Intake of *Trans* Fatty Acid in Japanese University Students

Terue KAWABATA¹, Sachiko SHIGEMITSU¹, Naoko ADACHI¹, Chie HAGIWARA¹, Shigeji MIYAGI¹,
Sumie SHINJO², Takenori MARUYAMA³ and Michihiro SUGANO⁴

¹Faculty of Nutrition, Kagawa Nutrition University, 3–9–21 Chiyoda, Sakado, Saitama 350–0288, Japan

²Faculty of Education, University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa 903–0213, Japan

³Japan Institute for Oils & Fats & Foods Inspection, 3–27–8 Nihonbashi-Hamacho, Chuo-ku,
Tokyo 103–0007, Japan

⁴Kyushu University, 5–38–23 Najima, Higashi-ku, Fukuoka 813–0043, Japan

(Received July 2, 2009)

Summary Because *trans* fatty acids (TFAs) are a potent risk factor for coronary heart disease, it is important to know the amount of TFA consumed. We estimated TFA intakes of Japanese university students by direct measurement. Subjects included 118 students (57 males and 61 females) in two regions of Japan: Kanto (Tokyo area) and Okinawa. A dietary survey was conducted over six consecutive days using dietary records and photographic records. A single-day meal in the survey period was reproduced to measure TFA content by gas chromatography. The median values of TFA intakes (and energy percentage) estimated by the contents of reproduced meals for men were 0.43 g/d (0.22%) in Kanto and 0.30 g/d (0.14%) in Okinawa. Corresponding values for women were 0.49 g/d (0.29%) and 0.73 g/d (0.35%), respectively. Compared to the group with a low TFA intake, the subjects with a high TFA intake consumed significantly more energy from total fat and saturated fatty acids, and had a high ratio of TFA/linoleic acid. In addition, multiple regression analysis showed the intakes of TFA were positively associated with those of saturated fatty acids and groups of nonessential groceries such as cookies, cakes and pastries. In conclusion, the TFA intakes of these survey subjects were relatively lower than the WHO recommended energy ratio (<1%). However, nutritional education on dietary habits seems indispensable for those subjects who are consuming high volumes of TFA.

Key Words *trans* fatty acids, dietary intake, Okinawa, Japanese university students, direct measurement

Partially hydrogenated vegetable oils containing various amounts of *trans* fatty acids (TFAs) are commonly used worldwide in the preparation of margarines, shortenings, fast foods, and processed foods. TFAs increase the risk of coronary heart disease (CHD) through their adverse effects on blood cholesterol metabolism and aortic function (1–3). Several prospective cohort studies have also shown a positive correlation between TFA intake and the risk of CHD (4–6). To avoid the adverse effects, TFA intake of less than 1% of total energy is recommended in the report of the Joint WHO/FAO Expert Consultation (7). The French Food Safety Agency (AFSSA) has recommended a value of 2% of total energy intake as the maximum TFA consumption level (8).

Several countries are now regulating TFA contents in commercially available processed foods and in foods served in restaurants. In the United States, processed foods containing more than 0.5 g of TFA per serving are required to indicate the contents on food labels (9). Several cities, including New York, NY, are currently restricting the use of TFA in restaurants to less than 0.5 g/serving (10). In contrast to other countries, there

is no TFA ban in Japan and no TFA content is provided on food labels, although legislation of TFA contents is currently under examination. Because the TFA content of food is not shown in the Japanese standard food table currently available, the Fifth Revised and Enlarged Edition of the “Tables of Fatty Acid Composition in Japan” (11), TFA intake cannot be estimated in dietary surveys based on weighing foods or subject interviews. Consequently, reports on TFA intake by Japanese subjects are limited and insufficient (12–17). In its current fact sheet (18), the Food Safety Commission of the Cabinet of Japan reported that, although the mean intake of TFA by Japanese individuals, estimated by the build-up method, is not at an excessive level (that is, 0.7 g/d or 0.3% energy), guidance should be provided for those who are consuming dietary fats above the mean level, particularly in younger generations who typically consume more fast foods and processed foods compared with older generations.

When discussing the adverse effects of TFA, it is important to consider the amounts and types of other fatty acids (FAs) in dietary fats consumed simultaneously, because individual FAs have different effects on serum cholesterol levels. Among people in developed countries, Japanese have a proper pattern of fat intake,

E-mail: kawabata@eiyo.ac.jp

as characterized by low intakes of total fats and saturated fatty acids (SFAs) and high intakes of *n*-3 polyunsaturated fatty acids (PUFAs) (19). This tendency has been considered a healthy pattern of fat intake compared to the high-fat diets in Western countries. If the actual values of the amounts of TFA and other FAs consumed by Japanese can be assessed, useful information could be provided to avoid the harmful effects of TFA.

In this study, we estimated TFA intakes by 118 Japanese university students (57 males and 61 females) in two regions of Japan: Kanto (Tokyo area) and Okinawa. A dietary survey was conducted over six consecutive days using dietary records and photographic records. Of 6 d, 1 day's meals were reproduced and TFA contents were analyzed directly using gas chromatography. We were thus able to assess the mean and individual TFA and other FAs consumed.

SUBJECTS AND METHODS

Subjects. The survey was conducted in two regions of Japan, Kanto and Okinawa. Kanto, including the Tokyo Metropolitan Area, is in mainland Japan and served as the reference area. Okinawa is located in the southwestern-most part of Japan. We recruited volunteers under the inclusion criteria for subjects with no signs of any disease, no allergies, and no extreme dietary limitations. A total of 119 university students were recruited in the two regions, but one man from the Okinawa region did not submit digital images of meals or dietary records. Thus, data from 118 subjects, aged 18 to 26 y, were analyzed, including 32 Kanto men, 25 Okinawa men, 31 Kanto women, and 30 Okinawa women. Most of the Kanto men were university students from the Department of Science, and the Kanto women were dietetic university students; the Okinawa men and women were university students from the Department of Education.

Survey period. In Kanto subjects, the survey was conducted for 6 consecutive days, starting on October 6, 2007 for men, and on September 29, 2007 for women. In Okinawa, the survey was similarly conducted, starting on October 19, 2007 for both men and women.

Dietary survey. The dietary survey was conducted for 6 consecutive days using a written dietary record and a photographic record. Before the survey, subjects were instructed on how to keep dietary records and take pictures of their meals. All digital images of "before" and "after" meals, even if there were no leftovers, were recorded by subjects. When pictures were taken, subjects were requested to place a card (6×8 cm²) alongside the dishes to provide a size scale. The camera was set 30–80 cm above the food at an approximately 45° angle. Photographic conditions were as follows: digital camera, DiMAGE X21 (Konica Minolta Photo Imaging, Inc., Tokyo, Japan); image size, 1,600×1,200 pixels, standard type; and number of pixels, 1.9 million. The digital cameras were lent to subjects during the survey period. For processed foods, subjects were asked to photograph food labels that showed the product name and

ingredients.

We interviewed subjects at the end of the survey investigation, collected dietary records and digital images of the meals, and confirmed the brand name of processed foods, the location of the grocery store where the food was purchased, and any missing items on dietary records. Weights of food consumed were estimated from images taken before and after meals. The Fifth Revised and Enlarged Edition of the "Standard Tables of Food Consumption in Japan" (11) was used as a reference for energy intake.

The study protocol and informed consent form were approved by the Medical Committee of Kagawa Nutrition University. Written informed consent was obtained from all participants.

Sample preparation for TFA analysis. Meals were reproduced based on 1 day's diet records from the fifth day of the survey period and offered for total fat and FA analyses. We selected the fifth day because by that time, subjects were accustomed to and not conscious about recording meals. During the survey, subjects were not informed which of their meals for 1 d would be reproduced. The reproductions were done from December 2007 to April 2008 in our laboratory. Food for the reproduction of meals was purchased in December 2007 for Okinawa subjects and from December 2007 to April 2008 for Kanto subjects. The purchase of ingredients was conducted as follows:

- 1) For prepared foods such as boxed lunches, ready-to-eat foods, and fast foods, the same foods as those eaten by subjects were purchased from the identical grocery stores the subjects purchased them from in both regions.

- 2) For nationwide and generally available processed foods (sweets, bread, vegetable oil and fat, mayonnaise, and dairy products), the same brands were purchased at grocery stores near our laboratory.

- 3) For fresh foods, the same types of foods were purchased at grocery stores near our laboratory.

- 4) For products available for a limited period that were unavailable later, we substituted a similar product sold at the same grocery store where the subjects purchased them in both regions. Foods from Okinawa were frozen and transported by air to our laboratory.

To completely reproduce the meals consumed during 1 d, foods that were obtained based on food records were weighed and prepared for eating. After reviewing the food records, all the foods for 1 d (breakfast, lunch, dinner, and snacks) were weighed, homogenized in a food cutter (CQM-50, Toshiba, Tokyo, Japan), and 200 g of the homogenate was then re-homogenized more finely in a homogenizer (IFM-700G, Iwatani, Tokyo, Japan). The homogenates were stored at –20°C until used for analyses.

Analysis of total fats and FA. The total fats were extracted by the chloroform-methanol mixture, purified, and weighed (20). After adding nonadecanoic acid (C19:0) to the extract as an internal standard, fats were converted to fatty acid methyl esters (FAMES) using boron trifluoride-methanol solution (21). FAME compo-

Table 1. Age, BMI, energy intake, and fat and FA intakes estimated by the contents of reproduced meals by university students in Kanto and Okinawa.¹⁻³

	Men			Women		
	Kanto	Okinawa	<i>p</i> ⁷	Kanto	Okinawa	<i>p</i> ⁷
No. of subjects	32	25		31	30	
Age, y	20.7±0.9 ⁴	20.0±1.6	0.057	19.7±1.2	19.9±1.5	0.586
Height, cm	173.1±7.5	170.9±6.3	0.261	157.8±5.8	156.9±5.2	0.544
Weight, kg	64.2±11.8	66.2±10.7	0.520	49.8±6.4	51.3±6	0.354
BMI, kg/m ²	21.3±2.7	22.6±3.4	0.116	20.0±2.2	20.9±2.3	0.153
Energy intake, kcal/d	2,004±705	2,109±567	0.550	1,522±422	1,732±437	0.061
Fat intake, g/d	61.4±22.1	64.9±32.1	0.625	49.0±20.9	61.0±32.8	0.094
Fat intake, % of energy	29.3±11.2	28.1±12.6	0.700	29.5±9.9	31.6±14.8	0.530
LA intake, % of energy	5.2±2.9	4.9±2.7	0.700	4.4±2.6	5.1±2.5	0.330
TFA intake, g/d						
Total TFA ⁵	0.43 ⁶	0.30	0.885	0.49	0.73	0.175
	(0.20, 0.81)	(0.25, 1.22)		(0.29, 0.86)	(0.38, 1.14)	
18:1 <i>t</i>	0.25	0.30	0.687	0.47	0.47	0.489
	(0.13, 0.67)	(0.14, 1.02)		(0.18, 0.6)	(0.30, 0.89)	
TFA intake, % of energy						
Total TFA	0.22	0.14	0.760	0.29	0.35	0.516
	(0.10, 0.36)	(0.12, 0.57)		(0.19, 0.51)	(0.22, 0.58)	
18:1 <i>t</i>	0.13	0.13	0.872	0.25	0.23	0.686
	(0.07, 0.29)	(0.07, 0.44)		(0.12, 0.38)	(0.16, 0.49)	
18:1 <i>t</i> /total TFA	0.71±0.35	0.76±0.29	0.570	0.80±0.25	0.75±0.25	0.455
Total TFA/LA	0.07±0.11	0.07±0.06	0.860	0.11±0.11	0.12±0.12	0.942

BMI, body mass index; TFA, *trans* fatty acid; LA, linoleic acid.

¹ Height and weight were based on values provided on the questionnaire by the subjects themselves.

² Energy intake was the calculated value.

³ Fat and FA intakes were estimated by the contents of the reproduced meals.

⁴ Values are mean±SD.

⁵ Total TFA contents are expressed as the sum of *trans* isomer of 18:1, 18:2 and 18:3.

⁶ Values are medians; interquartile ranges in parentheses.

⁷ Student's *t*-test or the Wilcoxon rank sum test was used to test for significant differences between the regions.

sition was analyzed by gas chromatography using a DB-23 capillary column (30 m×0.25 mm i.d., 0.25 μm film thickness, J&W Scientific, Folsom, CA) (22). An aliquot of FAME was fractionated by silver nitrate-impregnated silica gel thin-layer chromatography according to the number and geometry of double bonds. The developing solvent was a mixture of *n*-hexane/ethyl and acetate/xylene (90 : 5 : 5 v/v). The SEA and TFA fractions were collected together, eluted several times with diethyl ether, and the FA composition was analyzed by gas chromatography as described above. The various *cis* and *trans* FAs in the samples were identified by comparing retention time of the standard mixtures (Sigma-Aldrich, St. Louis, MO).

Although our gas chromatographic conditions well separated *trans* isomers of 16- to 22-carbons, we detected only *trans* isomers of 18:1, 18:2 and 18:3. Consequently, total TFAs are expressed as the sum of *trans* isomer of 18:1, 18:2 and 18:3. In general, 18:1*t* isomers were the most prominent component in all samples, 70–80% of total TFA (see Table 1).

Statistical analysis. Data are presented as mean values (±standard deviations) for the day the meals were reproduced. Because the TFA content on the day the

meals were reproduced for each group was not assessed for normal distribution and variance, these data are presented as medians (interquartile range (IQR), 25th–75th percentile). To clarify the characteristics of food consumption of subjects with a high TFA intake, total subjects were categorized according to the median of total TFA for men (0.39 g/d) and women (0.60 g/d). In addition, to predict the TFA intake, stepwise multiple regression analysis was performed. The TFA intake was estimated by the content of the reproduced meal as the dependent variable and the intakes of SEA, instant noodles, cookies and cakes and pastries as the independent variable. Individual food groups were classified according to the report of the Food Safety Commission in Cabinet Office, Government of Japan (15). The food groups were transformed into categorical data (0, not eaten; 1, eaten).

Statistical differences of groups were examined with Student's *t*-test, the Wilcoxon rank sum test, or the χ^2 test. Results were considered significant at a level of $p<0.05$. The Statistical Package for the Social Sciences (SPSS) for Windows version 17.0 (SPSS Inc., Chicago, IL) was used for statistical analyses.

Fig. 1. Box and whisker plots for total TFA intakes estimated by the contents of reproduced meals for men ($n=57$) and women ($n=61$), regardless of region. Values are expressed as intakes (A) and energy percentages (B) on the day meals were reproduced. Total TFA intakes are expressed as the sum of *trans* isomer of 18:1, 18:2 and 18:3. In a box and whisker plot, a box is drawn around the median and quartile values, and the whiskers extend from each quartile to the extreme data points. The closed squares are outlier values, and asterisks are extreme values. The value in each box is the median.

Table 2. Energy, fat and FA intakes categorized according to median total TFA intake estimated from the contents of the reproduced meals for men (0.39 g/d) and women (0.60 g/d).^{1,2}

	Men			Women		
	Low TFA intake	High TFA intake	p^5	Low TFA intake	High TFA intake	p^5
No. of subjects	28	29		30	31	
Energy intake, kcal/d	$1,831 \pm 577^3$	$2,261 \pm 645$	0.010	$1,524 \pm 417$	$1,720 \pm 443$	0.081
Fat intake, g/d	46.8 ± 14.9	78.5 ± 26.6	<0.001	43.4 ± 17.4	66.0 ± 31.6	0.001
Fat intake, % of energy	24.1 ± 8.0	33.3 ± 13.1	0.003	26.5 ± 9.8	34.5 ± 13.7	0.011
FA intake, % of energy						
Total FA ⁴	20.7 ± 7.2	29.0 ± 12.2	0.003	22.3 ± 8.9	29.3 ± 11.1	0.009
SEA	6.4 ± 2.9	9.5 ± 4.4	0.003	7.1 ± 2.5	11.3 ± 4.5	<0.001
MUFA	8.9 ± 3.3	12.2 ± 5.6	0.008	9.2 ± 5.1	11.5 ± 4.8	0.084
PUFA	5.2 ± 2.3	6.7 ± 3.6	0.066	5.6 ± 3.6	5.6 ± 2.7	0.966
Total <i>n</i> -3 FA	0.7 ± 0.5	0.9 ± 0.6	0.221	0.9 ± 0.9	0.7 ± 0.3	0.218
Total <i>n</i> -6 FA	4.5 ± 2.0	5.8 ± 3.0	0.057	4.7 ± 2.8	4.9 ± 2.4	0.789
18:1t/total TFA	0.7 ± 0.4	0.8 ± 0.2	0.193	0.8 ± 0.3	0.8 ± 0.2	0.587
Total TFA/LA	0.03 ± 0.02	0.11 ± 0.11	<0.001	0.06 ± 0.05	0.17 ± 0.13	<0.001
Vegetable oil intake, g/d	12.0 ± 10.0	14.5 ± 12.6	0.407	7.9 ± 8.2	9.1 ± 8.9	0.590

FA, fatty acid; SEA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; LA, linoleic acid; TFA, *trans* fatty acid.

¹Energy and vegetable oil intake were the calculated values.

²Fat and FA intakes were estimated from the contents of the reproduced meals.

³Values are mean $\pm$ SD.

⁴Total TFA contents are expressed as the sum of *trans* isomer of 18:1, 18:2 and 18:3.

⁵Significant differences were examined using Student's *t*-test.

RESULTS

Table 1 shows age, body mass index (BMI), energy intake estimated by calculation, and fat and FA intakes estimated by the contents of reproduced meals for all subjects. In this study, no limitations were set on physique in the recruitment of subjects. The subjects' heights and weights were quoted from values on questionnaire forms written by the subjects themselves at

the start of the dietary survey. No significant differences were seen in height, weight, or BMI between subjects of the same gender from different regions. In addition, there were no significant differences in intakes or energy percentages of total TFA between subjects of the same gender from different regions. The 18:1 *t* accounted for 70–80% of total TFA, and the contents of other *trans* polyunsaturated isomers were low.

The box and whisker plots for intake and energy per-

Table 3. Results of stepwise multiple regression analysis of total TFA intake estimated by the contents of the reproduced meals as a dependent variable.¹⁻³

Independent variable	Partial regression coefficient	Standard error of the regression coefficient	<i>p</i>	95% confidence interval of partial regression coefficient	
				Lower	Upper
Constant	-0.084	0.106	0.434	-0.295	0.127
SFA	0.046	0.006	<0.001	0.034	0.058
Instant noodles	-0.465	0.172	0.008	-0.806	-0.123
Cookies	0.389	0.162	0.018	0.067	0.711
Cakes and pastries	0.345	0.159	0.033	0.029	0.661

¹ SFA, saturated fatty acid; TFA, *trans* fatty acid.

² Coefficient of determination adjusted for the degrees of freedom was 0.52 and ANOVA of multiple regression was significant ($p < 0.001$).

³ $n = 118$.

percentage of total TFA in subjects are shown in Fig. 1. In both genders, these parameters were distributed in a positive direction. For total TFA intakes, six men and four women had outlier values (men: 1.93, 1.95, 2.03, 2.38, 2.43 and 2.47 g/d; women: 2.26, 2.50, 2.51 and 3.13 g/d), and one woman had an extreme value (3.88 g/d). In energy percentage from total TFA, two men and five women had outlier values (men: 0.97 and 1.04% energy; women: 1.32, 1.34, 1.37, 1.41 and 1.45% energy) and two women had extreme values (1.60 and 2.80% energy). Within all subjects, one man (1.8% of all men) and seven women (11.5% of all women) exceeded 1% energy from total TFA, and only one Okinawan woman exceeded 2% energy from total TFA.

Energy, fat and FA intakes categorized according to median total TFA intake estimated by the contents of the reproduced meals by men (0.39 g/d) and women (0.60 g/d) are shown in Table 2. Compared with the low TFA group, the high TFA group had significantly higher values for the intakes and energy percentages of fats in both men and women (intake of fat: men $p < 0.001$, women $p = 0.001$; energy percentage of fat: men $p = 0.003$, women $p = 0.011$). In addition, the high TFA group had significantly higher percentages of energy from total FA and SFA in both men and women (total FA: men $p = 0.003$, women $p = 0.009$; SFA: men $p = 0.003$, women $p < 0.001$). The ratio of total TFA/linoleic acid (LA) of the high TFA group was significantly higher in both genders (both $p < 0.001$).

Results of stepwise multiple regression analysis of total TFA intakes estimated by the contents of reproduced meals as a dependent variable are shown in Table 3. Total TFA intakes were positively associated with the intakes of SFA ($p < 0.001$) and the appearances of cookies ($p = 0.018$), cakes and pastries (both $p = 0.033$), and inversely associated with the appearance of instant noodles ($p = 0.008$).

DISCUSSION

In the present study, the median values of the content (and energy percentage) of TFA in reproduced meals for

men were 0.43 g/d (0.22%) in Kanto and 0.30 g/d (0.14%) in Okinawa. Corresponding values for women were 0.49 g/d (0.29%) and 0.73 g/d (0.35%), respectively. One man (1.8% of all men) and seven women (11.5% of all women) exceeded the value recommended by the WHO/FAO, less than 1% energy (7), and only one Okinawan woman exceeded the value recommended by the AFSSA of less than 2% energy (8).

In a previous study among Japanese people, the means of TFA intake were estimated at 1.56 (12) and 1.8 g/capita/d (13) (both based on the amounts of oils produced), 0.3–0.5% of energy (24-h dietary recall) (14), and 0.7 g/capita/d or 0.3% energy (build-up method) (15). The total TFA intakes measured in the present survey were almost the same or even lower than the values reported by these previous studies. However, our data could not be compared directly with available data, because of the difference in the analytical methods. In addition, three of these previous studies (12–14) were analyzed during the 1990s, and there is a possibility that the contents of TFA differ from those of our study as reflecting the regulation of the contents. Recently, the results of studies among Japanese women dietetic students (16), and people of four districts (17) were reported. Although the reported values for total TFA intakes were comparable, the proportion of subjects in our study who consumed TFA exceeding the recommended WHO value was still lower (men: 1.8% vs 5.7%; women: 11.5% vs 24.4%) (17), probably due to inclusion in their food database of data reported after 1992 (16, 17). In recent years, the TFA contents in margarines and shortenings have been decreasing worldwide in response to regulation (23–25). Despite the lack of regulation, Japanese food industries have also been making efforts to reduce TFA contents over the past few years (26), particularly motivated by the TFA regulations in the United States (9) and New York, NY (10). Consequently, in the present study, total TFA contents of the meals were relatively low, reflecting in part the recent decreasing trend of TFA contents of processed foods.

In a separate study, we measured the intake of TFA in

25 young Japanese women, and found that subjects with a high dietary intake of processed foods rich in TFA may exceed predicted levels (27). When assessing TFA intake, therefore, it is necessary to pay attention to subjects who are consuming TFA more than on the average. In the present survey, compared to the group with a low intake of TFA, the group with a high intake of TFA consumed significantly more energy from total fats and SFA, and had a high ratio of TFA/LA, suggesting the risk of serum cholesterol elevation (28). In addition, the intakes of TFA were positively associated with those of SFA, and nonessential groceries such as groups of cookies, cakes and pastries by multiple regression analysis. Because similar tendencies have also been reported by young Japanese women (16) and even people in Western countries (5, 6), it is probable that our subjects also have a similar nutritional environment. To avoid the harmful effects of TFA, therefore, nutritional education on dietary habits, including TFA, is indispensable (29).

There is, however, a limitation in applying these results to the general Japanese population, as all of our subjects were university students. In addition, the Kanto women were enrolled in a registered dietitian training course. As most of the subjects have nutritional knowledge and are educated in completing dietary surveys, their dietary records might be more reliable than those of general university students (30). However, the fat intakes in Kanto women tended to be lower compared to the reported data, in which a self-administered diet history questionnaire was estimated using a sample population consisting of selected female students who enrolled in dietetic courses (31). In an orientation preceding the survey, the study outline was explained and the measurements of fats and FA (including TFA) contents of the meals were described. Therefore, food selection bias, especially in Kanto women, might be present.

In conclusion, the TFA intakes estimated by the contents of the meals reproduced in this survey were relatively lower than the FAO/WHO recommended energy ratio, less than 1%. However, the intakes of TFA were positively associated with those of SFA, and nonessential groceries such as groups of cookies, cakes and pastries. Nutritional education on dietary habits seems indispensable for those subjects who are consuming high amounts of TFA.

Acknowledgments

This study was supported by the Japan Margarine, Shortening & Lard Industries Association. We thank all the subjects in Kanto and Okinawa who generously participated in this study. We also thank the research students of Kagawa Nutrition University for their assistance in sample preparation.

REFERENCES

- 1) Hunter JE. 2006. Dietary *trans* fatty acids: review of recent human studies and food industry responses. *Lipids* **41**: 967–992.
- 2) Woodside JV, McKinley MC, Young IS. 2008. Saturated

- and *trans* fatty acids and coronary heart disease. *Curr Atheroscler Rep* **10**: 460–466.
- 3) Micha R, Mozaffarian D. 2008. *Trans* fatty acids: Effects on cardiometabolic health and implications for policy. *Prostaglandins Leukot Essent Fatty Acids* **79**: 147–152.
- 4) Sun Q, Ma J, Campos H, Hankinson SE, Manson JE, Stampfer MJ, Rexrode KM, Willett WC, Hu FB. 2007. A prospective study of *trans* fatty acids in erythrocytes and risk of coronary heart disease. *Circulation* **115**: 1858–1865.
- 5) Oh K, Hu FB, Manson JE, Stampfer MJ, Willett WC. 2005. Dietary fat intake and risk of coronary heart disease in women: 20 years of follow-up of the Nurses' Heart Study. *Am J Epidemiol* **161**: 672–679.
- 6) Oomen CM, Ocke MC, Feskens EJ, van Erp-Baart MA, Kok FJ, Kromhout D. 2001. Association between *trans* fatty acid intake and 10-year risk of coronary heart disease in the Zutphen Elderly Study: a prospective population-based study. *Lancet* **357**: 746–751.
- 7) WHO/FAO. 2003. Diet, nutrition and the prevention of chronic diseases. *World Health Organ Tech Rep Ser* **916**: 1–149, backcover.
- 8) Leger CL, Razanamahefa L, Margaritis I. 2007. Health risks and benefits of *trans* fatty acids including conjugated fatty acids in food—Synopsis of the AFSSA report and recommendations. *Eur J Lipid Sci Technol* **109**: 887–890.
- 9) Food and Drug Administration. 2003. Food labeling: *Trans* fatty acids in nutrition labeling, nutrient content claims, and health claims. *Federal Register* **68**: 41433–41506.
- 10) Okie S. 2007. New York to *trans* fats: you're out! *N Engl J Med* **356**: 2017–2021.
- 11) Ministry of Education, Culture, Sports, Science and Technology. 2005. Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition, Fatty Acids Section. National Printing Bureau, Tokyo (in Japanese).
- 12) Okamoto T, Matsuzaki H, Maruyama T, Niiya I, Sugano M. 1999. *Trans* fatty acid content in hydrogenated oils and estimated intake. *J Jpn Oil Chem Soc* **48**: 1411–1414 (in Japanese).
- 13) Okamoto T, Kinoshita Y, Kanematsu H, Niiya I, Sugano M. 1993. *Trans*-fatty acid contents of various foods cooked with oils and fats in Japan. *J Jpn Oil Chem Soc* **42**: 996–1001 (in Japanese).
- 14) Zhou BF, Stamler J, Dennis B, Moag-Stahlberg A, Okuda N, Robertson C, Zhao L, Chan Q, Elliott P, for the INTERMAP Research Group. 2003. Nutrient intakes of middle-aged men and women in China, Japan, United Kingdom, and United States in the late 1990s: the INTERMAP study. *J Hum Hypertens* **17**: 623–630.
- 15) Food Safety Commission in Cabinet Office, Government of Japan. 2007. Basal report of evaluation of *trans* fatty acids in food, p 1–45. Tokyo (in Japanese).
- 16) Yamada M, Sasaki S, Murakami K, Takahashi Y, Uenishi K. 2009. Association of *trans* fatty acid intake with metabolic risk factors among free-living young Japanese women. *Asia Pac J Clin Nutr* **18**: 359–371.
- 17) Yamada M, Sasaki S, Murakami K, Takahashi Y, Okubo H, Hirota N, Notsu A, Todoriki H, Miura A, Fukui M, Date C. 2010. Estimation of *trans* fatty acid intake in Japanese adults using 16-day diet records based on a food composition database developed for the Japanese population. *J Epidemiol* **20**: 119–127.
- 18) Food Safety Commission in Cabinet Office, Government

- of Japan. 2007. Fact sheet with *trans* fatty acids. [Online]. Available: <http://www.fsc.go.jp/sonota/54kai-factsheets-trans.pdf> [accessed December 7, 2008] (in Japanese).
- 19) Sugano M. 2006. Seeking better dietary fats for human health. In: Dietary Fats and Risk of Chronic Disease (Huang Y-S, Yanagita T, Knapp HR, eds), p 3–9. AOCS Press, Champaign, IL.
 - 20) The Japanese Society of Food Science and Technology. 1996. Shin-Shokuhinbunsekihou, p 51–53. Kourin, Tokyo (in Japanese).
 - 21) Japan Oil Chemists' Society. 1996. Standard Methods for the Analysis of Fats, Oils and Related Materials. 2.4.1.2–1996 (in Japanese).
 - 22) Matsuzaki H, Okamoto T, Aoyama M, Maruyama T, Niiya I, Yanagita T, Sugano M. 2002. *Trans* fatty acids in margarines marketed in eleven countries. *J Oleo Sci* **51**: 555–561.
 - 23) Harnack L, Seungmin L, Schakel SF, Duvall S, Luepker RV, Arnett DK. 2003. Trends in the *trans*-fatty acid composition of the diet in a Metropolitan area; The Minnesota Heart Study. *J Am Diet Assoc* **103**: 1160–1166.
 - 24) Albers MJ, Harnack LJ, Steffen LM, Jacobs DR. 2008. 2006 Marketplace survey of *trans*-fatty acid content of margarines and butters, cookies and snack cakes, and savory snacks. *J Am Diet Assoc* **108**: 367–370.
 - 25) Stender S, Astrup A, Dyerberg J. 2008. Ruminant and industrially produced *trans* fatty acids: health aspects. *Food Nutr Res*. DOI: 10.3402/fnr.v52i0.1651.
 - 26) Maruyama T. 2008. Recent trend in *trans* fatty acids field. *Oleoscience* **8**: 107–114 (in Japanese).
 - 27) Kawabata T, Hyogo H, Hagiwara C, Matsuzaki S, Shinjo S. 2008. Intake of *trans* fatty acids estimated by direct dietary measurement in young women. *J Jpn Soc Nutr Food Sci* **61**: 161–168 (in Japanese).
 - 28) Kritchevsky D. 1997. *Trans* fatty acids and cardiovascular risk. *Prostaglandins Leukot Essent Fatty Acids* **57**: 399–402.
 - 29) Eckel RH, Kris-Etherton P, Lichtenstein AH, Wylie-Rosett J, Groom A, Stitzel KF, Yin-Piazza S. 2009. Americans' awareness, knowledge, and behaviors regarding fats: 2006–2007. *J Am Diet Assoc* **109**: 288–292.
 - 30) Kuriki K, Nagaya T, Imaeda N, Tokudome Y, Fujiwara N, Sato J, Ikeda M, Maki S, Tokudome S. 2002. Discrepancies in dietary intakes and plasma concentrations of fatty acids according to age among Japanese female dietitians. *Eur J Clin Nutr* **56**: 524–531.
 - 31) Murakami K, Sasaki S, Takahashi Y, Uenishi K, Watanabe T, Kohri T, Yamasaki M, Watanabe R, Baba K, Shibata K, Takahashi T, Hayabuchi H, Ohki K, Suzuki J. 2008. Lower estimates of delta-5 desaturase and elongase activity are related to adverse profiles for several metabolic risk factors in young Japanese women. *Nutr Res* **28**: 816–824.