee, and green tea on *Kimchi* flavor (particularly acetic acid), and to evaluate the potential applications of natural deodorants in *Kimchi* packaging.

Materials and Methods

1. Materials

Baking soda (99% sodium bicarbonate and 1% potash alum) was purchased from Recipia (Chungen F&B, Gyeonggi-do, Korea). Charcoal was purchased from Hansae Co., Ltd. Coffee was purchased from Lotte Shopping Co., Ltd. An extracted coffee powder was prepared by pouring boiling water over the coffee powder to extract coffee, followed by drying. Green tea powder was purchased from Dong Suh Food Co., Ltd (Seoul, Korea).

2. Scanning electron microscopy (SEM)

The scanning electron microscopy (SEM) images were obtained from a Quanta FEG 250 SEM system (FEI Co., Ltd., Oregon, USA) to characterize the deodorant morphologies. Before imaging, the samples were coated with a thin platinum layer.

3. Particle size analysis

A particle size analyzer was employed to determine size distribution. The particle sizes of the deodorants were determined using an LS 13 320 laser diffraction particle size analyzer (Beckman Coulter, USA) according to ISO 13320 (particle size analysis by laser diffraction).

4. Thermogravimetric analysis (TGA)

The thermal stabilities of the deodorants were investigated

using a thermogravimetric and differential scanning calorimetric 1 analyzer (Mettler Toledo, USA) at a heating rate of 10 °C/min under nitrogen atmosphere.

5. Electronic nose analysis

Flavor patterns were analyzed using a fast gas chromatography (GC) analyzer (Electronic Nose, Model 7100; Electronic Sensor Technology). For electronic nose analysis, *Kimchi* and deodorant samples were contained in small separate dishes inside the same packaging container. The ratio of *Kimchi* to deodorants was set at 8:2. Briefly, 1 g of *Kimchi* was placed in a 20-mL vial at 50°C for 15 min. Next, 2.5 mL of the gas was extracted with an injection speed of 250 µL/s and injected into an electronic nose sensor array room. The electronic nose was set at 25, 40, 270, and 240°C as the trap, column, detector, and trap final temperatures, respectively. The results of the flavor pattern with *Kimchi* were analyzed using the Vapor Print program.

6. Gas chromatography–mass spectrometry (GC–MS)

Kimchi samples treated with deodorants were analyzed using gas chromatography–mass spectrometry (GC–MS) using an Agilent 6890N-series GC system interfaced with a LECO Pegasus IV (Leco, MI, USA) time-of-flight mass spectrometer and an Agilent J&W GC column DB-5ms (30 m × 0.25 mm × 0.25 µm) to identify the chemical constituents. For GC–MS, samples of *Kimchi* and deodorants were contained in small separate dishes in the same package. The ratio of *Kimchi* to deodorants was set to 8:2. A 1-mL volume of the sample was injected with a split ratio of 30:100 and carrier gas of H₂ at the injection temperature of 70°C. The temperature of the oven was increased from 30 to 100°C at 5°C/min and from 100 to 200°C at 25°C/min. Then, GC–MS was performed using a mass spectrometry detector. The mass spectrometer was used for the peak analysis of the volatile components.

7. Acetic acid removal rate measurement (%)

The detector tube method was used to investigate the deodorizing effects of the natural deodorants. Briefly, 1.0 g of each specimen was placed in a 5 L plastic bag, and 3 L of the master gas (acetic acid) was then introduced at standard atmospheric pressure at 25°C. The initial concentration of acetic acid was 50 ppm. The concentration of the residual master gas in the plastic bag was detected with a No. 81 detector tube (GASTEC, Seoul, Korea) after maintaining the bag stationary for 30, 60, 90, 120, and 150 min.

$$\text{Reduction rate (\%)} = ((C_b - C_s) / C_b) \times 100$$

*C_b: Concentration of acetic acid in the plastic bag (blank) after 30, 60, 90, 120, and 150 min

*C_s: Concentration of acetic acid in the plastic bag with sample after 30, 60, 90, 120, and 150 min

8. Sensory evaluation

The sample is prepared in a plastic bag (polyester, 25 cm × 25 cm, 3 L volume, 20 μm) by filling it with 100 g of *Kimchi* and 1 g of natural deodorants and closed with silicone rubber stoppers to investigate the sensory properties of the deodorants. A sniffing mask nose shaped cover was made of PET and connected to the pipe of the odor bag. The deodorant was attached to the sampling pipe of the odor bag (Figure 1). After the samples were prepared, it was coded with three-digit random numbers and presented to a panel. The sensory quality of the deodorants was evaluated by a sensory panel comprising 15 trained people. Nine-point scales were described for the sensory evaluation (hedonic test), and each sample was rated from 1 (strongly dislike) to 9 (strongly like) in order to assess the statistical significance of the test; higher scores indicated a higher preference. The *Kimchi* packaged with deodorants was evaluated for the *Kimchi* smell, off-odors, and overall preference.

9. Statistical analysis

The obtained data were analyzed using the SPSS IBM SPSS Statistics 19 (SPSS Inc., 2011, Chicago, IL, USA) software. Two-way analyses of variance (ANOVA) with mean values separated using Duncan's multiple-range tests were used. Dif-



Fig. 1. Sample bag and location of deodorants. (part of the red circle ring)

ferences with p values of less than 0.05 were considered significant.

Results and Discussion

1. Particle size distribution and morphology

The particle size and shape are the main characteristics of powders.²⁷⁾ The technological properties of powders (bulk density, flow, and surface area) and their potential application both depend on these characteristics.^{27,28)} Moreover, with decreasing particle size, the surface-to-volume ratio increases; hence, the surface properties become more meaningful.²⁹⁾ The dispersibility of the fillers affects various physical properties of the packaging materials, particularly their thermal stability, mechanical strength, and barrier properties.²⁸⁾

The form and size of a deodorant are crucial factors for improving the properties of a film.²⁸⁾ Therefore, to investigate the particle size and morphology of the tested deodorants particle size analysis and SEM analysis were used. As shown in Table 1, the average sizes of baking soda, charcoal, and green tea are approximately 50–140 μm; this size range is suitable for dispersibility and processing in film manufacturing. Especially, in Table 1, it shows charcoal and green tea had a fairly narrow range of particle size with a D50 of 14.0 and 13.4 μm and size range between 29.0 and 2.8 μm (D10) and 86.2 and 35.3 μm (D90), respectively. The most commonly used metrics when describing particle size distributions are D-Values (D10, D50 & D90) that are the intercepts for 10%, 50% and 90% of the cumulative mass.³⁰⁾ The parameter D90 signifies the point in the size distribution, up to and including wherein, 90% of the total volume of material in the sample is ‘contained’³⁰⁾ However, the average particle size of coffee is approximately 670.0 μm, and size range between 383.0 μm (D10) and 949.5 μm (D90) which is not appropriate for packaging because of the difficulty in obtaining an even film surface during manufacturing.

The morphology of a powder is generally characterized by the particle shape (i.e., spherical, angular, dendritic, disc, or circular) or in a quasi-quantitative manner (i.e., geometrical shape parameters).²⁷⁾ Qualitative descriptions of the visual appearance of particles, such as “rounded,” “semi-angular,” or “angular,” can be used to classify and differentiate different particle groups.²⁷⁾ The results showed that charcoal and coffee have similar morphology with honeycomb-shaped structures. They

Table 1. Average particle size distributions of baking soda, charcoal, coffee, and green tea (mean±S.D., $n = 3$)

	Baking soda	Charcoal	Coffee	Green tea
Average particle size	137.5±0.7	29.0±0.1	676.0±36.8	17.0±0.1
D10	24.9±0.0	2.4±0.3	383.0±35.4	2.8±0.0
D50	105.5±0.7	14.0±0.1	684.0±32.5	13.4±0.1
D90	301.0±2.8	86.2±1.0	949.5±123.7	35.3±0.2

*D-Values (D10, D50 & D90) that are the intercepts for 10%, 50% and 90% of the cumulative mass

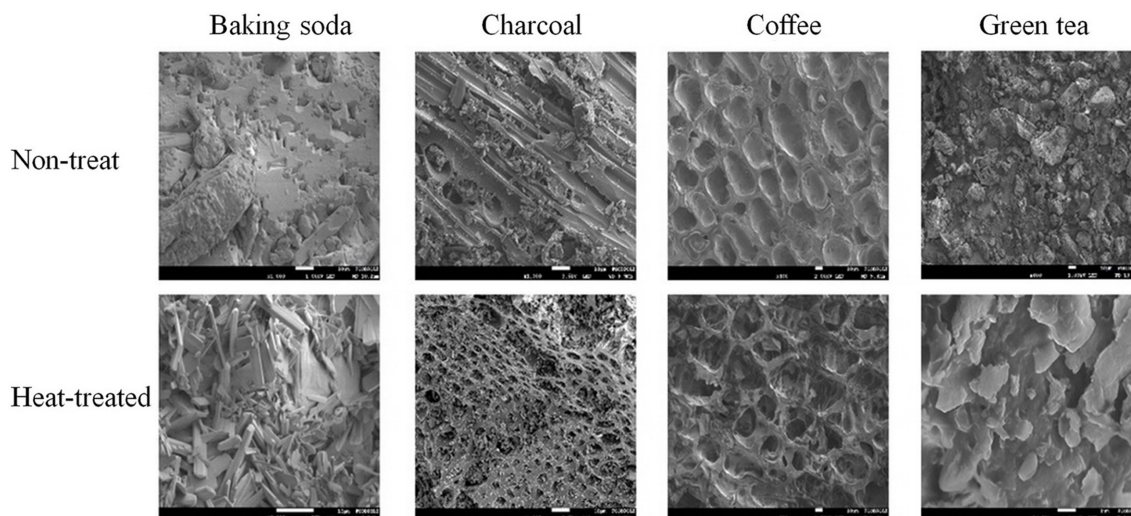


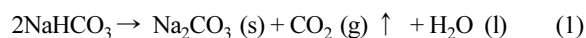
Fig. 2. SEM images of baking soda, charcoal, coffee, and green tea.

can absorb odorous compounds and VOCs from *Kimchi* because they possess high surface areas and large pore volumes. Some of the natural materials are lost at high temperatures, causing structural changes. However, no real structural difference is apparent between coffee and heat-treated coffee. Baking soda and green tea particles have irregular shapes with rough surfaces, along with some adhered fine microparticles (Figure 2).

2. Thermal stability

Nobile *et al.* (2009) found that the processing temperatures play a major role in determining the efficiency of the investigated active films.³¹⁾ The choices of active materials are often limited owing to their low thermal stability and volatility during extrusion or injection molding or the incompatibility of the component with the matrix polymer materials.^{31,32)} Therefore, to investigate the thermal decomposition of the natural deodorants and confirm their applicability in high-temperature

melt-extrusion processing, TGA was performed. As shown in Figure 3, charcoal exhibits good thermal stability at temperatures exceeding 200°C. In case of coffee and green tea, there is a gradual decrease in the mass without significant degradation. Baking soda shows a two-step decomposition pattern, with decomposition occurring at approximately 90–100°C and 120–200°C, as shown in Figure 3. The decomposition reaction of sodium bicarbonate is shown in Equation 1 and is both time- and temperature-dependent.^{19,20)} The heat-treated baking soda decomposes to sodium carbonate (Na_2CO_3), as shown in Equation 1.



These results indicate that charcoal has the best thermal stability among the tested samples.

3. Electronic nose analysis

An electronic nose is a device that identifies specific components of an odor and analyzes its chemical constituents using pattern recognition software³³⁾, mimicking the olfactory senses of human beings. Instead of analyzing the product by separating the components, as in GC, the electronic nose detects the entire odor of the product in a manner similar to that experienced by human beings.^{33,34)} The electronic nose comprises an array of electronic sensors that react with volatile substances to provide a distinctive scent pattern (fingerprint of scent); therefore, it is feasible to compare the patterns and hence distinguish the products.³³⁾

Figure 4 shows the results obtained from the Vapor Print image analysis in the form of polar frequency patterns. From the obtained Vapor Print images, a large diversity in odor is observed. The flavor patterns shown in Figure 4 correspond with the peaks obtained from various odor-producing volatile compounds in *Kimchi* samples.

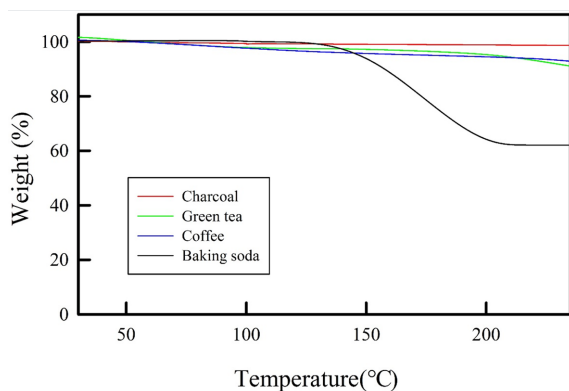


Fig. 3. TGA thermograms of baking soda, charcoal, coffee, and green tea.

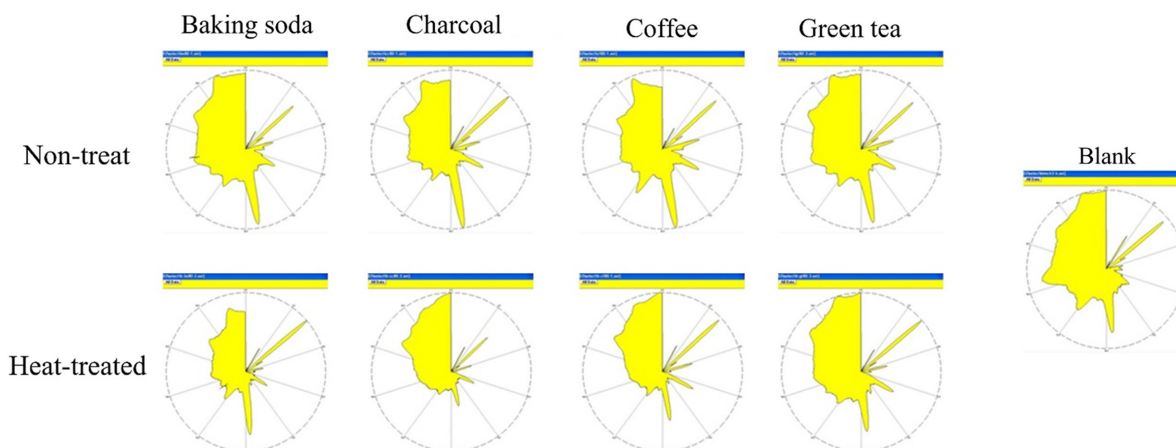


Fig. 4. Polar frequency patterns of the flavors in Kimchi after the addition of natural deodorants.

The *Kimchi* samples treated with natural deodorants tend to exhibit different patterns, which correspond to decreased smell intensity. In the case of all of the deodorants used, intensity changes are observed. The charcoal-treated *Kimchi* exhibits the highest intensity change, while green tea-treated *Kimchi* exhibits the lowest. To evaluate the effect of thermal decomposition sustained during extrusion on the deodorizing effects of the different agents, natural and heat-treated deodorants are compared. The image (blank) on the far right shown in Figure 4 depicts the peaks in a control *Kimchi* sample. A comparison of the data corresponding to the four deodorants and heat-treated deodorants with that of the blank clearly indicates decreased smell intensities in the former. However, no significant change in the intensity of the scent ingredients is observed, confirming that heating does not affect the overall deodorizing effect.

4. GC/MS of volatile compounds

The volatile odor-producing ingredients in *Kimchi* are the

main factors affecting its taste and functional characteristics.⁹⁾ Approximately 40 types of volatile ingredients have been identified in *Kimchi*, with the majority constituting sulfides¹⁰⁾ such as alkyl, allyl, or alkyl allyl sulfides.¹⁰⁾ These compounds are assumed to be generated from their precursors such as sulf-oxides, thioglucosides, sulfur-containing amino acids, and sulfonium compounds.^{1,10,35)} Volatile compounds (allyl mercaptan, methyl allyl sulfide, dimethyl disulfide, diallyl sulfide, methyl trisulfide, and diallyl disulfide) are mainly responsible for the odor associated with the fermentation of *Kimchi*.^{9,10,35)}

Table 2 summarizes the changes in the major volatile smell-producing compounds and other ingredients after treating with different natural deodorants. The differences among the samples are compared in terms of the peak areas divided by those of the standard substances (benzene and fluoro-). *Blank means non-treated Kimchi sample*. The results showed that the peak areas of allyl mercaptan and allyl methyl sulfide, which originate from garlic, are reduced after treatment with the all

Table 2. Changes in the volatile composition of *Kimchi* treated with natural deodorants by GC–MS analysis

NO.	Compound	RT ¹⁾ (s)	MF ²⁾	Blank	Peak area (%) ³⁾							
					Baking soda		Charcoal		Coffee		Green tea	
					Nontreat	Heattreated	Nontreat	Heattreated	Nontreat	Heattreated	Nontreat	Heattreated
1	Allyl mercaptan	165.8	C ₃ H ₆ S	1.49	1.31	1.21	0.30	1.75	2.31	1.83	0.88	2.41
2	Allyl methyl sulfide	280.2	C ₄ H ₈ S	0.91	0.39	1.16	0.15	-	1.32	1.02	0.27	1.44
3	Dimethyl disulfide	386.4	C ₂ H ₆ S ₂	0.23	0.17	0.09	0.05	0.05	0.11	0.13	0.06	0.25
4	Diallyl sulfide	843.5	C ₆ H ₁₀ S	0.07	0.22	-	0.06	0.28	0.46	0.35	0.10	0.47
5	Dimethyl trisulfide	1163.1	C ₂ H ₆ S ₃	0.01	-	0.01	-	-	-	-	-	-
6	Diallyl disulfide	1425.1	C ₆ H ₁₀ S ₂	0.03	0.02	0.03	-	-	-	0.24	0.01	-

¹⁾ Retention time and ²⁾ Molecular formula ³⁾ Peak area/peak area of fluorobenzene

deodorants. The contents of dimethyl disulfide and dimethyl trisulfide also significantly decreased with all types deodorants. The most effective treatment in decreasing the VOCs content was charcoal. However, new odors are generated by the addition of the natural deodorants, particularly in case of green tea and coffee. Therefore, green tea and coffee are not suitable for packaging *Kimchi* because they create other strong smells. Thus, baking soda and charcoal are the optimum deodorants among the four materials tested. In particular, heat-treated baking soda was considerably effective for removal of the numbers of off-odor compounds.

5. Acetic acid removal rate (%)

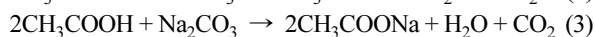
Upon ripening, *Kimchi* emits a unique odor and becomes sour because of the increased amounts of organic acids.^{2,35)} Before ripening, most of the organic acids in *Kimchi* are present as salts rather than as free acids. In addition, the amount of free acids in *Kimchi* increases with fermentation.⁶⁾ Among the various volatile organic acids in *Kimchi*, acetic acid is produced by *Leuconostoc mesenteroides* and *Lactobacillus brevis* as well as by heterofermentative lactic acid bacteria.^{6,10,35)}

With fermentation, the amounts of the major acids of lactic acid and acetic acid increase among the identified organic acids.^{1,3,35)} The deodorizing effects of the natural deodorants were extensively investigated by an indicator tube method using acetic acid as the carrier gas for 150 min at 30-min intervals.

Regardless of the heat treatment, the acetic acid removal rates (%) of the natural deodorants increased with the measurement time. As summarized in Table 3, the deodorization rates of baking soda gradually increased: 31.3% (30 min), 61.3% (60 min), 70.0% (90 min), 81.3% (120 min), and 86.3% (150 min). Charcoal exhibits an outstanding deodorization rate of 99.9% for the removal of acetic acid after 30 min. The deodorization rate of coffee increased slightly: 19.2% (30 min), 24.0% (60 min), 32.7% (90 min), 36.5% (120 min), and 47.1% (150 min); that of green tea also increased gradually: 58.0% (30 min), 71.0% (60 min), 79.0% (90 min), 80.0% (120 min), and 82.0% (150 min).

High deodorization rates ($\geq 99.9\%$) are observed for charcoal, regardless of the heat treatment. However, the deodorization rates of baking soda, coffee, and green tea changed after heating. The deodorizing function of green tea and coffee decreased upon heating. The range of usable natural additives is often limited by the low thermal stability of the additive components under high-temperature shear polymer processing, e.g., extrusion and injection molding, and by the incompatibility of the components with the matrix polymer materials.^{1, 12, 36, 37)} Conversely, heating increases the deodorizing effects of baking soda. Heat-treated baking soda deodorizes a significant amount of acetic acid in the first 30 min before the deodorization rate decreases; hence, heat-treated baking soda is more effective than the untreated one.

Further, baking soda chemically reacts with acetic acid, which causes off-odors in *Kimchi*. The reactions between baking soda, heat-treated baking soda, and acetic acid are summarized as follows^{18,19)}:



Baking soda exhibits a high acetic acid removal rate even when heated, implying that baking soda could be used as an additive in general melt-extrusion processes. This result demonstrates that the irregular, rough, and aggregated particle structure of baking soda described in Section 3.1 and shown in Figure 2 does not hinder its deodorizing efficiency.

6. Sensory evaluation

The smell index of *Kimchi*, the off-odor index, and the overall preferences were evaluated to investigate the sensory properties of baking soda, charcoal, coffee, and green tea as deodorants. (Table 4). The non-treated *Kimchi* sample showed a *Kimchi* smell intensity of 5.5 ± 1.38 . The *Kimchi* smell intensities of the samples that were packaged with deodorants were significantly reduced ($p < 0.05$), as noted by the panelists for all tested deodorants. Among the deodorants, packaging with baking soda and charcoal was the most effective way to reduce

Table 3. Acetic acid removal rates of baking soda, charcoal, coffee, and green tea (mean \pm S.D., $n = 3$)

Sample code		Acetic acid removal rate (%)					
		0 min	30 min	60 min	90 min	120 min	150 min
Baking soda	Non-treat	0	31.3 \pm 1.3	61.3 \pm 3.8	70.0 \pm 5.0	81.3 \pm 1.3	86.3 \pm 1.3
	Heat-treated	0	95.0 \pm 0.0	97.5 \pm 2.9	>99.9 \pm 0.0	>99.9 \pm 0.0	>99.9 \pm 0.0
Charcoal	Non-treat	0	>99.9 \pm 0.0	>99.9 \pm 0.0	>99.9 \pm 0.0	>99.9 \pm 0.0	>99.9 \pm 0.0
	Heat-treated	0	>99.9 \pm 0.0	>99.9 \pm 0.0	>99.9 \pm 0.0	>99.9 \pm 0.0	>99.9 \pm 0.0
Coffee	Non-treat	0	19.2 \pm 2.0	24.0 \pm 1.0	32.7 \pm 0.0	36.5 \pm 2.0	47.1 \pm 1.0
	Heat-treated	0	15.2 \pm 3.2	24.3 \pm 4.3	30.4 \pm 6.4	32.3 \pm 6.4	38.4 \pm 0.4
Green tea	Non-treat	0	58.0 \pm 2.0	71.0 \pm 1.0	79.0 \pm 1.0	80.0 \pm 0.0	82.0 \pm 2.0
	Heat-treated	0	60.4 \pm 0.4	68.3 \pm 1.7	74.3 \pm 1.8	78.2 \pm 1.8	80.2 \pm 0.2

Table 4. Sensory evaluation of packaged *Kimchi* with deodorants

		<i>Kimchi</i> smell intensity	Off-odor intensity	Overall preference
Blank		5.50±1.38 ^A	2.83±1.34 ^{ABCD}	3.17±0.94 ^A
Baking soda	Non-treat	2.83±2.21 ^{CD}	2.08±1.08 ^{CD}	5.42±2.11 ^{BC}
	Heat-treated	2.00±1.04 ^{BCD}	1.67±1.44 ^D	6.17±2.33 ^C
Charcoal	Non-treat	1.75±0.97 ^D	1.58±1.16 ^D	6.08±2.39 ^C
	Heat-treated	2.92±1.83 ^{BCD}	2.17±1.59 ^{BCD}	6.00±1.65 ^C
Coffee	Non-treat	4.08±1.62 ^B	3.42±1.73 ^{ABC}	4.33±0.98 ^{AB}
	Heat-treated	3.67±1.61 ^B	3.25±1.06 ^{ABC}	4.42±1.51 ^{AB}
Green tea	Non-treat	3.17±1.59 ^{BCD}	3.58±2.02 ^A	4.17±2.04 ^{AB}
	Heat-treated	3.33±2.15 ^{BC}	3.50±1.73 ^{AB}	3.75±1.71 ^A

All values are means ± SDs.

^{A-D}Means sharing different letters in the same column are significantly different ($p < 0.05$).

the *Kimchi* smell intensity. The *Kimchi* smell intensities of the samples treated with baking soda and charcoal were decreased from 5.5 to less than 3. There was no significant difference between the four samples regardless of the heat treatment.

Although deodorants may absorb the unpleasant smell of *Kimchi*, their application may be undesirable if the sensory properties of the packaged *Kimchi* products are negatively affected because of the strong and characteristic smells of the deodorants themselves. Therefore, the off-odor intensity of the samples was evaluated, and the panelists failed to differentiate the off-odors between the blank and deodorant-treated product. That means that the four type natural deodorants do not affect the sensory properties by their strong and characteristic odors.

A sensory evaluation of packaged *Kimchi* with a deodorant treatment is critical to determine the influence of natural deodorants on consumer preferences. The subjective panelist preferences for the deodorant-treated *Kimchi* samples are presented in Table 4. The overall preference for the samples is in the following order: blank < heat-treated green tea < green tea (untreated) < coffee (untreated) < heat-treated coffee < baking soda < heat-treated charcoal < charcoal < heat-treated baking soda. There is a significant increase ($p < 0.05$) in the overall preference for the *Kimchi* samples packaged with charcoal and baking soda as deodorants. As a result of the sensory evaluation, *Kimchi* packaged with baking soda and charcoal showed the highest score for the overall preference.

Conclusion

This study investigates the effects of baking soda, charcoal, coffee, and green tea as a natural deodorant in *Kimchi* packaging in order to remove *Kimchi* flavor. To determine the suitability of these deodorants for incorporation in *Kimchi* packaging, they were subjected to high-temperature processing (i.e., a high temperature during extrusion and injection mold-

ing) to assess the changes in their deodorizing effects. Moreover, through electronic nose, GC/MS, detector tube method, and sensory evaluation, we found that baking soda and charcoal have excellent deodorization activities against *Kimchi* smell, especially acetic acid, and they are also suitable for high-temperature processing. In particular, after heat treatment, both baking soda and charcoal exhibited acetic acid removal rates of 99%. Moreover, *Kimchi* packaged with baking soda and charcoal demonstrated the highest preference from a sensory evaluation, regardless of the heat treatment. Based on these findings, we concluded that baking soda and charcoal have potential applications in *Kimchi* deodorizing packaging.

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Declaration of Conflicting Interests

The authors declare that there is no conflict of interest.

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