Modelling Salt Intake Reduction with Umami Substance's Incorporation Into Japanese Foods: A Cross-Sectional Study

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Abstract

Background

Evidence has demonstrated that excess salt intake is associated with the development of several non-communicable diseases. Therefore, reformulating the sodium content of foods is an important global public health effort to achieve salt reduction and improve health. This study aimed to model sodium replacement with 'umami' substances and estimate the possible reduction effects of the umami substances on the daily salt intake among Japanese adults. The umami substances considered in this study include glutamate or monosodium glutamates (MSG), calcium diglutamate (CDG), inosinate, and guanylate.

Methods

A sample of 21,805 participants aged 57.8 years on average from the National Health and Nutrition Survey (NHNS) were used in the analysis. First, we employed a multivariable linear regression approach, with overall salt intake (g/day) as a dependent variable, adjusting for intake (g/day) from food items and other covariates, to estimate the contributions of each food item to daily salt intake. We then considered three hypothetical scenarios with varying market share percentages of umami substitute foods (30%, 60%, and 100%). We estimated the population-level salt reduction for each scenario, by age and gender, based on the contribution of each food to salt intake estimated by the regression model and the estimated salt reduction rates by food item based on an extensive literature review. Under the 100% scenario, the achievement rates for national and global dietary goals of salt intake in the Japanese population were also calculated.

Results

Without compromising the taste, the universal incorporation of umami substances can reduce the salt intake of adult Japanese persons by 12.0-21.1% in the population level, which is equivalent to 1.27-2.22g of salt reduction. A mean daily salt intake before and after scenario in universal umami substance's incorporation changes from 9.95g to 7.73g for the total population, from 10.83g to 8.40g for men and from 9.21g to 7.17g for women, respectively. Approximately 60% of Japanese adults could achieve the national dietary goal of 8g/day, while only 7.6% could meet the global target of 5.0g/day.

Conclusions

Our study provides essential information on the potential salt reduction from sodium replacement with alternatives. The universal incorporation of umami substances into some foods could achieve the national dietary goals for the Japanese. However, the reduced salt intake level still falls short of the global dietary recommendation of 5g of salt daily.

Background

The latest Global Burden of Disease Study 2019 (GBD) highlighted that the global prevalence of non-communicable diseases (NCDs), as well as inadequate public health efforts to control preventable risk factors, may have spurred the pandemic of coronavirus disease 2019 (COVID-19)(1). In 2013, the World Health Organization (WHO) developed the NCDs Global Monitoring Framework, in which seven NCDs prevention targets were set(2). Of the seven goals, the only specific goal related to nutrients called for member countries to aim for a 30% reduction in salt intake between 2011 and 2025. Since then, many salt reduction campaigns have been initiated around the world(3), and the global

salt reduction movement has been accelerating(4–6), but no country has achieved that 30% reduction goal(7). In the GBD 2019, high salt intake was listed as one of the top dietary risks contributing to the global burden of disease due to NCDs (8) highlighting the need for an urgent approach.

Japan is one of the countries with the most prolonged longevity globally (9). However, a high salt intake is a major dietary risk factor for both mortality and morbidity of its population (8, 10). Japan's nationwide population-based campaign for salt reduction started in the 1960s and successfully reduced the population's salt intake and stroke mortality over time (11). According to the National Nutrition Survey (NNS) (renamed to the National Health and Nutrition Survey (NHNS) in 2013) revealed that the daily salt intake has steadily decreased from 14.5g in 1973 to 9.5g in 2017(12). However, Japanese regularly consume more salt than people in other countries (13). For instance, the population averages between 1990 and 2010 in the United Kingdom was 8.83-9.17g/day and 8.74-9.14g/day in the United States (US). The Japanese government aims to reduce the daily salt intake of Japanese adults to 8g by 2023 according to their 10-year national health promotion plan titled The Second Term of National Health Promotion Movement in the Twenty-First Century, also known as "Health Japan 21 (the second term)" (14). Another dietary guideline called the Dietary Reference Intakes for Japanese (DRIs), which was determined based on scientific findings to prevent lifestyle-related diseases and extend healthy life expectancy (15), recommends daily salt intake of 7.5g/day for men and 6.5g/day for women. However, the average salt intake for Japanese adults is higher than the recommendations made by both guidelines. The intake target set for the Japanese is unlikely to be attained if current conditions persist (16, 17).

Sodium replacement in foods is one of the most widely used approaches to reduce salt intake. The technical challenge is ensuring that the sodium alternative is palatable and safe to eat (18). Umami is a common and familiar taste in Japanese cuisine and is perhaps more known globally as the fifth flavour discovered by Japanese scientists in 1908, in addition to the classic four basic tastes, such as saltiness, sweetness, bitterness, and sourness (19). Umami substances, including glutamate or monosodium glutamates (MSG), calcium diglutamate (CDG), inosinate and guanilate have been proposed as enhancers of savory when combined with sodium chloride (NaCl) (20–22). A large number of studies have suggested the potential of using umami taste and substances as a healthy and natural solution for salt reduction (23–25). In recent years, academic institutions such as the Institute of Medicine in the United States have identified umami substances as candidates for practical salt reduction alternatives (18). Wallace et al. (2019) estimated that incorporating MSG into a savoury seasoning of processed foods in the United States could reduce the sodium intake by at least 3–8% in the population (26). However, given that the source of salt intake is highly dependent on the dietary habits and the cooking processes of each country (27), the effectiveness of the umami substances for reducing salt intake at the population level in the context of other cultures is not well known. Therefore, our study investigates the effects of umami substances substitution on the daily salt intake among Japanese adults using data from the nationwide dietary survey.

Methods

Study design and participants

We conducted a cross-sectional study using de-identified nationwide data from the 2016 NHNS. The NHNS is a nationally representative household survey conducted annually by the Japanese Ministry of Health, Labour and Welfare (MHLW) to collect data on the population's dietary habits, nutrition intake, and lifestyle (28). Residents from census enumeration areas above the age of one are selected using a stratified single-stage cluster sample design. The 2016 survey, the latest large-scale survey data available from the NHNS at the time of the study, encompasses 24,187 households from 475 randomly selected districts. The response rate of households was 44.4%. The NHNS

consists of three parts: 1) physical examination, 2) an in-person survey of a weighted single-day dietary record of households, and 3) a self-reported lifestyle questionnaire. Details of the survey design and the procedures used to collect the data are available elsewhere (16, 28). In the present analysis, we included persons older than 20 years old because of Health Japan 21's criteria that required those above the age of 20 to complete and provide the dietary intake data. We further excluded participants who consumed less than 1.5g of salt per day, which is equivalent to the minimum physiological requirement of sodium for survival, because their data may not reflect accurately on the daily diet or may be a measurement error.

This study was performed under the Declaration of Helsinki and approved by the Research Ethics Committee of the Graduate School of Medicine, The University of Tokyo (authorization number 11964). Furthermore, the ethical committee waived the need for informed consent because this study was a secondary analysis of anonymized data routinely collected by the MHLW.

Dietary assessment

The dietary intake survey was conducted on a single designated day by household representatives, who were usually responsible for food preparation. Trained interviewers, mainly registered dietitians, instructed household representatives on how to measure the food and beverages consumed by members of the household and verified their compliance with the survey. The proportion of shared dishes, food waste, and foods eaten out were also recorded. The nutrient intake and food consumption were estimated using the dietary record and the corresponding food composition list of the Japanese Standard Tables of Food Composition (29). In addition, food intake (g/day) and overall sodium intake (mg/d) were recorded. Salt equivalent intake (g) was defined as sodium (mg) $\times$ 2.54/1,000. NHNS did not measure urine sodium.

Salt intake modelling

According to an extensive review of the scientific literature, umami substances such as glutamate or MSG, CDG, inosinate, and gualilate have been used to reduce sodium levels among various mainstream products. Table1 shows the percentage of salt reduction by food group estimated by previous studies using one or more of these umami substances. The food groups listed in Table 1 were then matched with NHNS food categories in consultation with food and nutrition experts (co-authors). In addition, we assumed that the study's participants already consume a certain amount of low-sodium foods containing umami substances in their daily diet. Therefore, the market share of low-salt products was used as a proxy indicator of the baseline consumption of low-sodium foods with umami substances today (30). This market share was estimated from the total sales and the sales of low-sodium foods for 15 food groups based on surveys conducted in 2017 by Fuji Keizai Management Co., Ltd. (a Japanese market research company) among various food companies supplying food products in the country. Low-sodium food was defined as products labelled with reduced salt, salt cut, salt off, or no salt on the package. The market share of low-sodium products for each food group was also summarized in Table 1. Accordingly, our baseline scenario assumed that the consumers already had a certain amount of low-salt foods containing umami substances. We also considered three alternative scenarios in which consumers in food groups increased the intake of low-sodium food with umami substances from the baseline scenario to 30% (30-percent scenario), 60% (60-percent scenario), and 100% (100-percent scenario or universal incorporation scenario).

Statistical analysis

We first constructed a linear regression model with overall daily salt intake (g/day, continuous) as a dependent variable. To estimate the contribution to the overall salt intake from 13 selected food items (continuous), we included

age (continuous), sex (two groups), food intake (g/day) from the 13 items and other remaining 35 food groups or sub-groups (continuous) in the following model (1).

$$Y_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_{13} X_{13i} + Z_i \gamma + \epsilon_i \quad (1)$$

where Y_i and X_{ij} (for $j=1, \dots, 13$) are the overall daily salt intake and the food intake (g/day) from each of the 13 food items for the i th individual, respectively. Z_i is the covariate vector for the other remaining 35 items and sex and age for the i th individual. α, β_j, γ are regression coefficients and ϵ_i is a gaussian error term. The regression coefficients were estimated by ordinary least squared method.

The food-specific upper and lower changes in salt intake by umami substances incorporation were estimated using the current market share of low-sodium products for the j th selected item (denoted as M_j), the upper and lower sodium reduction rates for the j th selected food (denoted as U_j and L_j , respectively), as well as scenario-based increased consumption (denoted as $S_k = 30, 60$ or 100% increase ($k=1, 2, 3$)) as follows.

Upper changes in salt intake of the j th item under the k th scenario

$$= \hat{\beta}_j - \hat{\beta}_j \times U_j \times (S_k - M_j),$$

Lower changes in salt intake of the j th item under the k th scenario

$$= \hat{\beta}_j - \hat{\beta}_j \times L_j \times (S_k - M_j),$$

The first term indicated the original contributions of the j th item to the overall salt intake. In the second term, U_j indicates how much salt intake we can reduce by incorporating umami substances and $(S_k - M_j)$ indicates how much intake we can change to low-sodium products.

The baseline salt intake and reduced salt intakes for varying scenarios among consumers of each food were estimated by total population, men and women. The percentage-wise contributions of each food to total sodium intake in the diets for total population, men and women were also estimated.

The achievement rate for the dietary goals of salt intake when umami substances were universally incorporated into all selected food groups were then calculated by age groups and sex. Health Japan 21's dietary goal is defined as a mean daily salt intake of less than 8g (14), while the dietary goal laid down in DRIs is 7.5g of salt for males and 6.5g of salt for females (15). The WHO, on the other hand, recommends a daily salt intake of 5.0g (31). We used STATA version 16 for all analyses (Stata Corp LLC).

Results

A total of 30,820 people joined the NHNS survey in 2016. We excluded ineligible subjects who were less than 20 years old ($n=4,595$), had missing values on dietary intake ($n=4,374$), and consumed salt less than 1.5g per day ($n=46$), yielding a final analytic sample of 21,805 Japanese persons with an average age of 57.8 (standard deviation

[SD] 17.6 years. Overall, the daily mean salt intake among the Japanese population was 9.95g, which is more than the daily salt intake recommended by Health Japan 21, the DRIs, and the WHO.

The sex-specific and age-specific mean daily salt intake and the achievement rate of dietary goals are shown in Table 2. Across age groups, salt intake was likely to be higher among older persons than younger persons. Of the total population, 28.7% has already achieved the daily salt intake recommended by Health Japan 21 while 15.3% and 2.8% achieved the daily salt intake recommended by the DRIs and the WHO, respectively. Men had a higher salt intake than women in all age groups. The mean daily salt intake was the highest among men aged 60-69 years (11.43g) and women aged 70-79 years (9.72g), while the lowest mean daily salt intake was among those aged 20-29 years for both men (10.37g) and women (8.60g). The gap in mean daily salt intake between the highest and lowest groups was 2.83g. The achievement rate of dietary goals was higher in women than men across all age groups.

The sex-specific estimated salt intake and potential reduction of salt intake for each food group in three scenarios are presented in Table 3. The selected food groups consumed by participants on any given day during the survey varied. The percentages of those who consumed the selected foods (i.e., “consumers”) among the participants were high for other seasonings (97.9%), soy sauce (85.9%), seasoning salt (83.1%), and miso paste (69.3%), and conversely low for beef (24.71%), cheese (17.3%), butter (14.9%), margarine (14.4%), and other confectionery (15.2%). Compared to women, men were more likely to consume salt, soy sauce, spices and other, ham and sausage, beef, and pickled vegetable, but they also consumed less cheese and other confectionery. The consumers of soy sauce, seasoning salt, and miso paste took more than one gram of salt daily from one food group, and all participants consumed at least one food group.

In the universal incorporation scenario where consumers increased their intake of low-sodium foods replaced with umami substances up to 100%, the highest amount of expected salt reduction was soy sauce (0.45–0.68g), followed by cheese (0.28–0.51g), pickled vegetable (0.50g),

ham and sausage (0.11–0.49g), seasoning salt (0.23–0.44g), and miso paste (0.19–0.45g). Negligible reductions in salt intake can be expected for spice and others, beef, and other confectionery (< 0.1g).

Table 4 presents salt contributions from different foods to overall salt intake in the diet for all participants in the baseline scenario and potential reduction in salt intakes for all participants in the umami substance’s universal incorporation scenario by sex. In the baseline scenario, among all participants, soy sauce (12.5%), miso paste (9.7%), and seasoning salt (8.9%) contributed the most to overall daily salt intake. In contrast, spice and others, beef, cheese, butter, margarine, and other confectionery were minor sources of salt (<1%). Although cheese had a higher reduction in salt intake among the consumers (0.28–0.51g) in the universal umami substance's scenario, there was less impact at the population level (0.05–0.09g) because of few cheese consumers among the overall participants. The total mean daily salt intake from all selected foods was 5.06g for all participants in the baseline scenario, resulting in a 48.0% contribution to the overall salt intake. Thus, the universal incorporation of umami substances into all selected foods could reduce 12.7–2.22g of salt intake for the total population in all participants on average, resulting in a 12.0-21.1% reduction of salt intake.

Figure 1 compares sex and age groups-specific mean daily salt intake between baseline scenario universal umami substance’s incorporation scenario. Table 5 shows sex and age groups-specific potential salt intake after the universal incorporation of umami substances into all selected foods and their rate of achieving various dietary goals. While the salt intake still varied by sex and age group, the difference in the mean salt intake between the highest and lowest groups was slightly smaller. The potential mean daily salt intake in all participants after the

universal incorporation of umami substances was 7.73–8.68g; thereby, suggesting a possibility to achieve Health Japan 21's goal of consuming less than 8g of salt daily by 2023. In addition, the rate of those who achieved Health Japan 21 Japan's dietary goal increased from 19.6% to 31.2–46.6% for men and 36.9% to 53.6–70.8% for women. On the other hand, approximately 24.8–38.1% of men and 25.6–39.2% of women could achieve the recommended daily salt intake outlined by the DRIs after the universal incorporation of umami substances into all selected foods. However, only 2.2–3.8% of men and 6.4–10.8% of women were expected to achieve the WHO's dietary goal of 5g of salt daily, proving that the potential daily salt intake in even the most optimistic scenario still exceeds the global daily salt consumption goal.

Discussion

Excess salt intake is now a global public health challenge (32). Reducing salt intake has been identified as one of the most cost-effective measures to improve population health outcomes (31). High sodium intake is a crucial risk factor for chronic disease and has posed a high burden in Japan for decades (8, 10). The current mean daily salt intake in Japan exceeds public recommendations across all age and sex subgroups. This study shows that it is possible to reduce the Japanese population's salt intake by up to 2.22g (21.1%) without compromising the taste of certain food groups by substituting NaCl with umami substances. In addition to reducing the salt intake among consumers, this study demonstrates that the universal incorporation of umami substances in limited foods can effectively reduce salt intake at the population level.

In a previous study using the data from the National Health and Nutrition Examination Survey 2013–2016 in the US, which focused solely on MSG, the overall reduction rate in salt intake among the population was 7.3% (26). However, global recognition of MSG as an effective and practical solution for salt reduction remains a major challenge. In a widely reported study from 1968, MSG in Chinese food was suggested to be the cause behind numbness and palpitations in the neck and arms and has been linked to various health problems known as the Chinese restaurant syndrome (33). Following this study, several studies reported MSG association with asthma, urticaria, atopic dermatitis, dyspnea, and tachycardia (34, 35). However, more recent studies, including a double-blind placebo-controlled trial, have evaluated the reported reactions to MSG and have confirmed a lack of plausible association between MSG intake and the development of such symptoms. Further studies on the safety of MSG have found the lack of reproducibility of the different symptoms reported by patients who identify to be hypersensitive to MSG (36, 37).

Furthermore, there is no strong scientific evidence to suggest that MSG is associated with the development of asthma, hives, angioedema, or rhinitis (38). Major scientific committees and regulatory bodies, such as the Joint FAO/WHO Expert Committee on Food Additives (JECFA), the European Commission Scientific Committee on Food (SCF), and the U.S. Food and Drug Administration (FDA), have assessed the safety of MSG, all separately coming to a conclusion that MSG is safe to consume at a normal intake level and that there is no evidence linking the use of MSG foods to long-term medical problems for the general public (39).

Meanwhile, it is true that sodium is also in MSG. Reduction of sodium can also be achieved with sodium-free glutamates such as CDG, inosinate, and guanilate (40). Our study has expanded the scope from solely on MSG to umami substances and selected foods that were widely consumed by the Japanese. As such, our findings suggest umami substances' potential for a greater impact on reducing salt intake than the previous study. Seasoning salt, soy sauce, miso paste, other seasonings, and processed fish were more commonly consumed in Japan than the other selected food groups. In fact, soy sauce was one of the most consumed foods and, as shown by this study, has the most impact on reducing daily salt intake up to 0.68g among its consumer and 0.37g for the total

population. On the other hand, cheese, spices and other, beef, margarine, and other confectionery have less impact on reducing salt intake on the population level because they are consumed less than the other food groups.

To reduce the Japanese population's daily salt intake, the Japanese government took steps to enforce a new food labelling system and a nutrition labelling system in April 2020 (41, 42). These systems made it mandatory for food companies to disclose the amount of sodium in their products to ensure that their consumers are aware of the nutritional content of their foods. However, these measures alone may not be sufficient in addressing the problem because lowering sodium intake is not a priority among consumers (43). Furthermore, reducing the sodium in foods may influence the quality of foods; for example, the replacement of 75% of sodium chloride in sausages decreased the sausages' hardness, chewiness, and cohesiveness (44). Hence, food companies must also provide low-sodium alternatives that can give their consumers the taste and the quality they seek without the harmful amounts of sodium (45). Other alternatives, such as potassium chloride, calcium chloride, and magnesium sulfate, have all been used as substitutes for table salt. However, their bitter taste has repelled consumers and has resulted in their limited use. In contrast, umami substances, which are naturally present in various foods, are widely accepted by consumers (46). As the addition of umami substances have an enhancer effect of flavor in foods, the combination of umami substances and the additional flavor will be able to reduce the intake of salt more effectively (18, 47).

The food industry should take action to promote the benefits of eating reduced-salt foods by raising consumer awareness while reducing the salt in their products over time so that consumers can adapt to the changes in the taste (40). Accordingly, the food industry's role is essential in decreasing the daily sodium intake of Japanese people and reducing the Japanese population's various health risks (11). Moreover, reducing salt intake through food science and technological advances is an appropriate method to make the most impactful reduction in sodium intake at the population level (32). Our study provides essential data on the distribution of consumers, the market shares of selected food groups with low-sodium alternatives, and its impact on public health by showing the potential reduction in salt intake. This information may instruct and inspire the food industry to develop more low-sodium products and distribute more low-sodium alternatives in the market.

This study has some strengths. This is the first study to show the impact of salt reduction by replacing NaCl with umami substances in certain Japanese food products. Using nationally representative data guarantees the study's generalisability to the Japanese population. The modelling assumptions of sodium reduction were determined based on scientific evidence, made in consultation with food scientists, and were made considering market distributions. This study is subject to similar limitations in other studies concerning dietary patterns (48, 49). First, because the dietary data from the NHNS was based on a weighted single-day dietary record, the analysis may not have captured the long-term dietary patterns. Daily data do not reflect seasonal changes in dietary patterns. In dietary surveys and lifestyle questionnaires, participants' subjective self-reports tend to be associated with social desirability and recall bias. Unfortunately, there is no data to validate their survey responses. In addition, relying on household representatives to record dietary intake in the survey may lead to biased estimates of dietary intake for individual respondents, particularly for those who work and have lunch outside the home (such as in restaurants) on weekdays. NHNS's stratified two-cluster sampling design may have introduced selection bias, leading to biased estimates. Second, the data on food-specific salt intake was not publicly available. Thus, the estimation of an individual's food-specific salt intake by regression method may not have accurately reflected the actual amount of salt intake from each food group. Finally, age group-specific preferences for varying salt sources and how that may affect the potential overall salt reduction were not considered (50).

Conclusions

The addition of umami substances to certain foods has the potential to reduce the daily salt intake of the Japanese population by 21.1%, which is equivalent to 2.22g of daily salt intake. Universal incorporation of umami substances into limited foods could achieve dietary goals for the Japanese. However, that reduced salt intake level still falls short of the global dietary recommendation of 5g of salt daily. Along with the public health targets, a close collaboration between experts in food science is needed. Further investigation, innovation, and distribution of low-sodium foods are expected to reduce the adult Japanese population's daily salt intake and consequently reduce their chances of developing NCDs.

Abbreviations

CVDs: Cardiovascular diseases

DRIs: Dietary Reference Intakes

GBD: Global Burden of Disease

MHLW: Ministry of Health, Labour and Welfare

MSG: Monosodium glutamates

NaCl: sodium chloride

NHNS: National Health and Nutrition Survey

US: Unites States

WHO: World Health Organization

Declarations

Ethics approval and consent to participate

The Research Ethics Committee of the Graduate School of Medicine, The University of Tokyo approved this study (authorization number 11964) and waived the need for informed consent as this study was a secondary analysis of anonymised data that is collected routinely by the MHLW.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from MHLW, but restrictions apply to the availability of these data. The data were used with an approval from MHLW to be utilized for the current study without making it publicly available.

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Competing interests

S.N. and K.S. report a grant from the Ajinomoto Co., Inc. H.U. declares that he is employed by Ajinomoto Co., Inc. and has no other competing interests. All other authors declare no competing interests.

Authors' contributions

S.N. and K.S. led the study. All authors conceived and designed the study. S.T., D.Y., and S.N. took responsibility for the integrity of the data and the accuracy of the data analysis. S.T., D.Y., and S.N. acquired the data. S.T., D.Y., and S.N. analysed and interpreted the data. S.T. and D.Y. conducted the statistical analysis. S.T., D.Y., A.I. and S.N. drafted the article. All authors made critical revisions to the manuscript for important intellectual content and gave final approval of the manuscript. The opinions, results, and conclusions reported in this paper are those of the authors and are independent of the funding bodies.

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Tables

Table 1. Sodium reduction in foods by replacement with umami substances

References	Foodstuff	Sodium alternatives	Sodium reduction (%)	NHNS food group	Sodium reduction rate in the study (%)	Market share of low-sodium products (%)
JPA 01-304860(51)	Salt composition	MSG, inosinate	22-43	Seasoning salt	22-43	9.2
JPA58-198269	Salt composition	MSG, inosinate, guanilate	30			
JPA 2006-141226(52)	Liquid seasoning	MSG	40-49	Soy sauce	40-61	28.7
Ishida 2011(53)	Soy sauce	MSG, inosinate, guanilate	60			
JPA 09-275930(54)	Soy sauce	MSG, inosinate, guanilate	61			
Ishida 2011(53)	Miso paste	MSG, inosinate, guanilate	15	Miso paste	15-35	12.4
JPA5523618(55)	Low-salt bean miso	Glutamine acid	35			
Chi 1992(56)	Chicken broth	MSG	11	Other seasonings	11-40	4.1
Manabe 2008(57)	Japanese clear soup	Dried bonito (rich in inosinate)	15			
Goh 2011(58)	Japanese clear soup	Soy sauce (rich in glutamates)	15			
Huynh 2016	Tomato sauce	Fish sauce (rich in glutamates)	16			
Kremer 2009(59)	Tomato soup	Soy sauce (rich in glutamates)	17-33			
Ogasawara 2016(60)	Mentsuyu (Japanese noodle soup)	Dried bonito (rich in inosinate)	20			
Wang 2019(25)	Chicken soup	MSG	20			
Leong 2015(61)	Mee soto broth	MSG	22			

Jinap 2016(62)	Spicy soup	MSG	32.5			
Carter 2011(63)	Chicken broth	CDG	38			
Ball 2002(64)	Pumpkin soup	CDG	40			
Yamaguchi 1984(21)	Japanese clear soup	MSG	40			
Roininen 1996(65)	Minestrone; leek and potato soup	MSG, inosinate, guanilate	40			
Rodrigues2014(66)	Garlic and salt	MSG	50	Spices and other	50	4.1
JPA 59-118038(67)	Processed meat and fish	MSG, inosinate	30-40	Processed fish (including salted fish, canned fish, fish boiled in soy sauce and fish sausage)	30-50	3.5
de Quadros 2015(68)	Fish burgers (minced fish)	MSG	50			
Wooward 2003(69)	Sausage	CDG	17	Ham and sausage	17-75	0.3
JPA 59-118038(67)	Processed meat and fish	MSG, inosinate	30-40			
dos santos 2014(44)	Sausages	MSG	75			
Miller 2014(70)	Minced beef	Mushrooms (rich in glutamates)	25	Beef	25	0.3
JPA60-153751(71)	Pickled vegetable	MSG	55	Pickled vegetable	55	0.3
Rodrigues 2014(72)	Mozzarella cheese	MSG	54	Cheese	54-100	0.4
da Silva 2014	Creame cheese	MSG	up to 100			
de Souza 2014	Butter	MSG	up to 100	Butter	100	0.0
Goncalves 2017(73)	Margarine	MSG	33	Margarine	33	0.0
Kongstad 2020(24)	Potato chips	MSG	30	Other confectionery	30-57	0.3
Buechler 2020(23)	Chips and rice puffs	MSG, inosinate, guanilate	57			

CDG: Calcium diglutamate;; JPA: Japanese Patent Application; MSG: Monosodium glutamate; NHNS: National Health and Nutrition Survey

Table 2: Current sodium intake (baseline scenario) from dietary sources and the achievement rate of dietary goals by age and sex, NHNS 2016

Age (years)	N	Current salt intake (g/day) ^{*1}	Healthy Japan 21 (%) ^{*2}	DRIs Japan (%) ^{*3}	WHO (%) ^{*4}
Total population					
20-29	1,480	9.44 (3.2)	35.3	19.3	3.9
30-39	2,548	9.52 (3.2)	35.0	20.6	4.1
40-49	3,394	9.49 (3.1)	33.8	19.6	3.9
50-59	3,254	9.86 (3.1)	29.0	14.0	2.5
60-69	4,940	10.52 (3.2)	21.5	10.0	1.5
70-79	3,934	10.38 (3.3)	23.8	12.5	2.1
80+	2,255	9.58 (3.1)	33.5	18.6	3.5
All	21,805	9.95 (3.2)	28.7	15.3	2.8
Men					
20-29	707	10.37 (3.5)	24.2	19.0	2.1
30-39	1,205	10.51 (3.4)	23.7	18.0	1.8
40-49	1,581	10.47 (3.2)	23.3	17.5	1.8
50-59	1,481	10.77 (3.3)	18.7	13.2	1.6
60-69	2,304	11.43 (3.4)	13.3	9.0	0.4
70-79	1,802	11.09 (3.4)	17.5	13.3	1.2
80+	892	10.32 (3.2)	24.2	19.3	2.1
All	9,972	10.83 (3.4)	19.4	14.4	1.4
Women					
20-29	773	8.60 (2.6)	45.4	19.5	5.4
30-39	1,343	8.64 (2.7)	45.1	22.9	6.1
40-49	1,813	8.65 (2.6)	43.0	21.5	5.8
50-59	1,773	9.09 (2.6)	37.6	14.7	3.2
60-69	2,636	9.72 (2.9)	28.6	11.0	2.4
70-79	2,132	9.78 (3.0)	29.2	11.8	2.8
80+	1,363	9.10 (3.0)	39.6	18.2	4.4
All	11,833	9.21 (2.8)	36.5	16.0	4.0

DRIs: Dietary Reference Intakes; NHNS: National Health and Nutrition Survey; SD: Standard deviation; WHO: World Health Organization

^{*1} Mean (SD)

- *2 Recommend consumption of no more than 8g of salt intake a day.
- *3 Recommend consumption of no more than 7.5g of salt intake a day for men and 6.0g for women.
- *4 Recommend consumption of no more than 5g of salt intake a day.

Table 3. Estimated mean salt intake from selected food groups in the baseline scenario and potential salt reduction in the 30-, 60-, and 100-percent umami substances’ incorporation scenarios by sex

Figure		N (%)	Estimated mean salt Intake from food in the baseline scenario (g/day)* ¹	Potential reduction in salt intake in scenarios					
				30-percent scenario		60-percent scenario		100-percent scenario	
				g/day	%* ²	g/day	%* ²	g/day	%* ²
Seasoning salt									
	Total population	18,123 (83.1)	1.13 (1.00)	0.05–0.10	4.6–8.9	0.13–0.25	11.2–21.8	0.23–0.44	20.0–39.0
	Men	8,482 (85.1)	1.26 (1.10)	0.06–0.11		0.14–0.27		0.25–0.49	
	Women	9,641 (81.5)	1.02 (0.90)	0.05–0.09		0.11–0.22		0.20–0.40	
Soy sauce									
	Total population	18,726 (85.9)	1.57 (1.30)	0.01–0.01	0.5–0.8	0.20–0.30	12.5–19.1	0.45–0.68	28.5–43.5
	Men	8,736 (87.6)	1.71 (1.40)	0.01–0.01		0.21–0.33		0.49–0.74	
	Women	9,990 (84.4)	1.44 (1.20)	0.01–0.01		0.18–0.28		0.41–0.63	
Miso paste									
	Total population	15,105 (69.3)	1.48 (1.00)	0.04–0.09	2.6–6.2	0.11–0.25	7.1–16.7	0.19–0.45	13.1–30.7
	Men	6,971 (69.9)	1.55 (1.00)	0.04–0.10		0.11–0.26		0.20–0.47	
	Women	8,134 (68.7)	1.42 (0.90)	0.04–0.09		0.10–0.24		0.19–0.44	
Other seasoning									
	Total population	21,341 (97.9)	0.34 (0.50)	0.01–0.04	2.9–10.4	0.02–0.08	6.2–22.4	0.04–0.13	10.6–38.4
	Men	9,756 (97.8)	0.38 (0.50)	0.01–0.04		0.02–0.09		0.04–0.15	
	Women	11,585 (97.9)	0.31 (0.40)	0.01–0.03		0.02–0.07		0.03–0.12	
Spices and other									
	Total	5,567 (25.5)	0.08 (0.20)	0.01	13.0	0.02	28.0	0.04	48.0
	Men	2,707 (27.1)	0.08 (0.20)	0.01		0.02		0.04	
	Women	2,860 (24.2)	0.07 (0.10)	0.01		0.02		0.03	
Processed fish									

	Total population	13,783 (63.2)	0.80 (0.80)	0.06–0.11	0.5–0.8	0.14–0.23	12.5–19.1	0.23–0.39	28.5–43.5
	Men	6,393 (64.1)	0.86 (0.90)	0.07–0.11		0.15–0.24		0.25–0.42	
	Women	7,390 (62.5)	0.75 (0.80)	0.06–0.10		0.13–0.21		0.22–0.36	
Ham and sausage									
	Total population	8,899 (40.8)	0.66 (0.50)	0.03–0.15	8.0–13.3	0.07–0.29	17.0–28.3	0.11–0.49	29.0–48.3
	Men	4,245 (42.6)	0.72 (0.60)	0.04–0.16		0.07–0.32		0.12–0.54	
	Women	4,654 (39.3)	0.60 (0.50)	0.03–0.13		0.06–0.27		0.10–0.45	
Beef									
	Total population	5,380 (24.7)	0.19 (0.20)	0.01	7.4	0.03	14.9	0.05	24.9
	Men	2,717 (27.2)	0.21 (0.20)	0.02		0.03		0.05	
	Women	2,663 (22.5)	0.17 (0.10)	0.01		0.03		0.04	
Pickled vegetable									
	Total population	8,813 (40.4)	0.91 (1.00)	0.15	16.3	0.30	32.8	0.50	54.8
	Men	4,390 (44.0)	0.94 (1.10)	0.15		0.31		0.51	
	Women	4,423 (37.4)	0.89 (0.90)	0.14		0.29		0.49	
Cheese									
	Total population	3,767 (17.3)	0.51 (0.40)	0.08–0.15	16.0–29.6	0.17–0.31	32.2–59.6	0.28–0.51	53.8–99.6
	Men	1,551 (15.6)	0.52 (0.40)	0.08–0.15		0.17–0.31		0.28–0.51	
	Women	2,216 (18.7)	0.51 (0.40)	0.08–0.15		0.16–0.31		0.28–0.51	
Butter									
	Total population	3,253 (14.9)	0.24 (0.20)	0.07	30.0	0.14	60.0	0.24	100.0
	Men	1,397 (14.0)	0.24 (0.20)	0.07		0.14		0.24	
	Women	1,856 (15.7)	0.24 (0.20)	0.07		0.14		0.24	
Margarine									

	Total population	3,144 (14.4)	0.45 (0.40)	0.04	9.9	0.09	19.8	0.15	33.0
	Men	1,320 (13.2)	0.49 (0.40)	0.05		0.10		0.16	
	Women	1,824 (15.4)	0.42 (0.30)	0.04		0.08		0.14	
Other confectionery									
	Total population	3,323 (15.2)	0.10 (0.10)	0.01–0.02	8.9–16.9	0.02–0.04	17.9–34.0	0.03–0.06	29.9–56.8
	Men	1,161 (11.6)	0.12 (0.10)	0.01–0.02		0.02–0.04		0.04–0.07	
	Women	2,162 (18.3)	0.10 (0.10)	0.01–0.02		0.02–0.03		0.03–0.06	
All foods									
	Total population	21,801 (100.0)	5.06 (2.70)	0.24–0.43	2.3–4.1	0.68–1.20	6.4–11.4	1.27–2.22	12.0–21.1
	Men	9,970 (100.0)	5.57 (2.90)	0.26–0.47	2.3–4.2	0.74–1.31	6.5–11.5	1.39–2.43	12.1–21.3
	Women	11,831 (100.0)	4.63 (2.40)	0.22–0.40	2.3–4.1	0.63–1.10	6.4–11.3	1.16–2.03	11.9–20.9

SD: Standard deviation

*¹ Mean (SD) salt intake from each food among consumer, not all participants.

*² The reduction rate of each food was the same for men and women.

Table 4. Salt contributions by selected food groups to overall salt intake in the baseline scenario and potential reduction in salt intakes for all participants in the umami substances' universal incorporation scenario by sex

All (n=22,853)

		Salt contributions from food to overall salt intake in the baseline scenario (%)	Reduction in salt intake*	
			g/ day	%
Seasoning salt				
	Total population	8.9	0.19–0.37	1.8–3.5
	Men	9.4	0.21–0.42	1.9–3.7
	Women	8.6	0.17–0.32	1.7–3.4
Soy sauce				
	Total population	12.5	0.38–0.59	3.6–5.4
	Men	12.2	0.43–0.65	3.7–5.6
	Women	12.8	0.35–0.53	3.5–5.3
Miso paste				
	Total population	9.7	0.13–0.31	1.3–3.0
	Men	9.9	0.14–0.33	1.3–2.9
	Women	9.5	0.13–0.30	1.3–3.0
Other seasoning				
	Total population	3.2	0.04–0.13	0.3–1.2
	Men	3.2	0.04–0.14	0.3–1.3
	Women	3.3	0.03–0.12	0.3–1.2
Spices and other				
	Total population	0.2	0.01	0.1
	Men	0.2	0.01	0.1
	Women	0.2	0.01	0.1
Processed fish				
	Total population	4.8	0.15–0.24	1.4–2.3

	Men	4.8	0.16–0.27	1.4–2.3
	Women	4.9	0.14–0.23	1.4–2.3
Ham and sausage				
	Total population	2.6	0.05–0.20	0.5–2.0
	Men	2.5	0.05–0.23	0.5–2.1
	Women	2.8	0.04–0.18	0.4–1.9
Beef				
	Total population	0.5	0.01	0.1
	Men	0.4	0.01	0.1
	Women	0.6	0.01	0.1
Pickled vegetable				
	Total population	3.3	0.20	1.8
	Men	3.2	0.23	1.9
	Women	3.4	0.18	1.8
Cheese				
	Total population	0.9	0.05–0.09	0.5–0.9
	Men	1.1	0.04–0.08	0.4–0.8
	Women	0.8	0.05–0.10	0.6–1.1
Butter				
	Total population	0.4	0.04	0.4
	Men	0.4	0.03	0.3
	Women	0.3	0.04	0.4
Margarine				
	Total population	0.7	–0.02	0.2
	Men	0.8	0.02	0.2
	Women	0.6	0.02	0.3
Other confectionery				

	Total population	0.2	0.00–0.01	0.0–0.1
	Men	0.2	0.00–0.01	0.0–0.1
	Women	0.1	0.01–0.01	0.0–0.1
All foods				
	Total population	48.0	1.27–2.22	12.0–21.1
	Men	47.5	1.39–2.43	12.1–21.3
	Women	48.6	1.16–2.03	11.9–20.9

* The scenario in which umami substances were universally incorporated into selected food groups

Table 5. Estimated salt intake and achievement rate of dietary goals in the umami substances' universal incorporation scenario by sex and age groups

Age (years)	Potential salt intake (g/day)	Healthy Japan 21 (%) ¹	DRI _s Japan (%) ²	WHO (%) ³
Total population				
20-29	7.40–8.34	49.5–68.0	31.1–45.7	6.1–10.0
30-39	7.46–8.41	48.9–63.9	30.3–44.3	5.9–10.6
40-49	7.42–8.36	49.4–65.0	29.6–44.1	6.1–10.1
50-59	7.69–8.64	44.3–60.9	24.1–38.6	3.9–7.0
60-69	8.13–9.13	35.1–52.4	18.1–29.7	2.7–4.8
70-79	8.02–8.98	38.5–54.7	20.9–33.1	3.4–5.4
80+	7.43–8.29	49.2–65.0	29.8–43.2	5.7–9.6
All	7.73–8.68	43.4–59.7	24.8–38.1	4.4–7.6
Men				
20-29	8.12–9.15	36.9–54.2	29.8–44.4	3.1–5.1
30-39	8.19–9.25	35.2–50.3	27.7–39.9	2.4–5.0
40-49	8.15–9.20	35.2–50.2	27.1–41.4	3.0–4.8
50-59	8.38–9.43	31.1–46.9	22.6–36.5	2.6–3.9
60-69	8.79–9.90	24.3–39.2	17.7–29.1	1.0–2.1
70-79	8.58–9.61	28.9–44.0	21.8–34.4	1.8–2.9
80+	8.00–8.92	37.3–53.3	30.8–42.8	3.0–5.2
All	8.40–9.45	31.2–46.6	23.9–36.7	2.2–3.8
Women				
20-29	6.75–7.60	61.1–80.6	32.3–47.0	8.9–14.5
30-39	6.80–7.64	61.2–76.0	32.5–48.2	9.0–15.7
40-49	6.79–7.62	61.8–77.9	31.7–46.4	8.8–14.7
50-59	7.11–7.97	55.3–72.6	25.4–40.4	5.0–9.6
60-69	7.54–8.45	44.5–63.8	18.5–30.2	4.1–7.2
70-79	7.54–8.45	46.6–63.8	20.2–32.0	4.8–7.6
80+	7.06–7.88	57.0–72.7	29.1–43.4	7.5–12.5
All	7.17–8.04	53.6–70.8	25.6–39.2	6.4–10.8

SD: Standard deviation; DRI_s: Dietary Reference Intakes; WHO: World Health Organization

¹ Recommend consumption of no more than 8g of salt intake a day.

² Recommend consumption of no more than 7.5g of salt intake a day for men and 6.0g for women.

³ Recommend consumption of no more than 5g of salt intake a day.

Figures

Figure 1

Estimated salt intake after universally incorporating umami substances into foods in (A) the total population, by sex of (B) men, and (C) women, NHNS 2016