Estimated daily intakes of benzoic acid and sorbic acid in South Korea

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Summary
Processed foods were analysed by high performance liquid chromatography with ultraviolet detection for benzoic acid (n = 555) and sorbic acid (n = 829). The results were used to evaluate the estimated daily intakes (*EDI*s) of these additives from the Korean diet. Benzoic and sorbic acid were detected in 9.4 % and 42.3 % of the food items, respectively. The benzoic and sorbic acid contents in all the processed foods were below the Korean maximum permitted levels of 2000 mg·kg^{-1} and 3000 mg·kg^{-1}, respectively. *EDI*s of benzoic and sorbic acids for total consumers were 2.2 % and 0.6 % of the acceptable daily intakes (*ADI*s) stipulated by the Joint FAO/WHO Expert Committee on Food Additives (0–5 mg·kg^{-1}·d^{-1} benzoic acid, 0–25 mg·kg^{-1}·d^{-1} sorbic acid), respectively. *EDI*s of benzoic and sorbic acids for the high consumption group (90th percentile) were 26.1 % and 8.4 % of *ADI*s, respectively. The highest benzoic and sorbic acid intakes were found in the 3–6-year-olds at 7.2 % and 1.2 % of *ADI*s, respectively. Beverages were a major contributor to *EDI* of benzoic acid, and soybean paste, processed fish products and pickles were major contributors to *EDI* of sorbic acid.

Keywords
daily intake; preservative; benzoic acid; sorbic acid; South Korea

Benzoic acid, sorbic acid and their salts are widely used as food preservatives to protect consumers from the microbiological risks of various bacteria, yeasts and fungi [1]. Benzoic acid and its benzoate salts are added to many foods, such as fruit juices, jams, beverages, dressings and beer, at contents ranging from 200 mg·kg^{-1} to 5000 mg·kg^{-1}. Sorbic acid and its sorbate salts are used as food additives in various countries in a wide range of commonly consumed foods, such as margarine, fruit products, desserts, drinks and cheeses, at contents up to 2000 mg·kg^{-1} [2]. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has assessed benzoic acid (and benzoate salts) and sorbic acid (and sorbate salts) several times and established acceptable daily intakes (*ADI*s) of 0–5 mg·kg^{-1} for benzoic acid (and benzoate salts) and 0–25 mg·kg^{-1} for sorbic acid (and sorbate salts) [3, 4].

Some studies showed that benzoic acid and benzoate salts cause allergic reactions such as urticaria and asthma in humans [5–7]. Moreover, benzoic acid (and benzoate salts) can cause non-immunological contact reactions (pseudo allergies) in sensitive individuals at doses lower than 5 mg·kg^{-1} [8]. By contrast, sorbic acid and sorbate salts have low toxicity because they are rapidly metabolized in the human body, and only a few cases of non-immunological contact reactions have been reported in humans [3, 5, 7].

Assessing whether the intake levels of benzoic acid, sorbic acid and their salts are safe, and evaluating what age groups are the most vulnerable to these chemicals, is essential to ensure the safe use of these food additives. Therefore, the daily intakes of these chemicals were assessed in various countries using different methods. In Japan, the daily intakes of benzoic acid and sorbic acid were assessed using the market basket method from 2006 to 2008, and in Australia and

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New Zealand, the estimated daily intakes (*EDI*s) of these food additives were evaluated by age group using a household survey in 2005 [9, 10]. In Denmark, *EDI*s of benzoic acid and sorbic acid by age group were studied using food intake data and monitoring data in 2001 and 2006, and in Austria, *EDI*s of these food additives were evaluated from 2007 to 2010 using national food consumption data by age group [11, 12]. In Korea, *EDI*s of benzoic and sorbic acid were evaluated in the 2000s. However, in the previous studies, there were insufficient food intake data for individual foods, and *EDI*s of benzoic and sorbic acid were calculated using food supply data, from intake data for only a few foods, or estimated theoretically.

The purpose of this study was to determine safe levels for the use of benzoic acid and sorbic acid in processed foods using experimental data, and to assess *EDI*s of these food additives in Korea using consumption data for these food additives from processed foods. The data were analysed for the total population, different age groups and a high consumption group (90th percentile for quantity of benzoic acid- and sorbic acid-containing foods consumed).

MATERIALS AND METHODS

Sampling

The food categories for analysis of benzoic acid and sorbic acid were selected based on regulations in the Korean Food Additives Code [13]. A total of 555 food items in eleven categories were analysed for benzoic acid, and 829 food items in twenty-nine categories were analysed for sorbic acid. These food items were all processed foods, contained benzoic acid or sorbic acid as an additive, and were selected because the Korean Report on Annual Production of Food and Food Additives indicated they are commonly consumed by Koreans [14]. The samples were purchased nationwide from March to September 2014, and included both local and imported foods. The samples were stored at either 4 °C or room temperature depending on manufacturer recommended storage conditions.

Reagents and standards

Benzoic acid and sorbic acid standards were purchased from Sigma Aldrich (St. Louis, Missouri, USA). Acetonitrile and phosphoric acid for use as the high-performance liquid chromatography (HPLC) mobile phase were HPLC-grade products from J&T Baker (Phillipsburg, New Jersey, USA). The benzoic acid certified reference material for evaluation of recovery (No. 108-06-001, benzoic acid 116.2 $mg \cdot kg^{-1}$) was purchased from the Korea Research Institute of Standards and Science (Daejeon, South Korea).

Stock solutions (100 $\mu g \cdot ml^{-1}$) of benzoic acid and sorbic acid were prepared in water. These two solutions were mixed together and the concentrations were adjusted to prepare working solutions at 0.5, 5, 10, 25, 50, and 100 $\mu g \cdot ml^{-1}$ for injection into the HPLC system.

Analysis of benzoic and sorbic acids

The contents of benzoic acid and sorbic acid in the processed foods were analysed according to the method of the Korean Food Code [15]. Approximately 50 g of the sample was precisely weighed into a Kjeldahl flask, and 10 ml of a 15% tartaric acid solution, 80 g of sodium chloride, and 100 ml of distilled water were added. A small amount of silicone resin was added if necessary to prevent bubbles, and the solution was submitted to steam distillation (Gerhardt, Konigsberg, Germany). Then, 20 ml of 1% sodium hydroxide was added to the distillate, and the solution was distilled again at a flow rate of 10 $ml \cdot min^{-1}$. Then, 500 ml of the final solution was taken and filtered through a membrane filter (pore size 0.45 μm; Millipore, Milford, Massachusetts, USA) to prepare a test solution for HPLC analysis on a Nanospace SI-2 HPLC system (Shiseido, Tokyo, Japan) with a photodiode array detector (Shiseido) and a Capcell-Pak MF C_8 Column (150 mm × 4.6 mm, particle size 5 μm; Shiseido). The HPLC conditions are shown in Tab. 1. All samples and standards were analysed in duplicate.

Tab. 1. HPLC conditions for analysis.

Detector	Photodiode array (217 nm, scan 200–600 nm)		
Mobile phase	Gradient conditions:		
	Time [min]	Solvent A [%]	Solvent B [%]
	0.0	75	25
	2.5	75	25
	7.0	65	35
	12.0	60	40
	15.0	70	30
Flow rate	1.0 $ml \cdot min^{-1}$		
Injection volume	10 μl		
Column temperature	40 °C		

Solvent A – 250 $mg \cdot l^{-1}$ tetrabutylammonium hydroxide (0.1% phosphoric acid), Solvent B – acetonitrile.

Tab. 2. Method validation for benzoic acid and sorbic acid.

Analytes	Matrix	Range [$\mu g \cdot ml^{-1}$]	Slope	Intercept	R^2	*LOD* [$\mu g \cdot ml^{-1}$]	*LOQ* [$\mu g \cdot ml^{-1}$]
Benzoic acid	Liquid	0.5–100	33.712	17.88193	0.998	0.08	0.25
	Solid	0.5–100	37.530	6.53244	0.999	0.11	0.34
	Paste	0.5–100	35.293	4.72909	0.999	0.17	0.51
Sorbic acid	Liquid	0.5–100	14.866	8.68546	0.999	0.10	0.30
	Solid	0.5–100	16.677	6.28542	0.999	0.11	0.34
	Paste	0.5–100	13.631	6.66433	0.999	0.19	0.57

R^2 – correlation coefficient, *LOD* – limit of detection, *LOQ* – limit of quantification.

Method validation and uncertainty assessment

Method validation for benzoic acid and sorbic acid was performed according to the method proposed by the Korea Research Institute of Standards and Science [16]. To verify the precision and linearity of the HPLC method under the present conditions, standard solutions of benzoic acid and sorbic acid were prepared in the concentration range 0.5–100 $\mu g \cdot ml^{-1}$, and a calibration curve was prepared based on 10 measurements of each standard solution. The value of correlation coefficient R^2 was >0.998, indicating excellent linearity. The limit of detection (*LOD*) and limit of quantification (*LOQ*) for the food additives were measured by dividing the matrix into liquid, solid (including powder) and paste phases. The ranges for *LOD* and *LOQ* of benzoic acid were 0.08–0.17 $\mu g \cdot ml^{-1}$ and 0.25–0.51 $\mu g \cdot ml^{-1}$, respectively. The ranges for *LOD* and *LOQ* of sorbic acid were 0.10–0.19 $\mu g \cdot ml^{-1}$ and 0.30–0.57 $\mu g \cdot ml^{-1}$, respectively (Tab. 2). Precision and recovery measurements for benzoic acid and sorbic acid were carried out based on spiking each sample matrix at two different concentrations, and all samples were analysed in triplicate. The precision and recovery ranges for benzoic acid were 0.01–0.5 % and 96–116 %, respectively. The precision and recovery ranges for sorbic acid were 0.01–0.8 % and 101–103 %, respectively (Tab. 3).

Tab. 3. Recoveries of benzoic acid and sorbic acid.

Analytes	Concentration [$\mu g \cdot ml^{-1}$]	Matrix	*RSD* [%]	Recovery [%]
Benzoic acid	4.8	Liquid	0.5	96.4
	5.0	Solid	0.5	99.1
	5.0	Paste	0.3	99.7
	50.3	Liquid	0.1	100.8
	51.0	Solid	0.1	102.2
	57.9	Paste	0.0	115.9
Sorbic acid	5.1	Liquid	0.5	102.8
	5.1	Solid	0.8	102.7
	5.0	Paste	0.4	101.7
	51.0	Liquid	0.1	102.1
	50.4	Solid	0.0	101.0
	50.4	Paste	0.0	100.9

RSD – relative standard deviation.

To estimate the measurement uncertainty for benzoic acid and sorbic acid, a model equation was established based on the Guide to the expression of Uncertainty in Measurement (GUM) [17] and applied using the uncertainty factors. Based on examination of the uncertainty factors using a fishbone diagram, the composite uncertainty was determined by calculating the standard uncertainty and the degree of freedom for each factor. The uncertainty factors were for preparation of standard solutions (reference material certification, balance calibration report), standard calibration curve, certified reference material (certified reference material uncertainty, repeatability of sample measurement). Then, the relative standard uncertainties and degrees of freedom for each uncertainty factor were obtained.

The relative standard uncertainty and synthetic standard uncertainty for benzoic acid and sorbic acid were estimated using a quality control sample for the Food Analysis Performance Assessment Scheme, and the expanded uncertainty and the measurement uncertainty were calculated using the inclusion factor (k). The measured concentration of benzoic acid was 91.6 $\mu g \cdot ml^{-1}$ and the expanded uncertainty was 4.6 $\mu g \cdot ml^{-1}$. The measured concentration of sorbic acid was 136.0 $\mu g \cdot ml^{-1}$ and the expanded uncertainty was 7.5 $\mu g \cdot ml^{-1}$. As a result, the measurement uncertainty for benzoic acid was calculated as 91.6 ± 4.6 (95% confidence level, $k = 2$), and the measurement uncertainty of sorbic acid was calculated as 136.0 ± 7.5 (95% confidence level, $k = 2$).

Tab. 4. Daily intakes of foods contained benzoic acid and sorbic acid by average and high cosumer [18].

Foodstuffs	Daily intakes for average consumer [g·d^{-1}]										Daily intake for 90th percentile consumer group [g·d^{-1}]
	1–2 year (n = 182)	3–6 year (n = 344)	7–12 year (n = 551)	13–19 year (n = 496)	20–29 year (n = 489)	30–39 year (n = 863)	40–49 year (n = 853)	50–64 year (n = 1489)	Over 65 year (n = 1511)	All subjects (n = 6778)	
Processed fish product	2.17	6.30	7.82	9.93	9.02	12.66	5.85	3.28	2.20	5.98	74.80
Dressing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sugaring pickle	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Wine	0.00	0.01	0.01	0.04	4.76	1.37	2.47	0.87	0.46	1.13	209.00
Cheeses	0.15	0.33	0.99	1.87	0.88	1.08	0.51	0.27	0.05	0.58	28.85
Processed cheeses	4.85	2.07	0.64	0.74	0.27	0.35	0.38	0.29	0.24	0.56	63.10
Dried meat	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bacon	0.01	0.36	0.61	0.70	0.38	0.46	0.14	0.14	0.03	0.26	13.43
Sausage	0.93	1.86	1.99	3.32	1.72	2.09	1.88	0.12	0.31	1.26	82.82
Processed meat product	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ham	1.61	2.39	4.25	5.62	5.05	4.11	2.46	1.06	0.51	2.48	36.50
Salted and fermented seafood	0.21	0.31	0.55	0.58	1.14	1.45	2.01	1.58	1.79	1.37	14.04
Gochujang	0.25	1.07	3.83	5.82	4.95	5.39	5.73	4.46	2.89	4.20	18.90
Soybean paste	1.38	1.82	2.87	3.18	3.44	5.41	6.21	8.91	9.21	6.30	39.33
Chungjang (kind of soybean paste)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mixed soybean paste with gochujang	0.00	0.26	0.89	0.55	2.75	4.04	4.75	3.81	2.07	2.74	42.50
Dried seasoning fish fillet	0.02	0.04	0.15	0.58	0.11	0.48	0.21	0.12	0.10	0.20	24.00
Tomato ketchup	0.49	1.60	3.15	5.19	3.78	2.07	1.30	0.45	0.21	1.59	18.10
Processed sugaring product	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fermented drink	0.00	0.00	1.80	3.05	1.85	0.58	0.13	0.65	0.04	0.75	572.40
Seasonings	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cocoa	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Breads	22.67	24.58	34.60	37.48	37.47	30.57	22.97	16.24	8.58	22.49	175.05
Sauces	0.45	1.05	2.33	3.38	3.76	1.93	1.44	0.85	0.35	1.48	27.30
Pickles	0.76	3.03	5.37	7.28	9.87	9.14	7.71	5.65	4.19	6.18	66.75
Margarine	0.00	0.00	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.01	1.47
Peanut and nuts	0.09	0.17	0.18	0.08	0.08	0.12	0.23	0.06	0.01	0.10	0.00
Jams	0.48	0.80	1.11	0.67	0.87	0.43	0.73	0.24	0.38	0.54	68.46
Soy sauce	1.99	3.43	5.04	5.76	6.39	7.65	7.09	6.86	5.76	6.19	16.96
Fruit and vegetable beverages	33.13	44.77	36.76	55.62	48.25	35.01	28.70	22.89	13.39	29.92	204.00
Carbonated beverages	7.22	26.78	58.90	107.99	78.75	46.34	21.31	9.81	4.75	32.02	240.00
Other beverages	8.78	7.42	20.40	33.96	19.92	14.40	10.87	9.18	4.46	12.48	320.25
Beverage base	0.00	0.07	0.00	0.00	0.02	0.06	0.00	0.00	0.00	0.01	34.80

NA – not available.

Consumption data

Food consumption data to assess intakes of both benzoic acid and sorbic acid were obtained from the Korea National Health and Nutrition Examination Survey (KNHANES) 2012 (Tab. 4) [18]. KNHANES was a random nationwide survey of 6778 subjects in different age groups (ages ≥1 year) that used the 24 h dietary recall method. Foodstuffs containing benzoic acid were grouped into eleven categories (e.g. margarine, jams, beverages), and those containing sorbic acid were grouped into twenty-nine categories (e.g. processed fish products, processed meat products, pickles). The consumption data for each food category for the total population, different age groups and those with high consumption of processed foods (90th percentile) were collected to calculate *EDI*s of benzoic acid and sorbic acid from these foods (Tab. 4).

Estimated daily intakes for benzoic and sorbic acids

*EDI*s of benzoic acid and sorbic acid were obtained by coupling the mean contents of benzoic acid and sorbic acid found in each food category with individual food consumption data for consumers with average consumption by age group and consumers in the 90th percentile consumption group for these food additives. If benzoic acid and sorbic acid were not detected, the content of the sample was assigned a value of zero. Average food consumption data by food category for the total population and different age groups were obtained from KNHANES of 2012 [18]. The 90th percentile consumption data were obtained from the same survey.

To evaluate whether the daily intakes of benzoic acid and sorbic acid were a health risk to consumers, the daily intakes of these food additives were divided by the standard body weights (in kilograms) for the total population, different age groups, and consumers in the 90th percentile consumption group, which were obtained from KNHANES [18]. For each food additive, *EDI* was compared with *ADI*s established by JECFA [4].

$$EDI_{\text{mean}} = \frac{\sum c \cdot FC}{BW} \quad (1)$$

where, EDI_{mean} is estimated daily intake of additive for average consumer (in micrograms per kilogram body weight per day), c is mean additive content (in micrograms per gram), FC is mean food consumption (in grams per day), BW is standard body weight (in kilograms).

$$EDI_{90} = \frac{\sum c \cdot FC_{90}}{BW_{90}} \quad (2)$$

where, EDI_{90} is estimated daily intake of additive for 90th percentile consumer (in micrograms per kilogram body weight per day), c is mean additive content (in micrograms per gram), FC_{90} is food consumption for 90th percentile consumer (in grams per day), BW_{90} is body weight for 90th percentile consumer (in kilograms).

RESULTS AND DISCUSSION

Contents of benzoic acid and sorbic acid

Tab. 5 shows the concentration of benzoic acid in 555 processed foods from 11 food categories. Benzoic acid was detected in 10 of the food categories, with the exception being soy sauce. In total, benzoic acid was detected in 52 food items, which gave a detection rate of 9.4 %. Benzoic acid was mainly detected in beverage samples, which accounted for 84.6 % of the samples containing ben-

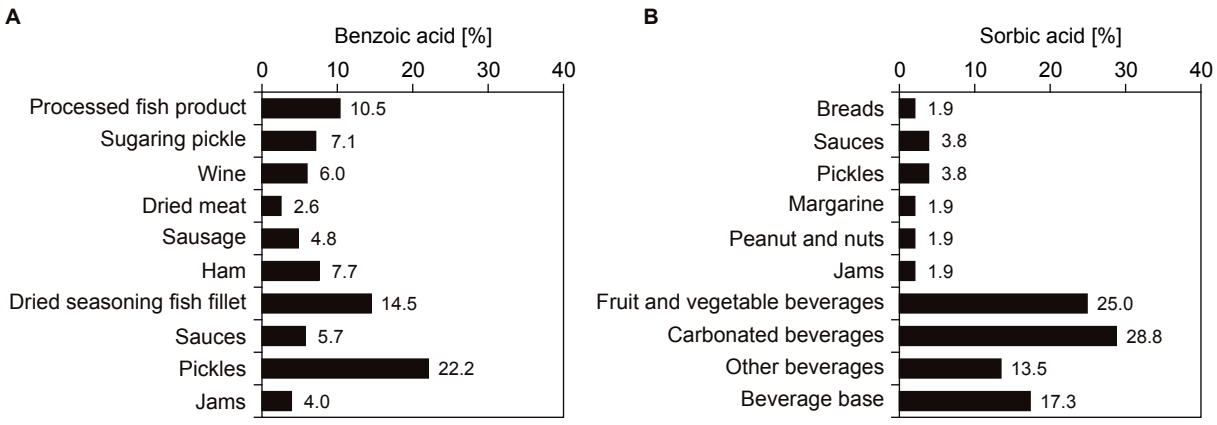

Fig. 1. Proportions of top ten different food categories accounting for the detected benzoic acid and sorbic acid. A – Benzoic acid, B – Sorbic acid.

Tab. 5. Concentrations of benzoic acid and sorbic acid in processed foods.

Foodstuff	Benzoic acid				Sorbic acid			
	n	n_D	Mean [$\mu g \cdot ml^{-1}$]	Max. [$\mu g \cdot ml^{-1}$]	*n*	n_D	Mean [$\mu g \cdot ml^{-1}$]	Max. [$\mu g \cdot ml^{-1}$]
Processed fish product	–	–	–	–	56	37	324.54	1440.38
Dressing	–	–	–	–	21	1	30.12	632.46
Sugaring pickle	–	–	–	–	41	25	133.14	479.25
Wine	–	–	–	–	37	21	59.28	148.36
Natural cheeses	–	–	–	–	12	1	42.84	514.05
Processed cheeses	–	–	–	–	14	3	134.26	724.55
Dried meat	–	–	–	–	15	9	182.13	489.37
Bacon	–	–	–	–	8	4	273.00	781.70
Sausage	–	–	–	–	31	17	195.65	767.50
Processed meat product	–	–	–	–	3	1	72.20	216.60
Ham	–	–	–	–	52	27	218.71	745.31
Salted and fermented seafood	–	–	–	–	15	3	77.23	476.13
Gochujang	–	–	–	–	12	2	112.31	701.95
Soybean paste	–	–	–	–	9	7	436.73	839.06
Chungjang (kind of soybean paste)	–	–	–	–	4	1	131.44	525.72
Mixed soybean paste with gochujang	–	–	–	–	16	5	75.12	523.81
Dried seasoning fish fillet	–	–	–	–	78	51	183.69	703.09
Tomato chechup	–	–	–	–	17	0	ND	ND
Processed sugaring product	–	–	–	–	20	11	326.64	825.98
Fermented drink	–	–	–	–	13	0	ND	ND
Seasonings	–	–	–	–	11	1	45.81	503.90
Cocoa	–	–	–	–	3	3	591.18	634.88
Cheonggukjang (kind of soybean paste)	–	–			2	0	ND	ND
Breads	141	1	0.28	43.44	17	3	13.55	172.77
Sauces	145	2	0.07	36.94	145	20	19.12	822.69
Pickles	129	2	0.12	60.00	129	78	290.68	995.70
Margarine	5	1	76.91	384.57	7	3	230.04	806.62
Peanut and nuts	4	1	5.07	20.29	4	3	141.05	300.30
Jams	10	1	46.64	466.43	37	14	161.47	688.93
Soy sauce	16	0	ND	ND	–	–	–	–
Fruit & vegetable beverages	39	13	81.76	358.98	–	–	–	–
Carbonated beverages	34	15	89.68	473.34	–	–	–	–
Other beverages	15	7	95.20	279.89	–	–	–	–
Beverage base	17	9	124.35	346.92	–	–	–	–
Total	555	52			829	351		

Mean was calculated from all samples.
n – total number of samples, n_D – number of samples with positive detection, ND – not detected.

zoic acid (Fig. 1). The detection rates of benzoic acid in the 11 food categories were in the following order: beverage bases (52.9%), mixed beverages (46.7%), carbonated beverages (44.1%), and fruit and vegetable beverages (33.3%; Tab. 5). The highest concentrations of benzoic acid were found in beverage base (124.4 $\mu g \cdot ml^{-1}$) and other beverages (95.2 $\mu g \cdot ml^{-1}$). LAZAREVIC et al. [19] found a higher detection rate for benzoic acid in non-alcoholic beverages (96%) than in this study. The highest contents of benzoic acid were found in tomato products (534.7 $mg \cdot kg^{-1}$) and pickled vegetables (424.8 $mg \cdot kg^{-1}$), and were higher than those found in this study.

Sorbic acid was detected in 351 of the 829 food items tested. The exceptions were fermented milk, mixed soybean paste with gochujang and tomato ketchup. Sorbic acid was detected in 42.3% of the samples (Tab. 5). Sorbic acid was mostly detected in pickles (salted and fermented food; 22.2% of

Tab. 6. Estimated daily intakes of benzoic acid for consumers with average and high consumption of processed foods.

Foodstuffs	*EDI* for average consumer [μg·kg^{-1}·d^{-1}]										*EDI* for 90th percentile consumer group [μg·kg^{-1}·d^{-1}]
	1–2 year	3–6 year	7–12 year	13–19 year	20–29 year	30–39 year	40–49 year	50–64 year	Over 65 year	All ages	
Breads	0.52	0.35	0.23	0.18	0.18	0.14	0.09	0.07	0.04	6.30	49.01
Sauces	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.91
Pickles	0.00	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.74	2.23
Margarine	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.77	1104.43
Peanut and nuts	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.00	0.00	0.51	0.00
Jams	2.03	2.88	1.08	0.43	0.74	0.30	0.42	0.21	0.35	25.19	3192.97
Soy sauce	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fruit and vegetable beverages	198.68	212.30	86.45	86.35	65.43	48.15	30.96	30.04	16.48	2446.26	16679.04
Carbonated beverages	58.45	100.99	141.06	172.46	119.02	75.65	29.88	15.29	6.83	2871.55	21523.20
Other beverages	77.67	35.69	49.40	68.45	29.71	24.04	12.21	21.16	9.08	1188.10	30487.80
Beverage base	0.00	0.35	0.00	0.00	0.10	0.13	0.00	0.00	0.00	1.24	4327.38
EDI [μg·kg^{-1}·d^{-1}]	358.05	360.22	269.47	296.50	199.86	126.36	81.25	57.63	33.44	110.28	1304.47
ADI [%]	7.2	7.2	5.4	5.9	4.0	2.5	1.6	1.2	0.7	2.2	26.1

Samples where benzoic acid was not detected were given a value of zero.
EDI – estimated daily intake, calculated based on analytical data obtained in this study and the Korea National Health and Nutrition Examination Survey (2012) [18], *ADI* – acceptable daily intake set by the Joint FAO/WHO Expert Committee on Food Additives [4].

samples containing sorbic acid) and dried seasoning fish fillet (14.5% of samples; Fig. 1). The food types with the highest average levels of sorbic acid were cocoa (591.2 μg·ml^{-1}), soybean paste (436.7 mg·kg^{-1}), processed sugar products (326.6 mg·kg^{-1}) and processed fish products (324.5 mg·kg^{-1}). The maximum content of sorbic acid was detected in a processed fish product, which as a category had a content range of not detected to 1440.4 mg·kg^{-1}. High contents of sorbic acid were detected in all three cocoa products analysed, which suggests that cocoa products should be examined further in future.

The maximum contents of benzoic acid and sorbic acid detected in all the samples were lower than the maximum permitted levels set by the Korean government.

Estimated daily intakes of food additives

Benzoic acid

*EDI*s of benzoic acid for consumers with average and high consumption (90th percentile) of processed food items, and various age groups, in Korea are shown in Tab. 6. *EDI* of benzoic acid (expressed per kilogram of body weight per day) by the average consumer was 110.3 μg·kg^{-1}·d^{-1}, and this contributed 2.2% of *ADI* set by JECFA (Tab. 6). In Japan, the intake of benzoic acid was evaluated by the market basket method in 2007 [9], and *EDI* of benzoic acid by the average consumer in Japan (0.6% of the *ADI*) was one-fourth of the result obtained in the present study. This could be because the benzoic acid content in the Japanese study was only determined after cooking the food in water, which would have diluted the benzoic acid. In this study, the samples were analysed in the state as they were purchased and not after being cooked. Dixit et al. [20] evaluated the intake of benzoic acid in 238 Indian people through their intake of 248 fast food items. The mean intake of benzoic acid in Indian adults was reported to be about 130–290 μg·kg^{-1}·d^{-1}, which was 2.6–5.8% of *ADI* and higher than *EDI* of benzoic acid for the average consum-

er in this study. LAZAREVIC et al. [19] reported that *EDI* of benzoic acid through intake of 748 food types by the average consumer in Serbia was 6.4 % of *ADI* in 2011, which is about three times higher than *EDI* of benzoic acid in the present study.

In the present study, *EDI* of benzoic acid in the 90th percentile consumption group was 1 304.5 $\mu g \cdot kg^{-1} \cdot d^{-1}$, which is about 10 times that of the average consumer (Tab. 6). However, it contributed to only 26.1 % of ADI, indicating that *EDI* of benzoic acid by the high consumption group (90th percentile) was still safe. These results were slightly higher than those of LAZAREVIC et al. [19], who reported that *EDI* of benzoic acid contributed 22.6 % of *ADI* in a Serbian high consumption group (95th percentile). DIXIT et al. [20] reported that *EDI*s of benzoic acid in the 95th percentile consumption group for fast food items containing benzoic acid contributed to 16.2–32.8 % of *ADI* in children and 8.0–16.4 % of *ADI* in adults. These results were similar to *EDI* of benzoic acid in the high consumption group (90th percentile) in South Korea. However, *EDI* in our study was calculated based on a broader range of food items (11 categories) than that of the study of DIXIT et al. (only fast food).

In this study, the major contributors to the intake of benzoic acid were carbonated drinks (43.9 %), fruit and vegetable beverages (37.5 %), and other beverages (18.2 %) for the average consumer. For the 90th percentile consumption group, the major contributors were other beverages (39.4 %), carbonated beverages (27.8 %) and fruit beverages (21.6 %; Tab. 6). Therefore, beverages are the largest contributors to the intake of benzoic acid by consumers with both average and high rates of processed food consumption in Korea. A study in Australia and New Zealand [10] found that orange juice and carbonated beverages (excluding cola) were major contributors to the consumption of benzoic acid. The World Health Organization [21] also reported that beverages were major contributors to the intake of benzoic acid. Our current findings are consistent with these reports.

EDI range for benzoic acid by all age groups over 1-year old in South Korea was 33.4–360.2 $\mu g \cdot kg^{-1} \cdot d^{-1}$, and *EDI* contributed to 0.7–7.2 % of *ADI* (5 000 $\mu g \cdot kg^{-1} \cdot d^{-1}$) set by JECFA (Tab. 6). The highest intakes of benzoic acid were found in 3–6-year-old and 1–2-year-old children (7.2 % of *ADI*), followed by 13-19-year-old adolescents (5.9 % of *ADI*), and adults (≥ 30 years old, 2.5–0.7 % of *ADI*; Tab. 6). In an Austrian study [12], *EDI*s of benzoic acid based on national food consumption data from 2007 to 2010 contributed to 32 % of *ADI* for 3–6-year-old children, 31 % of *ADI* for adult males and 36 % of *ADI* for adult females. *EDI*s of benzoic acid in the Austrian study were more than 4.5 times that for children and nine times that for adults in the present study. In a study in Australia and New Zealand [10], the market basket method was used to investigate *EDI*s of benzoic acid by age group in 2005. The highest intake of benzoic acid was in 2–5-year-old boys (140 % of ADI), and *EDI*s at all other ages were lower than *ADI* [10]. EL-ZINEY [3] calculated *EDI*s of benzoic acid from 11 food categories, including beverages, using a weekly recording method for 100 Saudi students aged between 18–25 years, and found an intake range of 10.0–5 170.0 $\mu g \cdot kg^{-1} \cdot d^{-1}$. *EDI* of benzoic acid (5 170.0 $\mu g \cdot kg^{-1} \cdot d^{-1}$) from yoghurt dressing was the highest and accounted for 103.4 % of *ADI*. Based on the results of EL-ZINEY [3], if consumers ate food from all 11 categories, *EDI* of benzoic acid would be 12 690.0 $\mu g \cdot kg^{-1} \cdot d^{-1}$ and 253.8 % of *ADI*. *EDI* of benzoic acid for the 18–25-year-old Saudi Arabian students was much higher than *EDI*s for the same age group in Australia and New Zealand, Austria, and South Korea. Comparison of these studies suggests that *EDI* of benzoic acid in South Korea is much lower than that in Western and Middle Eastern countries.

Sorbic acid

Tab. 7 shows *EDI*s of sorbic acid for the average consumer, different age groups and the high consumption group (90th percentile), which were calculated by applying the food intake data obtained from KNHANES [18] and analytical data for sorbic acid obtained by analysing 351 food categories and 829 items. *EDI* of sorbic acid for the average consumer was 140.9 $\mu g \cdot kg^{-1} \cdot d^{-1}$, which was 0.6 % of *ADI* defined by JECFA. *EDI* of sorbic acid for the 90th percentile consumption group was 2 105.4 $\mu g \cdot kg^{-1} \cdot d^{-1}$ and 8.4 % of *ADI* (Tab. 7).

In Japan [9], *EDI* of sorbic acid for the average consumer from a market basket method study conducted in 2007 was reported to be 0.5 % of *ADI*, which was very similar to the present study. According to a study conducted in Australia and New Zealand in 2005 [10], *EDI* of sorbic acid for adults aged 19 and over was 7–8 % of *ADI*. A study in Austria [12] found that *EDI* of sorbic acid for the average consumer aged 19–65 years was 6 % of *ADI*. These results show that *EDI*s of sorbic acid in Western countries are more than 10 times higher than *EDI* of sorbic acid for the average consumer in this study.

As shown in Tab. 7, soybean paste (28.9 %), processed fish products (26.4 %) and pickles (22.4 %) were the main contributors to *EDI* of

Tab. 7. Estimated daily intakes of sorbic acid for consumers with average and high consumption of processed foods.

Foodstuffs	*EDI* for average consumer [$\mu g \cdot kg^{-1} \cdot d^{-1}$]										*EDI* for 90th percentile consumer group [$\mu g \cdot kg^{-1} \cdot d^{-1}$]
	1–2 year	3–6 year	7–12 year	13–19 year	20–29 year	30–39 year	40–49 year	50–64 year	Over 65 year	All ages	
Processed fish product	73.94	113.58	67.52	60.38	47.78	64.23	28.75	18.12	10.67	1940.75	24275.59
Dressing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wine	0.00	0.02	0.01	0.02	3.99	1.25	1.78	0.75	0.35	66.99	12389.52
Natural cheeses	0.44	0.60	0.86	1.28	0.65	0.56	0.27	0.13	0.03	24.85	1235.93
Processed cheeses	53.65	11.60	2.51	1.40	0.40	0.64	0.54	0.48	0.33	75.19	8471.81
Dried meat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bacon	0.25	5.05	3.49	3.23	1.92	1.63	0.86	0.62	0.15	70.98	3666.39
Sausage	10.17	21.88	10.46	14.44	6.07	4.56	4.33	0.40	0.78	246.52	16203.73
Processed meat product	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ham	22.86	22.65	21.98	23.17	16.32	17.85	8.24	4.25	1.35	542.40	7982.92
Salted and fermented seafood	1.51	1.36	1.26	0.60	2.03	2.07	2.55	2.10	2.25	105.81	1084.31
Gochujang	2.07	5.96	9.69	10.75	8.69	9.80	10.19	8.26	5.32	471.70	2122.66
Soybean paste	55.35	42.28	37.11	27.07	24.13	40.29	46.09	63.02	69.88	2751.40	17176.59
Chungjang (kind of soybean paste)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mixed soybean paste with gochujang	0.01	0.93	2.00	0.68	3.26	5.25	5.90	4.91	2.04	205.83	3192.60
Dried seasoning fish fillet	0.45	0.37	0.78	1.27	0.31	1.53	0.68	0.33	0.34	36.74	4408.56
Tomato ketchup	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fermented drink	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cocoa	62.16	10.15	12.27	6.79	4.40	7.24	0.06	0.15	1.74	0.00	0.00
Breads	24.91	16.50	10.75	8.56	8.81	6.50	4.41	3.23	1.88	304.74	2371.93
Sauces	0.71	0.94	1.20	0.87	1.11	0.58	0.35	0.24	0.12	28.30	521.98
Pickles	10.22	33.40	43.15	33.43	47.48	50.94	30.71	30.71	20.36	1796.40	5406.65
Margarine	0.00	0.00	0.09	0.00	0.00	0.00	0.10	0.01	0.01	2.30	3303.37
Peanut and nuts	0.51	0.57	0.47	0.22	0.26	0.15	0.49	0.08	0.02	14.11	0.00
Jams	7.03	9.97	3.75	1.49	2.56	1.03	1.47	0.71	1.20	87.19	11054.24
EDI [$\mu g \cdot kg^{-1} \cdot d^{-1}$]	269.40	299.63	216.07	178.11	166.59	185.67	147.76	129.88	119.36	140.90	2105.36
ADI [%]	1.1	1.2	0.9	0.7	0.7	0.7	0.6	0.5	0.5	0.6	8.4

Samples where sorbic acid was not detected were given a value of zero.
EDI – estimated daily intake, calculated based on analytical data obtained in this study and the Korea National Health and Nutrition Examination Survey (2012) [18], *ADI* – acceptable daily intake set by the Joint FAO/WHO Expert Committee on Food Additives [2].

sorbic acid for the average consumer, and these three food categories accounted for 77.7% of the total sorbic acid intake. In the Austrian study [12], the foods that contributed to sorbic acid intake were bread products. The study in Australia and New Zealand [10] reported that orange juice contributed more than 50% of the total sorbic acid intake, with other contributions from processed cheese, chocolate cake, meat, processed vegetables, and margarine. In Saudi Arabia [3], dairy products such as yoghurt were reported to be the largest contributors, accounting for about 50% of the total intake of sorbic acid. These results suggest that the dietary sources of sorbic acid vary from country to country because of regional dietary differences.

In this study, 1–6-year-old children consumed the most sorbic acid. This was further divided into 1–2-year-old children (1.1% of *ADI*) and 3–6-year-old children (1.2% of *ADI*). These results show that the sorbic acid intake decreased with increasing age (Tab. 7). A study in Australia and New Zealand in 2005 [10] found that the contributions of sorbic acid *EDI* to *ADI* for average consumers in different age groups were in the following order: 2–5-years-old, 35–40%; 6–12 years old, 20–15%; and 13–18-years-old, 15%. A study in Austria [12] also reported that the mean sorbic acid intake for children aged 3–6 years was 7% of *ADI*, and higher than that for adults. El-Ziney [3] studied the intake of sorbic acid by 18–25-year-old students in Saudi Arabia and found that the *EDI* range for sorbic acid from 11 food categories, including beverages, was 1.0–5660.0 $\mu g \cdot kg^{-1} \cdot d^{-1}$ (4–26% of *ADI*). The authors estimated that if an individual consumed food from all 11 categories, *EDI* of sorbic acid would be 46.7% of *ADI*. According to our and the above studies, young children have the highest consumption of sorbic acid in Korea and in some Western countries. Moreover, the intake of sorbic acid in children under 6 years was lower than one fifth that of the intakes in Austria, Australia and New Zealand.

CONCLUSIONS

*EDI*s for benzoic acid and sorbic acid for the average consumer, different age groups, and those with high consumption of processed foods (90th percentile) in this study were less than 26.1% of *ADI* set by JECFA, which indicated that the intake levels of benzoic acid and sorbic acid in South Korea were safe. The highest intake of benzoic acid was in the 3–6-years old group, and the highest intake of sorbic acid was in the 1–6-years-old group. These results suggest that children aged between 1 and 6 years are the most likely to consume preservatives such as benzoic acid and sorbic acid. This could be because benzoic acid and sorbic acid are abundant in drinks and processed foods that are popular with children. Therefore, the use of benzoic acid and sorbic acid in these foods should be evaluated, and the health risks associated with intake of benzoic acid and sorbic acid from these foods should be considered continuously.

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