A System Dynamics Model of Salt Reduction at a National Level

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Abstract
Average salt intake of the Japanese population remains high and needs to be reduced by half from 10 to 5 g to meet the target value set by the World Health Organization. People take salt from food products and by adding salt during cooking and at the table, and it is important not only to raise people's awareness of the need to reduce salt intake but also to reduce the salt content in food products. In this study, a system dynamics model was developed to simulate salt reduction at a national level. The model consisted of three sets of a pair of stocks and a flow between them; two sets related to people and one to food products. Stocks of people who are not aware of and who are aware of the need to reduce salt intake and the flow of becoming aware of the need were core components of the people's awareness subsystem, and a diffusion model was applied to the subsystem. The people's awareness subsystem was linked with a subsystem of the people's taste for salt, which consisted of stocks of people with strong and weak tastes for salt, and a flow of change toward a weak taste for salt. The people's taste for salt subsystem was further linked with a food product subsystem, which consisted of stocks of products with high and low salt contents and a flow of change toward low-salt products. To estimate the average salt intake of the population, selections of high-salt food by people with a strong taste for salt and low-salt food by people with a weak taste for salt were provided by look-up functions in four scenarios: 1) no preference, 2) early adoption, 3) late adoption, and 4) both early and late adoptions. The no-preference scenario assumed both people with a strong taste for salt and people with a weak taste for salt consume products with high and low salt contents as they are available, and average salt intake decreases as the average salt level of all products decreases. Compared with the no-preference scenario, the early adoption scenario where people with a weak taste for salt consume products with low salt content twice as much as they are available reduces the average salt level, but the late adoption scenario where people with a strong taste for salt consume products with a high salt content twice as much as they are available, and the both early and late adoptions scenario largely delayed the decrease in the average salt level of the population. In conclusion, to lower the average salt intake of the population, it is crucial that people with a strong taste for salt select products with low salt content earlier.

1. Introduction

Salt intake by the Japanese population has decreased over the past decade, but average intake among adults remains around 10 g per day (Fig. 1) (1), which is twice the World Health Organization's target value of 5 g(2). The traditional Japanese diet, characterized by pickles, *miso* soup and rice, tends to lead to high salt intake (3).

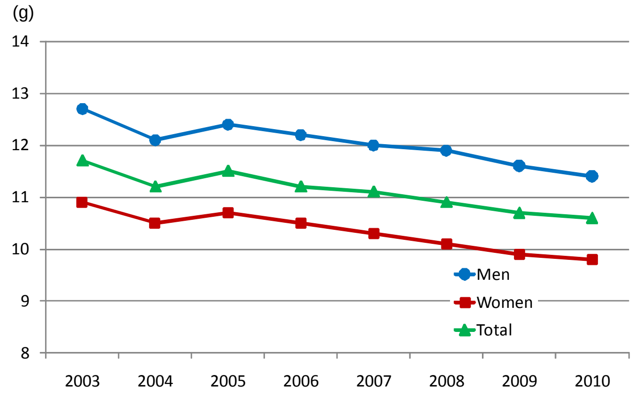

Fig. 1 Trends of salt intake in Japan (over 20 years old)(The National Health and Nutrition Survey, Japan)

With the decrease in salt intake, the calorie intake of the Japanese population has also decreased, except for those aged 70 years or more, and it is thus assumed that the preference for the salt taste has not changed substantially in the Japanese population. Thus, a drastic policy for the reduction of salt intake is needed in both the consumer and business sectors.

People consume salt from food products and by adding salt during cooking and at the table. It is thus important to both raise people's awareness of the need to reduce salt intake and reduce the salt content in food products. This study applies system dynamics to simulate salt reduction at a national level.

2. Model structure

The present study developed a system dynamics model of salt reduction comprising four subsystems of people's awareness of the need to reduce salt intake, people's taste for salt, the salt content in food products and the salt intake calculation (Fig. 2).

2.1. Subsystem of people's awareness of the need to reduce salt intake

The first subsystem focuses on people's awareness of the need to reduce salt intake. A diffusion model (Susceptible-Infected-Recovered (SIR) Model) is applied to the subsystem, and people who are not aware of the need to reduce salt intake become aware by encountering people who are aware. The subsystem has 100,000 people, with 80,000 initially aware of the need to reduce salt intake and 20,000 initially unaware.

2.2 Subsystem of people's taste for salt

It was assumed that changes in people's awareness of the need to reduce salt intake and changes in people's taste for salt do not occur simultaneously. (Usually a change in taste for salt will follow a change in awareness.) The subsystem of people's taste for salt has the same number of people as the subsystem of people's awareness, with 95,000 people initially having a strong taste for salt and 5000 a weak taste for salt.

The subsystems of people's awareness and taste for salt are set apart, but linked together. When there are more people aware of the need to reduce salt intake, there is a faster shift toward people having a weak taste for salt. A divisor of two is adopted to take a delay into account. In turn, when there are more people with a weak taste for salt, there is a faster shift in people becoming aware of the need to reduce salt intake.

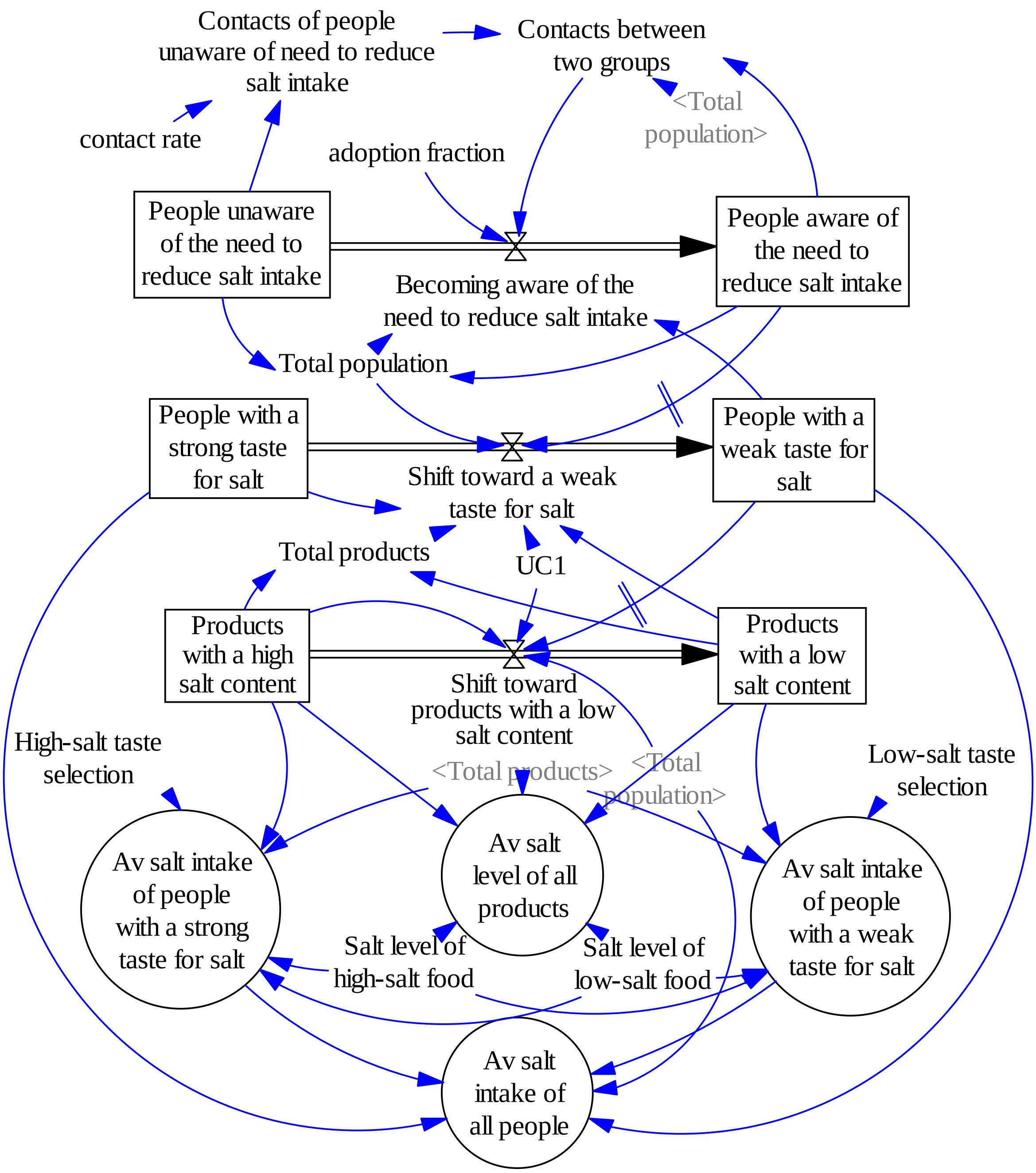

Fig. 2 A system dynamics model of salt reduction at a national level

2.3 Subsystem of salt content in food products

A subsystem of salt content in food products was established. The initial numbers of products with high and low salt contents are 90 and 10, respectively.

The food products subsystem is linked with the subsystem of people's taste for salt. When there are more people with a weak taste for salt, there is a faster shift toward products with a low salt content while the same divisor of two is adopted as on the shift toward a weak taste for salt. In turn, when there are more products with a low salt content, there is a faster shift of people having a strong taste for salt developing a weak taste for salt.

2.4 Subsystem of the salt intake calculation

To calculate average salt intake for all people, the salt levels of high- and low-salt foods and the high- and low-salt taste selections were set. The salt level of food was assumed to be the same as the total salt intake of people when they consume food of the same salt level. In this study, the salt levels of high- and low-salt food were set as 15 and 5 g, respectively. High-salt taste selection was the selection of high-salt food by people with a strong taste for salt and low-salt taste selection was the selection of low-salt food by people with a weak taste for salt, and these selections were provided by look-up functions in four scenarios (stated below).

The average salt level of all products was calculated from the number of products with high and low salt contents and the salt levels of the high- and low-salt foods. Average salt intake by people with strong and weak tastes for salt were calculated from the number of products with high and low salt contents and the salt levels of high- and low-salt foods according to the respective look-up function. Average salt intake of all people was calculated from the numbers of people with strong and weak tastes for salt and the average salt intakes of people with strong and weak tastes for salt.

3. Simulation of the model

Simulation results for 20 years are given for each subsystem.

3.1 Subsystem of people's awareness of the need to reduce salt intake

The numbers of people not aware of the need to reduce salt intake and aware of the need were initially 80,000 and 20,000, respectively, and became equal after approximately 10 years. The flow of becoming aware of the need to reduce salt intake reached a maximum after approximately 12 years (Fig. 3).

3.2 Subsystem of people's taste for salt

The numbers of people with strong and weak tastes for salt were initially 95,000 and 5,000, respectively, and became equal after 11 to 12 years. The flow of change toward a weak taste for salt reached a maximum after approximately 12 years (Fig. 4).

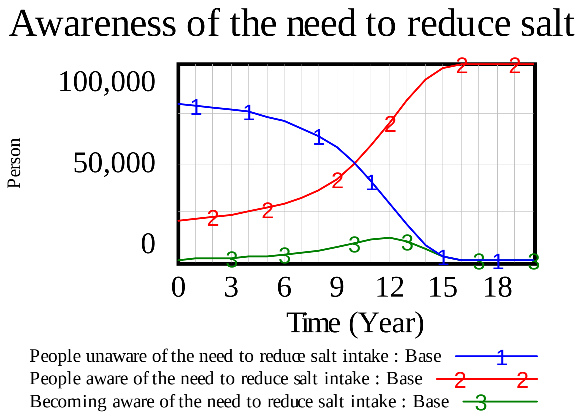

Fig. 3 Change in people's awareness of the need to reduce salt intake

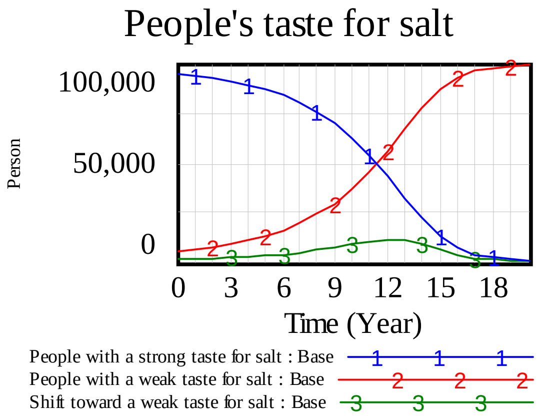

Fig. 4 Change in people's taste for salt

3.3 Subsystem of salt content in food products

The numbers of food products with high and low salt contents were initially 90 and 10, respectively, and became equal after approximately 9 years. The flow of change toward low-salt products reached a maximum after 10 to 11 years (Fig. 5).

The numbers of the two stocks of the subsystem became equal earlier in the food products subsystem (9 years) than in the people's awareness subsystem (10 years) and people's taste for salt subsystem (11 to 12 years). Similarly, the flow reached a maximum earlier in the food product subsystem (10 to 11 years) than in the people's awareness subsystem (12 years) and people's taste for salt subsystem (12 years). Even though only about one third (32,300) of the 95,000 people with a strong taste for salt taste developed a weak taste for salt in 10 years, there was a large shift toward low-salt food in this period.

3.4 Subsystem of the salt intake calculation

The salt levels of high- and low-salt food were constant, 15 and 5 g respectively, and the average salt level for all products changed according to numbers of food products with high and low salt contents (Fig. 6).

Average salt intake of people is described in the four scenarios below.

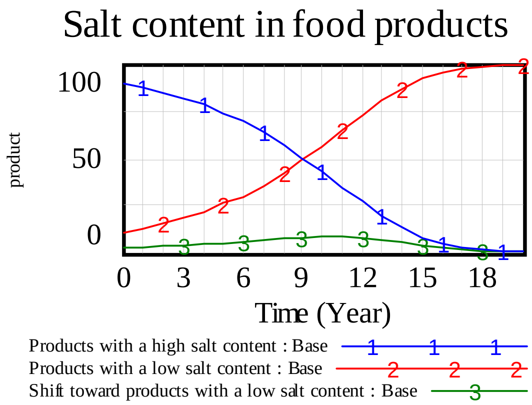

Fig. 5 Change in food products

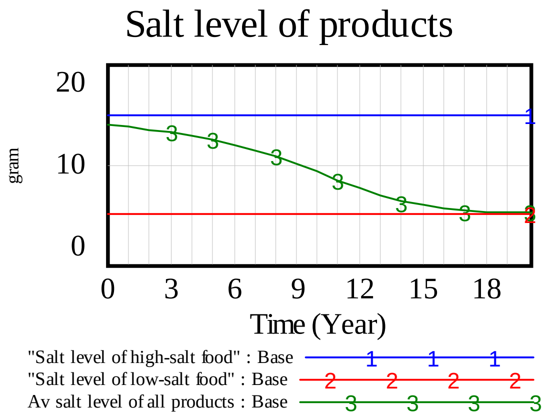

Fig. 6 Change in salt level of products

4. Simulation in four scenarios

Four scenarios, namely no preference, early adoption, late adoption and both early and late adoptions, were developed by changing either or both of the high-salt taste selection or/and low-salt taste selection. Simulations of average salt intakes of people with a strong taste for salt, people with a weak taste for salt and all people are described for the four scenarios.

4.1 No preference

The first scenario assumes that both people with a strong taste for salt and people with a weak taste for salt choose food products with high salt content and with low salt content without any preference. Thus, the percentages of food products with high (or low) salt available and chosen by people with a strong (or weak) taste for salt are equal (Fig. 7).

In the no-preference scenario, average intakes of people with a strong taste for salt and people with a weak taste for salt are the same as the average salt level for all products, and the average salt intake of all people is also the same (Fig. 8).

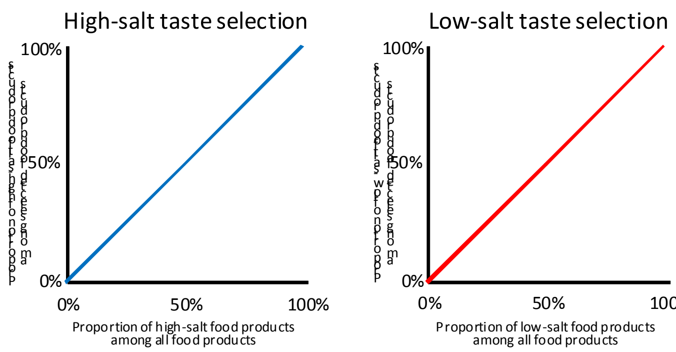

Fig. 7 Look-up function of selection in the no-preference scenario

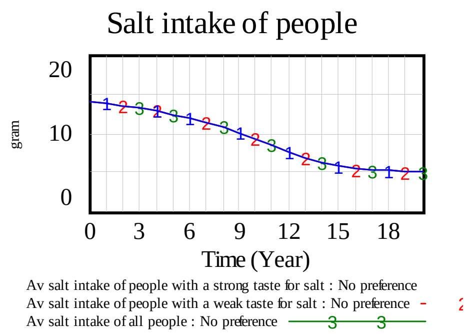

Fig. 8 Change in salt intake of people in the no-preference scenario

4.2 Early adoption

In the second scenario, when the actual percentage of food products with low salt among all food products is less than 50%, people with a weak taste for salt consume those products at twice the rate they are available. When the actual percentage is 50% or higher, people with a weak taste for salt only consume products with low salt content. People with a strong taste for salt consume food products with high salt content and low salt content without any preference (Fig. 9).

Average salt intake of people with a weak taste for salt dropped steeply in the first 9 years. However, as the number of people with a weak taste for salt remained rather small in the first 9 years, the average salt intake of all people was not different from that of people with a strong taste for salt (the same as in the no-preference scenario) (Fig. 10).

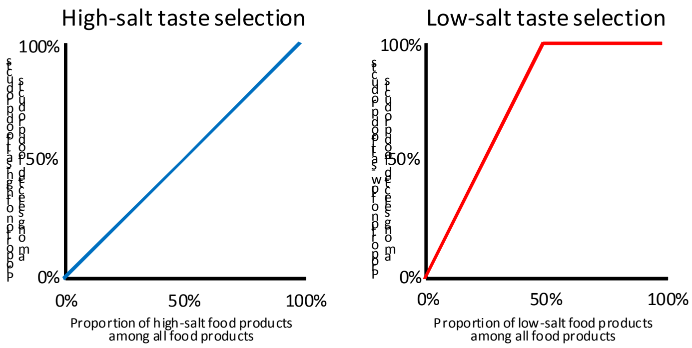

Fig. 9 Look-up function of selection in the early adoption scenario

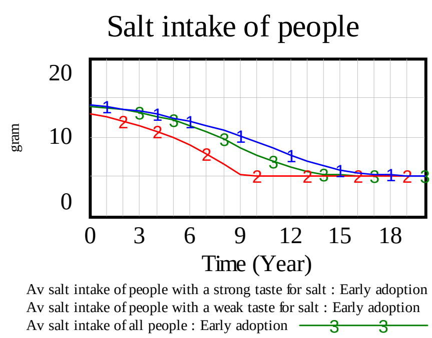

Fig. 10 Change in salt intake of people in the early adoption scenario

4.3 Late adoption

In the third scenario, when the actual percentage of food products with high salt content among all food products exceeds 50%, people with a strong taste for salt select only those products. When the actual percentage is 50% or lower, people with a strong taste for salt consume food products with high salt at twice the rate they are available. People with a weak taste for salt consume food products with high salt content and with low salt content without any preference (Fig. 11).

Average salt intake of people with a strong taste for salt starts to decline after 9 years, and the average salt intake of all people is not greatly different from that of people with a strong taste for salt (Fig. 12).

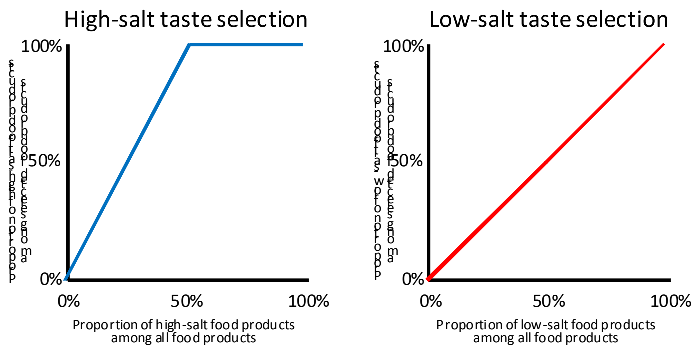

Fig. 11 Look-up function of selection in the late adoption scenario

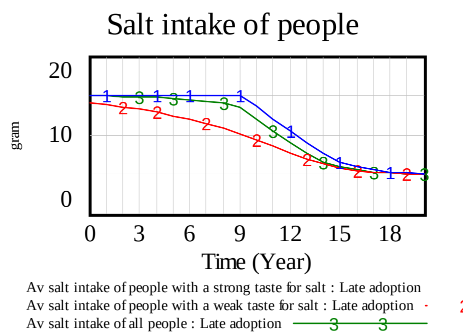

Fig. 12 Change in salt intake of people in the late adoption scenario

4.4 Both early and late adoption

The final scenario is a combination of early adoption by people with a weak taste for salt and late adoption by people with a strong taste for salt (Fig. 13). Average salt intake of all people shifted, in most years, towards that of people with a strong taste for salt rather than towards that of people with a weak taste for salt (Fig. 14).

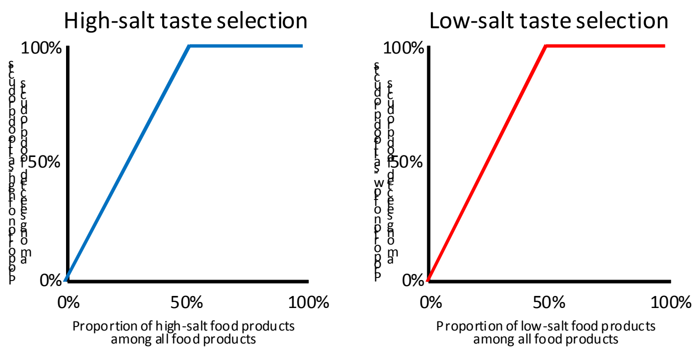

Fig. 13 Look-up function of selection in the early and late adoption scenario

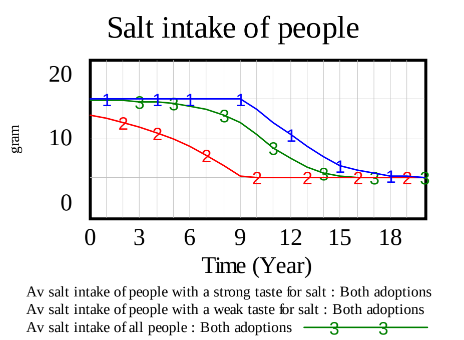

Fig. 14 Change in salt intake of people in the early and late adoption scenario

4.5 Comparison of the four scenarios

Changes in average salt intakes of all people in the four scenarios are shown in Fig. 15. Changes in the four scenarios were split into two parts in the early stage (approximately the first 7 years): the first is for late adoption and both early and late adoptions, and the second is for no preference and early adoption. It is clear that food selection by people with a strong taste for salt in the early stage is important in lowering average salt intake of all people.

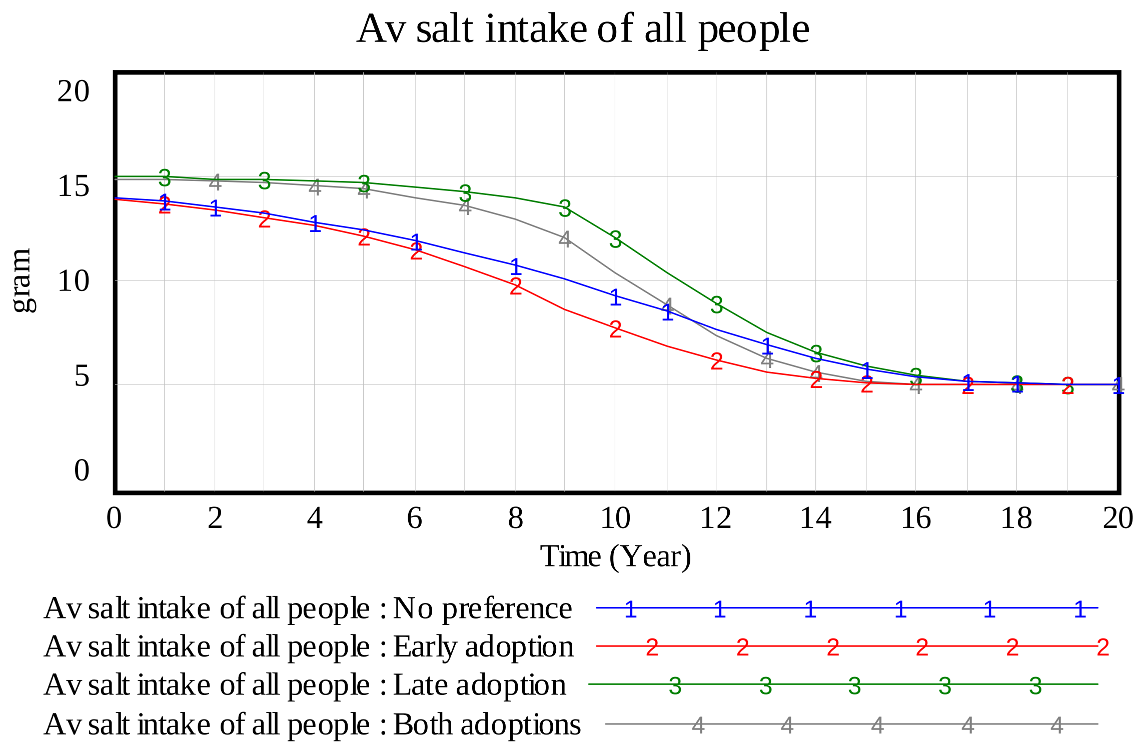

Fig. 15 Change in average salt intake of all people in four scenarios

5. Future challenges

The study aimed to develop a basic system dynamics model to simulate average salt intake of all people. For further application in the future, three limitations to the present study need to be addressed.

First, the average salt intake of all people was not calibrated with any existing data in this study. In applying the model to a country or sex/age group, calibration can be made mainly by changing the salt levels of high-salt food and low-salt food.

Second, salt levels of food products are used in the model, but salt added during cooking and at the table was not taken into account. Salt other than that in the food products needs to be added to the model.

Third, simulation in this study was limited to 20 years. It is known that salt intake differs by age group [1], and the aging of people needs to be taken into account in the model for a longer period.

6. Conclusion

Salt intake of a population was studied using a basic system dynamics model according to four scenarios. To lower the average salt intake of the population, it is important that people with a strong taste for salt consume products with low salt content earlier.

Acknowledgment

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