

Amino acid and fatty acid profiles of the average Japanese diet: Fusion of the National Health and Nutrition Examination Survey and the Food Composition Database

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ABSTRACT

Objectives: Dietary assessment requires standards, but for the correct evaluation and understanding, not only quantity but also quality; source information is essential. In particular, protein and fat, the major nutrients in the diet, are important to consider from a focused perspective because their constituent amino acids (AA) and fatty acids (FA) themselves are associated with various outcomes. Therefore, we utilized the average nutrient intake data of the Japanese population to construct a profile of the current dietary intake of AA and FA.

Methods: We used daily dietary survey data of approximately 6,000 men and women from the Japanese National Health and Nutrition Survey 2019. The estimated AA and FA intakes of actual diets were calculated by tying the Japanese Food Composition Table, seventh Revision, to approximately 1,500 foods in the food group table, for which inputs are published by category and multiplied by the intake.

Results: Of the 18 total AA, rice, pork, and beef contributed the highest percentage of intake in that order, which were similar for the individual AA. On the other hand, for a total of 47 FA, vegetable oil, pork, and beef were the highest contributors in that order, but the contribution profiles differed among the individuals' FA. The Japanese had the highest intake of 18:1 total among 47 FA types.

Conclusions: This study clarified the dietary AA and FA profiles of the current average Japanese diet based on the simultaneous assessment of quality and quantity and tied it to the amount and source of intake.

1. Introduction

When assessing a diet, we can consider it in terms of foods and nutrients, but to properly understand and assess it, we need to understand and evaluate these in a layered approach. For example, the major nutrients that comprise the diet, protein, and fat, are not single nutrients but carriers of many essential nutrients. Moreover, different sources of these nutrients cause marked differences in the composition of their constituent units, amino acids (AA) and fatty acids (FA), and metabolic pathways [1–3].

Evidence is needed to construct indicators, but studies have yet to capture a population's diet in AA and FA units. For example, the National Health and Nutrition Survey (NHNS), conducted annually by the Ministry of Health, Labour and Welfare (MHLW), is an epidemiological survey of a nationwide Japanese population and provides data on average dietary intake. Nevertheless, the component items in the published data are classified up to macronutrients and micronutrients by food group, not from the AA and FA perspective.

Along with the quantity of intake, it is also essential to understand what each nutrient is obtained from and the quality; source information

Abbreviations: AA, amino acids; ALA, 18:3 n-3 (Alpha-linolenic acid); **Category**, Table of Food Category of NHNS; CAT, category; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; FA, fatty acids; FAME, fatty acid methyl ester; JFCT, Japanese Food Composition Tables; LA, 18:2 n-6 (Linoleic acid); MUFA, monounsaturated fatty acids; NHNS, National Health and Nutrition Survey; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids; SUB, subcategory; SUBS, sub-sub category; TAA, total amino acids; TFA, total fatty acids; %E, %energy.

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is also necessary to understand dietary assessment correctly. Traditionally, nutrition research has taken a reductionist perspective focusing on single nutrients or specific foods. However, a shift to a dietary-food-nutrient layered approach has been recommended recently, as it may miss the influence of other components or foods [4–6]. For example, the market for animal-derived to plant-derived alternatives has expanded over the past few years [7,8]. Still, these products have a different nutrient composition than existing foods, and the nutritional benefits of substitution as part of a healthy diet still need to be discovered [8–10]. In other words, the intake source information may be essential when considering the effects of nutrients.

Therefore, this study aimed to construct a dietary AA and FA profile with access to intake source data by utilizing existing epidemiological survey data, NHNS, and to clarify the Japanese population's current dietary AA and FA average values. In addition, we utilized this profile to unravel the characteristics of the current Japanese diet from the perspectives of AA and FA.

2. Methods

This study employed the dietary intake data NHNS2019 for analysis subject. In addition, the Japanese Food Composition Tables (JFCT)2020 seventh and eighth revisions (Ishiyaku Co.) were used to link AA and FA data of foods to calculate AA and FA intakes.

2.1. Data source, study sample, and setting

NHNS is an annual cross-sectional survey conducted in November. However, the 2020 and 2021 surveys were canceled due to COVID-19, so the 2019 data was the most recent. This study adopted the “Nutrient Intakes by Food category – Food Category, Nutrient, Intake-Total, 20 years and older (g, average/person, day)” from NHNS 2019 Nutrient Intake Status Survey results. Other papers have already described NHNS [11]. Briefly, of the units established in the Comprehensive Survey of Living Conditions (approximately 60,000 households within 146,000 household members), 300 units were randomly sampled. There were 5,032 NHNS 2019 eligible households, of which 3,268 (64.9%) participated. A total of 3,260 males and 3,666 females participated in the nutrition intake survey, of which 2,663 males and 3,080 females were aged 20 years or older.

NHNS 2019 was conducted on a single arbitrary day during November 2019, excluding Sundays and holidays and dietary intake data from one day of weighed household food records. After reviewing the survey records, trained surveyors entered the dietary intake data according to the NHNS manual. Nutrient intake was calculated using JFCT 2015 (seventh revisions, supplementary 2016, 2017, and 2018). NHNS is designed to survey the actual intake from a diet. If the weight recorded in the survey was after cooking, JFCT 2015 post-cooking component values (boiled, boiled, and baked) for each food were used; if the weight was before cooking, the calculated values were used with the percentage weight change described in JFCT 2015 weight. NHNS does not consider nutritional supplements. The food intake data were recorded, collected, and classified according to the Table of Food Category of NHNS (Category), and the results were published. Category classifies foods into 1–17 categories (CAT), 1–33 subcategories (SUB), and 1–98 sub-subcategories (SUBS).

2.2. Calculation of intake of AA and FA

The minimum unit of food classification in NHNS nutrient intake data is the SUBS in Category. However, the composition value data in the AA and FA composition table in JFCT is per-food. Therefore, foods in JFCT corresponding to each SUBS in Category were selected, and estimated value intakes of AA and FA were calculated for each SUBS. In principle, JFCT 2020 seventh was used, but foods not listed were selected from 2020 eighth. This study created a dataset with food

selection by AA and FA to maximize the number of adopted foods. Table 1 details employed 18 AA and 47 FA. JFCT-listed values include measured, unmeasured, Tr (trace), estimated values, and no data (JFCT-listed food but no entry in the AA and FA ingredient tables). Estimated values and Tr were adopted, and for unmeasured and no-data, if measured and estimated data were available in 2020 eighth, 2020 eighth data were adopted. If not, rules were established and selected (Suppl. Table 1). Since NHNS surveys and records the weight of the food at the stage it enters the mouth, one food may possess multiple preparation forms in SUBS. It is well known that the nutritional value of the same food may vary depending on the method of preparation. However, individual food intakes are not published for estimating AA and FA intakes. Therefore, in this study, AA and FA intakes were estimated by employing the maximum number of foods listed in the Category in accordance with the NHNS. After preparing AA and FA datasets, the average value of each nutrient was calculated from the composition value data of the selected foods in each SUBS, and the estimated representative value (/100 g) was calculated. Then, multiplied by each SUBS intake (g) in NHNS, the estimated mean intake (/person, daily) for each SUBS was determined and adjusted (/1,000 kcal).

In this study, not all foods listed in CAT were used but were selected according to the availability of food items and AA and FA data, thus confirming the validity of the published NHNS 2019 results and the calculated estimated intake. SUBS with a difference of more than 1% of the estimated total intake from NHNS2019 were extracted by protein (g) values in the AA data set and either fat (g) or fat (g) and n-6 FA (g), fat (g) and n-3 FA (g), or n-6 and n-3 FA (g) in the FA data set. The extracted SUBS was again calculated as estimated intake, considering food intake referring to the food intake frequency and intake result data from the survey report conducted by the MHLW in 2010 [12].

2.3. Data statistics and analysis

Hierarchical clustering was conducted using the average distance

Table 1
Assessment items (amino acid and fatty acid).

Amino acid ^{*1}	Essential amino acid	Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan, Valine
	Non-essential amino acid	Arginine, Cysteine, Glycine, Proline, Tyrosine, Alanine, Aspartic acid, Glutamic acid, Serine
Fatty acid	SFA ^{*2}	4:0, 6:0, 7:0, 8:0, 10:0, 12:0, 13:0, 14:0, 15:0, 15:0 ant, 16:0, 16:0 iso, 17:0, 17:0 ant, 18:0, 20:0, 22:0, 24:0
	MUFA	10:1, 14:1, 15:1, 16:1, 17:1, 18:1 total ^{*3} , 20:1, 22:1, 24:1
	PUFA n-6	18:2 n-6, 18:3 n-6, 20:2 n-6, 20:3 n-6, 20:4 n-6, 22:4 n-6, 22:5 n-6
	PUFA n-3	18:3 n-6, 18:4 n-6, 20:3 n-6, 20:5 n-6, 21:5 n-6, 22:5 n-6, 22:6 n-3
	PUFA others	16:2, 16:3, 16:4, 22:2
	Unidentified substances	

^{*1}: amino acids, which constitute one protein, include Asparagine and Glutamine, but since Asparagine and Glutamine cannot be distinguished from Aspartic acid and Glutamic acid in the measurement process, they are included in Aspartic acid and Glutamic acid, respectively, in the Food Composition Table. This study follows the method used in the Food Composition Table.

^{*2}: 15:0 ant, 16:0 iso, and 17:0 ant are branched-chain fatty acids found in dairy products.

^{*3}: 18:1 total includes oleic acid, positional and geometric isomers besides oleic acid. In the fifth Edition Fatty Acid Composition Table, these were listed as “oleic acid”, but in the seventh Edition, they are listed as “18:1 total”, and foods newly analyzed for 18:1 n-9 and 18:1 n-7 are listed with their respective component values and total values. In this study, however, only 18:1 total was collected because all food data are not listed (Japan, Standard Food Composition Table 2015 seventh Edition Fatty Acid Composition Table, Chapter 1 explanation).

agglomerative method to determine the association between consumed AA and FA and the 98 SUBS that were the intake source. Analysis was performed using the web platform 'MetaboAnalyst 5.0' (<https://www.metaboanalyst.ca/>). The X-axis shows 98 SUBS, the Y-axis shows 18 AA and 47 FA, and the output of the hierarchical clustering was visualized in a dendrogram and heatmap.

3. Results

3.1. Details of AA and FA datasets

This study created food items for which AA and FA data were available or estimable employed to the maximum possible extent from CAT, and datasets for AA and FA, respectively, were created. Suppl. Tables 2 and 3 detail the number of foods employed. A total of 1,462 food items were available in the AA dataset and 1,580 in the FA dataset. We used the Category of NHNS as classification, but the available data were for each CAT, not for each food unit in each SUBS, and it could not consider the contribution of each food product. However, the validity of our estimates and NHNS results, calculated regarding the results of previous studies, was less than a 5% error for all SUBS in the AA and FA datasets.

3.2. Estimated intake by SUBS of category

The estimated total amino acids (TAA) intake by the 98 SUBS of Category (mg/1,000 kcal) and the contribution percentage (%) of 17 CAT to the estimated TAA intake are shown in Fig. 1-a and 2-a, respectively. Of the 98 SUBS, estimated TAA intakes were higher in the order of SUBS1 rice, SUBS62 pork, and SUBS61 beef (3,885, 3,860, and 2,995 mg/1,000 kcal), accounting for 10.4, 10.3, and 8.0% of the total, respectively. Of the 17 CAT, estimated TAA intakes were higher in the order of CAT11 meat, CAT1 grains, and CAT10 seafood (10,695, 7,406, and 5,998 mg/1,000 kcal), accounting for 28.5, 19.7, and 16.0% to the total, respectively, and these top three categories for 64.2% to TAA.

The estimated total fatty acids (TFA) intake by the 98 SUBS of Category (mg/1,000 kcal) and the contribution percentage (%) of 17 CAT to the estimated TFA intake are shown in Fig. 1-b and 2-b, respectively. Of the 98 SUBS, estimated TFA intakes were higher in the order of SUBS78 vegetable oil, SUBS62 pork, and SUBS61 beef (3,930, 3,113, 1,644 mg/1,000 kcal), accounting for 15.1, 12.0, and 6.3%, respectively. Of the SUBS78 vegetable oil, vegetable oil and blend accounted for 84.5%, with olive oil, sesame oil, and canola oil accounting for 5.0, 4.6, and 3.4% of the total, respectively (data not shown). Of the 17 CAT, estimated TFA intake was higher in the order CAT11 meat, and CAT14 fats and oils accounted for 29.5 and 18.4%, respectively, followed by CAT17 seasonings and spices, CAT13 dairy, CAT4 beans, CAT1 grains, and CAT10 seafood with 8.1, 7.8, 7.7, 7.5, and 7.0%, respectively. As for estimated TFA intake of CAT14 fats and oils, SUBS78 vegetable oil accounted for 82.3%, with SUBS76 butter, SUBS77 margarine, and SUBS79 animal oil accounted for 8.5, 7.4, and 1.8%, respectively (results not shown). The estimated TFA intake was 23.4% energy (%E), and the %E of saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) were 7.7, 9.6, and 5.9%E, respectively. The n-6/n-3 ratio was 4.6 (data not shown).

3.3. Estimated intake by 18 AA and 47 FA

Fig. 3-a and 4-a show the estimated intake by AA (mg/1,000 kcal) and the contribution percentage (%) of 17 CAT to the estimated intake by TAA. Of the 18 AA, estimated intakes were higher in glutamic acid, aspartic acid, and leucine (7,073, 3,524, and 2,930 mg/1,000 kcal), accounting for 18.8, 9.4 and 7.8% of the total, respectively (Fig. 3-a). In Fig. 4-a, proline, glutamic acid, and cysteine contributed most by CAT1 grains, while CAT11 meat contributed the most to the other 15 types.

Details of the contribution rates differ, but the top three intake sources for all 18 types consisted of CAT1 grains, CAT10 seafood, and CAT11 meat. Also, detailed contribution rates for each of the 17 individual CAT in each AA differed. However, the overall intake source profiles tended to be similar. In methionine and alanine, the rates of CAT4 beans are low, 4.8 and 6.9%, respectively, but maintained consistent contribution rates between 7.4 and 10.9% in the other AA (data not shown).

Estimated intakes (mg/1,000 kcal) for each of the contribution percentage (%) of CAT to the estimated intake by the 47 FA, SFA, MUFA, PUFA, PUFA n-6, and n-3 are shown in Fig. 3-b, 4-b, and 5-ae. Estimated FA intakes were higher in the order of 18:1 total, 18:2 n-6 (Linoleic acid, LA), and 16:0 (9,713, 5,164, and 5,068 mg/1,000 kcal), accounting for 37.3, 19.9, and 19.5% to the total, respectively, and these top three categories for 76.7% to the total (Fig. 3-b). In contrast to AA, the CAT contribution profiles for each FA had characteristics for each FA.

SFA accounted for 35.5% of CAT11 meat and 15.2% of CAT13 dairy, with these top two categories supplying about 50% of the SFA total (Fig. 5-a). In Fig. 4-b, the contribution of CAT13 dairy is more than 50% in 4:0, 6:0, 10:0, 13:0, 15:0 ant, 16:0 iso, and 17:0 ant. 16:0, the highest intake in SFA, 18:0, the second highest intake, and 17:0 had the highest CAT11 meat contribution, followed by CAT13 dairy and CAT14 fats and oils. 20:0, 22:0, and 24:0 had the highest contribution from CAT14 fats and oils (29.1, 30.9, and 32.1%) and CAT4 beans (9.2, 14.1, and 6.7%). MUFA accounted for 35.9% of CAT10 meat and 19.8% of CAT14 fats and oils, with the top two categories accounting for more than 50% of the MUFA total, followed by CAT17 seasonings and spices, CAT12 eggs, CAT10 seafood, CAT13 dairy, CAT1 grains, and CAT4 beans at 8.2, 7.1, 6.6, 5.8, 5.4, and 5.1%, respectively (Fig. 5-b). 18:1 total, accounting for 91.0% of the MUFA, were CAT11 meat and CAT14 fats and oils for 34.8% and 21.2% of the MUFA total, respectively. CAT17 seasonings and spices and CAT12 eggs followed with 8.7 and 7.3% of the total. 20:1, 22:1, and 24:1 had the highest contribution from CAT10 seafood, accounting for 47.5, 93.3, and 73.1%, respectively (Fig. 4-b). In PUFA, CAT14 fats and oils and CAT4 beans accounted for 26.9 and 17.4%, followed by CAT11 meat, CAT17 seasonings and spices, CAT10 seafood, and CAT1 grains at 12.4, 12.3, 8.8, and 8.3%, respectively (Fig. 5-c). PUFA n-6, which constituted 81.9% of PUFA, accounted for 27.8 and 18.4% of CAT14 fats and oils and CAT4 beans, followed by CAT11 meat, CAT17 seasonings and spices, and CAT1 grains at 14.2, 12.6, and 9.5%, respectively. LA, which accounted for 97.0% of PUFA n-6, CAT14 fats and oils, CAT4 beans, CAT11 meat, and CAT17 seasonings and spices, accounted for 27.8, 18.4, and 14.3%, in that order. 18:3 n-3 (Alpha-linolenic acid, ALA), which accounted for 64.2% of the PUFA n-3, CAT14 fats and oils, CAT4 beans, and CAT17 seasonings and spices accounted for 36.1, 20.1, and 17.2%, respectively. All the other PUFA n-3 were CAT10 seafood, which accounted for more than 90% of the total. 20:5 n-3 (eicosapentaenoic acid, EPA) and 22:6 n-3 (docosahexaenoic acid, DHA) were CAT10 seafood with 94.8 and 90.7%, respectively, the latter followed by CAT12 eggs, which accounted for 6.4%.

3.4. Heatmap analysis for 18 AA and 47 FA, and 98 SUBS

The heatmap depicts the relative strength of the associations. In a heatmap, the color variations may be by hue or intensity, indicating how clustered they are and visualizing the relative patterns of high-abundance SUBS against a background of SUBS primarily low-abundance or absent. The heatmap analysis constructed double dendrograms, dendrogram 1 in the vertical direction, the cluster of AA and FA, and dendrogram 2 in the horizontal direction representing SUBS that influenced this diffusion (Fig. 6).

Dendrogram 1 showed the two major groups. The SUBS with high AA and FA intake contribution percentages belonged to cluster (a), while the SUBS with low contribution percentages belonged to cluster (b). 15:1, 20:1, 22:1, 24:1, PUFA n-3 except for ALA (18:4 n-3, 20:4 n-3, EPA, 21:5 n-3, 22:5 n-3 (docosapentaenoic acid, DPA), and DHA), and PUFA others (16:2, 16:3, 16:4, and 22:2) belonged to cluster (a). These FA

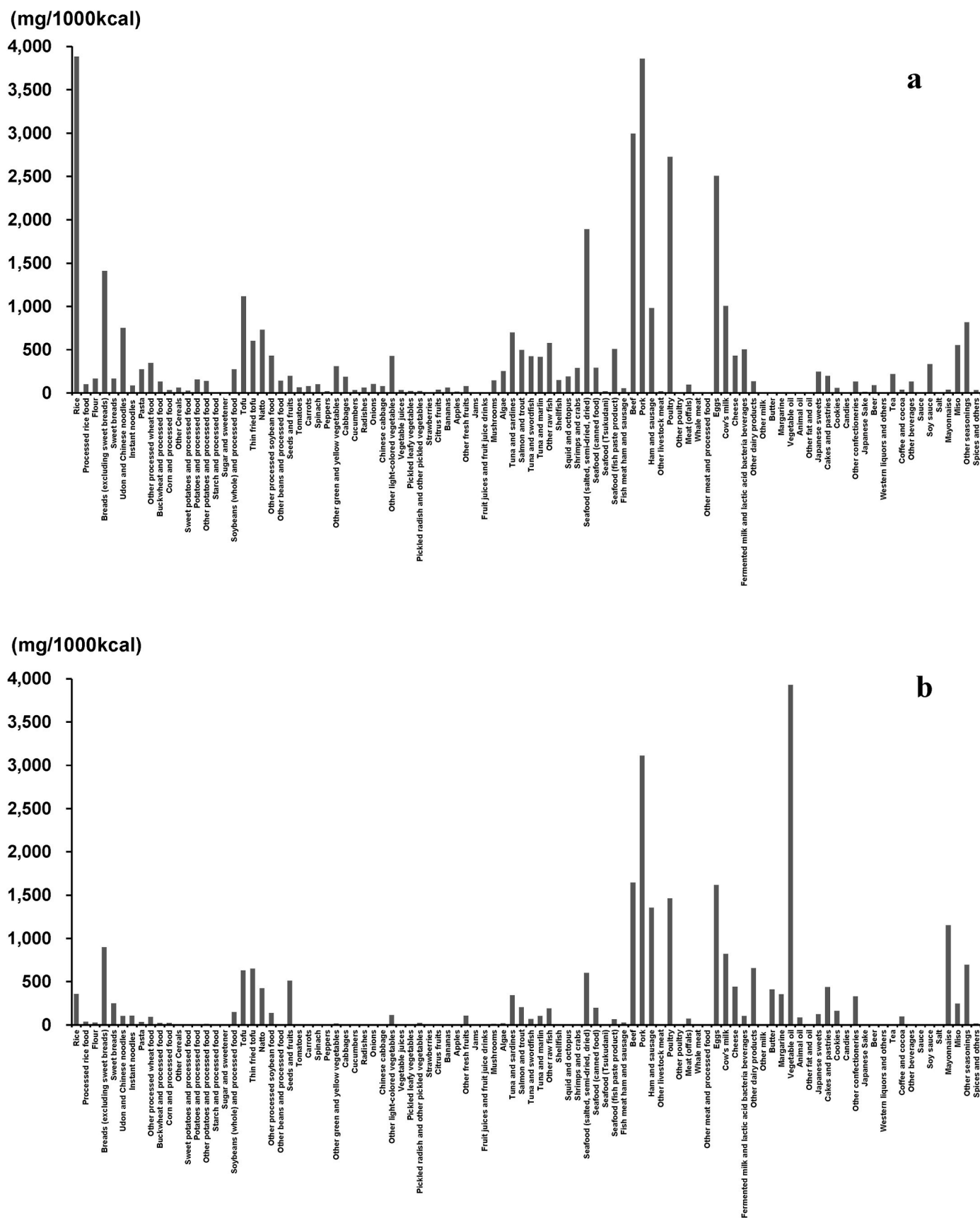


Fig. 1. Estimated total amino acids (a) and fatty acids (B) intake by sub-subcategories (total number of men and women 20 years and over).

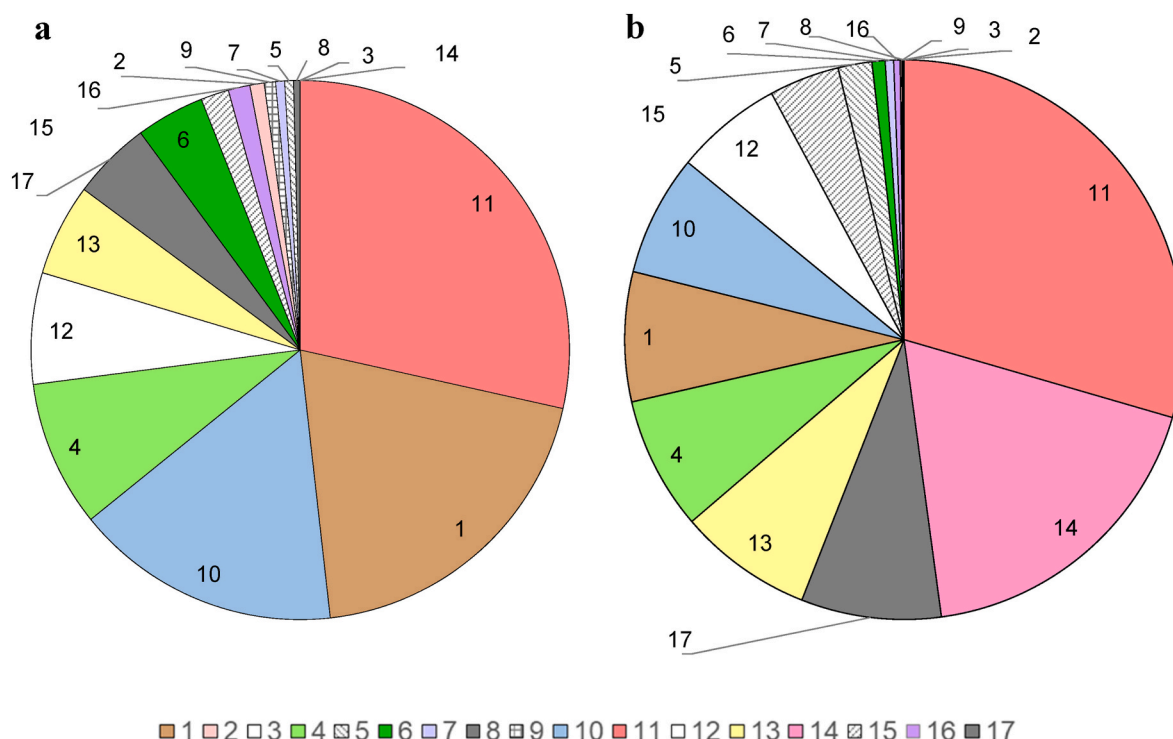


Fig. 2. Contribution (%) of the 17 Categories in the Table of Food Category to the estimated amino acids (a) and fatty acids (b) intake.

Mean intakes from the category contributing to the estimated total amino and fatty acids intakes are displayed. (CAT1 grains, CAT2 potatoes, CAT3 sugar and sweetener, CAT4 beans, CAT5 seeds and fruits, CAT6 vegetables, CAT7 fruits, CAT8 mushrooms, CAT9 algae, CAT10 seafood, CAT11 meat, CAT12 eggs, CAT13 dairy, CAT14 fats and oils, CAT15 confectionary, CAT16 beverages, CAT17 seasonings and spices).

recorded higher values for SUBS48 tuna and sardines and SUBS56 seafood (salted, semi-dried, and dried). Cluster (b) showed the two sub-clusters; all AA belonged to cluster (c). As for AA, SUBS65 chicken, SUBS62 pork, SUBS61 beef, and SUBS1 rice recorded higher values and lower than these, followed by SUBS56 seafood (salted, semi-dried, and dried), which was higher than the other SUBS. Even though there were some differences in the degree of shading, the 18 AA was relatively high in their SUBS with high AA intake contribution rates. It was different from the FA clustered in the first layer. All FA except those that belonged to cluster (a) was recorded in cluster (d), 20:0, LA, ALA, 22:0, and 24:0 belonged to cluster (e). These FA recorded higher values for SUBS78 vegetable oil, SUBS95 mayonnaise, SUBS20 fried Tofu, and SUBS19 Tofu also recorded higher values than the other SUBS. 10:0, 12:0, 14:0, 15:0, 10:1, 18:3 n-6, and unidentified substance belonged to cluster (f). Most FA recorded higher values for SUBS71 cow's milk, SUBS72 cheese, SUBS75 other dairy products, and SUBS76 butter. 16:0, 17:0, 18:0, 14:1, 17:1, 18:1 total, 20:2 n-6, 20:3 n-6, 20:4 n-6, 22:4 n-6, and 22:5 n-6 belonged to cluster (g). Most FA recorded higher values for SUBS61 beef, SUBS62 pork, and SUBS65 chicken. 16:0, 18:0, and 18:1 total recorded higher value for SUBS78 vegetable oil, especially 18:1 total, the highest of the 98 SUBS.

4. Discussion

The highest intake contribution rates in the estimated TAA were CAT11 meat, CAT1 grains, CAT10 seafood, and CAT4 beans. It is consistent with various countries' reports [13,14] that the top protein sources indicated meat and grains as significant [15]. Nevertheless, compared to studies conducted in other countries, the contribution rate of meat was low, and that of grains was high in the Japanese population. Even within the same food category name, the contribution rate and the types of food differed. Also, the prominent grains consumed by the Japanese were rice rather than wheat products, as the primary source in many other countries. In general, grains, including rice, are recognized

as a source of carbohydrate intake despite their protein content [15], and a recent review of food-based dietary guidelines in 90 countries [16] also did not mention grains as a source of protein. However, reflecting both quantity and quality, the intake of CAT 1 grains was second only to CAT 11 meat, indicating that grains are a significant contributor to AA intake sources in the Japanese diet. Another unique feature was the third-highest TAA intake contribution from seafood compared to other country populations.

The fourth contribution was CAT4 beans, with 98% of the intake consisting of soybeans and soybean products from SUBS18-22, which included soybeans, Tofu, fried Tofu, and Natto. Asian countries have consumed soybeans for a long time, and the Japanese are one of the groups that consume large amounts of soybeans [17]. It may be one of the characteristics of the Japanese diet that protein intake from plant-based foods such as rice and soy products is high, followed by meat. TAA source profiles, and each AA source profile, were similar, with no significant differences among the individual AA, even though detailed contribution rates differed among the AA. While the source profile of a single AA or the AA profile of a single food may have its characteristics, the food intake itself may influence the overall dietary AA source profile.

The high intake contribution rates in SFA were CAT 11 meat and CAT13 dairy, accounting for more than 50% of the total. The results of meat and dairy as the primary sources of SFA are like studies on Japanese schoolchildren [18] and previous reports from other countries [19, 20]. On the other hand, the contribution of CAT14 fats and oils and CAT1 grains is lower than those reported, which can probably result from the fact that the staple food of the Japanese is rice, which has a low-fat content. In Western countries, bread, cereals, cakes, biscuits, and pies, to which fats and oils are added during processing [21], are primary staple foods, but according to NHNS 2019, Japanese rice intake was 293.1 g, white bread, cakes, pastries, and biscuits were 47.4 g in total. Regarding fats and oils, the Japanese had a low intake of animal fats and oils, such as butter and lard, which have high SFA ratios

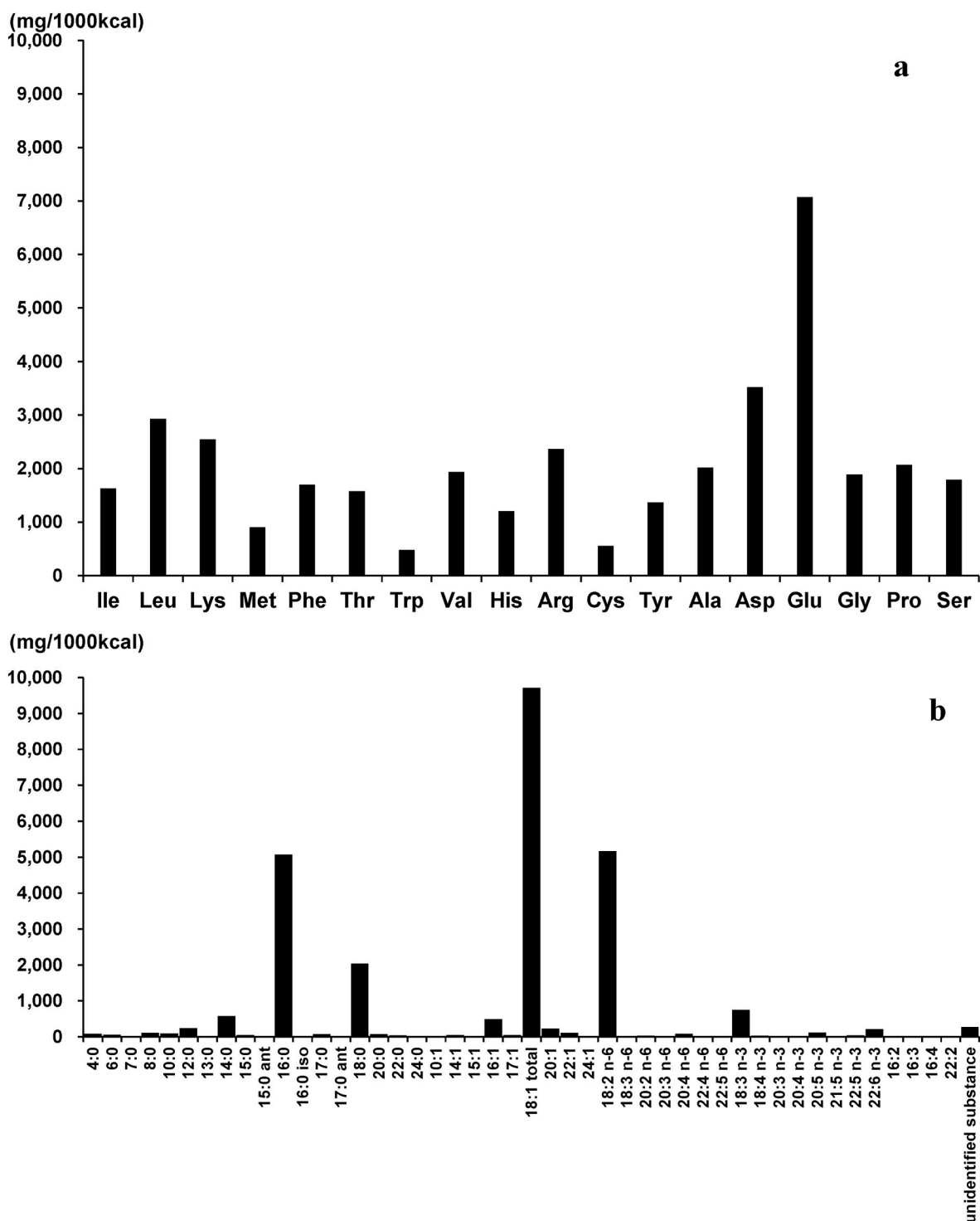


Fig. 3. Estimated intakes of 18 amino acids (a) and 47 fatty acids (b) (total number of men and women 20 years and over)

Histidine (His), Isoleucine (Iso), Leucine (Leu), Lysine (Lys), Methionine (Met), Phenylalanine (Phe), Threonine (Thr), Tryptophan (Trp), Valine (Val), Arginine (Arg), Cysteine (Cys), Glycine (Gly), Proline (Pro), Tyrosine (Tyr), Alanine (Ala), Aspartic acid (Asp), Glutamic acid (Glu), Serine (Ser).

(SUBS76 butter 1.2 and SUBS79 animal fat 0.2 g/day). There were similar food groups listed as sources of intake, but there were differences in food lineups and their rates within each group.

The 18:1 total, which accounted for 91.0% of the MUFA, had the highest intake of TFA. Given the focus on the high consumption of olive oil, the Mediterranean diet is well-known as a high MUFA diet [22], but the Japanese diet also has a high 18:1 total percentage. The high intake contribution rates in MUFA were CAT 11 meat and CAT14 fats and oils,

accounting for more than 50% of the MUFA total. In CAT14 fats and oils, SUBS78 vegetable oil had the highest intake (8.9 g/day), consistent with the results of the previous study referred to in this study [12]. There is a wide variety of vegetable oils, each with a specific FA profile [23]. For example, Mediterranean diets with high olive oil and MUFA (for the most part 18:1) content have higher MUFA%E. In contrast, diets from Indonesia and Cameroon, where higher SFA ratios of palm and coconut oil are the central edible fats and oils, have higher SFA%E [24,25].

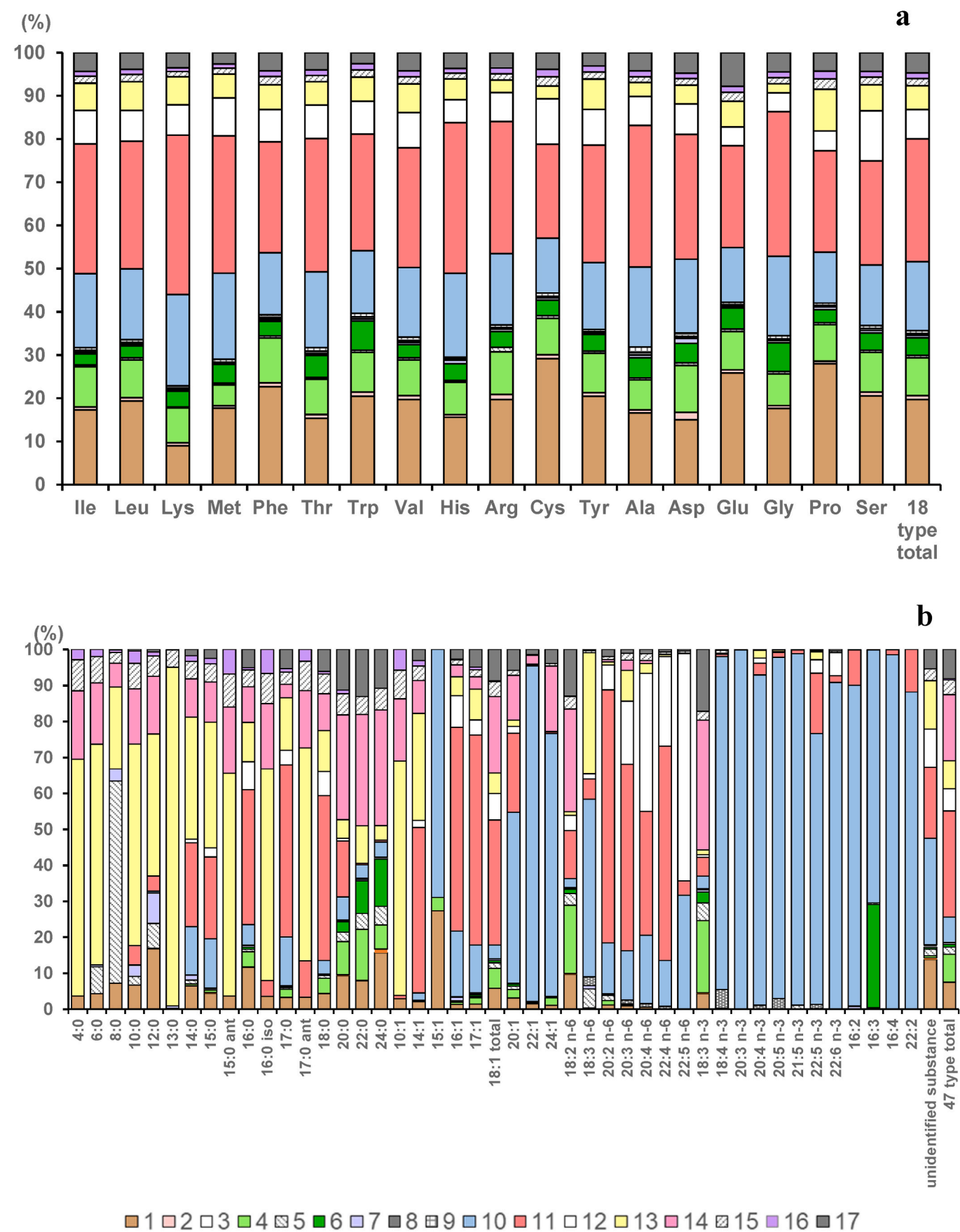


Fig. 4. Contribution (%) of the 17 Categories in the Food Category Table to the estimated amino acids (a) and fatty acids (b) intake.

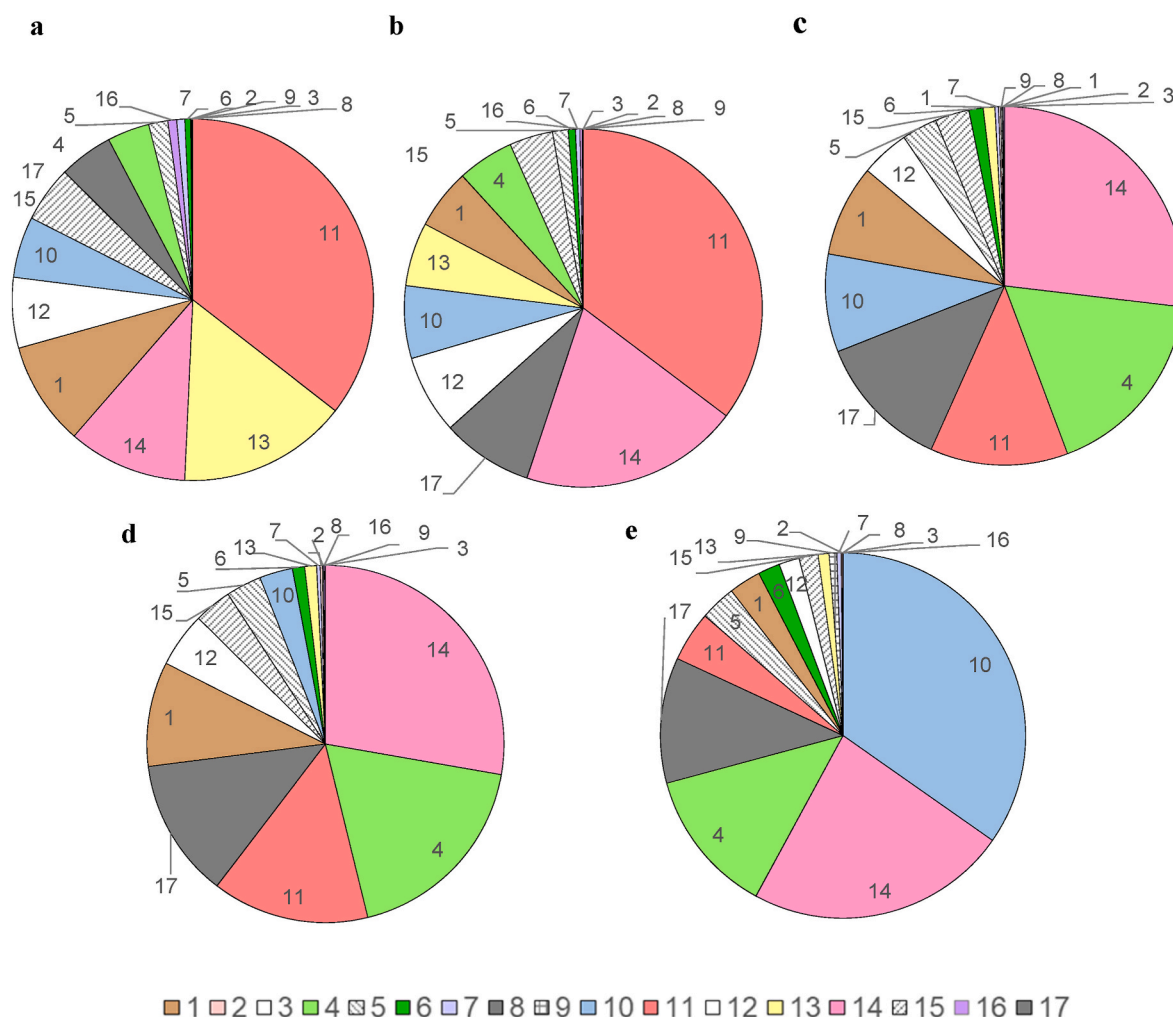


Fig. 5. Contribution (%) of the 17 Categories in the Food Category Table to the estimated amino acids and fatty acids intake.

a) SFA, b) MUFA, c) PUFA, d) PUFA n-6, e) PUFA n-3.

Significant Japanese vegetable oil, canola, and soybean oil are among the vegetable oils with MUFA as the major FA (63.3, 41.5%/FAME, fatty acid methyl ester) [23]. It is suggested that the high ratio of fats and oils in the MUFA intake source is related to the Japanese consumption of canola and soybean oil as edible fats. The MUFA%E was 9.6%E higher than SFA and PUFA, suggesting that the type of edible fats and oils may affect the TFA profile, as in other countries [25]. In the Japanese diet, the sources of MUFA are a variety of plant and animal foods. MUFA (principally 18:1) is FA found in various foods provided by plant and animal foods [26]. The study [27] that examined the ambiguous association between MUFA intake and chronic disease reported that differences in other components in foods may confound the association, caused by whether the source of MUFA intake is animal or vegetable, may confound the association. To properly understand diet and health, it is important to consider and identify the source of intake as well as the amount of intake [28] in a layered diet-food-nutrient approach [5,6].

The high intake contribution rates in LA were CAT 14 fats and oils and CAT4 beans, accounting for about 50%. It was similar to other country reports in that fats and oils were the primary sources [29,30], with the difference that beans were the second largest contributor along with fats and oils. Although vegetable oil consumption has been increasing worldwide in recent years, Japanese people have long used vegetable fats and oils (mainly soybean oil and canola oil) as their main edible fats and oils. Many vegetable oils are high in LA content; these two are no exception (40.9, 19.6%/FAME) [23]. However, the Japanese have a low n-6/n-3 ratio compared to the other countries [31]. This

result is probably due to soybeans, a source of PUFA n-6 intake, being rich in ALA, PUFA n-3, the n-6/n-3 balance of Japanese dietary oils, and the high seafood intake with high PUFA n-3 content. The high intake contribution rates in ALA were CAT14 fats and oils and CAT4 beans, accounting for more than 50%. The reports from Western countries indicate that the sources of ALA were fats and oils, meat, and grains [29, 30]. The difference between these results reflects the dietary characteristics of the Japanese who consume soybeans/soybean products. CAT4 beans include many fermented and unfermented foods such as soybeans/soybean products (Tofu, Natto, Okara, Abura-age, and Yuba), indicating that the Japanese have long consumed a wide variety of soybean products [32]. Soybeans, a plant-based food, recently attracted increasing attention as an alternative to animal foods; they are not only a source of protein but also an essential source of fat. On the other hand, there are differences between soy products consumed in Asia and those commonly distributed in the US [17]. Therefore, it suggests that increases or decreases in soy product intake may also affect the dietary FA profile, even if it is unclear whether this affects the FA composition.

Many studies have reported that seafood is the primary source of EPA, DPA, and DHA in PUFA n-3 other than ALA [33,34]. This study showed that not only EPA and DHA but all PUFA n-3 except ALA were CAT10 seafood accounted for more than 90% of the intake sources. Seafood belongs to the same animal food category as meat, but they are completely different in terms of FA composition. Biologically, livestock animals: ruminants, and monogastric animals have high SFA and MUFA proportions [35], whereas seafood has a high PUFA proportion relative



Human rights

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This study does not involve human participants and informed consent was therefore not required.

The welfare of animals

This article does not contain any studies with animals performed by any of the authors.

Authorship

AT and HYO contributed equally to this work. HYO designed the study; AT collected data samples and analyzed the data; HK, SY, and MO provided support.; KO, MM, and YT provided helpful comments about the study. All authors read and approved the final manuscript.

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CRediT authorship contribution statement

Ayari Tsumura: Data curation, Formal analysis, Investigation, Visualization, Writing – original draft. **Hisami Yamanaka-Okumura:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Hana Kawakami:** Investigation. **Shiori Yamamoto:** Investigation. **Mayu Oura:** Investigation. **Hirokazu Ohminami:** Writing – review & editing. **Masashi Masuda:** Writing – review & editing. **Yutaka Taketani:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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