Nutritional Sciences 9(4), November, 2006, pp.323-329

Tocopherol and Carotenoid Contents of Selected Korean Cooked Combination Foods Consumed by Young Korean Children*

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To more accurately estimate vitamin A and vitamin E intake of Koreans, food composition databases of the tocopherol and carotenoid contents of Korean foods are needed. In this study, the tocopherol (α-, γ-, and δ-) and carotenoid (α-carotene, β-carotene, β-cryptoxanthin, lutein, and zeaxanthin) contents of 12 Korean cooked combination foods commonly consumed by children in Kwangju, Republic of Korea, were determined using reversed-phase HPLC. All samples were obtained from 3 different households in Kwangju during summer, 2005. All cooked foods in this study had detectable quantities of α-tocopherol, γ-tocopherol except for shoegogimugook, and δ-tocopherol except for myulchibokkeum. Doejigogibokkeum had the highest α-tocopherol content (0.64 mg/100 g edible portion), and γ-tocopherol and δ-tocopherol contents of gimbab were the highest among the foods (1.01 and 0.26 mg/100 g edible portion). β-carotene was found in all food samples. Gimbab had the highest contents of α-carotene, β-carotene, and lutein among Korean cooked combination foods (158.3, 266.6, and 375.4 μg/100 g edible portion). Miyukgook contained only β-carotene (2.5 μg/100 g edible portion). Considerable sample-to-sample variability in tocopherol and carotenoid compositions were observed in several Korean cooked combination foods included in this study. Some of these carotenoids (α-carotene, β-carotene, and β-cryptoxanthin) are vitamin A precursors. The findings of this study may be valuable for use in Korean databases as well as nutrient consumption research for vitamin A and vitamin E.

Key words: Tocopherols, Carotenoids, Vitamin A, Vitamin E, Cooked foods

Received August 30, 2006; Revised October 19, 2006; Accepted October 29, 2006

INTRODUCTION

Assessment of dietary intake is essential in investigating the relationships between diet and health in epidemiological studies and to design nutrient intervention studies. The reliability of assessing dietary intake depends not only the accuracy of food composition estimates but also on the food composition data on which these estimates are based.[1)] Food consumption databases should give the nutrient content of foods as consumed. Problems are incurred with cooked combination foods which have several ingredients due to differences in nutrient content of raw ingredients, food preparation losses, cooking conditions (e.g. time and temperature), the use of different ingredients being added depending on household preferences, and the use of different analytical methods. Thus, most reported food consumption data are based on raw foods, although many foods are eaten cooked.

Recently established Korean Dietary Reference Intakes (DRIs)[2)] are given as retinol equivalent (RE) for vitamin A recommendations and α-tocopherol equivalent (α-TE) for vitamin E recommendations. α-carotene, β-carotene, and β-cryptoxanthin are among the carotenoids that function as provitamin A in the body, which can be beneficial in preventing vitamin A deficiency.[3)] These carotenoids are included in the calculation of vitamin A intakes as REs along with retinoids (preformed vitamin A measured in the form of retinol) in foods. Lutein and zeaxanthin are carotenoids that in addition to the 3 previously mentioned, have been reported to have antioxidant activities.[4,5)] The Korean food composition table used to calculate nutrient consumptions in Republic of Korea[6)] contains only the retinol and β-carotene contents of each food without the content of other carotenoids being given. The Korean table provides vitamin E contents as α-TE of each food as adapted from the Japanese food composition table, without providing content values for

* A contribution of the University of Nebraska Agricultural Research Division, supported in part by funds provided through the Hatch Act.
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each tocopherol in foods.[6] One α-TE unit is equal to the amount of any form of tocopherol that provides the function of 1 mg of α-tocopherol. However, the Institute of Medicine, the group that sets reference nutrient intake value for healthy populations in the USA and Canada, in 2000, indicated that α-tocopherol is the only form of the vitamin possessing vitamin E activity in the human body.[3]

Losses of tocopherols and carotenoids may occur in cooking and processing of foods. Tocopherols in foods can be oxidized by atmospheric oxygen, and the oxidation is accelerated by heat, light, alkali, and metal ions.[7] Processing of fruits and vegetables increase exposure to oxygen and release enzymes that catalyze carotenoid degradation. In addition, prolonged cooking procedures such as stir-frying or boiling also result in considerable losses of tocopherols and carotenoids.[8-10] Tocopherols[11] and carotenoids[12-14] contents in foods have been reported to be decreased after cooking or processing. Thus, information is needed on the contents of each tocopherol and carotenoid in Korean cooked combination foods commonly consumed by Koreans in order to more accurately estimate vitamin A and vitamin E intakes. The objective of the present study was to determine the tocopherol, retinoid, and carotenoid contents of selected Korean cooked combination foods, collected from 3 different households, and consumed by young Korean children living in Kwangju.

MATERIALS AND METHODS

1. Sampling of the Foods

Analyzed Korean cooked combination foods in this study were the foods reportedly consumed by 2-6 y old Korean children over a 3-day period during summer, 2005, in Kwangju. Each of these foods contained several ingredients. Each cooked combination food was collected from 3 different households which had a child participating in the current study. Edible portions of each food were homogenized using a food processor (Black & Decker, Model FP 1510, Towson, MD, USA), put into sealed plastic bags, wrapped in aluminum foil to protect from light, and frozen at -20 ℃. The frozen samples were flown to the University of Nebraska at Lincoln, NE, USA in dry ice. The samples were stored at -70 ℃ for up to 3 months prior to analyses. Samples were thawed for 12 h at 5 ℃ before analyses. All assays were conducted in duplicate.

2. Chemicals and Standards

Acetonitrile, tetrahydrofuran (THF), methanol, hexane, potassium hydroxide (KOH), and ammonium acetate were purchased from Fisher Scientific Company (Hampton, NH, USA). Butylated hydroxyl toluene (BHT) was obtained from ICN Biomedicals Inc. (Irvine, CA, USA), and triethylamine from Sigma Chemical Company (St. Louis, MO, USA). α-tocopherol, γ-tocopherol, δ-tocopherol, all-trans-retinol, β-carotene, and lutein were purchased from Sigma Chemical Company. β-cryptoxanthin and zeaxanthin were purchased from Indofine Chemical Company, Inc. (Somerville, NJ, USA). α-carotene extracted from fresh carrots was used as the α-carotene standard; proof of identity was proven as described by Bushway and Wilson[15] and Chandler and Schwartz.[16] Identities and concentrations of standards were measured using extinction coefficients ($E1\%_{1cm}$) values[17] by a spectrophotometer (Beckman DU 640, Beckman Instruments, Inc., Fullerton, CA, USA).

3. HPLC Instrumentation

Instrumentation included a 600 E solvent delivery system, 484 UV detector, 745 B data integrator (Waters Associates, Inc., Milford, MA, USA), and Rheodyne 7725 injector (Rheodyne, Rohnert Park, CA, USA). The reversed-phase HPLC column (201 TP54, Vydac, Columbia, MD, USA), 25 cm x 4.6 mm, 5 μm particle size, was used with a guard column of C_{18} material (Rainin, Woburn, MA, USA), 3 cm x 22.6 mm, 5 μm particle size. A photodiode array detector (Shimadzu Scientific Instruments, Inc., Columbia, MD, USA) was coupled to the UV detector to assess peak homogeneity and confirm spectral identity of tocopherols and carotenoids. Wavelengths of 290 nm, 325 nm, and 450 nm were used for the determination of tocopherols, retinoids, and carotenoids, respectively. The mobile phase for separations of tocopherols, retinoids, and carotenoids consisted of acetonitrile:THF:methanol:1% ammonium acetate in distilled water (80:10:6:4, v/v) containing 0.1% BHT as an antioxidant and 0.05% triethylamine.

4. Sample Extraction and Quantification

Extraction of food samples in the present study was performed by the method of Lederman *et al.*[18] Approximately 2 g of each sample was homogenized in 5 mL of absolute ethanol containing BHT (1 g/L) and treated with saturated KOH (1 mL) for 30 min in a water bath (70 ℃) to convert retinyl esters to retinol and to separate tocopherols and carotenoids from fats in the food samples.[19] After cooling to room temperature, the food samples were extracted with hexane containing 0.1% BHT at least 3 times until hexane layer became colorless. Extracted solutions were evaporated under nitrogen gas and then made to the appropriate concentration of tocopherols and carotenoids with mobile phase for HPLC analysis. All extractions were performed under low light and in ice to minimize degradation. The injection volume was 50 µL and flow rate was 1.0 mL/min for tocopherols. Percent recoveries of tocopherols were 90-93%. Minimum detectable levels were 0.004 µg α-tocopherol, 0.005 µg γ-tocopherol, and 0.004 µg δ-tocopherol. For retinol and carotenoids, the flow rate was 0.6 mL/min until 20 min, and then was increased to 1.0 mL/min until complete elution of carotenoids. Percent recoveries of retinol and carotenoids were 92-101% and 86-94%, respectively. Minimum detectable levels were 0.50 ng retinol, 0.35 ng α-carotene, 0.33 ng β-carotene, 0.18 ng β-cryptoxanthin, 0.18 ng lutein, and 0.03 ng zeaxanthin.

The tocopherol, retinol, and carotenoid concentrations of cooked Korean foods were calculated in mg/100 g wet weight, edible portion, for tocopherols and µg/100 g wet weight, edible portion, for retinol and carotenoids by using the average peak height or area comparisons between standards and samples after duplicate injections. The means and the ranges of tocopherol and carotenoid concentrations of each food obtained from 3 different households were calculated.

RESULTS AND DISCUSSION

The Korean names and descriptions of selected cooked combination foods included in this study are given in Table 1. Descriptions and ingredients of each food are those given by the Korean Nutrition Society, the Korean Nutrition Information Center.[20] However, depending on household preferences, kinds as well as quantities of ingredients added in each food varied. These are the cooked foods, containing several ingredients excluding kimchi, reportedly consumed by 2-6 y old Korean children over a 3-day period during summer, 2005, in Kwangju, Republic of Korea. The tocopherol and carotenoid contents of fruits, vegetables, and kimchi consumed by these children during same time period in Kwangju was reported elsewhere.[21]

The means and ranges of tocopherol and carotenoid contents of selected Korean cooked combination foods included in this study are shown in Table 2. All of the foods in the current study had non-detectable levels of retinol. α-tocopherol was detectable in all foods. Doejigogibokkeum had the highest α-tocopherol content (0.64 mg/100 g edible portion). Gamjadoenjanggook, kongguksoo, miyukgook, and shoegogimugook contained less than 0.3 mg α-tocopherol/100 g edible portion. γ-tocopherol was also detected in the Korean foods in the current study with exception of shoegogimugook. Gimbab contained the highest γ-tocopherol (1.01 mg/100 g edible portion) among the cooked foods, and also had a high α-tocopherol content (0.57 mg/100 g edible por-

Table 1. Korean names and descriptions of selected Korean cooked combination foods included in this study[1)]

Korean name	Description (ingredients)[2)]
Amukbokkeum	Stir-fried fish paste(fish paste, carrot, onion, soybean oil, garlic, potato, green onion, sesame seeds, salt)
Byungajorim	Braised harvest fish(harvest fish, radish, hot pepper, red pepper powder, green onion, garlic, pepper, soy sauce, salt)
Doejigogibokkeum	Stir-fried pork (pork, cabbage, onion, green onion, garlic, red pepper powder, soy sauce, sugar, red pepper paste, ginger, pepper, sesame oil)
Donyookkimchijigae	Hot pork and kimchi stew (pork, kimchi, onion, green onion, garlic)
Gamjachaebokkeum	Stir-fried shredded potato (potato, carrot, onion, hot pepper, soybean oil, salt)
Gamjadoenjanggook	Soybean paste soup with potato (anchovy, soybean paste, crown daisy, onion, potato, tofu, green onion, garlic, soy sauce)
Gimbab	Rolled rice (rice, seaweed, frankfurter, pickled radish, fish paste, egg, sesame oil, soybean oil, carrot)
Jabchae	Mixed dish of vegetables and beef (starch vermicelli, spinach, beef, onion, carrot, garlic, soybean sauce, sesame oil, salt, oyster mushroom, sugar)
Kongguksoo	Noodles in soybean broth (soybean, sesame seeds, red pepper, cucumber, noodle, salt)
Miyukgook	Sea mustard soup (Sea mustard, sesame oil, garlic, beef, salt, soy sauce, green onion)
Myulchibokkeum	Stir-fried anchovy (anchovy, salt, garlic, soybean oil, soy sauce)
Shoegogimugook	Beef and radish soup (beef, radish, green onion, red pepper powder, garlic, sesame oil, soy sauce, salt, pepper)

1) Analyzed combination foods were obtained from 3 different households during June and July, 2005 in Kwangju.
2) Description and ingredients of each food are those given by the Korean Nutrition Society, the Korean Nutrition Information Center.[20] Depending on household preferences, kinds and quantities of ingredients added in each combination food were varied.

Table 2. Tocopherol and carotenoid contents, edible portion, of selected Korean cooked combination foods[1)]

Name	Tocopherols (mg/100 g)			Carotenoids (μg/100 g)				
	Alpha-	Gamma-	Delta-	α-carotene	β-carotene	β-crypto-xanthin	Lutein	Zeaxanthin
Amukbokkeum	0.36	0.61	0.10	nd[2)]	49.5	22.3	10.3	5.2
	0.27-0.43	0.43-0.74	0.07-0.13		42.7-54.7	18.0-29.6	8.5-13.8	4.8-5.5
Byungajorim	0.42	0.08	0.09	nd	27.2	13.1	36.7	4.2
	0.28-0.56	0.06-0.10	0.02-0.19		25.9-29.5	10.3-15.5	25.4-46.2	3.5-4.9
Doejigogibokkeum	0.64	0.67	0.26	nd	137.8	86.2	77.0	18.2
	0.53-0.73	0.33-0.87	0.16-0.34		99.8-177.5	65.1-99.8	30.9-149.3	15.2-22.2
Donyookkimchijigae	0.32	0.14	0.10	nd	62.3	17.8	63.5	9.4
	0.23-0.48	0.11-0.16	0-0.21		47.4-72.6	12.0-26.7	29.5-95.0	5.7-11.5
Gamjachaebokkeum	0.33	0.17	0.07	60.0	67.4	nd	29.5	4.1
	0.19-0.46	0.12-0.27	0.03-0.09	9.7-117.0	12.3-132.2		20.6-45.1	3.6-4.8
Gamjadoenjanggook	0.07	0.21	0.08	nd	15.0	nd	26.7	nd
	0.06-0.09	0.18-0.26	0.05-0.13		11.4-20.0		19.4-40.5	
Gimbab	0.57	1.01	0.26	238.2	266.6	nd	375.4	14.2
	0.44-0.65	0.79-1.95	0.22-0.34	175.7-331.8	194.0-390.9		336.2-402.1	12.9-15.4
Jabchae	0.34	0.51	0.09	82.1	97.4	nd	92.6	0.7
	0.30-0.40	0.44-0.63	0.04-0.12	57.2-118.5	66.8-136.0		34.9-149.3	0-1.0
Kongguksoo	0.04	0.21	0.08	nd	9.1	nd	30.0	nd
	0-0.10	0.16-0.28	0.06-0.09		5.9-14.1		15.4-57.1	
Miyukgook	0.23	0.09	0.04	nd	2.5	nd	nd	nd
	0-0.48	0.06-0.11	0-0.07		2.3-2.9			
Myulchibokkeum	0.31	0.18	nd	nd	6.2	nd	nd	1.4
	0.26-0.39	0.16-0.20			0-18.7			1.4-1.4
Shoègogimugook	0.10	nd	0.00	nd	3.5	nd	2.1	nd
	0.09-0.11		0-0.01		1.2-5.5		1.3-2.9	

1) Values represent mean contents of cooked combination food from 3 different sources measured in duplicate and ranges from the lowest and the highest contents of food from each of the 3 sources. All of these foods had non-detectable levels of retinol.
2) Not detectable.

tion). Also, both doejigogibokkeum and gimbab had the highest δ-tocopherol contents, 0.26 mg/100 g edible portion. δ-tocopherol contents of miyukgook, myulchibokkeum, and shoegogimugook were less than 0.05 mg/100 g edible portion or lower than the detectable level of δ- tocopherol. Considerable sample-to-sample variability in tocopherol contents was observed for the Korean cooked combination foods in the current study. Most foods included in this study contained added soybean oil and/or sesame oil as ingredients which contained large amounts of tocopherols.[22)] The quantities of these oils used by Korean households in making the foods in the present study are small, but varied among households. These added oils may have contributed to the large range of various tocopherol compositions in this study. Therefore, it may be that the name and amount of oils added in foods should be considered for more accurate estimation of vitamin E intakes when vitamin E intake data are collected in Korea.

Generally, α-tocopherol is the predominant tocopherol in the diet.[23)] α-tocopherol contents of byungajorim, donyookkimchijigae, gamjachaebokkeum, miyukgook, myulchibokkeum, and shoegogimugook were higher than γ-tocopherol contents. However, amukbokkeum, gimbab, jabchae, and kongguksoo contained much higher quantities of γ-tocopherol compared with α-tocopherol of the foods. In some oils, including the soybean oils and sesame oils, γ-tocopherol occurs in larger amounts than α-tocopherol. Also, legumes contain large amounts of γ-tocopherol.[22,23)] In the Korean food composition table,[6)] vitamin E contents in foods are reported as α-TE; the DRIs for Koreans use α-TE for vitamin E recommendations.[2)] The 1989 Recommended Dietary Allowances for the USA indicated that γ-tocopherol is estimated to be equivalent to 10% of the activity of α-tocopherol.[24)] Factors for the conversion of the tocopherols and tocotrienols to α-TE units were based on the biological activity of the various forms as determined using the rat fetal resorption assay.[3)] However, the latest recommended vitamin E intakes for Americans and Canadians, in 2000, are based only on the α-tocopherol form of vitamin E because other tocopherols (β-, γ-, and δ-) and tocotrienols are not converted to α-tocopherol by humans and fail to bind with the α-tocopherol transfer protein (TTP).[3] All forms of dietary vitamin E are absorbed and delivered to the liver, but only α-tocopherol is preferentially recognized by α-TTP which has sufficient affinity for α-tocopherol to serve as a physiologic α-TTP complex in the body. Only α-TTP serves as a regulator of plasma and tissue α-tocopherol concentrations in humans.[25,26] However, β-, γ-, and δ- tocopherols may also have important, but as yet unknown, physiological functions. Recent research has indicated that γ-tocopherol may have beneficial properties as an anti-inflammatory and possibly anti-atherogenic and anticancer agent.[27,28] Thus, a food composition table containing vitamin E contents expressed as mg α-tocopherol along with other tocopherols may be more desirable for use in Korea.

All cooked Korean combination foods in this study contained β-carotene, while α-carotene was detected only in gamjachaebokkeum, gimbab, and jabchae in the present study (Table 2). Gimbab had the highest α-carotene and β-carotene composition (158.3 and 266.6 μg/100 g edible portion, respectively). β-cryptoxanthin was found in amukbokkeum, byungajorim, doejigogibokkeum, and donyookkimchijigae, and the quantity of β-cryptoxanthin in doejigogibokkeum was the highest among cooked Korean foods (86.2 μg/100 g edible portion), and the second highest in β-carotene content (137.8 μg/100 g edible portion). Lutein and zeaxanthin contents of gimbab were the highest and the second highest among the cooked foods in the current study (375.4 and 14.2 μg/100 g edible portion, respectively). Miyukgook contained only β-carotene, the lowest value among the Korean foods in this study (2.5 μg/100 g edible portion).

β-carotene, α-carotene, and β-cryptoxanthin are known to possess provitamin A activity. The Korean food composition table expresses the vitamin A activity of foods as μg RE based on the equivalent weight of retinol.[6] One μg RE is equivalent to 1 μg all-trans-retinol, 6 μg β-carotene, or 12 μg of other provitamin A carotenoids.[24] Panel members involved in writing the USA/Canada DRIs evaluated recent research on carotenoid absorption and conversion to vitamin A, and the vitamin A activity of provitamin A was recognized as being half of what was previously believed.[29] The unit of expression was changed to μg retinol activity equivalents (RAE), with μg RAE being equivalent to 1 μg all-trans-retinol, 12 μg β-carotene, or 24 μg other provitamin A carotenoids. However, the Korean DRIs for vitamin A issued in 2005[2] are given as μg RE. Thus, mean provitamin A contents of selected Korean cooked combination foods in this study represented by μg RE/100 g edible portion and by μg RAE/100 g edible portion are shown in Figure 1 as the authors of the current paper are in agreement with USA/Canada DRIs that vitamin A activity should be expressed in μg RAE. Only gimbab had >30 μg RAE/100 g edible portion. Gamjadoenjanggook, kongguksoo, miyukgook, myulchibokkeum, and shoegogimugook contained <5 μg RAE/100 g edible portion in this study.

Like tocopherols, considerable sample-to-sample variability in carotenoid contents was observed for several cooked foods in the current study (Table 2). Most foods in the present study were made up of vegetables such as carrot, green onion, spinach, or seaweed containing significant amount of carotenoids. Depending on household preferences, some vegetables might be added in larger or smaller amounts than those given by Korean Nutrition Society, Korean Nutrition Information Center,[20] or not be added in the foods at all, which may contribute to the large range of provitamin A contents

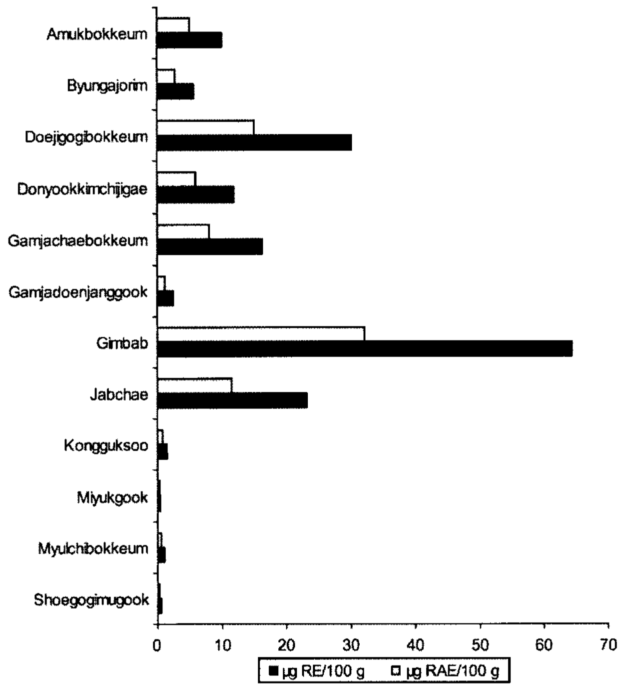

Fig. 1. Mean provitamin A contents of selected Korean cooked combination foods in this study represented by μg retinol equivalent (μg RE) and μg retinol activity equivalent (μg RAE) per 100 g edible portion

in Korean cooked combination foods. Thus, combination foods containing large amounts of provitamin A such as doejigogibokkeum, gamjachaebokkeum, or gimbab could result in large differences between actual and estimated intakes of vitamin A in vitamin A consumption research.

CONCLUSION

This study provides tocopherol and carotenoid values for Korean cooked combination foods commonly consumed by young children in Republic of Korea during summer. α-tocopherol and β-carotene were found in all selected foods of the current study. Gimbab contained higher quantities of tocopherols and carotenoids than other foods in this study and would be a good source of vitamin E and provitamin A. The results of this study should be helpful in estimating more accurately the dietary intakes and adequacies of vitamin E and vitamin A from food consumption surveys conducted in Republic of Korea and possibly in other countries. Future research on the tocopherol and carotenoid composition of Korean cooked combination foods is needed regarding the effects of food preparation, cooking conditions, and use of different ingredients in Korean cooked combination foods.

Acknowledgement

The authors are grateful to Dr. Youn-Ok Cho, Professor of Food and Nutrition, Duksung Women's University, Seoul, Korea, for her beneficial suggestions in performing this study in Korea.

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