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Original Article

Folate Intake and Food Sources in Japanese Female Dietitians

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Abstract

Objective: To assess intake of folate/folic acid and food sources in Japanese female dietitians.

Subjects and Methods: We evaluated folate consumption based on four season 7 consecutive day weighed diet records (WDRs) provided by 80 Japanese female dietitians and compared the results with data from a national survey. We then selected informative foods for folate intake on the basis of 2,240 WDRs according to contribution and multiple regression analyses.

Results: Daily folate consumption (mean±SD) among Japanese dietitians was 413±158 μg from raw foods and 343±128 μg from cooked foods. Average residual rate after cooking was 84±8%. Folate intake in summer was lower than that in other seasons by analysis of variance. According to contribution and multiple regression analyses, the major contributors were vegetables, fruit and green tea.

Conclusions: Daily folate intake among Japanese female dietitians was far greater than the 200 μg recommended daily allowance for the Japanese. Irrespective of selection methods and raw/cooked foods, major folate sources were found to be green tea along with vegetables and fruit.

Key words: cooking loss, folate/folic acid, food sources, green tea, weighed diet records

Introduction

Folate/folic acid, one of the water-soluble B vitamins, is essential for processes of DNA synthesis/repair and folate-dependent metabolic pathways (1). Deficits of folate and vitamin B_{12} predispose to megaloblastic anemia. Folate is particularly important during the gestation period because its lack brings about neural tube defects such as spina bifida (2, 3). Links between folate intake and onset of cardiovascular disease have also been suggested because folate is associated with the metabolism of homocysteine to methionine as a cofactor (4, 5). Recently, attention has been focused on epigenetic carcinogenesis via DNA synthesis or DNA hypermethylation by folate, modified by genetic polymorphisms of methylenetetrahydrofolate reductase (*MTHFR*) (6, 7).

Since folate is an essential vitamin, supplementation is now recommended in Western countries for expecting women to prevent neural tube defects, including spina bifida (8, 9). The incidence of spina bifida has been low in Japan (10, 11), but decreased consumption of vegetables and fruit has been reported in the younger generation (11, 12). Thus, the Ministry of Health, Labor and Welfare, Japan, distributed information on appropriate folate intake in December, 2000 (11), according to the findings of a National Nutrition Survey carried out in 1998 (12), in which folate concentrations were, however, primarily based on values for raw/uncooked foods.

In November, 2000, the Standard Tables of Food Composition, 5th revised edition (13), first included after 18 years, in addition to pantothenic acid, folate concentrations in raw and cooked foods, with reference to weight reduction, cooking method and cooking time. Since there is limited information regarding food/beverage sources for folate in the world (14–20) and Japan (21), we newly calculated the daily intake of folate on the basis of four season 7 consecutive day weighed diet records (WDRs hereafter) supplied by Japanese female dietitians in the Japanese Dietitians' Epidemiologic (JADE) Study. We then computed not only raw but also cooked food sources for folate based on 2,240 WDRs according to contribution and multiple regression analyses. In addition, a comparison was made with the recently provided data from the Japanese National Nutrition Survey (11, 12).

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Subjects and Methods

Subjects

To validate a data-based semi-quantitative food frequency questionnaire (SQFFQ) (22) in terms of energy and 30 macro- and micro-nutrients, we conducted four season 7 consecutive day WDRs, as described elsewhere (23). Briefly, we recruited 106 (21 male and 85 female) Japanese dietitians living in Aichi prefecture, Central Japan, and first mail-administered the SQFFQ in autumn, 1996. We surveyed 7 consecutive day WDRs approximately one week later, and at about 3 month intervals in winter, spring and summer, 1997.

Male dietitians were excluded because they were rather small in number. This investigation was therefore based on 2,240 WDRs from the four season 7 consecutive day WDRs provided by eighty female dietitians. Their mean age (years of age)±standard deviation (minimum–maximum) was 48±8 (32–66) in autumn, 1996. The values for height (cm), weight (kg) and BMI (kg/m^2) were 156.9±5.1 (146.1–172.1), 52.2±5.5 (37.5–69.4), and 21.5±2.2 (15.9–29.5), respectively.

Intake of Folate

Folate intake was calculated according to a standardized manual (24). We ascertained daily folate consumption by multiplying the food intake (in grams) or serving size and the folate content per 100 grams of food as newly listed in the 5th edition of the Standard Tables of Food Composition (13). The food numbers originally coded according to the 4th edition in our earlier study (23) were converted to fit with the 5th edition.

To compare our values with folate intake in females from the national survey (11, 12), we similarly calculated folate intake from food groups largely based on raw/uncooked foods classified according to the food categorization adopted for the National Nutrition Survey, except for items including dry noodles, beans, dry seaweed and tea. In the national survey they used folate concentrations in either dry or cooked foods; however, we adopted those in cooked/prepared foods. For green tea, dry leaves were employed in the former, whereas we used the first infusion of tea tabulated in the 5th edition of the Standard Tables of Food Composition.

When calculating the daily intake of folate from cooked/prepared foods, residual weight and folate contents after cooking were used for most foods (13). We applied the concentrations in raw foods for those limited/without content description for cooked foods which are most frequently consumed raw, such as cucumber, lettuce and most fruit, and for cooked meat, milk, dairy products and soy beans. For fish, common cooking procedures were chosen, and for chicken eggs without information of recipes, the intake was assumed as cooked. Folate from supplements, if any, was not taken into account in this analysis. Some foods including fortified rice and wheat unlisted in the 5th edition were coded as for the case without fortification.

Selection of foods

For selecting informative foods for folate, similar procedures were undertaken as reported elsewhere (23). In brief, a contribution analysis was applied as follows. Similar items in 1,128 foods consumed were combined to give 494 groups. Based on these we first chose forty-eight foods providing up to a 90 cumulative % contribution. We then selected 28 raw and 30 cooked items giving up to a 90 cumulative % contribution, and chose seven raw and 8 cooked foods providing up to a 0.90 cumulative multiple regression coefficient/cumulative R^2.

Statistical Procedures

Differences in daily folate intake by season were tested by analysis of variance. Contribution and multiple regression analyses, as mentioned elsewhere (23, 25–27), were executed to select informative foods. For the statistical analysis, EXCEL and SPSS 9.0 J Windows were employed.

Results

Daily Folate Intake

Daily folate intake (mean±SD) from raw foods among Japanese dietitians was 413±158 μg (Figure 1). Residual folate was 343±128 μg when taking into account the cooking loss. The average residual rate was 84±8%. There was seasonal variation in folate consumption, intake in summer being lower than in other seasons, by analysis of variance ($p<0.01$).

Comparison with the National Nutrition Survey

The average daily folate intake in this study 413 μg (min–max) (235–846) from raw foods was greater than the 363 μg in the national survey (Table 1). Our study subjects consumed somewhat more green-yellow vegetables, milk and dairy products, and confectionery than the subjects in the national survey. Of the total, 103 μg (25% in this study), 79 μg (19%) and 26 μg (6%) were supplied by green-yellow vegetables, other vegetables (e.g. cucumber, lettuce *etc.*) and fruit, respectively, the figures being 87 μg (24% of the total), 76 μg (21%) and 24 μg (6%), in that order in the national survey. Approximately fifty percent of the folate was supplied by vegetables and fruit in both studies. While 51 μg (12%) was provided by green tea in the present study population, no information was available for this source in the national survey. Folate consumption from green tea in addition to vegetables and fruit was lower in the younger generation than in older individuals not only in this study but also in the national survey, intake increasing along with age in both studies.

Foods Contributing to Folate Intake according to Contribution Analysis

Following the food categorization in our SQFFQ, foods con-

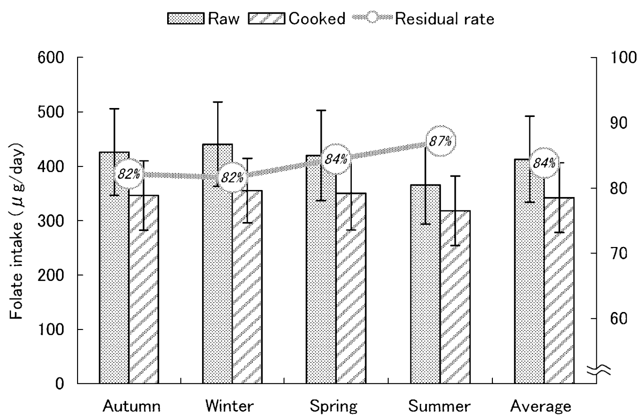

Fig. 1 Seasonal daily folate intake from raw and cooked foods based on four season 7 consecutive day WDRs and the residual rate after cooking (±SD).

Table 1 Folate intake by food group calculated from the four season 7 consecutive day WDRs vs. the National Nutrition Survey

	From four season concecutive 7 day WDRs in this study										From National Nutrition Survey, 1999									
	Age category (years)								Mean age		Age category (years)								Mean age	
	30–39 (n=15)		40–49 (n=33)		50–59 (n=25)		60–66 (n=7)		47.6±8.0 (n=80)		30–39 (n=931)		40–49 (n=1,040)		50–59 (n=1,112)		60–69 (n=982)		49.8 (n=4,065)	
Food group[1)]	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)	Portion size (g)	Folate (µg)
Rice	137	17	124	15	134	16	128	15	130	16	137	16	142	17	151	18	153	18	146	17
Bread and Noodles	118	20	126	19	109	17	112	16	118	19	106	17	93	16	88	14	81	12	91	15
Potatoes	44	9	46	10	50	10	45	10	47	10	61	14	68	14	76	17	75	18	71	16
Sugar and Sweeteners	9	0	10	0	9	0	9	0	9	0	9	0	10	0	11	0	10	0	10	0
Pulses	45	11	50	13	63	17	74	18	55	14	61	16	70	17	79	20	89	22	75	19
Nuts and Seeds	3	3	4	4	5	5	5	5	4	4	1	1	2	2	3	3	3	3	2	2
Green-yellow vegetables	105	83	119	95	132	116	162	141	124	103	80	75	86	75	106	97	107	102	95	87
Other vegetables (e.g. Cucumber, Lettuce etc.)	164	74	162	74	183	84	202	100	172	79	163	63	180	76	193	83	187	78	181	76
Fruit	90	17	125	24	164	31	161	31	134	26	84	13	120	20	170	29	172	31	138	24
Mushrooms	10	6	13	7	13	7	17	9	13	7	14	7	15	7	18	8	15	7	16	7
Seaweed and Seeds	6	8	9	10	11	13	8	14	9	11	5	9	6	12	8	12	8	12	7	11
Fish and Shellfishes	71	11	91	15	88	15	110	17	88	14	77	11	91	13	111	15	102	15	96	14
Meat	61	8	63	12	54	7	56	18	59	10	76	11	74	10	65	9	52	10	67	10
Eggs	35	15	40	18	42	18	41	17	40	17	38	16	42	18	37	16	32	14	37	16
Milk and Dairy products	111	6	184	9	205	9	223	12	180	9	121	5	114	5	116	5	122	5	118	5
Fats and Oil	13	0	13	0	9	0	10	0	12	0	18	0	17	0	15	0	12	0	15	0
Confectionery	55	7	59	7	49	6	40	4	53	7	27	3	28	3	27	3	21	2	26	3
Seasonings and Spices	43	10	50	11	44	11	49	12	47	11										
Prepared foods	8	0	12	0	8	0	5	0	9	0										
Tea	373	35	406	42	551	63	668	89	468	51										
Coffee	166	0	128	0	75	0	68	0	113	0	143	31	153	38	135	50	98	51	133	43
Beer	81	6	64	5	54	4	19	1	60	4										
Sake, Wine and Whiskey	12	0	7	0	11	0	28	0	11	0										
Other beverages	25	0	16	0	13	0	18	0	17	0										
Total	1,784	346	1,921	391	2,075	450	2,255	530	1,973	413	1,220	311	1,309	342	1,409	397	1,339	399	1,323	363

[1)] Foods were classified according to the food categorization adopted for the National Nutrition Survey.

tributing to folate intake are shown with or without considering cooking loss (Table 2). With both methods, a top contributor was green tea infusion followed by raw spinach, other vegetables (e.g. cucumber, lettuce etc.), cabbage and broccoli, the residuals after cooking being 46%, 78%, 55% and 63%, respectively. The 90 cumulative % contribution was covered by 28 raw and by 30 cooked foods.

Foods Contributing to Variance of Folate Intake according to Multiple Regression Analysis

Seven raw and 8 cooked foods provided up to a 0.90 cumulative multiple regression coefficient (R^2) by multiple regression analysis (Table 3). Obviously the number of foods necessary to estimate folate intake up to the designated cumulative percentage in the multiple regression analysis was far fewer than that for the contribution analysis. Spinach was the top folate contributor followed by green tea and other vegetables for uncooked foods, green tea infusion being the top followed by spinach and other vegetables for cooked foods.

Discussion

The value for daily folate intake of 413±158 µg, mainly from raw/uncooked foods, obtained for Japanese dietitians was greater than the 363 µg, generated in the national survey (11, 12). The average value for daily folate intake thus easily satisfied the 200 µg recommended daily allowance (RDA) for the Japanese (28) without any supplementation; however, the latter was less than the 400 µg of RDA and the medical guideline for expecting women in the USA (8, 16). The difference appears conservative because folate is heat-labile and water-soluble and the residual weight is decreased because of cooking. Folate intake in the JADE Study was rather elevated partly because the subjects are food and health cautious dietitians who consume more vegetables and fruit than the general populace. Thus, the data from the present study cannot necessarily be generalized; however, they are precise (23) as well as reliable (29) and provide useful information on folate intake and cooked food sources.

The findings of the present study demonstrated seasonal

Table 2 Raw and cooked foods for folate providing up to a cumulative 90% contribution

Rank	Raw food	Portion size (g)	% contribution	% cumulative contribution	Cooked food	Residual rate (%)	% contribution	% cumulative contribution
1	Green tea	161	13.3	13.3	Green tea infusion	100	16.0	16.0
2	Spinach	44	11.6	24.9	Other vegetables (eg, Cucumber, Lettuce etc.)	78	9.9	25.9
3	Other vegetables (eg, Cucumber, Lettuce etc.)	27	10.5	35.4	Spinach	46	6.4	32.3
4	Cabbage	43	4.6	40.0	White bread and Soft bread rolls	100	4.6	37.0
5	Eggs	32	4.4	44.4	Eggs	84	4.5	41.5
6	White bread and Soft bread rolls	61	3.8	48.3	Cabbage	55	3.0	44.5
7	Broccoli	40	3.6	51.9	Citrus fruit	100	3.0	47.5
8	Rice	64	3.5	55.4	Potatoes	95	3.0	50.5
9	Japanese radish	44	2.7	58.1	Toasted laver and Toasted and seasoned laver	100	2.9	53.4
10	Potatoes	48	2.6	60.7	Japanese radish	88	2.9	56.3
11	Citrus fruit	84	2.5	63.2	Broccoli	63	2.7	59.0
12	Toasted laver and Toasted and seasoned laver	1.5	2.4	65.6	Liver	100	2.4	61.4
13	Green soybeans	23	2.1	67.7	Rice	54	2.3	63.7
14	Rape flower buds and stems	45	2.0	69.7	Natto (Fermented soybean) and Soybean	98	2.2	65.9
15	Liver	34	2.0	71.6	Green soybeans	85	2.1	68.0
16	Shiitake (raw)	15	1.9	73.6	Vegetable juice and Tomato juice	100	2.0	70.0
17	Natto (Fermented soybean) and Soybean	30	1.9	75.4	Milk (whole)	100	1.9	71.9
18	Vegetable juice and Tomato juice	45	1.6	77.0	Burdock and Bamboo shoot	88	1.7	73.6
19	Burdock and Bamboo shoot	27	1.6	78.7	Strawberries	100	1.6	75.2
20	Milk (whole)	130	1.6	80.2	Soy sauce	100	1.6	76.9
21	Strawberries	52	1.4	81.6	Koji-miso (Soybean paste for miso soup)	100	1.5	78.4
22	Soy sauce	5	1.3	82.9	Welsh onion leaves	100	1.4	79.8
23	Koji-miso (Soybean paste for miso soup)	10	1.3	84.2	Shiitake (raw)	59	1.4	81.2
24	Welsh onion leaves	11	1.2	85.4	Beer	100	1.4	82.5
25	Carrots	16	1.1	86.5	Tofu	100	1.4	83.9
26	Beer	330	1.1	87.6	Rape flower buds and stems	55	1.3	85.2
27	Tofu	63	1.1	88.8	Other fruits	100	1.2	86.4
28	Pumpkin/Squash	48	1.0	89.8	Pickles	100	1.1	87.6
29					Pumpkin/Squash	89	1.1	88.7
30					Asparagus	91	1.0	89.7

Table 3 Raw and cooked foods for folate providing up to a 0.90 cumulative R^2

Rank	Raw food	Cumulative R^2	Cooked food	Cumulative R^2
1	Spinach	0.40	Green tea infusion	0.44
2	Green tea	0.67	Spinach	0.66
3	Other vegetables (eg, Cucumber, Lettuce etc.)	0.79	Other vegetables (eg, Cucumber, Lettuce etc.)	0.78
4	Cabbage	0.83	Liver	0.82
5	Liver	0.86	Cabbage	0.85
6	Green soybeans	0.89	Green soybeans	0.87
7	Toasted laver, Toasted and seasoned laver	0.90	Soy sauce	0.89
8			White bread and Soft bread rolls	0.90

variation in folate consumption, the intake in summer being lower than in any other season. This is plausible in that intake of vegetables and fruit is decreased due to the lowered market supply and reduced appetite in summer. Thus, in epidemiological studies, seasonal variation should be taken into account in terms of folate consumption as well as other foods/nutrients of interest.

Folate is named because it is highly concentrated in leafy vegetables (1, 3) and major folate contributors were here found to be vegetables. Folate intake from beer, related to barley, yeast and hops (19, 20), cannot be overlooked when studies are conducted in males. Seaweed was a significant folate contributor according to multiple regression analysis, which is not surprising given its nature as a sea vegetable (30). It has high concentrations not only of folate but also other essential minerals, dietary fiber and fatty acids. We should, however, stress that portion sizes for dry seaweed are highly variable from person to person and systematic error is likely to occur. High contents in eggs and liver are in line with the finding that it is essential for DNA synthesis/repair and folate-associated metabolic pathways.

On the basis of the food categorization in our SQFFQ, green tea or green tea infusion was the top contributor not only for cooked and raw foods according to the contribution analysis but also for cooked foods according to multiple regression analysis. Folate intake from green tea was slightly overestimated in the present study because the concentration was based on the first infusion but the magnitude is far less than the value based on dry tea leaves adopted in the national survey. However, we could not measure the contribution by green tea in the national survey in which this variable was not universally included because tea is a non-calorie food. Thus, folate intake from green tea may have been underestimated in the national survey and Hiraoka's analysis (21), which was based on an American database.

As with epigallocatechin gallate (EGCG), folate concentration differs with the type of tea. The values per 150 ml (serving size) of "*Gyokuro*," the highest grade, "*Sencha*" common grade, "*Bancha*" coarse grade, "*Houjicha*" roasted, "*Genmaicha*", Oolong tea, black tea and "*Mugicha*" wheat tea are 225 μg, 24 μg, 11 μg, 20 μg, 5 μg, 3 μg, 5 μg and 0 μg, respectively (13). To precisely categorize the type of tea would be laborious and unrealistic for epidemiological studies; however, we should at least differentiate green tea from non-green tea, including oolong and black tea, not only from the standpoint of the content of folate but also other chemical ingredients in order not to incur misclassification.

The anti-carcinogenic actions of green tea have largely been discussed in terms of components like polyphenols including EGCG, flavonoids and vitamin C (31–33), and folate appears to have been overlooked as a factor. Furthermore, any association between folate and cancer should be carefully considered because the protective effects by green tea may be influenced/confounded by the correlation proposed between the consumption of green tea and vegetables and fruit (31, 34–36).

Since the Japanese enjoy several cups of green tea daily and consume substantial vegetables and fruit, their folate intake is generally satisfactory. However, from statistics issued by the Ministry of Health, Labor and Welfare (10, 11), the incidence of neutral tube defects is slowly increasing in Japan, which may be related partly to westernization of the diet in the young generation, in particular. As discussed above, green tea drinking is favorable for health not only with regard to folate but also polyphenols and vitamin C. It should, therefore, be particularly recommended to young females during the gestation period.

While the 5th edition of Standard Tables of Food Composition (13) newly listed folate contents not only in the raw but also cooked foods along with cooking methods, weight loss and cooking time, making feasible the present study, the database is not complete: that is, values for cooked foods are partially missing for meat, soy products and some vegetables including Welsh onion leaves. Therefore, a comprehensive approach needs to be adopted, and updating and validating procedures are prerequisite for estimating accurate folate intake.

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