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Distribution of Ascorbic Acid in Potato Tubers and in Home-Processed and Commercial Potato Foods

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HPLC was used to analyze the content of ascorbic acid (AA) in tubers of four Korean potato cultivars (Chaju, Sumi, Deso, and Dejima), in a series of baked, boiled, braised, fried, microwaved, pressure-cooked, and sautéed potato slices from the Dejima cultivar and in 14 commercial Korean and 14 processed potato foods sold in the United States (chips, snacks, mashed potatoes, fries). The AA content for the four cultivars ranged from 16 to 46 mg/100 g of fresh weight. The distribution of AA in each of the eight potato slices (sticks, plugs) cut horizontally from the stem end of the Dejima potato ranged from 6.8 to 19.3% of the total. The corresponding distribution in seven sticks cut vertically was much narrower, ranging from 11.7 to 17.5% of the total. Losses of AA in water (pH 5.2) were significantly greater than in 5% metaphosphoric acid (pH 1.0). Less degradation occurred in water solutions of the vitamin stored at 1 °C than at 25 °C. Losses of AA observed during home-processing of three varieties with low (Dejima, 16 mg/100 g), intermediate (Sumi, 32 mg/100 g), and high (Chaju, 42 mg/100 g) AA contents were as follows: boiling in water, 77−88%; boiling in water containing 1−3% NaCl, 61−79%; frying in oil, 55−79%; sautéing, 61−67%; pressure-cooking in water, 56−60%; braising, 50−63%; baking, 33−51%; and microwaving, 21−33%. The content of the Korean foods ranged from trace amounts to 25 mg/100 g and that of the U.S. foods from 0.4 to 46 mg/100 g. These results permit optimization of the vitamin C content of the diet by (a) using high-vitamin C potato varieties such as Chaju, (b) selecting sticks cut horizontally for frying, (c) baking or microwaving rather than boiling or frying, and (d) selecting commercial potato foods with a high vitamin C content.

KEYWORDS: Ascorbic acid; vitamin C; HPLC; potatoes; degradation; food processing

INTRODUCTION

Ascorbic acid (AA, vitamin C) has been reported to play multiple roles in nutrition, human health, and food chemistry. Dietary deficiency of the vitamin causes the human disease scurvy due to formation of abnormal collagen resulting in skin and gum lesions and fragility of blood vessels. AA is widely reported to protect both plants and animals against oxidative stress induced by potentially toxic as well as cancer- and ateriosclerosis-inducing reactive oxygen species (ROS) including hydroxyl radicals, superoxide anions, singlet oxygen, and hydrogen peroxide (*1*−*3*). In foods, AA is reported to prevent formation of carcinogenic nitrosamines in cured meats, to protect against toxic metal toxicity, to inhibit oxidized fat rancidity and food browning, and to improve baking characteristics of doughs (*4*).

The recommended dietary allowance (RDA) of vitamin C ranges from 30 to 120 mg. The higher values are recommended for populations with increased needs including undernourished children, pregnant and lactating women, and smokers (*2*). Consumption of still higher amounts may be desirable for dietary protection against cancer and other chronic diseases. A recent survey of the plasma vitamin C levels of 632 British men and 635 women, aged 25−74 years, revealed that although the intake of vitamin C from potatoes was uniform across categories, 26% of men and 14% of women were in the low category for vitamin C status (*5*).

Fruits and vegetables are the major food sources of the vitamin. Consumption data indicate that inexpensive potatoes appear to be the most widely consumed vegetable in Europe and possibly also in many other countries. The reported content of vitamin C in potatoes ranges from ∼8 to ∼30 mg/100 g of fresh weight (*3*, *6*). Because humans do not consume fresh potatoes and because the vitamin is known to be susceptible to degradation by conditions used in home and commercial food processing as well as by human pathogens such as *Eschericha coli* (*7*), extensive studies have been carried out to ascertain

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the effects of processing on the vitamin C content of potatoes (discussed below).

The main objectives of this study are to complement the available information on this subject by defining the content of the vitamin in four widely consumed Korean potato cultivars, in several potato foods prepared in the home from three of the cultivars and in a number of commercial potato products available in Korea and the United States. Because the dehydroascorbic acid content of potato tubers is low (*6*), it was not included in this study. The data suggest that selection of high-vitamin C foods sold commercially, the use of high-vitamin C-containing potatoes for home processing, and the use of processing conditions in the home resulting in minimal degradation may enhance the vitamin C content of the diet.

MATERIALS AND METHODS

Potatoes and Potato Products. The two potato varieties Sumi and Dejima were purchased from a farmer's market in Daegu City in Korea. The other two varieties, Deso and Chaju, were obtained from a supermarket in Daegu City. The commercial potato foods processed in Korea were purchased from a supermarket in Daegu City, Korea, and the potato products in the United States from a grocery store in Moraga, CA. Authentic AA was obtained from Wako Chemicals (Osaka, Japan). Shindongbang Corp. of Korea produced the oil used for frying (trade name, Haipyo). HPLC grade acetonitrile and analytical grade dihydrogen phosphate (KH_2PO_4) and metaphosphoric acid were obtained from commercial sources. The solvents were filtered through a 0.45 μM membrane filter (Millipore, Bedford, MA) and degassed with an ultrasonic bath before use.

Preparations of Samples for Analysis. *Ascorbic Acid from Four Potato Varieties.* Chaju, Sumi, Deso, and Dejima potatoes were used for analysis of AA. Fresh potatoes from three uniform-size tubers (weight, 150−200 g; 1ength, 80−l00 mm; width, 50−60 mm) were chosen for analysis. Tubers were penetrated from the stem end to the opposite end with a stainless steel cork borer (internal diameter, 1.5 cm). The potato plug obtained from each tuber was cut every 1 cm by a clasp knife, and the central part of the plug was used for AA determination. Each weighed sample (~2 g) was macerated in a mortar with 5 mL of 5% metaphosphoric acid and filtered through a 3G3 glass filter, and the residue was rinsed three times with 5 mL of 5% metaphosphoric acid. After the washings were combined with the original filtrate and centrifuged at 18000*g* for 10 min at 1 °C, each sample was then diluted to 25 mL with 5% metaphosphoric acid. This solution (20 μL) was used for HPLC analysis of the AA content.

Distribution of Ascorbic Acid across the Potato Flesh. Dejima potatoes (weight, 150−200 g; 1ength, 80−100 mm; width, 50−60 mm) were used for analysis of the distribution of AA throughout the tuber flesh. Two methods were adopted for this purpose. In the first cutting method, the potato tubers were penetrated with a cork borer (i.d., 1.5 cm) from the stem end to the opposite horizontally. The plugs obtained were cut with a clasp knife into eight equal 1-cm-long sticks. In the second cutting method, the potato tubers were penetrated with a cork borer from the upper surface to below vertically and divided into seven equal plugs. Each plug was weighed and extracted for AA determination according to the same method as that used for the analysis of the four potato varieties described earlier.

Commercial Potato Foods. Potato foods were finely ground into powders with a pestle in a mortar. Each powder (~1.0 g) was extracted with 10 mL of 5% metaphosphoric acid accompanied by ultrasonication for 10 min at room temperature. After centrifugation at 18000*g* for 10 min at 1 °C, the residue was rinsed twice with 5 mL of 5% metaphosphoric acid and again centrifuged. The extracts were combined and made up to 25 mL with 5% metaphosphoric acid. This solution (25 μL) was analyzed by HPLC for vitamin C content.

Home-Processing Methods. *Heat Stability of Ascorbic Acid in Water and in 5% Metaphosphoric Acid.* AA (4.08 mg) was placed into a 100 mL volumetric flask to which was added 100 mL of distilled water (pH 5.2). Aliquots (1.0 mL) were then placed in glass vials with Teflon packing and heated in a water bath at 20, 40, 60, 80, and 100 °C, each for 20, 40, or 60 min. Each vial was then cooled under ice water. Aliquots (20 μL) were used for analysis. An analogous experiment was carried out with AA solutions in 5% metaphosphoric acid (pH 1.0).

Sample Preparation for Home Processing. Dejima, Sumi, and Chaju potatoes were used to analyze changes in AA content induced by the different cooking methods. Fresh potatoes (weight, 150−200 g; 1ength, 80−l00 mm; height, 50−60 mm) were rinsed with water and patted dry. Potato plugs were obtained by penetration with a cork borer from the stem end to the opposite end and cut with a clasp knife. The plugs of the central part (length, 2 cm) were divided into two plugs (each 1 cm long) with a clasp knife. One plug was used as the control for determination of the AA content in untreated potatoes, and the others were used for the determination of AA content as influenced by the following home-processing methods typically used in Korea.

Baking. Samples wrapped with aluminum foil were baked for 10 min in a gas oven range (Dongyang Magic Co.) that had been preheated at 200 °C.

Boiling. To determine the changes of AA content induced by boiling water, l00 mL of distilled water was placed into an aluminum pot and heated at 100 °C. When the water started boiling, the sample (one plug) was put into the pot and boiled for 10 min. For boiling with salt (NaCl), each plug was boiled for 10 min in distilled water containing 1 or 3% salt, respectively. The cooled samples were used for analysis.

Braising. Distilled water (100 mL) was mixed with 10 mL of soy sauce and 7.5 g of sugar and then brought to the boiling point. Samples were then added to an open pot and braised for 13 min. The cooled samples were analyzed for AA content.

Frying. Distilled water (500 mL) in a metal pot was heated to the boiling point. Samples were added to the pot and then parboiled for 7 min. The slices were removed from the pot, and moisture was then removed from the cooled samples with a paper towel. The samples (2 g) were then fried in the oil (300 mL) for 30 s in a frying pan heated at 170 °C. The samples were kept for 5 min at room temperature and then fried for an additional 30 s.

Microwaving. Samples were placed onto the middle of a china plate and then cooked at high heat for l min in a microwave oven with a power rating of 2450 MHz (Mistubishi-RO-D52).

Pressure-Cooking. A pressure cooker with a pressure of 0.8 kg/cm/G (Saekwang Aluminum) containing 500 mL of distilled water and the potato samples was placed on a steamer. The potato samples were cooked at high heat setting for l.5 min after the pressure regulator knob started spinning. The pressure was removed from the cooker after 5 min. The cooled samples were analyzed for AA content.

Sautéing. Each sample was chopped into pieces 0.3 cm wide and 0.5 cm long and sautéed for 3 min with 5 mL of oil without any salt.

Analysis of Ascorbic Acid. *HPLC.* The method was adapted from the literature (*8*). HPLC was carried out on a Hitachi liquid chromatograph model 665-II equipped with a Shimadzu UV−vis detector (model SPD-10Avp, Kyoto, Japan) set at 254 nm. Column temperature was controlled with a Shimadzu CTO-10Asvp thermometer. Chromatogram peak areas were integrated with a Hitachi D-2500 chromatointegrator. A SpherisorbS NH_2 column [5 μm, 4.0 × 250 mm (Waters, Bedford, MA)] was used to analyze the AA. The mobile phase was acetonitrile/5 mM KH_2PO_4 (88:12, v/v). The flow rate was 1 mL/min at a column temperature of 20 °C. Three separate analyses were carried out with each sample.

Quantification. Quantification was accomplished by comparing integrated chromatographic peak areas from the test samples to peak areas of known amounts of standard AA.

Recovery Test. Potato extracts were analyzed before and after addition of known amounts of AA. Recovery (%) = (concentration of AA in spiked sample)/concentration of endogenous AA + spike) × 100.

RESULTS AND DISCUSSION

HPLC Analysis of Ascorbic Acid. The HPLC-UV detection method responded linearly over the concentration range of about ~100−2000 ng of AA (**Figure 1A**). The symmetrical AA peak eluted at ~15 min (**Figure 1B**). The limit of detection is

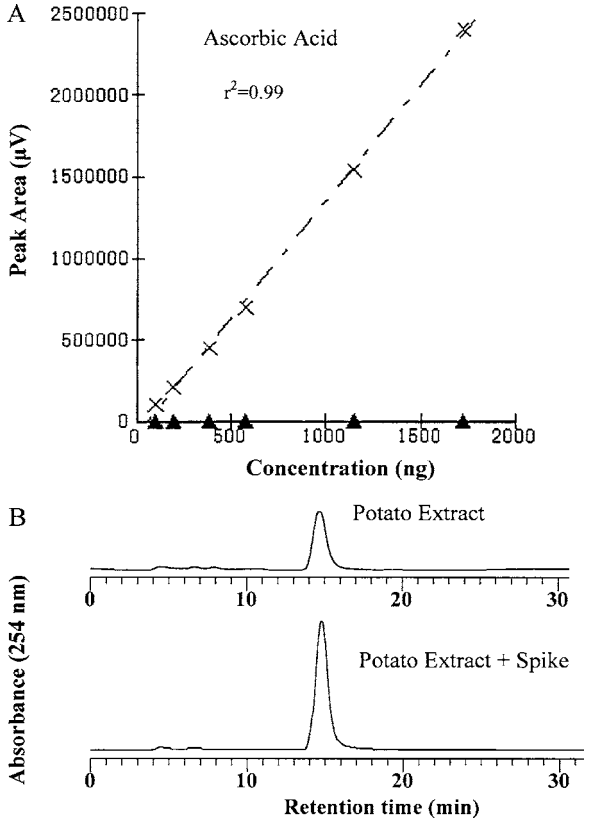

Figure 1. HPLC analysis of ascorbic acid: (**A**) linear relationship between the concentration of AA standards and integrated peaks on HPLC chromatograms; (**B**) AA chromatograms present in a potato extract before and after spiking with authentic vitamin C.

Table 1. Ascorbic Acid Contents of Potato Tubers

var.	AA[a] (mg/100 g of fresh wt)
Chaju	42.0 ± 1.8
Sumi	32.9 ± 3.9
Deso	17.3 ± 2.7
Dejima	16.1 ± 1.2

[a] Mean ± SD, $n = 3$.

estimated to be ~100 ng. Recoveries from extracts spiked with authentic AA were 92.8 ± 3.1% ($n = 4$). The validity of the method is supported by the good symmetry of the ascorbic acid peaks, lack of baseline noise in the chromatograms, linear concentration response of integrated peak areas, and >90% recoveries of AA from spiked potato extracts.

Ascorbic Acid Content of Fresh Potatoes. Table 1 shows that the AA content of four widely consumed commercial potato varieties ranged from 16.1 to 42.0 mg/100 g. This 2.6-fold variation from the lowest to the highest value affords the consumer the option of choosing a high-vitamin C potato variety (Chaju) for home use. About 300 g of this variety provides the high RDA requirement of ~120 mg of AA. This amount will, however, be significantly reduced after the fresh potatoes are subjected to home-processing conditions to make them edible, as discussed below.

Tables 2 and **3** list the distribution of AA in horizontal and vertical slices (sticks) of the fresh Dejima potatoes illustrated in **Figure 2**. The AA content of the horizontal slices ranged from 6.8 to 19.3 mg/100 g. The corresponding range for the vertical slices was from 11.0 to 17.5 mg/100 g. These results indicate that AA is not evenly distributed across the entire length

Table 2. Distribution of Ascorbic Acid in Dejima Horizontal Potato Sticks

potato part (**Figure 2A**)	AA[a] (mg/100 g of fresh wt)	% of total
A	34.2 ± 5.7	19.3
B	32.0 ± 4.6	18.0
C	26.7 ± 2.1	15.2
D	23.3 ± 2.2	13.2
E	20.0 ± 3.1	11.1
F	17.4 ± 0.7	9.9
F	11.9 ± 0.3	6.8
H	11.8 ± 0.0	6.8

[a] Mean ± SD, $n = 3$.

Table 3. Distribution of Ascorbic Acid in Different Parts of a Dejima Potato Tuber

potato part (**Figure 2B**)	AA[a] (mg/100 g of fresh wt)	% of total
1	10.2 ± 0.6	12.8
2	9.3 ± 0.9	11.7
3	11.0 ± 0.9	13.8
4	8.8 ± 0.5	11.0
5	12.7 ± 0.3	15.9
6	13.9 ± 0.1	17.5
7	13.8 ± 0.7	17.3

[a] Mean ± SD, $n = 3$.

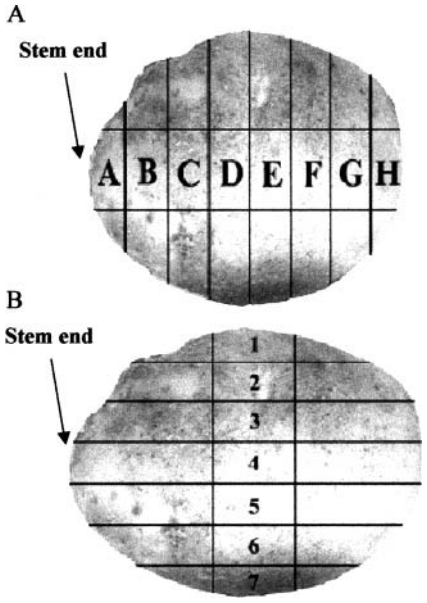

Figure 2. Photographs of the surface of a potato tuber showing vertical and horizontal cuts of slices (sticks) used for analysis of ascorbic acid.

and width of the potato flesh. Especially striking is the nearly 3-fold variation in AA levels of horizontal sections F and H in **Figure 2** compared to the levels in sections A and B. These results suggest that it should be possible to select high-vitamin C potato slices for the preparation of potato-based foods, where there is a special need for high-vitamin C potato-based diets. Such diets would benefit people with an inadequate intake of vitamin C. Such selection should take into account possible variability of vitamin C content in different tubers of the same cultivar.

Stability of Ascorbic Acid in Water. Table 4 shows that heating of a solution of AA in water (pH 5.2) for 20 min from 20 to 100 °C resulted in losses of the vitamin ranging from 1.2

Table 4. Heat Stability of Ascorbic Acid in Water and in 5% Metaphosphoric Acid (MA)[a]

	% lost during heating time of					
	20 min		40 min		60 min	
temp (°C)	water	MA	water	MA	water	MA
20	1.2	nd[b]	10.1	nd	13.7	nd
40	30.4	0	49.0	0	59.4	0
60	67.4	0	97.5	0	100	0
80	97.3	0	100	5.1	100	11.9
100	100	39.6	100	73.3	100	89.5

[a] $n = 3$. [b] Not determined.

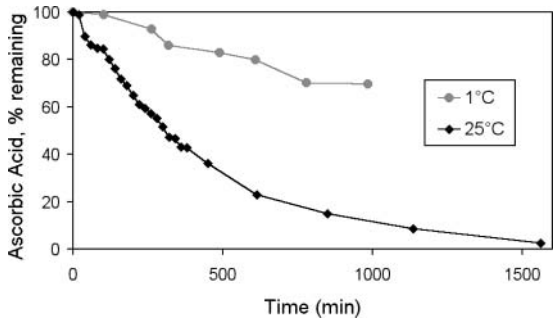

Figure 3. Effect of time on the loss of vitamin C in water at 1 °C and 25 °C.

to 100% of the original amount. Losses were greater at each of the temperatures when heating time was increased to 40 or 60 min. In contrast, **Table 4** shows that heating of a solution of AA in 5% metaphosphoric acid (pH 1.0) at 40, 60, 80, or 100 °C for 20, 40, or 60 min resulted in much less degradation of AA. These results and additional studies on the long-term stability of AA in water at 1 and 25 °C shown in **Figure 3** indicate that temperature-, pH-, and time-dependent degradation of AA takes place in the absence of any other food ingredient.

Stability of Ascorbic Acid in Potatoes to Home Processing. **Table 5** summarizes results from a series of experiments on the influence of home-processing conditions on the AA content of potatoes. Losses of AA observed during home processing of three varieties with low (Dejima, 16 mg/100 g), intermediate (Sumi, 32 mg/100 g), and high (Chaju, 42 mg/100 g) AA contents were as follows: boiling in water, 77−88%; boiling in water containing 1−3% NaCl, 61−79%; frying in oil, 55−79%; sautéing, 61−67%; pressure-cooking in water, 56−59%; braising, 50−63%; baking, 33−51%; and microwaving, 21−33%.

It is also instructive to compare the absolute amounts of AA left after home processing of the three varieties; boiling, 1.7, 7.2, and 7.3 mg/100 g; boiling with 1% NaCl, 3.4, 6.9, and 6.9 mg/100 g; boiling with 3% NaCl, 5.5, 12.2, and 13.4 mg/100 g; pressure-cooking, 7.6, 13.4, and 13.2 mg/100 g; frying, 2.3, 13.1, and 12.0 mg/100 g; sautéing, 8.1, 8.6, and 11.8 mg/100 g; braising, 6.9, 14.1, and 13.3 mg/100 g; baking, 11.1, 18.7, and 21.7 mg/100 g; and microwaving, 8.4, 21.3, and 24.0 mg/100 g, respectively. It appears that the amount that survives processing is proportional to the amounts initially present for the first two varieties. For the third variety, the amounts left did not differ from the corresponding amounts observed with the second variety, with an initial lower level of AA. **Table 5** also shows that the vitamin C content of the untreated controls from the same variety but from different potatoes varied significantly. Such variability in the vitamin C content within the same cultivar should be considered when slices are sampled for analysis.

These observations show that AA in potatoes is highly susceptible to degradation during boiling and frying and less so during braising, sautéing, and pressure-cooking and that baking and microwaving had the least impact on the stability of the vitamin. The presence of salt (NaCl) during boiling seems to partly protect the vitamin from degradation. The data also suggest that heat-induced (boiling) degradation of AA in an aqueous medium is pH-dependent. The data on the effect of different home-processing methods offer the consumer a choice of selecting conditions, for example, baking and microwaving, that result in low losses of vitamin C.

Ascorbic Acid Content of Commercial Potato Foods. **Table 6** lists the AA levels of 14 potato-containing foods sold in Korea. Two of the products contained trace amounts of vitamin C; 10 products contained from 1 to 9 mg/100 g, and 2 products contained ∼21 and ∼25 mg/100 g, respectively.

Table 7 lists the vitamin C contents of l4 commercial potato foods sold in the United States. The vitamin C content for five products ranged from 0.4 to 7.0 mg/100 g; four products contained from 13 to 19 mg/100 g, two products contained from 21 to 24 mg/100 g, and three products contained from 42 to 46 mg/100 g.

The wide-ranging values of AA in the commercial potato foods are presumably associated with the original vitamin C content of the tubers and the severity of heating and other processing conditions used to prepare these foods. The data in the tables offer the consumer a choice of potato foods with a relatively high content of vitamin C.

Degradation Products of Vitamin C. The major factors that catalyze the oxidative degradation of the vitamin are pH, oxygen, and the trace metals copper and iron (*1*). Degradation involves oxidation of AA to dehydroascrobic acid followed by hydrolysis to 2,3-diketogulonic acid and further oxidation, dehydration, polymerization, and reaction with amino acids and proteins to generate up to 50 nutritionally inactive products (*2*−*4*). Polyphenol oxidase (PPO)-catalyzed enzymatic browning of AA may also contribute to storage- and processing-induced chemical modification of the vitamin (*9*). Numerous papers report the loss of AA during storage processing of potatoes (*10*−*20*) as well as in other plant-derived foods (*21*). To place our findings in proper perspective, it is relevant to briefly examine selected reported studies on the content and stability of AA in stored and processed potatoes.

The AA content of two Japanese potato cultivars decreased more rapidly when stored for 9 weeks at 1 °C than at 20 °C (*22*). Because they did not turn brown and retained 89% of initial vitamin C content, vacuum packaging was found to be the best storage condition for fresh-cut potatoes (*19*). The vitamin C content of 33 potato genotypes grown in Europe decreased significantly during storage (*6*).

Unpeeled potatoes lose less vitamin C during cooking than do peeled potatoes (*23*). Low water content and the presence of air in the cooking atmosphere increased the rate of destruction of vitamin C during home processing (*24*). Exposing mashed potatoes served to hospitalized patients to a cook−chill−plated catering system used in hospitals results in a 76% loss of the vitamin (*25*).

These observations imply that the differences in the amount of ascorbic acid in different potato varieties may be partly due to the storage history of the potatoes rather than to an actual indication of their levels in the cultivar. We do not know the storage history of the potato tubers used in this study.

The greater loss of AA observed by boiling the potato in water and 3% salt solution could partly be explained by the

Table 5. Effect of Home Processing on Ascorbic Acid Content[a] of the Central Part of Dejima, Sumi, and Chaju Potato Tubers

conditions		Dejima potato		Sumi potato		Chaju potato	
		mg/100 g of fresh wt	% lost	mg/100 g of fresh wt	% lost	mg/100 g of fresh wt	% lost
boiling	untreated	14.7 ± 0.4		31.6 ± 2.1		45.7 ± 2.7	
	boiled	1.7 ± 0.2	88.4	7.2 ± 0.1	77.2	7.3 ± 0.1	84.0
boiling, 1% salt	untreated	14.8 ± 0.2		27.8 ± 1.5		33.0 ± 0.9	
	boiled	3.4 ± 0.01	77.0	6.9 ± 0.2	75.2	6.9 ± 0.2	79.1
boiling, 3% salt	untreated	15.7 ± 4.2		31.5 ± 1.2		34.5 ± 1.2	
	boiled	5.5 ± 2.3	58.7	12.2 ± 0.8	61.3	13.4 ± 0.8	61.2
pressure-cooking	untreated	18.4 ± 1.1		33.7 ± 0.8		29.7 ± 2.1	
	cooked	7.6 ± 0.2	65.0	13.4 ± 0.9	60.2	13.2 ± 0.2	55.6
frying	untreated	10.9 ± 1.2		29.2 ± 1.0		38.8 ± 1.3	
	fried	2.3 ± 0.2	78.9	13.1 ± 0.5	55.1	12.0 ± 0.3	69.1
sautéing	untreated	22.0 ± 3.7		22.3 ± 0.5		35.6 ± 1.1.	
	sautéed	8.1 ± 0.03	63.2	8.6 ± 0.3	61.4	11.8 ± 0.7	66.9
braising	untreated	18.6 ± 1.3		28.4 ± 1.1		31.1 ± 1.2	
	braised	6.9 ± 0.6	62.9	14.1 ± 0.7	50.4	13.3 ± 0.9	57.2
baking	untreated	22.6 ± 1.3		28.0 ± 0.7		42.6 ± 1.6	
	baked	11.1 ± 0.4	50.9	18.7 ± 0.5	33.2	21.7 ± 1.2	49.1
microwaving	untreated	11.9 ± 0.5		26.9 ± 1.1		35.6 ± 2.4	
	microwaved	8.4 ± 0.1	29.4	21.3 ± 1.2	20.8	24.0 ± 1.0	32.6

[a] Mean ± SD, $n = 3$.

Table 6. Ascorbic Acid Content of Commercial Potato-Containing Foods Processed in Korea

potato food	company	AA[a] (mg/100 g)
Swingchip seafood	Orion	24.7 ± 2.7
Calbee potato chips	Haitai	21.7 ± 9.4
Pizza potato chips	Nongshim	9.0 ± 3.9
Pocachip Onion	Orion	8.0 ± 0.4
Swingchip Hot	Orion	7.1 ± 1.8
Pocachip salted	Orion	6.9 ± 1.7
Gamjakkang (snack)	Nongshim	3.9 ± 0.4
potato snack (snack)	Haitai	3.7 ± 0.8
potato stick (snack)	Nongshim	3.0 ± 0.2
Oh! Gamja Chili Chili (snack)	Orion	0.7 ± 0.1
Oh! Gamja Original (snack)	Orion	0.7 ± 0.1
Pringles Orignal (chip)	Procter & Gamble	0.5 ± 0.1
Goowoon Gamja (stick)	Haitai	trace
Gamjabonseik (baked potato crackers)	Crown	trace

[a] Mean ± SD, $n = 3$.

Table 7. Ascorbic Acid Content of Commercial Potato-Containing Foods Processed in the United States

potato food	company	AA[a] (mg/100 g)
mashed potatoes	Safeway	45.7 ± 1.0
Lay's salt and vinegar potato chips	Frito-Lay	42.1 ± 0.8
scalloped potatoes	Safeway	41.8 ± 0.4
Lay's barbecue flavor potato chips	Frito-Lay	24.4 ± 0.4
Lay's Classic potato chips	Frito-Lay	21.2 ± 1.0
Betty Crocker scalloped potatoes	General Mills	18.9 ± 0.2
au gratin potatoes	Safeway	16.5 ± 0.9
Betty Crocker roasted garlic mashed potatoes	General Mills	12.7 ± 0.7
Betty Crocker Potato Buds	General Mills	12.3 ± 0.4
Betty Crocker au gratin potatoes	General Mills	7.1 ± 1.8
Ore Ida hash brown shredded potato patties	Heinz	5.1 ± 0.1
French fries	MacDonald	2.3 ± 0.2
twice baked potatoes	Safeway	2.1 ± 0.2
potato pancake mix	Manischewitz	0.4 ± 0

[a] Mean ± SD, $n = 3$.

increased diffusion rate of ascorbic acid into the water. The data in **Table 4** and **Figure 3** show that it is unlikely that any AA leached from potatoes during boiling would survive the 100 °C temperature of the boiling water. Pressure-cooking in water showed a relatively smaller loss of vitamin C because the cooking time was 1.5 versus 10 min used in water boiling. Baking and microwave-cooking retained most of the ascorbic acid presumably because the potato was cooked without the use of water. Frying and sautéing may generate free radical reactions, resulting in considerable loss of vitamin C (*1*).

The question also arises whether it is safe to consume degradation products of vitamin C. To help answer this question, we previously explored compositional and nutritional effects of amino acid− and protein−ascorbate reactions under simulated bread crust baking conditions (*26*−*29*). We found that sodium ascorbate (but not ascorbic acid) heated with wheat gluten, soy protein, and casein inhibited the growth of mice when added to an otherwise nutritionally adequate diet. Additional studies with heated amino acid−sodium ascorbate mixtures revealed that products derived from sodium ascorbate and tryptophan also induced significant growth inhibition in mice (*29*). These results indicate that it is probably safe to fortify foods prior to heating with vitamin C. However, fortification with sodium ascorbate prior to home or commercial processing should probably be avoided.

Research Needs. Home-processing conditions selected for evaluation in this study are those widely used in most Korean homes. We do not know whether exposing potatoes to different conditions used in other parts of the world will have similar effects on the vitamin C content of potato foods. It would also be of interest to find out whether or not the extent of the described home-processing-induced degradations of vitamin C in potatoes parallels concurrent acrylamide formation (*30*).

Related studies showed that (a) vitamin C decreased the number of nonpathogenic microorganisms of stored sliced raw potatoes (*31*) and (b) milk and plasma levels of vitamin C in dairy cows decreased by 62 and 39%, respectively, after infection of the mammary glands with *E. coli* (*7*). It is not known whether the reported contamination of potatoes and other foods by human pathogens such *E. coli* (*32*, *33*) may adversely affect the content of vitamin C analogous to the in vivo effect in cows mentioned above.

The observations of the present and earlier studies indicate that the vitamin C content of potatoes is influenced by both preharvest conditions (soil, climate, genotype, etc.) and post-harvest storage and processing of the harvested potatoes and

possibly also by contamination with microorganisms. The results suggest the need to create new high-vitamin C potato cultivars. A possible approach to achieve this goal is to amplify genes that govern the formation of enzymes that are involved in the biosynthesis of the vitamin (*3*, *19*, *34*, *35*) through plant breeding and plant molecular biology techniques. As suggested by Dale et al. (*6*), another objective should be the development of new potato genotypes with a low susceptibility to vitamin C losses during storage.

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