Intake Ratio of Water-insoluble Dietary Fiber to the Water-soluble One in Japanese: An Estimation on Dietary Records and the Secular Consideration on the National Nutrition Survey

Takahiro NISHIMUNE,* Tatsuo SUMIMOTO, Kenji SUEKI, Shigeru MORITA,1 Kunio OKAZAKI,1 Ikuho NAKAYAMA,1 Akihiro ICHIHASHI,1 Masaaki IMANAKA,1 Kiyoko SAeki,1 Yuzo YAMAMOTO,1 Toru ADACHI,1 Syuusuke KURASHINA,1 Yukio YOSHIDA,1 Tadashige MORI,1 Yoshinori MIYAMURA,1 Norihiko KAWABATA,1 Shin-ichi SATo,2 and Yoshio KOMACHI

Osaka Prefectural Institute of Public Health, Osaka 537, Japan
1Japan Association of Prefectural and Municipal Public Health Institutes,
Tokyo Metropolitan Research Laboratory of Public Health,
Shinjuku-ku, Tokyo 169, Japan
2Osaka Prefectural Center for Adult Diseases, Osaka 537, Japan

(Received September 29, 1995)

Summary Thirty-four foods were analyzed in order to determine the content of water-soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). Using the results with the standard table for 227 foods, the intake ratio of IDF/SDF of an average Japanese was calculated for the period 1946–1990. The ratio was 3.22 in 1990 as calculated on the food intakes shown in the national nutrition survey, and the secular change was not detected since 1946 when the ratio was 3.30. The ratio was also shown to be well preserved between types of households including the age of the head. Using dietary records of 60 healthy city workers (average 42.8 years) for 4 weeks, however, the weekly average ratio for an individual was found to vary in the range of 2.25–5.13 although the total average for 60 individuals was 3.33. Thus, the well preserved IDF/SDF intake ratio for an average Japanese showed, on the contrary, a wide variation of food selection between each person.

Key Words dietary fiber, water soluble dietary fiber, water insoluble dietary fiber, intake ratio, dietary record, national nutrition survey

*Present address: Musashigaoka College, Yoshimicho, Hikigun, Saitama 355-01, Japan.
There are many suggestions describing difference in physiological effects on human health between water-soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) (1, 2). No study, however, has estimated the intake ratio of IDF against SDF to the extent that stands wider discussion, partly because of the lack of basic data for the estimation of intakes of these fiber components. In this study, we tried to evaluate the IDF/SDF intake ratio in daily meals, and found that the ratio for an average Japanese was quite conserved through decades and between generations. Between individuals, however, the ratio varied widely and it was possibly a parameter indicating the extent of deviation of dietary habits from the average. As to nutritional information for the general public, the total amount of dietary fiber (TDF) is sometimes insufficient for someone who is anxious about the blood glucose level (3) or blood cholesterol (bl. CHL) level. Thus, we propose the intake ratio of IDF/SDF as another parameter usable for a nutritional indication directed to, e.g., those people whose trend of food selection in daily meals is far deviated from the average Japanese (in IDF/SDF ratio, see "RESULTS"), or to those requiring relatively closer dietary control.

MATERIALS AND METHODS

Measurement of water-insoluble and water-soluble dietary fibers. The method proposed by Prosky et al. (4) partly as revised by Lee et al. (5) was used as far as possible. When it was insufficient, minor modifications were applied to the standard method as reported earlier (6). A ceramic filtering aid (0.2 g/assay) named “Filcer” (Hayashibara Biochemical Laboratories, Okayama, Japan) was often preferred to the celite 545. Some Japanese foods of frequent use were not included in the recently published IDF, SDF table (7), and 34 foods were selected and purchased from retail stores in Tokyo, Kyoto, Osaka, Amagasaki, Okayama, Yamaguchi, and Miyazaki cities and analyzed. Sample preparation and reagent usage were as described in the earlier report (6).

Calculation of IDF/SDF intake ratio for an average Japanese. National Nutrition Survey (NNS) data (8) were consulted for the daily intake per capita of each food or food group from 1956 to the present. This survey is based on weighing every food item consumed for 3 days in 7,000 randomly selected households each year throughout Japan. The results have been analyzed and published on the basis of a household categorized into groups, e.g. by the age of the head of household, or by the location of residence, etc. together with the data for the national average per capita.

Dietary record. A menu-oriented questionnaire was used as described before (9). In short, the first column of the record form carried approx. 70 popular names of menu with a space for notes and more detailed records. In the second column, names of representative foodstuffs for the menu, including alternative items of popular selection and fiber-rich materials, were listed together with fatty acid-containing foods of animal, fish, and plant origins. In the third column, the
amounts consumed were shown for the participant's selection as regular amount, big size dish, or small bowl etc. Participants were requested to choose or write down (if not found) the name of dishes they consumed, any major addition or deletion of food items for the recipe, and major deviation from the usual amounts served per person. The records were checked rather vigorously through an interview by experienced dietitians.

**Calculation of IDF and SDF intakes by the dietary record.** Similar method as used for TDF (9) was applied. A table of IDF and SDF content for the 164 representative menus, together with a table of IDF and SDF of each food item for a standard amount used in typical recipes (per dish size) and for its 1/3 amount, were used to substitute the intake of nutrients for the dishes consumed. Those tables also contained the amount of saturated fatty acids, cholesterol and n-3 fatty acids for their estimation of intakes. The intakes were calculated for each meal, and averaged per day and per week.

**Survey of IDF and SDF intakes of healthy volunteers.** Four weeks' dietary records of 60 healthy participants were collected for 7 consecutive days in every other week. Participants were members of Osaka Prefectural Institute of Public Health or their families and the average age was 42.8 years (42 males and 18 females).

**RESULTS AND DISCUSSION**

**IDF and SDF content of 34 Japanese foods**

In order to estimate the intakes of IDF and SDF separately, 34 Japanese foods were newly analyzed by the enzymatic gravimetric method. The results are shown in Table 1. The relatively large standard deviations were within the originally reported level (4) and practically inevitable because of the low contents of those fiber components in samples analyzed, or because of the difficulty differentiating by filtering SDF from IDF. Six measurements in 3 independent laboratories were averaged in foods other than agar and chicken egg, in which 4 measurements in 2 laboratories were averaged after the rejection of 2 results as an outlier.

**Secular trend of IDF and SDF intakes**

IDF and SDF intakes by the average Japanese in 1946–1990 were estimated on the statistics of NNS. The results are shown in Fig. 1 and Table 2. The decreasing trend of TDF intake obtained by summing IDF and SDF in Fig. 1 confirmed the results we reported earlier using a TDF table (9). In Table 2, it is shown that the IDF/SDF ratio has been conserved through decades in meals of the average Japanese. The strongly conserved IDF/SDF intake ratio through tens of years might indicate an unknown physiological significance to be studied.

**Constituent foods contributing to IDF and SDF intakes of Japanese**

The constitution of IDF or SDF has changed through the years as shown in
Table 1. Soluble and insoluble dietary fiber content of some Japanese foods.

| Food                                      | Wet % | Dry % | SD*  |
|-------------------------------------------|-------|-------|------|
|                                           | IDF  | SDF  | TDF  | IDF  | SDF  | TDF  | IDF  | SDF  | TDF  |
| Rye bread                                 | 5.1  | 1.5  | 6.6  | 7.4  | 2.2  | 9.5  | 0.93 | 0.30 | 0.71 |
| Devil’s tongue, noodle type               | 2.4  | 0.0  | 2.4  | 87.4 | 0.4  | 87.8 | 0.03 | 0.01 | 0.03 |
| Corn starch                               | 0.2  | 0.1  | 0.3  | 0.2  | 0.1  | 0.3  | 0.09 | 0.18 | 0.17 |
| Peanut butter                             | 5.1  | 0.3  | 5.4  | 10.6 | 0.5  | 11.1 | 0.56 | 0.19 | 0.44 |
| Natto, soybeans, itohiki                  | 4.8  | 2.9  | 7.7  | 8.6  | 5.2  | 13.8 | 1.14 | 0.72 | 1.50 |
| Red pepper, fruit, dried                  | 36.1 | 4.6  | 40.7 | 41.4 | 5.3  | 46.6 | 0.56 | 0.63 | 0.48 |
| Japanese radish, immature leaves          | 1.0  | 0.2  | 1.2  | 20.0 | 4.1  | 24.1 | 0.04 | 0.06 | 0.05 |
| Shiba-shrimp, raw                         | 2.5  | 0.3  | 2.8  | 3.2  | 0.3  | 3.6  | 0.66 | 0.30 | 0.81 |
| Kambako, fish paste, steamed              | 0.3  | 0.0  | 0.3  | 1.1  | 0.2  | 1.3  | 0.14 | 0.01 | 0.13 |
| Chikuwa, fish paste, broiled              | 0.1  | 0.1  | 0.2  | 0.4  | 0.3  | 0.7  | 0.07 | 0.03 | 0.08 |
| Nama-age, soybean paste, boiled           | 1.0  | 0.2  | 1.2  | 6.5  | 1.3  | 7.8  | 0.20 | 0.11 | 0.21 |
| Abura-age                                 | 1.2  | 0.2  | 1.4  | 4.9  | 0.8  | 5.7  | 0.55 | 0.28 | 0.69 |
| Beef flank, Japanese cattle               | 0.5  | 0.1  | 0.6  | 1.7  | 0.5  | 2.1  | 0.26 | 0.23 | 0.47 |
| Swine, boston butt                        | 0.5  | 0.1  | 0.6  | 1.5  | 0.3  | 1.9  | 0.20 | 0.15 | 0.34 |
| Swine, inside ham                         | 0.7  | 0.0  | 0.7  | 2.7  | 0.1  | 2.8  | 0.28 | 0.03 | 0.29 |
| Chicken breast, fresh                     | 0.4  | 0.1  | 0.5  | 1.6  | 0.4  | 2.0  | 0.14 | 0.13 | 0.26 |
| Chicken thigh, fresh                      | 0.4  | 0.2  | 0.6  | 1.7  | 0.9  | 2.6  | 0.21 | 0.16 | 0.34 |
| Chicken, Sasami                          | 0.7  | 0.2  | 0.9  | 2.7  | 0.6  | 3.3  | 0.47 | 0.14 | 0.36 |
| Chicken whole egg                        | 0.3  | 0.3  | 0.3  | 1.3  | 0.0  | 1.3  | 0.72 | 0.15 | 0.85 |
| Whale bacon                               | 0.3  | 0.2  | 0.5  | 0.8  | 0.6  | 1.4  | 0.18 | 0.34 | 0.31 |
| Strawberry jam                            | 0.5  | 1.0  | 1.5  | 0.9  | 1.8  | 2.7  | 0.27 | 0.23 | 0.20 |
| Jew’s ear, white dried                    | 49.3 | 18.0 | 67.3 | 56.0 | 20.4 | 76.5 | 4.03 | 4.19 | 3.68 |
| Wakame, dried                             | 11.3 | 17.7 | 29.0 | 12.0 | 18.8 | 30.8 | 7.27 | 9.35 | 2.65 |
| Agar-agar                                 | 61.9 | 19.0 | 80.9 | 69.6 | 21.4 | 91.0 | 2.98 | 2.63 | —    |
| Purple laver, seasoned & dried            | 17.9 | 9.0  | 26.9 | 18.9 | 9.4  | 28.3 | 3.64 | 1.87 | 5.51 |
| Kelp, Ma-konbu, dried                     | 13.4 | 13.7 | 27.1 | 14.8 | 15.1 | 29.9 | 12.22 | 14.46 | 2.95 |
| Purple laver, dried                       | 18.0 | 11.1 | 29.1 | 18.9 | 11.6 | 30.5 | 4.38 | 1.04 | 5.12 |
| Mozuku, desalted                          | 2.0  | 1.3  | 3.3  | 60.6 | 39.4 | 100.0 | 0.43 | 0.40 | 0.36 |
| Hijiki, boiled & dried                    | 21.7 | 21.5 | 43.3 | 22.7 | 22.5 | 45.3 | 5.97 | 6.04 | 3.29 |
| Consomme, dried                           | 0.3  | 0.3  | 0.6  | 0.3  | 0.3  | 0.7  | 0.33 | 0.32 | 0.56 |
| Worcester sauces                          | 0.1  | 0.5  | 0.6  | 0.3  | 1.7  | 2.1  | 0.10 | 0.43 | 0.52 |
| Tomato ketchup                            | 0.9  | 0.5  | 1.4  | 3.1  | 1.5  | 4.6  | 0.12 | 0.45 | 0.43 |
| Soy sauce, light                          | 0.0  | 0.3  | 0.3  | 0.0  | 1.0  | 1.0  | 0.01 | 0.16 | 0.15 |
| Salted pollack roe                        | 2.3  | 0.3  | 2.6  | 6.5  | 0.8  | 7.3  | 0.79 | 0.31 | 0.55 |

*Results are SD of wet % data.

Figs. 2 and 3. These figures show that mixed components of various origins are involved in both IDF and SDF, and the overall physiological effects are composite intrinsically.

It is shown in Fig. 2 that the decreasing tendency of SDF in rice and cereals in 1955–1975, that is deduced to be the result of milling rice grain and refined breads.

* J. Nutr. Sci. Vitaminol.*
replacing staple rice, has been compensated by the increased intake of algae and fruits. The apparent constancy of IDF/SDF in Table 2 is, therefore, based on intakes of different kinds of SDF.

**IDF and SDF intakes in various family styles**

Using the data of NNS, IDF/SDF intake ratio was calculated for households of various age (single family data), of various site of residence, of farmers and city workers, and of various family sizes. The results shown in Table 3 indicate that there is no practical difference between those types of households, and the value of IDF/SDF was extremely well preserved across various household styles.
Table 2. Secular change of IDF/SDF intake ratio in Japan.

| Year | IDF/SDF |
|------|---------|
| 1946 | 3.30    |
| 1950 | 3.15    |
| 1955 | 3.15    |
| 1960 | 3.24    |
| 1965 | 3.46    |
| 1970 | 3.28    |
| 1975 | 3.21    |
| 1980 | 3.22    |
| 1985 | 3.23    |
| 1990 | 3.22    |

*IDF and SDF intakes of 60 healthy individuals*

From the dietary records of 60 volunteers for 4 weeks, the intakes of IDF and SDF were evaluated. The IDF/SDF ratio varied between 5.13 and 2.25 for 1-week average data, between 6.71 and 1.46 for the sum of each day meal, and between 43.0 and 0.08 for each single meal. The ratio for 1-week average and 4-week average correlated well ($r=0.67-0.84, p<0.001$), and we propose to use the 1-week average for future analyses on the relation between IDF/SDF and various health-related parameters. The importance of the specific IDF/SDF value for each individual in relation to their health status is still open to study. The 1-week average data are shown in Table 4. Two individuals whose IDF/SDF ratio was the maximum and the minimum (5.13 and 2.25) in the 7th week were chosen. For the two individuals, the maximum and the minimum ratio for each meal were 43.0 and 0.08, and for each day-average they were 6.71 and 1.46. From these results, it was shown that the value of IDF/SDF could vary from meal to meal in usual diets, but the average value for a longer period of e.g. 1 week could also indicate a trend of food selection in each person.

Intakes from daily meals of saturated fatty acids and cholesterol were also calculated. Regression lines with negative regression coefficients were obtained between IDF/SDF and saturated fatty acids ($r=-0.269, n=240, p<0.001$) or dietary cholesterol ($r=-0.138, n=240, p<0.05$). Intake of n-3 fatty acids was also estimated and found to be 2.85 g/day as an average.

*IDF/SDF intake ratio as a dietary parameter for improving dietary habit*

A number of foods show IDF/SDF values higher than the average ratio of Japanese intake (3.2–3.3), whereas a relatively smaller number of foods, as e.g. algae or fruits, contain more abundant SDFs and contribute to smaller intake ratios. As shown in Fig. 2, three major SDF supplier food groups in the latest decade were algae, non-colored vegetables and mushrooms, and fruits. Supplementary suppliers following the major group were wheat and flour, and colored vegetables. Figure 3 shows, on the other hand, that the chief IDF supplier in the

*J. Nutr. Sci. Vitaminol.*
latest decade was non-colored vegetables and mushrooms (the contribution of mushrooms was approximately 8% within this group). The second group of IDF suppliers was rice, colored vegetables, fruits, and wheat and flour. The non-colored vegetables are composed mainly of Japanese radish, cabbage, Chinese cabbage, edible burdock, bamboo shoots, east Indian lotus root, Welsh onion, and mugbean sprouts.

Japanese traditional menus basically offer higher intakes of total dietary fiber, and the foodstuffs for the traditional menu, as shown in Fig. 3, contain relatively higher amounts of IDF than SDF. Thus, the higher IDF/SDF intake ratio might be interpreted to indicate the tendency to choose traditional dishes. In Table 3, it
is shown that both the IDF/SDF ratio and the total fiber intake were higher in the households of full time farmers. In the households of teenagers, however, although the IDF/SDF ratio was relatively high, the total amount of fiber intake was very low and the trend to choose traditional dishes in teenagers’ households is questionable. The IDF/SDF ratio of food groups in 1990 was calculated as follows: rice grains 17.00, mushrooms 10.86, legumes 5.91, potatoes 5.63, colored vegetables 4.06, non-colored vegetables 3.61, snacks 2.94, wheat and minor grains 2.87, fruits 2.62, and sea weeds 0.84. The main reason for the higher IDF/SDF of the teenagers’ households compared with the twenties’ families was found to be the nearly equal intake of rice groups and mushrooms among the slightly decreased intake of other food groups.

As to the IDF/SDF intake ratio, household size and the ratio correlate
positively, and the ratio was lower when the site of residence was more urbanized, or the age of the head of household was younger except for the teenagers. The IDF/SDF intake ratio might, therefore, be an indication of the trend to choose Japanese traditional dishes only when the total amount of fiber was taken into

Vol. 42, No. 4, 1996

Table 3. Intake ratio of IDF against SDF in different family styles.

| Number of household members | IDF   | SDF   | IDF/SDF |
|-----------------------------|-------|-------|---------|
| 1                           | 12.38 | 3.92  | 3.16    |
| 2                           | 14.19 | 4.39  | 3.23    |
| 3                           | 13.62 | 4.15  | 3.28    |
| 4                           | 12.79 | 3.88  | 3.20    |
| 5                           | 12.57 | 3.85  | 3.27    |
| >6                          | 12.09 | 3.62  | 3.34    |

| Age of the head of household | IDF   | SDF   | IDF/SDF |
|-------------------------------|-------|-------|---------|
| <20                           | 8.35  | 2.48  | 3.37    |
| 20–29                         | 10.01 | 3.24  | 3.09    |
| 30–39                         | 11.40 | 3.74  | 3.05    |
| 40–49                         | 12.79 | 4.29  | 2.98    |
| 50–59                         | 13.33 | 4.05  | 3.29    |
| 60–69                         | 14.67 | 4.65  | 3.15    |
| 69<                          | 12.74 | 3.93  | 3.24    |

| Site of residence             | IDF   | SDF   | IDF/SDF |
|-------------------------------|-------|-------|---------|
| 11 big cities                 | 12.63 | 3.91  | 3.23    |
| population >150,000           | 12.93 | 3.95  | 3.27    |
| population 150,000–50,000     | 13.01 | 3.98  | 3.27    |
| population <50,000            | 13.20 | 3.92  | 3.37    |
| smaller town, village         | 13.12 | 3.96  | 3.31    |

| Vocation of the head of household | IDF   | SDF   | IDF/SDF |
|-----------------------------------|-------|-------|---------|
| full-time farmer                  | 14.49 | 4.20  | 3.45    |
| city worker                       | 12.87 | 3.96  | 3.25    |

Table 4. IDF and SDF intakes of 60 healthy individuals.

| Average intake | 1st experimental week | 3rd experimental week | 5th experimental week | 7th experimental week |
|----------------|------------------------|------------------------|------------------------|------------------------|
| IDF*           | 11.26±2.55             | 10.70±2.18             | 10.76±2.43             | 10.29±2.25             |
| SDF*           | 3.42±0.90              | 3.26±0.77              | 3.33±0.88              | 3.17±0.92              |
| IDF/SDF ratio* | 3.36±0.56              | 3.32±0.40              | 3.30±0.53              | 3.34±0.57              |
| Maximum        | 4.98                   | 4.28                   | 5.11                   | 5.13                   |
| Minimum        | 2.45                   | 2.63                   | 2.25                   | 2.25                   |

*Results are M±SD for 60 individuals.
account simultaneously, and the IDF/SDF intake ratio itself might show, as shown in the teenagers result, a trend to choose rice and some other food groups of higher IDF content than just a preference for the traditional dishes.

The authors are grateful for the collaboration of Drs. Manzo Nagahama and Shin Ito when they were the members of the association. Part of this work was accomplished by the Japan Association of Prefectural and Municipal Public Health Institutes as a contrast research of the Japan Health Promotion and Fitness Foundation.

REFERENCES

1) Pilch, S. M. (ed.) (1987): Physiological Effects and Health Consequences of Dietary Fiber, Life Science Research Office, Federation of American Societies for Experimental Biology, Bethesda, MD, pp. 159–164.

2) Dreher, M. L. (1987): Handbook of Dietary Fiber, Marcel Dekker, N.Y. and Basel, pp. 241–255.

3) Nishimune, T., Yakushiji, T., Sumimoto, T., Taguchi, S., Konishi, Y., Nakahara, S., Ichikawa, T., and Kunita, N. (1991): Glycemic response and fiber content of some foods. Am. J. Clin. Nutr., 54, 414–419.

4) Prosky, L., Asp, N., Schweizer, T., Devries, J. W., and Furda, I. (1988): Determination of insoluble, soluble, and total dietary fiber in foods and food products: interlaboratory study. J.A.O.A.C., 71, 1017–1023.

5) Lee, C. S., Prosky, L., and De Vries, J. W. (1992): Determination of total, soluble, and insoluble dietary fiber in foods- enzymatic-gravimetric methods, MES-TRIS buffer: collaborative study. J.A.O.A.C., 75, 395–416.

6) Nishimune, T., Sumimoto, T., Yakushiji, T., Kunita, N., Ichikawa, T., Deguchi, M., and Nakahara, S. (1991): Determination of total dietary fiber in Japanese foods. J.A.O.A.C., 74, 350–359.

7) Resources Council, Science & Technology Agency, Japan (1992): Standard Tables of Food Composition in Japan—Dietary Fiber—.

8) Health Promotion and Nutrition Div., Health Service Bureau, Min. Health and Welfare (supervised), Current Nutritional Status of the Nation (1951–1990), Daiichi Publishing, Tokyo.

9) Nishimune, T., Sumimoto, T., Konishi, Y., Yakushiji, T., Komachi, Y., Mitsuhashi, Y., Nakayama, I., Okazaki, K., Tsuda, T., Ichihashi, A., Adachi, T., Imanaka, M., Kirigaya, T., Ushio, H., Kasuga, Y., Saeki, K., Yamamoto, Y., Ichikawa, T., Nakahara, S., and Oda, S. (1993): Dietary fiber intake of Japanese younger generations and the recommended daily allowance. J. Nutr. Sci. Vitaminol., 39, 263–278.