Salt intake reduction using umami substance-incorporated food in the United States

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Abstract

Background

Excessive salt intake has been linked to the development of several non-communicable diseases. Reducing the sodium content of foods is an important global public health activity to achieve salt reduction and health promotion. The objective of this study was to estimate the effect of sodium substitution with umami substances on the reduction of daily salt intake among adults in the United States. The umami substances considered in this study were glutamate, inosinate, and guanilate.

Methods

Our analysis included 4,139 participants aged 20 years and older from the National Health and Nutrition Examination Survey. Four hypothetical scenarios (0%, 30%, 60%, and 90%) on the market share of umami substitute foods were developed. For several food groups, salt reduction rates due to substitution with umami substances were estimated based on previous studies. Daily salt intake corresponding to the NHANES food groups in each scenario was calculated for each participant, and the total daily salt intake was aggregated by gender and 10-year age groups.

Results

Without compromising the taste, substitution with umami substances can reduce the salt intake among adults in the United States by 5.51–10.54% at the population level, which is equivalent to 0.46–0.88g of salt reduction (women 5.69–10.56% and 0.41–0.76g; men 5.31–10.51% and 0.51–1.01g). Approximately 23.73–20.25% of adults could achieve the World Health Organization's recommendation of 5g/day.

Conclusions

Our study provides essential information on the potential salt reduction from sodium replacement with alternatives in the United States. However, the reduced salt intake level still falls short of the WHO recommendation of 5g of salt intake per day.

Introduction

Inadequate public health efforts to prevent and control the global burden and risk factors for non-communicable diseases (NCDs) may have contributed to the Coronavirus Infections 2019 (COVID-19) pandemic [1]. After smoking, the second major preventable behavioural risk factor for NCDs is an unhealthy diet [2]. Among these unhealthy diets, high-salt diets are one the greatest contributors to the disease burden of NCDs - high-salt diets raise blood pressure [3], trigger cardiovascular disease [4, 5] and chronic kidney disease [6], and increase the risk of stomach cancer [7, 8]. In 2019, approximately 1.9 million deaths worldwide were attributed to high-salt diets, and the number of deaths per capita attributed to high-salt diets has increased by 3.8% in the last 20 years [2]. Moreover, among the seven prevention goals set by the World Health Organization (WHO)'s 2013 NCDs Global Monitoring Framework [9], the reduction of salt intake was the only goal related to diet. However, as of 2020, no country has achieved the goal of a 30% reduction in salt intake between 2011 and 2025 [10].

High salt diets are a major policy issue, especially in East Asian countries, Eastern European countries, and the United States [11–13]. While the World Health Organization recommends a daily intake of 5g or less [14], adults aged 20 years and older were consuming 8.97g/day in the United States in 2017–2018 [15] and 10.9g/day in Japan in 2019[16].

In recent years, the replacement of sodium chloride (NaCl, the chemical name for salt) with umami has been discussed as a healthy and natural solution to reduce salt intake [17–19]. Umami, which means pleasant savoury taste in Japanese, is induced by monosodium glutamate (MSG) and 5'-ribonucleotides such as guanosine monophosphate (GMP) and inosine monophosphate (IMP). It is considered to be the fifth basic taste alongside the classical four basic tastes of saltiness, sweetness, bitterness, and acidity [20].

Yet, few studies have been conducted to empirically evaluate the impact of umami on salt reduction at the population level. Recently, it was reported in Japan that the daily salt intake per adult could be reduced by up to 2.22g if the umami substances were incorporated into selected marketed foods [21]. In this study, we examined the impact of incorporating umami on the daily salt intake of adults in the United States using data from the Centers for Disease and Control and Prevention's National Health and Nutrition Examination Survey (NHANES).

Methods

Study design and participants

We used anonymous secondary open data from NHANES for noninstitutionalized adults aged 20 years and older between 2017-2018 in the United States [22]. NHANES, conducted by the National Center for Health Statistics (NCHS), is a cross-sectional survey with a stratified, multi-stage probability sample design. NHANES collects 24-hour dietary intake recalls for two days using the interview-administered Automated Multiple Pass Method (AMPM) for a nationally representative sample over a two-year study period. The AMPM is a validated, multi-pass approach that aims to facilitate complete and accurate food recalls and reduce respondent burden [23, 24]. The first day of the dietary interview is conducted in-person in the mobile examination center (MEC) and the second day dietary interview was performed 3–10 days later over the phone. The questionnaires, data sets, and all related documents for each NHANES cycle are available on the NCHS website [25].

Demographic Data

For the first day of interviews, interviewees collected demographic information at each household, including gender and age. For age, we considered 10-year age groups (20-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80+).

Food And Sodium Intake Data

All foods and beverages reported in the interviews were assigned a food code using the Food and Nutrient Database for Dietary Studies (FNDDS) 2017-2018 edition. The food code converts consumed foods and beverages reported in the interviews into gram quantities and determines the corresponding nutrient (e.g. sodium) content. It should be noted that a previous study analyzing 24-hour urinary sodium data collected using AMPM suggests that AMPM is a valid means of determining sodium intake in adults [26].

The FNDDS provides an 8-digit food code to uniquely identify each food/beverage. The first digit in the food code identifies one of nine major food groups: (1) milk, (2) meat and fish, (3) eggs, (4) legumes, nuts and seeds, (5) grains, (6) fruits, (7) vegetables, (8) fats, oils and salad dressings, and (9) sugars, sweets and beverages. The second and subsequent digits of the food code indicate the specific sub-groups within the nine major food groups. In this study, all analyses were conducted at the subgroup level, but the estimation results are presented for the 10 major food groups, separating fish and meat.

In this study, the average intake of each food group and the corresponding sodium intake from the two-day dietary interview was calculated and analyzed as a daily value. Salt equivalent intake (g) was defined as sodium (mg) × 2.54/1,000. Appropriate sample weights were used to generate national, representative estimates [27].

Sodium reduction rate in various food products with the incorporation of umami substances

According to scientific literature, the incorporation of umami substances can reduce sodium in various food products, while maintaining their palatability. We obtained potential salt reduction rates for several food products from an extensive review by Tanaka et al. (2021) [21]. Based on previous studies and input from several food and nutrition experts (co-authors), we estimated salt reduction rates for umami substances by NHANES food subgroups as listed in Table 1.

Table 1
Sodium reduction assumptions due to incorporation of umami substances by FNDDS food code

Main group	Subgroup	FNDDS food code	Sodium reduction rate (%)	References			Umami substance
Milk	Cheese	14XXXXXX	54–100%	Rodriques (2014)[45]	da Silva (2014)[46]		MSG
Meat	Sausage	252XXXXX	17–75%	Wooward (2003)[47]	Ichikawa Chemical Institution (1984)[48]	dos Santos (2014) [49]	MSG, CDG, Inosinate
	Chicken broth	283XXXXX, 285XXXXX	11–38%	Chi (1992)[50]	Carter (2011)[51]	Wang (2019) [52]	MSG, CDG
Fish	Salted fish	26109170, 26109180	30–40%	Ichikawa Chemical Institution (1984) [48]			MSG, Inosinate
Legume	Miso	41601070	15–35%	Ishida (2011) [53]	Yamasa Corporation (2014)[54]		MSG, Inosinate, Guanilate
	Soy sause	41420300	40–61%	Kao Corporation (2006)[55]	Ishida (2011)[53]	Kameda Seika Co., Ltd. (1997) [56]	MSG, Inosinate, Guanilate
Grain	Snack	540XXXXX, 543XXXXX, 544XXXXX	51%	Buechler (2019)[57]			MSG, Inosinate, Guanilate
Vegetable	Vegetable soup	718XXXXX, 723XXXXX, 735XXXXX, 746XXXXX, 756XXXXX, 775XXXXX	17–40%	Kremer (2009) [58]	Ball (2002) [59]		Glutamates, CDG
	Potate chips	712XXXXX	30%	Kongstad (2020)[60]			MSG
	Salted vegetable	755XXXXX	55%	Tampei Pharmaceutical Co., Ltd. (1985) [61]			MSG
Oil	Butter	811XXXXX	100%	de Souza (2014)[62]			MSG

FNDDS: Food and Nutrient Database for Dietary Studies; MSG: monosodium glutamate; CDG: calcium diglutamate; X refers to all food codes for which the first one or two digits correspond.

(Table 1 about here)

Estimating salt intake reduction with the incorporation of umami substances

As people in the United States may already consume a certain amount of low-sodium foods containing umami substances in their daily diets, we, therefore, set four hypothetical scenarios for the market share of low-sodium products: 0% (i.e. no low-sodium foods in the market); 30% 60%, 90%.

For each of the major food groups, at the population level, we calculated the amount of salt reduction possible for each of the four scenarios by gender. The salt reduction rate for each NHANES subgroup, expressed as an upper-lower interval in Table 1, represents the range of possible salt reduction rates estimated in the literature. The upper and lower limits were then used to calculate the maximum and minimum possible salt reduction for each subgroup at the individual level.

The following equations give the upper and lower limits of the *j*-th food subgroup-specific reduction in salt intake due to the incorporation of umami substances in the *i*-th individual;

$$Upperreductioninsaltintakeofthejthitemunderthekthscenariointheithindividual$$

$$= S_{ij} - S_{ij} \times U_j \times \left(1 - M_k\right),$$

$$Lowerreductioninsaltintakeofthejthitemunderthekthscenariointheithindividual$$

$$= S_{ij} - S_{ij} \times L_j \times \left(1 - M_k\right),$$

where S_{ij} refers to the current salt intake of the *j*-th food subgroup in the *i*-th participant; U_j and L_j refer to the upper and lower limits of the sodium reduction rate of the *j*-th food subgroup, and M_k refers to the *k*-th scenario of the market share of low-sodium products (denoted as M_k= 0, 0.3, 0.6 or 0.9 (*k*=1, 2, 3, 4, respectively)).

Salt reduction was assumed to be zero in food groups with no evidence in the literature. After calculating the individual-level salt reduction for each scenario and subgroup using the formula above, we aggregated the amount of salt that could be reduced per major group and calculated and the average value per population.

We also calculated the percentage of the population achieving the WHO recommended intake (5 g/day) for salt intake currently and for each scenario by gender and 10-year age groups [28]. R version 4.0.5 was used for all analyses.

Results

The NHANES 2017-2018 cohort comprised a total of 5,569 respondents aged 20 years and older (2,867 women and 2,702 men), with mean age of 51.50 and standard deviation [SD] of 17.81. The analysis included a total of 4,139 individuals (2,161 women and 1,977 men), with mean age of 51.36 and SD of 17.50, who had two days of dietary intake data on the usual amount of food consumed for both days.

Table 2 shows the gender- and age group-specific mean daily salt intake, and the population percentage achieving the WHO recommendation salt intake level. Women had a lower salt intake than men across all age groups. The mean daily salt intake was highest among women aged 20–29 years (8.03g) and men aged 30–39 years (10.73g), but lowest among those aged 80+ years for both women (6.40g) and men (7.71g). By age groups, salt intake tended to be higher among older than younger persons. Of the total population, 17.2% has already achieved the WHO recommendation.

Table 2
Demographic characteristics of the study participants and their current salt intake

Age (years)	Number of participants	Current mean salt intake (SD) (g/day)	Percentage of people below WHO recommendation (%)
Total population			
20–29	585	9.14 (4.17)	13.68
30–39	647	9.04 (4.19)	12.52
40–49	615	8.87 (3.92)	15.28
50–59	706	8.24 (3.73)	17.14
60–69	869	7.89 (3.49)	19.91
70–79	463	7.46 (3.34)	23.97
80+	254	7.03 (2.46)	20.08
All	4,139	8.35 (3.80)	17.18
Women			
20–29	304	8.03 (3.40)	18.75
30–39	362	7.70 (3.14)	17.40
40–49	329	7.42 (3.33)	23.71
50–59	381	7.04 (2.78)	23.10
60–69	431	6.76 (2.77)	28.07
70–79	223	6.51 (2.82)	33.18
80+	132	6.40 (2.19)	27.27
All	2,162	7.20 (3.04)	23.91
Men			
20–29	281	10.34 (4.58)	8.19
30–39	285	10.73 (4.72)	6.32
40–49	286	10.54 (3.89)	5.59
50–59	325	9.63 (4.19)	10.15
60–69	438	9.01 (3.75)	11.87
70–79	240	8.35 (3.54)	15.42
80+	122	7.71 (2.55)	12.30
All	1,977	9.61 (4.14)	9.81

SD: standard deviation; World Health Organization

For each of the four scenarios, the potential salt intake reduction for each NHANES major food group by gender is presented in Table 3. In particular, for the scenario that assumes no low-sodium products on the market, the highest amount of expected salt reduction was identified in meat (0.09–0.38g), followed by milk (0.17–0.32g) and vegetable (0.09–0.12g). The total amount of salt reduction across all major food groups for each scenario (0%, 30%, 60%, 90% of the market share of low-sodium products) was 0.46–0.88g, 0.32–0.62g, 0.18–0.35g, and 0.05–0.09g, respectively.

Table 3
Estimated salt reduction by scenarios, gender, and NHANES major food groups

		Current mean salt intake (SD) (g/day)	Estimated lower-upper mean reduction in salt intake (g/day)			
			Scenario 1 (current market share of low-sodium products = 0%)	**Scenario 2** (current market share of low-sodium products = 30%)	**Scenario 3** (current market share of low-sodium products = 60%)	**Scenario 4** (current market share of low-sodium products = 90%)
Milk						
	Total population	0.56 (0.61)	0.17–0.32	0.12–0.22	0.07–0.13	0.02–0.03
	Women	0.52 (0.56)	0.16–0.30	0.11–0.21	0.07–0.12	0.02–0.03
	Men	0.61 (0.67)	0.18–0.34	0.13–0.24	0.07–0.14	0.02–0.03
Meat						
	Total population	2.61 (1.96)	0.09–0.38	0.06–0.27	0.04–0.15	0.01–0.04
	Women	2.08 (1.50)	0.07–0.30	0.05–0.21	0.03–0.12	0.01–0.03
	Men	3.16 (2.22)	0.11–0.48	0.07–0.30	0.05–0.12	0.01–0.03
Fish						
	Total population	1.14 (1.13)	0.00–0.00	0.00–0.00	0.00–0.00	0.00–0.00
	Women	1.02 (1.03)	0.00–0.00	0.00–0.00	0.00–0.00	0.00–0.00
	Men	1.31 (1.23)	0.00–0.00	0.00–0.00	0.00–0.00	0.00–0.00
Eggs						
	Total population	0.54 (0.52)	NA	NA	NA	NA
	Women	0.46 (0.44)	NA	NA	NA	NA
	Men	0.62 (0.58)	NA	NA	NA	NA
Legumes, nuts, and seeds						

SD: standard deviation; NHANES: National Health and Nutrition Examination Survey; NA referrers to no evidence on the salt reduction with the incorporation of umami substances.

		Current mean salt intake (SD) (g/day)	Estimated lower-upper mean reduction in salt intake (g/day)			
			Scenario 1 (current market share of low-sodium products = 0%)	Scenario 2 (current market share of low-sodium products = 30%)	Scenario 3 (current market share of low-sodium products = 60%)	Scenario 4 (current market share of low-sodium products = 90%)
	Total population	0.70 (0.88)	0.03–0.04	0.02–0.03	0.01–0.02	0.00–0.00
	Women	0.60 (0.81)	0.03–0.03	0.02–0.02	0.01–0.01	0.00–0.00
	Men	0.82 (0.95)	0.03–0.04	0.02–0.03	0.01–0.02	0.00–0.00
Grains						
	Total population	3.06 (2.28)	0.10	0.07	0.04	0.01
	Women	2.69 (1.90)	0.09	0.06	0.04	0.01
	Men	3.47 (2.59)	0.10	0.07	0.04	0.01
Fruits						
	Total population	0.04 (0.13)	NA	NA	NA	NA
	Women	0.04 (0.15)	NA	NA	NA	NA
	Men	0.03 (0.10)	NA	NA	NA	NA
Vegetables						
	Total population	1.08 (1.08)	0.09–0.12	0.06–0.08	0.04–0.05	0.01–0.01
	Women	0.97 (0.91)	0.08–0.11	0.06–0.07	0.03–0.04	0.01–0.01
	Men	1.19 (1.23)	0.10–0.13	0.07–0.09	0.04–0.05	0.01–0.01
Fats, oils, and salad dressings						
	Total population	0.39 (0.50)	0.05	0.03	0.02	0.00

SD: standard deviation; NHANES: National Health and Nutrition Examination Survey; NA referrers to no evidence on the salt reduction with the incorporation of umami substances.

		Current mean salt intake (SD) (g/day)	Estimated lower-upper mean reduction in salt intake (g/day)			
			Scenario 1 (current market share of low-sodium products = 0%)	Scenario 2 (current market share of low-sodium products = 30%)	Scenario 3 (current market share of low-sodium products = 60%)	Scenario 4 (current market share of low-sodium products = 90%)
	Women	0.36 (0.46)	0.04	0.03	0.02	0.00
	Men	0.41 (0.54)	0.06	0.04	0.02	0.01
Sugar, sweets, and beverages						
	Total population	0.31 (0.35)	NA	NA	NA	NA
	Women	0.27 (0.29)	NA	NA	NA	NA
	Men	0.36 (0.41)	NA	NA	NA	NA
All foods						
	Total population	8.35 (3.80)	0.46–0.88	0.32–0.62	0.18–0.35	0.05–0.09
	Women	7.20 (3.04)	0.41–0.76	0.29–0.54	0.16–0.31	0.04–0.08
	Men	9.61 (4.14)	0.51–1.01	0.35–0.71	0.20–0.40	0.05–0.10

SD: standard deviation; NHANES: National Health and Nutrition Examination Survey; NA referrers to no evidence on the salt reduction with the incorporation of umami substances.

Table 4 presents potential salt intake by gender and age-specific groups in the four scenarios. The potential mean daily salt intake in all participants was 7.47–7.89g, 7.73–8.03g, 8.00–8.17g, and 8.26–8.30g for the 0%, 30%, 60%, 90% market scenarios, respectively. In addition, the percentage of women and men who achieved WHO recommendation was 28.17-32.42% and 11.58-14.21%; 27.06-29.42% and10.88-12.54%; 25.39-26.92% and 10.42-11.28%; and 24.24-24.70% and 9.96–9.96%, for the 0%, 30%, 60%, 90% market scenarios respectively.

Table 4
Estimated salt reduction by scenarios, gender, and 10-year age groups

Age (years)	Estimated lower-upper interval of mean salt intake (g/day), percentage of people below WHO recommendation (%)			
	Scenario 1 (current market share of low-sodium products = 0%)	**Scenario 2** (current market share of low-sodium products = 30%)	**Scenario 3** (current market share of low-sodium products = 60%)	**Scenario 4** (current market share of low-sodium products = 90%)
Total population				
20−29	8.37−8.72 (18.80−15.90)	8.60−8.85 (16.75−15.21)	8.83−8.97 (15.04−14.19)	9.06−9.10 (13.85−13.68)
30−39	8.15−8.58 (17.47−14.99)	8.41−8.72 (15.61−14.22)	8.68−8.86 (13.60−13.14)	8.95−8.99 (12.98−12.83)
40−49	8.02−8.42 (20.49−17.72)	8.27−8.55 (18.86−17.24)	8.53−8.69 (17.72−16.26)	8.78−8.82 (15.93−15.77)
50−59	7.34−7.77 (24.22−20.25)	7.61−7.91 (21.25−19.26)	7.88−8.05 (19.41−17.99)	8.15−8.19 (17.56−17.28)
60−69	6.97−7.42 (27.39−22.78)	7.25−7.56 (24.28−21.98)	7.52−7.71 (22.32−21.29)	7.80−7.85 (20.48−20.14)
70−79	6.48−6.97 (31.32−28.73)	6.78−7.11 (29.81−27.00)	7.07−7.26 (27.86−25.92)	7.36−7.41 (24.41−24.19)
80+	6.23−6.62 (31.10−25.59)	6.47−6.74 (27.56−24.02)	6.71−6.86(23.62−21.65)	6.95−6.99 (20.87−20.08)
All	7.47−7.89 (23.73−20.25)	7.73−8.03 (21.36−19.33)	8.00−8.17 (19.45−18.24)	8.26−8.30 (17.66−17.40)
Women				
20−29	7.32−7.63 (23.68−20.72)	7.53−7.75 (21.71−20.72)	7.75−7.87 (20.07−19.41)	7.96−7.99 (19.08−18.75)
30−39	6.92−7.28 (24.59−21.55)	7.16−7.41 (21.82−20.17)	7.39−7.54 (19.06−18.23)	7.63−7.66 (17.96−17.68)
40−49	6.67−7.02 (31.00−27.36)	6.89−7.14 (28.88−26.75)	7.12−7.26 (27.36−24.92)	7.35−7.38 (24.62−24.32)
50−59	6.25−6.62 (33.07−27.82)	6.49−6.75 (28.87−26.25)	6.73−6.88 (26.25−24.92)	6.97−7.00 (23.88−23.36)
60−69	6.00−6.35 (36.66−31.79)	6.23−6.48 (33.64−31.32)	6.45−6.60 (31.09−30.16)	6.68−6.72 (29.00−28.54)
70−79	5.72−6.07 (44.39−39.91)	5.96−6.20 (41.26−37.67)	6.19−6.34 (38.12−35.87)	6.43−6.47 (34.08−33.63)
80+	5.65−6.00 (41.67−34.85)	5.87−6.12 (37.12−31.82)	6.10−6.24 (32.58−29.55)	6.33−6.36 (28.79−27.27)

WHO: World Health Organization

Age (years)	Estimated lower-upper interval of mean salt intake (g/day), percentage of people below WHO recommendation (%)			
	Scenario 1 (current market share of low-sodium products = 0%)	Scenario 2 (current market share of low-sodium products = 30%)	Scenario 3 (current market share of low-sodium products = 60%)	Scenario 4 (current market share of low-sodium products = 90%)
All	6.44–6.79 (32.42–28.17)	6.66–6.91 (29.42–27.06)	6.89–7.03 (26.92–25.39)	7.12–7.16 (24.70–24.24)
Men				
20–29	9.51–9.90 (13.52–10.68)	9.75–10.03 (11.39–9.25)	10.00–10.16 (9.61–8.54)	10.25–10.29 (8.19–8.19)
30–39	9.70–10.23 (8.42–6.67)	10.01–10.54 (7.72–6.67)	10.32–10.53 (6.67–6.67)	10.63–10.68 (6.67–6.67)
40–49	9.56–10.02 (8.39–6.64)	9.85–10.18 (7.34–6.29)	10.15–10.33 (6.64–6.29)	10.44–10.48 (5.94–5.94)
50–59	8.61–9.11 (13.85–11.38)	8.91–9.27 (12.31–11.08)	9.22–9.42 (11.38–10.46)	9.53–9.58 (10.15–10.15)
60–69	7.93–8.48 (18.26–13.93)	8.25–8.64 (15.07–1279.)	8.58–8.80 (13.70–12.56)	8.90–8.96 (12.10–11.87)
70–79	7.19–7.79 (19.17–18.33)	7.54–7.96 (19.17–17.08)	7.89–8.13 (18.33–16.67)	8.23–8.29 (15.42–15.42)
80+	6.86–7.28 (19.67–15.57)	7.12–7.41 (17.21–15.57)	7.37–7.54 (13.93–13.11)	7.63–7.67 (12.30–12.30)
All	8.60–9.10 (14.21–11.58)	8.90–9.26 (12.54–10.88)	9.21–9.41 (11.28–10.42)	9.51–9.55 (9.96–9.96)
WHO: World Health Organization				

Discussion

Excess salt intake is a major public health challenge worldwide, and high sodium intake is a crucial risk factor for chronic diseases [29]. The reduction of salt intake has been identified as one of the most cost-effective measures to improve population health outcomes [28]. Yet, in the United States, average sodium intake has been high for decades, and the current mean daily salt intake exceeds the WHO recommendations for all age and gender subgroups [30, 31]. Our study shows that it is possible to reduce population-level salt intake in the United States by up to 0.46–0.88g (5.51–10.54%) without compromising the taste of certain food groups by substituting salt with umami substances.

Using NHANES 2013–2016 data, a previous study showed that salt intake could be reduced by 7.3% solely by replacing salt with MSG [32]. In comparison, our study expanded the scope from only MSG to umami substances and selected foods that were widely consumed in the United States. As such, our findings suggest umami substances have a greater potential to reduce salt intake than in the previous study. Also, our study shows that the replacement of salt in meat products has the most impact on reducing daily salt intake by up to 0.09–0.38g (3.45–

14.56%). However, fish, eggs, fruits, and sugar products have less impact on reducing salt intake and little evidence exists on their effects.

Public measures such as a new food labelling system or nutrition labelling system alone may not sufficiently reduce daily salt intake because lowering sodium intake may not be a priority among consumers [33]. However, it could be difficult to reduce sodium content in foods as it could affect their palatability [34]. Therefore, food industries should provide alternative food products for consumers that offer the taste that consumer's seek without high-levels of sodium [35]. In this context, consumers widely accept umami substances, which are naturally present in various foods [36]. Since the addition of umami substances could enhance the flavor of foods, combining umami substances with other flavors could be an effective way to reduce salt intake [37, 38]. As such, the food industry could play an essential role by utilizing umami substances to decrease daily sodium intake and reduce various health risks [39]. Our study provides essential information on the distribution of consumers, the market share of selected food groups with low-sodium alternatives, and the potential impact of reducing salt intake on public health. Our results may instruct and inspire the food industry to develop more low-sodium products and distribute more low-sodium alternatives in the market.

Our study has several strengths and limitations. First, the strength of our analysis is that NHANES is a large, nationally representative sample, which allows us to estimate average salt intake at the population level. However, our study also has limitations. This study used existing literature to derive salt reduction rates due umami substances, and evidence may be insufficient for all food groups. Also, each of the four scenarios assumed that the market share of low-sodium products was the same across all food groups. Yet, it is likely that the market share of foods products would differ. Unfortunately, we do not have the data to estimate the actual market share percentage or even the details for each food group. In addition, the intake and usage of low-sodium products may differ depending on the place where the meal is served or prepared (home or restaurant), but this was not taken into account in this study due to the lack of data to properly examine these factors. Additionally, we were unable to consider the acceptability of umami substances among consumers to fully demonstrate the effects of salt reduction [19, 40, 41]. Furthermore, NHANES has several limitations, including its reliance on self-reported dietary intake data and assumptions on the accuracy of the FNDDS reference database for estimating population-wide sodium intake [42, 43]. Finally, the possibility of self-selection bias cannot be completely ruled out, and people who participate in nutrition- and health-related surveys tend to differ by sociodemographic factors or are more interested in participating in the NHANES survey [44].

Conclusions

The incorporation of umami substances into certain foods could potentially reduce population-level daily salt intake in the United States by 5.51–10.54%, which is equivalent to 0.46–0.88g per day. However, this reduction in salt levels still falls short of the WHO's recommendation of 5g per day. To achieve healthy salt intake levels, close collaboration with the food industry is essential. It is expected that further research, innovation, and distribution of low-sodium products will reduce the daily salt intake of the adult population in the United States and thus reduce the likelihood of developing NCDs.

Abbreviations

NCDs: non-communicable diseases

COVID-19: Coronavirus Infections 2019

WHO: World Health Organization

NaCl: sodium chloride

MSG: monosodium glutamate

GMP: guanosine monophosphate

IMP: inosine monophosphate

NHANES: National Health and Nutrition Examination Survey

NCHS: National Center for Health Statistics

AMPM: Automated Multiple Pass Method

MEC: mobile examination center

FNDDS: Food and Nutrient Database for Dietary Studies

Declarations

Ethics approval and consent to participate

Ethics approval was not required because the analysis was performed on secondary data, which did not include personal identifiers.

Consent for publication

Not applicable.

Competing interests

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.

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Authors’ contributions

S.N. and K.S. led the study. All authors conceived and designed the study. S.N., S.T., A.E., T.K., D.Y., and Y.T. took responsibility for the integrity of the data and the accuracy of the data analysis. S.N., S.T., A.E., T.K., D.Y., and Y.T. acquired the data, and analysed and interpreted the data. S.N., S.T., A.E., T.K., D.Y., and Y.T. 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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Availability of data and materials

Analyses were based on anonymous secondary data from the National Health and Nutrition Examination Survey. These data are publicly available online through the Centers for Disease Control and Prevention (https://wwwn.cdc.gov/nchs/nhanes/Search/DataPage.aspx).

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